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# AN INVESTIGATION OF THE PROCESSES OF GRASSLAND DEVELOPMENT AND PERSISTENCE IN PAPUA NEW GUINEA : A SURVEY REPORT OF THE FALLOW VEGETATION AROUND LAE

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## Introduction

Although the vegetation of Papua New Guinea is dominated by forests, an appreciable area is under grasslands. The occurrence of these grasslands is, in some cases, fundamentally attributed to natural environmental conditions (*e. g.*, climate and soils) such as the subalpine grasslands of high mountains, river floodplains, swamps and savanna areas. However, by far the largest areas of grasslands also are seen in regions where neither soils nor climate would preclude the establishment of forests. The grasslands in these regions are believed to have been derived from human activities, particularly through shifting cultivation and burning (ROBBINS, 1960 ; REINER & ROBBINS, 1964 ; HAATJENS *et al.*, 1965 ; EDEN, 1974) and also through natural causes such as landslips and flooding occasioned by the frequent occurrence of earthquakes, volcanic activities and heavy rainfall, especially on rugged terrains (WHITE, 1971 ; JOHNS, 1986 : LAMB, 1990).

As a follow up to earlier observations by NAKANO (1984) and NAKANO *et al.* (1990) on the vegetation of the Markham Basin, several fallow sites of different seral stages of development were selected and surveyed around Boana, Markham and Labu areas in the Morobe Province. These areas were chosen for the survey because not only are they within or adjacent to the grassland areas of the Markham basin, but are also representative of grassland/forest transitional zone (Boana area) or genuine lowland forest areas (Markham and Labu areas).

The overall objective of this study is to determine the factors contributing to the establishment and maintenance of the degraded grasslands in the area where climatic conditions are favourable for the establishment and maintenance of forests. In this report, however, the vegetation of the fallows and the general observations from the three areas surveyed will be discussed in relation to the foregoing overall objective of this study.

## Descriptions of the Survey Areas

The Boana, Markham and Labu areas are located nearly 40km to the north-northwest, 14km to the west-northwest and 10km to the west-southwest of Lae, respectively, in Morobe Province (Fig. 1).

The Boana area is situated on the "Leron Formation" which comprises the Miocene siltstones, conglomerates and marine volcanics (LÖFFLER, 1977). Moreover, intrusions of

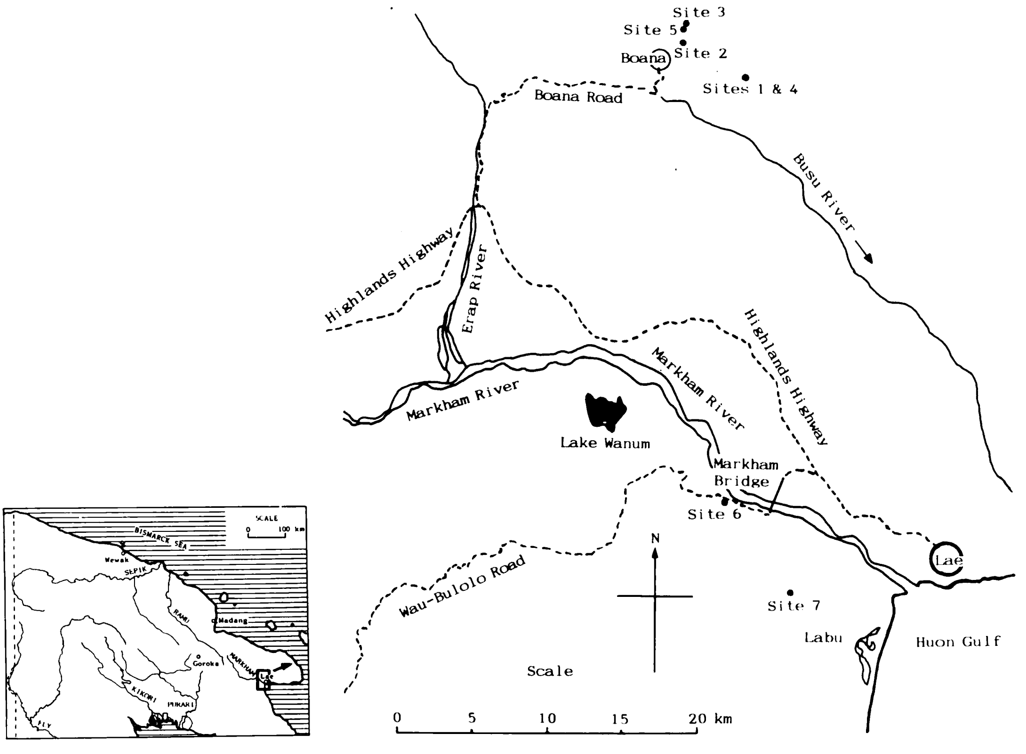


Fig. 1 Map showing the study areas in Morobe Province, Papua New Guinea.

