

## BUKTI KORESPONDENSI ARTIKEL

**Murdjoko, A.,** Brearley, F. Q., Ungirwalu, A., Djitmau, D. A., & Benu, N. M. H. (2022). Secondary Succession after Slash-and-Burn Cultivation in Papuan Lowland Forest, Indonesia. *Forests*, 13(3), 1–14.

Berikut adalah proses pengiriman artikel, proses, komentar reviewer, perbaikan dan korespondensi dengan pihak editor jurnal yang dilakukan oleh penulis korespondensi seperti di bawah ini:

### Contents

<a href="#">Pengiriman pertama</a> .....	2
<a href="#">Keputusan editor</a> .....	3
<a href="#">Surat respon terhadap komentar reviewer dan revisi</a> .....	3
<a href="#">Bentuk revisi</a> .....	7
<a href="#">Keputusan akhir journal</a> .....	23
<a href="#">Pengecekan terakhir sebelum cetak</a> .....	24

# Pengiriman pertama

The screenshot displays a web browser window with multiple tabs. The active tab is titled "Agustinus Murtidjo (2000)" and shows the "Article Information Overview" page for a manuscript. The browser's address bar contains the URL: `suay.mdpk.com/user/manuscripts/review_info/640a5903c88f006391cf6a3205492168`. The page content includes:

- Manuscript ID:** forests-1554658
- Status:** Website online
- DOI:** 10.3390/13030424
- Publication Certificate:** Downloaded Publication Certificate (PDF)
- Download Banner (PDF)**
- Website Link:** Abstract, HTML, XML, ECF, version, Manuscript
- Article type:** Article
- Title:** Secondary Succession after Slash-and-Burn Cultivation in Papuan Lowland Forest, Indonesia
- Journal:** Forests
- Volume:** 13
- Issue:** 3
- Section:** Forest Biodiversity
- Special Issue:** Mechanisms of Maintenance of Tree Species Diversity in Tropical Forests

**Abstract:** Papuan forests have been subjected to shifting cultivation for centuries by indigenous people affecting the ecological processes therein. During secondary succession, fallow forests recover naturally. However, the information on ecological succession after swidden practices remains poorly understood in Papuan lowland forests. This study aimed to examine the plant species richness and density of different plant lifeforms in fallows of increasing time after slash-and-burn cultivation along with basic edaphic factors. We performed data collection in the northern part of the island of New Guinea tropical forest near Manokwari, West Papua, Indonesia. The sampling consisted of 26 plots distributed in the primary forest ( $n = 5$ ) and in secondary fallow forests 2-, 4-, 7-, and 9 years after cultivation ( $n = 5$  for each age class). The plant community in primary forest stands differed from the secondary forests. The plant species richness was about twice as high in primary compared to secondary forests. The density of trees and shrubs increased during succession whereas that of ferns declined. The soil fertility declined in secondary forests, although soil organic matter was greatest two years after swidden and then decreased gradually over time. This research underlined that indigenous swidden practices alter ecological conditions and that secondary forests will take a long time to fully recover to resemble primary forest. Hence, the monitoring of vegetation during the process is necessary to inform conservation programs.

**Keywords:** Biforms, New Guinea, species richness, swidden, tropical secondary forest

**Data:** Data is of paramount importance to scientific progress, yet most research data departs in supplementary files and remains private. Enhancing the transparency of the data processes will help to render scientific.

The Windows taskbar at the bottom shows the search bar with "Type here to search", the system tray with a temperature of 27°C, and the date and time: 17:59, 20/12/2022.

## Keputusan editor

The screenshot shows a web interface for a journal submission system. The main content area is titled "Editor Decision" and "Review Report".

**Editor Decision**

- Decision: Accept in current form
- Decision Date: 4 March 2022

**Review Report**

- Reviewer 1: [Review Report \(Round 1\)](#)
- Reviewer 2: [Review Report \(Round 1\)](#)
- Reviewer 3: [Review Report \(Round 1\)](#)

**APC Information**

- Journal APC: 1,800.00 CHF
- IOAP Participant: Manchester Metropolitan University
- IOAP Payment: Non-central: Invoiced to author
- Author Eligible Central: No
- Discount Voucher: dtb0264565c992 (100.00%) (f.q.brearley@mmu.ac.uk)
- Total Payment Amount: 0.00 CHF

**Related Papers Published in MDPI Journals**

The browser's address bar shows the URL: [suzy.mdpi.com/user/manuscripts/review\\_info/640d5903c88006391c0fa3209492168](https://suzy.mdpi.com/user/manuscripts