gabbros, diorites, granodiorites and conglomerates of basalts and andesite clasts of limestones are also found in the area. These intrusions are poorly imbedded resulting in the formations of the low, rounded or irregular terraced hills common in the area with altitudes ranging from 600-1,480 m above sea level. While the Markham and Labu areas are located on the "Sepik-Ramu Fault" which forms a depression that extends from the Labu area in the south to the Sepik plains in the north. The geology of this fault is basically Quaternary in origin consisting of recent alluvium and swamp deposits as well as raised corals with volcanic intrusions of basic and ultrabasic igneous rocks, siltstones and conglomerates seen on the hillsides and riverbeds in the areas. The topographic elevations in these two areas vary from 10-200 m above sea level. There are numerous rivers, streams and creeks found in the areas of which the notable ones are the Markham and Busu Rivers.

As with the geology and topography, the soils in these areas are also variable, ranging from the weathered Entisols, Inceptisols, Alfisols and Ultisols of the Boana area where such soils are associated with the medium crowned lowland foothill forests common in the area to the Ustipsamments, Ustorthents or Troporthents and Tropopsamments of the Markham/Labu areas. Furthermore, the soils of the Markham/Labu areas also have various Aquent soils such as the Tropofluvents, Fluvaquents and Hydraquents which are associated with the swamps and floodplains in these two areas (BLEEKER, 1983). The fertility of these soils range from the moderate hilly soils of the Boana area to moderate and high floodplain alluvials of the Markham/Labu areas.

The vegetation of the Boana area, in general, comprises the lowland foothills and, to some extent, the remnants of the lower montane. The forests have lower stature of medium crowns due to less favourable conditions of temperature and steep slopes with shallow unstable soils, varying in height from 20-30 m and having the following abundant trees : the species of *Cryptocarya, Elaeocarpus, Saurauia, Pometia, Sloanea* and *Castanopsis*. There are also numerous mosaics of secondary forests and grasslands which in some instances are quite extensive. These types of vegetation could have been derived from both human and natural causes.

At both the Markham and Labu areas the prominent vegetation types are lowland, floodplain, mixed swamp woodlands and mangrove forests which occur mostly along the coast. As in the Boana area, secondary forests and grassland are also obvious in these two areas. The prevalent trees observed in the lowland forests of these two areas include *Terminalia, Pometia, Pterocarpus, Syzygium, Myristica, Cryptocarya* and *Alstonia*, a few of which are found in the data of NAKANO *et al.* (1990), while the mangrove forests are dominated by *Rhizophora* and *Bruguiera*. On the other hand, the mixed swamp woodlands and the floodplain forests abound with sago palms, *Campnosperma*, *Terminalia*, *Nauclea* and *Palaquium*. The heights of trees in these forests range from 20-40 m, and are associated with deeper soils and favourable temperatures.

The climate of the Boana area is typical of the humid premontanes (500-1,400 m above sea level) with annual rainfalls averaging around 2,000-2,500 mm and temperatures ranging from 15-26℃, while at both the Markham and Labu areas the climate is typical of the humid lowlands (MCALPINE *et al.*, 1983) with annual rainfalls between 2,500-4,000 mm and temperatures varying from 26-32℃.

## Descriptions of the Survey Sites and Methods of Survey

From the three study areas, a total of seven fallow sites of different seral stages of development were selected for enumeration. These include five from the Boana area and one each from the Markham and the Labu areas. The fallows from the Boana area were aged from 3-4 months, 1, 3, 11 and 15-20 years old while from the Labu and the Markham areas were 1.5 and 4 years old respectively.

The 3-4 month old and 11 year old fallows (Sites 1 & 4 respectively) in the Boana area are located 5.5km to the east-southeast of the Boana Station at an elevation of 1,120 m above sea level and are adjacent to each other, while the 3, 15-20 and 1 year old ones (Sites 3, 5 and 2 respectively) are located at the altitude 1,150, 1,070 and 1,090 m above sea level approximately 2.5, 2.0 and 1.5km to the northeast of the Station respectively (Fig. 1). All of these fallows as well as many others are mostly located on slopes, inasmuch as there are not enough flat land in the area, unlike in the Markham and Labu areas.

The 4 year old Markham fallow (Site 6) is located 1.5km from the Markham Bridge and 50 m east along the Wau-Bulolo Road at an elevation of 20 m above sea level, while the 1.5 year old one (Site 7) in the Labu area is located about 6km to the south of the Markham Bridge along a logging road at an altitude of 70 m above sea level on a gentle slope (Fig. 1).

On each site, a line transect of varying lengths depending on the size of the abandoned swiddens was set up, except at the 3 year old Boana fallow where two such transects were set up and enumerated. The enumeration of the transects was done as follows : at sites which are less than 3 years old, all plants encountered along the transect either when they come in contact with the line transect or their canopies were intercepted by the line were enumerated by species and height where required ; On sites that are 3 years old or more, but less than 10 years only the trees and shrubs with girths at breast height (b. h.) of more than 7 cm were enumerated by species, height and girth at b. h., and for older fallows (*i. e.*, more than or equal to 10 years) only those trees and shrubs with girths at b. h. of 10 cm or more were enumerated.

## Discussions of the Results and the Overall Implications

The summarised data of the survey results are presented in Tables 1a, b and Annexes 1, 2 and 3. The fallow vegetation from the Boana sites had the mean values of species maximum heights ranging from 1.0 m at the 3-4 months old site to slightly more than 9.9 m at the 15-20 year old site with the mean values of basal areas for the tree and shrub individuals varying from 86.2 $cm^2$ at the 3 year old fallow to 264.0 $cm^2$ at the oldest site (Table 1a). At the younger sites (*i. e.*, 3-4 month old site and the 1 year old site) the trees and shrubs have lower representation (14.9-28.8%) as compared with the representation by grasses and weeds. Furthermore, most of these trees and shrubs (41-80%) were established at the fallows by means of resprouting (Table 1a). In contrast, the fallow site at Labu area had a higher representation of trees and shrubs (*e. g.*, 70%) and most of these originated from seeds (98.5%). The mean value of species maximum height of plants in the 4 year old Markham fallow was 6.0 m with a basal area of 44.6 $cm^2$, while the 1.5 year old Labu fallow had a mean maximum height of 1.5 m (Table 1a).

The observations of the soils in the three areas indicated that, at Boana where most of the swiddens are on the slopes, the soils vary in depth from being shallower and stony. In some areas, however, the soil depths are sometimes deeper (more than 30 cm) comprising of clays. In such situations the B horizon is often not present. On the other hand, the Markham and Labu areas are relatively flat or, if hilly, have gentle slopes with deeper soil profiles consisting mostly of clay loams. Like the Boana area, they have undifferentiated soil profiles at some localities (Table 1b).

The process of vegetation development in the Boana swidden fallows is apparent. At an early stage, the grasses, weeds and the early pioneer trees invaded the clearings, but are removed during cultivation when they are weeded out. Once the swiddens are abandoned, these plants again reappeared. The most prevalent of these grasses and weeds are as follows: *Brachiaria mutica* (FORST.) STAPF, *Imperata conferta* (PRESL) OHWI, *Paspalum conjugatum* BERG. and *Setaria palmifolia* (KOEN.) STAPF representing the grasses and *Crassocephalum crepidioides* (BENTH.) S. MOORE, *Erechtites valerianifolia* (WOLF) DC., *Sida rhombifolia* L. and *Sphaerostephanos unitus* (L.) HOLTT. representing the weeds. While the early pioneer trees were represented by the various species of Moraceae (*Ficus*), Euphorbiaceae such as the *Macarangas*, *Homalanthus novoguineensis* and *Mallotus*, and Urticaceae (*Pipturus argenteus*). Moreover, other long-living pioneers such as *Euodia elleryana* F. MUELL., *Leea indica* (BURM. F.) MERR., and *Trema orientalis* (L.) BL. also invade and persist, forming part of the natural vegetation in the area though with reduced growth and densities as the primary species invade and maintain their occupancy of the sites. The overall progressive development of the fallows through time is shown by the increases in heights and basal areas (Table 1a). If human disturbances are neither too intensive nor too prolonged, woody plants seem to cover the upper layer of the vegetation there in a few years after the abandonment of a swidden.

Table 1a. Summary of all the enumeration data from the surveys at some fallows in Boana, Markham and Labu areas around Lae, Papua New Guinea.

| Area | Site no. | Site age yr(s). | Mean of max. heights of species m | Mean of avail. basal areas of indiv. $cm^2$ | Regeneration mode of trees & shrubs % of resprouts | Ratio of indiv. of tree & shrub species % |
|---|---|---|---|---|---|---|
| Boana | 1 | 0.3-0.4 | 1.0 | — | 41.2 | 28.8 |
| Boana | 2 | 1 | 2.5 | — | 80.0 | 14.9 |
| Boana | 3 | 3 | slightly more than 6.9 | 86.2 | 54.5* | — |
| Boana | 4 | 11 | 8.6 | 135.3 | 42.1 | — |
| Boana | 5 | 15-20 | slightly more than 9.9 | 264.0 | 61.1 | — |
| Markham | 6 | 4 | 6.0 | 44.6 | 47.6 | — |
| Labu | 7 | 1.5 | 1.5 | — | 1.5 | 70.0 |

* Excluding *Bambusa* sp.

Table 1b. Qualitative assessments of soils in the three survey areas around Lae, Papua New Guinea.

| Area | Site no. | Site age yr (s). | Soil description |
|---|---|---|---|
| Boana | 1 | 0.3-0.4 | Humus−2cm ; A horizon−24cm ; B horizon−nil ; C horizon−20cm. |
| Boana | 2 | 1 | Humus−1cm ; no horizons, because the soil was too stony and very shallow. |
| Boana | 3 | 3 | Humus−2cm ; no profile differentiation, deeper than 30cm. |
| Boana | 4 | 11 | Similar to Site 1. |
| Markham | 6 | 4 | Humus−5cm ; no profile differentiation, deep and mostly clay loam. |
| Labu | 7 | 1.5 | Humus−5cm ; A horizon−20cm ; B horizon−15cm ; C horizon−very deep. |

From the data shown in this paper, at least four main points worth discussing can be presented. They may be interpreted as carrying some implications for the development and maintenance of degraded grasslands in these three areas.

First, there appears to be slight differences between the vegetation growth of the fallows in the three areas surveyed. That is, the younger Boana fallows seemed to indicate higher mean maximum heights as well as mean basal area of tree and shrub individuals

(Table 1a). One plausible reason of the difference is the slower growth of the vegetation at the Markham fallow. This is probably due to the liability to inundation there. The stature growth of the vegetation at the Boana fallows may, however, become rather slow after the stage of the initial several years in the fallow period. Such slow growth in stature is perhaps related to the cooler climate, steep slopes of the terrain and shallow, unstable soils found there (Table 1b).

Secondly, there are significant differences between the Boana and the Markham/Labu fallows in regard to the representations of different plant life forms, especially in the early stages of vegetation development. The Boana fallows showed lower representation of trees and shrubs (14.9-28.8%) as compared with such life form representation, say, in the Labu area (70%). The grasses and weeds on the other hand have higher representation at the Boana fallows than at the Labu area (Table 1a). This trend could be interpreted in a number of ways : a) that the Boana fallows have insufficient seeds of the tree/shrub life forms in the soil seed bank and that there is a lack of their seeds being dispersed into the fallow areas immediately or thereafter when the swiddens are abandoned, compared with those at the Labu area ; b) that the Boana fallows are frequently being disturbed such that the trees and shrubs were not able to regenerate from seeds, but rather depend on their ability to resprout. Furthermore, if such a disturbance is quite extensive, this could affect the effective seed dispersal from the surrounding vegetation either by wind or animals into the clearings. This also may affect the time required by the seeds of trees and shrubs to germinate, to become established and developed, especially when the fallow periods are shortened.

Thirdly, there is an obvious difference in the regeneration modes of the plants enumerated from three areas, particularly for the trees and shrubs. At the Boana fallows most trees and shrubs (41-80% – Table 1a) were able to become established by means of resprouting as compared with the lower values of resprouting trees and shrubs (1.5%) encountered at the Labu fallows which appeared to have originated from seeds. This further stresses the point made above that in highly disturbed sites or where the occurrence of disturbances is so frequent and extensive, grasses and weeds become more prevalent and that the higher plant life forms such as the trees and shrubs can only survive by means of resprouting from their vegetative parts such as from stumps, stems and roots. In the case of the Markham fallow, the very moist condition of the soil owing to the liability to inundation there may be indirectly related with a considerably large value (48%) of the percentage of the resprouts to all the tree and shrub individuals, since such condition is considered unfavourable for the growth of tree seedlings.

Lastly, the variability in the soil depths and their physical aspect, coupled with the topographic variation between the sites and the areas are quite apparent. Thus, the Boana area has shallower soil depths and is stonier. Together with the steep hilly slopes, their susceptibility to landslips, rapid water loss and erosion is quite apparent, especially when exposed over a long period of time, or if such sites are subjected to continuous cultivation at shorter fallow intervals. Such sites may eventually become so degraded that only weeds and grasses could become established on them.

There exist a number of factors which could influence the distribution, establishment and maintenance of degraded grasslands in any type of habitat such as the climatic and edaphic conditions, topography and human activities (*e. g.*, cultivation and burning). When two of the maps in GARRET-JONES (1979) are combined, as pointed out by NAKANO *et al.*

(1990), the grassland vegetation in the Markham Basin coincides roughly with the region with less than 2,000mm of mean annual rainfall. On the other hand, the areas used in this survey are depicted as being covered by lowland rain forests with mean annual precipitations exceeding 2,000mm. The apparent presence of some extensive grasslands in these areas, however, may indicate that precipitation alone could not be the sole determining factor for the distribution and maintenance of the grassland vegetation in these areas, as has been already discussed by NAKANO *et al.* (1990).

The history of the vegetation in the Markham Basin as shown from the pollen analysis by GARRET-JONES (1979) indicated that the vegetation change from forests to grasslands began some 1,500-2,000 years ago through forest clearance followed by continual burning and cultivation by the people in the area (REINER & ROBBINS, 1964). Apart from continual burning and cultivation, the persistence of the grasslands in the area has been also attributed to the edaphic and climatic factors (HAATJENS *et al.*, 1965).

During this survey it was observed that burning and continual use of fallows for gardening were obvious in the three areas. This may have contributed to the persistency and the extent of the grasslands observed, especially with respect to the Boana area.

Furthermore, the soil depths and their stony nature together with the topographic variations could also have contributed to the maintenance and distribution of the degraded grasslands in these areas. The prevalence of resprouting trees and shrubs at the fallow sites around Boana is indicative of vegetation being consistently under frequent and extensive disturbance. In time it may not recover if the fallow intervals are continually curtailed by severe burning. The exposure of the shallow and stony soils on the steep slopes due to the impact of rainfall could eventually lead to further degradation resulting in the establishment of grasslands.

On many occasions, it was observed that the boundary between the grasslands and the forests in these three areas were very abrupt, especially along the valleys and hill slopes which may indicate favourable edaphic conditions. It ought to be pointed out, however, that there exist some areas where gradual transition between the two types of vegetation could be seen. This could mean that the topography rather than the differences in the edaphic conditions could be a more important contributing factor for grassland establishment and maintenance. A clue to this is provided by the fact that many of these boundaries run across the contours rather than along them and, owing to strong relief and uniform wind regime, fires burn mostly in uphill directions, while the side burns are relatively mild. Thus, the least fire pressure would generally be in a lateral direction and enhanced through positive feedback effects.

In conclusion, it appears likely that, apart from climatic condition, human activities through shifting cultivation and burning of fallows, soils and topographic factors may have contributed in enhancing the establishment, persistence and the distribution of the grasslands in these three areas. Furthermore, it was observed that the chances for some these grasslands to revert back to forest may be very remote considering that the soil conditions under grasslands have already been so degraded. This has been pointed out by NAKANO *et al.* (1990). Nevertheless, in some areas of the Markham and Labu, such development could be attained, but at longer periods of time, if burning and cultivation are prevented. This speculation, however, needs to be further investigated in the future to be able to know exactly what factors are influential in the distribution and establishment of grassland vegetation and what could be done to convert such degraded grasslands to forests.

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Annex la. Data by means of the respective 15m line transects for the 0.3-0.4 and 1 year old fallows (Sites 1 and 2, respectively) in Boana, Morobe Province, Papua New Guinea.

| Plant species | Family | Number of individual(s) Site 1 | Site 2 | (Maximum) height Site 1 m | Site 2 m |
|---|---|---|---|---|---|
| *Abelmoschus manihot* (L.) MEDIK. | Malv. | 3** | – | 2.4 | – |
| *Acalypha insulana* MUELL. -ARG. | Euph. | 2* | 1* | 0.8 | 1.7 |
| *Amydrium* sp. | Ara. | – | 1 | – | creeper |
| *Brachiaria mutica* (FORST.) STAPF | Gram. | – | 1 | – | creeper |
| *Crassocephalum crepidioides* (BENTH.) S. MOORE | Comp. | 4 | 3 | 0.9 | 0.7 |
| *Curculigo erecta* LAUT. | Hypox. | 1 | 1 | 0.3 | 1.0 |
| *Cypholophus decipiens* WINKL. | Urti. | 4 | – | 1.0 | – |
| *Elatostema beccarii* H. SCHROETER | Urti. | 1 | 6 | 0.2 | 0.7 |
| *Erechtites valerianifolia* (WOLF) DC. | Comp. | 4 | – | 1.7 | – |
| *Euodia elleryana* F. MUELL. | Ruta. | – | 1 | – | 3.2 |
| *Ficus* sp. | Mora. | – | 2 | – | 1.5 |
| *F. gul* LAUT. et K. SCHUM. | Mora. | 1* | – | 1.7 | – |
| *Gironniera* sp. | Ulma. | 1 | – | 0.3 | – |
| *Homalanthus novoguineensis* (WARB.) LAUT. et K. SCHUM. | Euph. | 1 | 1 | 1.5 | 8.1 |
| *Hornstedtia lycostoma* (LAUT. et K. SCHUM.) K. SCHUM. | Zing. | 3 | 4 | 0.9 | 1.7 |
| *Imperata conferta* (PRESL) OHWI | Gram. | 4 | – | 0.9 | – |
| *Ipomoea batatas* (L.) LAMK. | Conv. | – | 5** | – | creeper |
| *Leea indica* (BURM. F.) MERR. | Leea. | – | 1* | – | 2.4 |
| *Nothocnide* sp. | Urti. | – | 1* | – | 4.0 |
| *Paspalum conjugatum* BERG. | Gram. | 9 | 2 | creeper | creeper |
| *Pipturus argenteus* (FORST. F.) WEDD. | Urti. | 4 | – | 0.9 | – |
| *Pneumatopteris sogerensis* (GAPP.) HOLTT. | Thely. | 1 | – | 0.2 | – |
| *Pteridium aquilinum* (L.) KUHN | Denn. | 1 | – | 0.5 | – |
| *Rubus* sp. | Rosa. | – | 1 | – | climber |
| *Saccharum officinarum* L. | Gram. | – | 2** | – | 2.0 |
| *Saurauia conferta* WARB. | Saur. | 1* | 3* | 2.9 | 3.2 |
| *Setaria palmifolia* (KOEN.) STAPF | Gram. | 5 | 10 | 0.9 | 1.3 |
| *Sida rhombifolia* L. | Malv. | – | 9 | – | 1.3 |
| *Sphaerostephanos unitus* (L.) HOLTT. | Thel. | 8* | 10* | 1.1 | 1.1 |
| *Tapeinocheilos* sp. | Cost. | – | 2 | – | 5.4 |
| *Trema orientalis* (L.) BL. | Ulma. | 1 | – | 1.0 | – |

* Resprout(s) or coppice(s).

**Having been planted or cultivated.

Annex 1b. Data by means of two line transects (34m and 30m) for the 3 year old Boana fallow (Site 3).

| Plant species | Family | No. of indiv. | (Max.) height m | No. of girth(s) measured | (Total) basal area $cm^2$ |
|---|---|---|---|---|---|
| *Bambusa* sp. | Gram. | 16** (in clumps) | >10 | n.a.*** | n.a.*** |
| *Breynia cernua* (POIR.) MUELL.-ARG. | Euph. | 1 | 4.4 | 1 | 6.4 |
| *Cypholophus decipiens* WINKL. | Urti. | 1** | 5.5 | 2 | 20.2 |
| *Ficus botryocarpa* MIQ. | Mora. | 1 | 3.3 | 1 | 4.0 |
| *F. copiosa* STEUD. | Mora. | 1 | 2.1 | 1 | 8.0 |
| *F. dammaropsis* DIELS | Mora. | 1* | 7.2 | 2 | 57.2 |
| *F. subnervosa* CORNER | Mora. | 1 | 7.6 | 1 | 28.7 |
| *Garcinia* cf. *assugu* LAUT. | Gutt. | 1* | 4.8 | 2 | 15.1 |
| *Geunsia farinosa* BL. | Verb. | 1* | 7.6 | 3 | 240.0 |
| *Homalanthus novoguineensis* | Euph. | 2 | about 15 | 2 | 452.8 |
| *Maesa* sp. | Myrs. | 1 | 6.2 | 1 | 77.5 |
| *Macaranga aleuritoides* F. MUELL. | Euph. | 1 | 4.1 | 1 | 7.3 |
| *M. pilosula* AIRY-SHAW | Euph. | 1 | 6.1 | 1 | 13.4 |
| *M. tanarius* (L.) MUELL.-ARG. | Euph. | 2+1* | 10 | 4 | 161.4 |
| *Mallotus mollissimus* (GEISEL.) AIRY-SHAW | Euph. | 3 | 10 | 3 | 169.4 |
| *Musa maclayi* F. MUELL ex MICHL. et MACLAY | Musa. | 1** | 3.2 | 1 | 32.5 |
| *Piper aduncum* L. | Piper. | 5* | 8.5 | 8 | 304.9 |
| *P. gibbilimbum* C. DC. | Piper. | 5* | 5.6 | 13 | 107.5 |
| *Pipturus argenteus* | Urti. | 3 | 8.1 | 3 | 186.8 |
| *Saurauia conferta* | Saur. | 5* | 7.5 | 18 | 1276.9 |
| *S. decipiens* WINKL. | Saur. | 2* | 7.0 | 8 | 479.7 |
| *Sloanea* sp. | Elaeo. | 1 | 4.5 | 1 | 6.2 |
| *S. forbesii* F. MUELL. | Elaeo. | 1* | 6.3 | 1 | 8.6 |
| *Thespesia peekeli* (ULBR.) BORSSUM | Malv. | 1 | 10 | 2 | 107.6 |
| *Trema orientalis* | Ulma. | 1 | 8.0 | 1 | 20.9 |

* Resprout(s) or coppice(s).

** Having been planted or cultivated.

***Not available.

Annex 1c. Data by means of a 50m line transect for the 11 year old Boana fallow (Site 4).

| Plant species | Family | No. of indiv. | (Max.) height m | No. of girth(s) measured | (Total) basal area cm$^2$ |
|---|---|---|---|---|---|
| *Acmena acuminatissima* (BL.) MERR. et PERRY | Myrt. | 1* | 5.2 | 1 | 34.4 |
| *Artocarpus communis* FORST. | Mora. | 1 | 5.4 | 1 | 25.8 |
| *Cyathea contaminans* (WALL. ex HOOK.) COPEL. | Cyath. | 2 | 8.9 | 2 | 577.9 |
| *Ficus botryocarpa* | Mora. | 2 | 8.8 | 2 | 104.5 |
| *F. dammaropsis* | Mora. | 2* | 11 | 4 | 237.3 |
| *F. gul* | Mora. | 1 | 7.2 | 1 | 62.4 |
| *F. mollior* BENTH. | Mora. | 1* | 6.9 | 4 | 177.9 |
| *Homalanthus novoguineensis* | Euph. | 2 | 11 | 2 | 147.4 |
| *Litsea guppyi* (F. MUELL.) F. MUELL. ex FORMAN | Laur. | 2 | 11 | 2 | 171.2 |
| *Macaranga pilosula* | Euph. | 1 | 7.8 | 1 | 14.7 |
| *Saurauia conferta* | Saur. | 4* | 11 | 11 | 1016.5 |

Annex 1d. Data by means of a 30m line transect for the 15-20 year old Boana fallow (Site 5).

| | | | | | |
|---|---|---|---|---|---|
| *Cyathea contaminans* | Cyath. | 1 | 7.8 | 1 | 213.5 |
| *Euodia elleryana* | Ruta. | 2 | about 14 | 2 | 255.7 |
| *Ficus* sp. | Mora. | 1* | 5.3 | 3 | 78.6 |
| *F. botrycarpa* | Mora. | 1* | 8.0 | 4 | 339.8 |
| *F. copiosa* | Mora. | 1 | 4.7 | 1 | 8.0 |
| *Glochidion* cf. *angulatum* C. B. ROB. | Euph. | 1 | about 18 | 1 | 641.7 |
| *Hibiscus rosa-sinensis* L. | Malv. | 2** (in clumps) | 9.3 | n.a.*** | n.a.*** |
| *Laportea* sp. | Urti. | 1 | 9.7 | 1 | 85.6 |
| *Litsea irianensis* KOSTERM. | Laur. | 1 | 11 | 1 | 145.8 |
| *Macaranga tanarius* | Euph. | 2 | >20 | 2 | 1580.5 |
| *Musa maclayi* | Musa. | 6* | 9.7 (including 6 suckers) | 11 | 1587.5 |
| *Oreocnide trinervis* (BL.) MIQ. | Urti. | 1* | 4.7 | 2 | 25.7 |
| *Saurauia dielsiana* A. C. SMITH | Saur. | 1* | 6.8 | 2 | 53.5 |

* Resprout(s) or coppice(s).

** Having been planted or cultivated.

***Not available.

Annex 2. Data by means of a 30m line transect for the 4 year old Markham fallow (Site 6) near Lae, Papua New Guinea.

| Plant species | Family | No. of indiv. | (Max.) height m | No. of girth (s) measured | (Total) basal area $cm^2$ |
|---|---|---|---|---|---|
| *Anthocephalus chinensis* (LAMK.) RICH. ex WALP. | Rubi. | 1 | 1.7 | 1 | 5.5 |
| *Antidesma* sp. | Euph. | 3* | 5.1 | 8 | 34.3 |
| *Bischofia javanica* BL. | Bisch. | 1* | 4.9 | 2 | 44.0 |
| *Carallia brachiata* (LOUR.) MERR. | Rhiz. | 1 | 2.1 | 1 | 6.4 |
| *Ficus adenosperma* MIQ. | Mora. | 1+1* | 10 | 5 | 337.2 |
| *F. hispidioides* S. MOOR | Mora. | 1+1* | 6.2 | 4 | 51.8 |
| *F. nodosa* TEYSM. et BINN. | Mora. | 1* | 9.1 | 3 | 145.0 |
| *Leea indica* (BURM. F.) MERR. | Leea. | 2+1* | 6.6 | 3 | 32.8 |
| *Macaranga aleuritoides* F. MUELL. | Euph. | 2 | 8.5 | 2 | 107.7 |
| *Psychotria bracteosa* VALETON | Rubi. | 1* | 3.0 | 5 | 20.3 |
| *Pterocarpus indicus* WILLD. | Legu. | 1* | 6.4 | 7 | 49.8 |
| *Terminalia complanata* K. SCHUM. | Combre. | 1 | 5.3 | 1 | 14.7 |
| *Trichospermum pleiostigma* (F. MUELL.) KOSTERM. | Tilia. | 1 | 12 | 1 | 80.5 |
| *Tristiropsis acutangula* RADLK. | Sapin. | 1 | 3.2 | 1 | 5.9 |

*Resprout(s) or coppice(s).

Annex 3. Data by means of a 31m line transect for the 1.5 year old Labu fallow (Site 7) near Lae, Papua New Guinea.

| Plant species | Family | No. of indiv. | (Max.) height m | Remark |
|---|---|---|---|---|
| *Commersonia bartramia* (L.) MERR. | Sterc. | 25+1* | 3.8 | |
| *Crassocephalum crepidioides* (BENTH.) S. MOORE | Comp. | 1 | 1.2 | |
| *Dicranopteris ?linearis* (BURM. F.) UND. | Gleich. | 1 | 0.5 | |
| *Hornstedtia lycostoma* K. SCHUM. | Zing. | 1 | 0.5 | |
| *Macaranga pilosula* AIRY-SHAW | Euph. | 4 | 2.2 | |
| *M. quadriglandulosa* AIRY-SHAW | Euph. | 2 | 1.6 | |
| *Mallotus mollissimus* (GEISEL.) AIRY-SHAW | Euph. | 4 | 2.2 | |
| *Melinis minutiflora* P. BEAUV. | Gram. | 9 | 1.7 | creeper |
| *Pityrogramma calomelanus* (L.) LINK | Hemionit. | 3 | 0.9 | in clumps |
| *Scleria ciliaris* NEES | Cyper. | 6 | 1.8 | in clumps |
| *Stenochlaena palustris* (BURM. F.) BEDD. | Blechn. | 6 | 1.1 | creeper |
| *Timonius densiflora* VALETON | Rub. | 1 | 1.3 | |
| *Trichospermum pleiostigma* (F. MUELL.) KOSTERM. | Tilia. | 2 | 1.2 | |

*Resprout(s) or coppice(s).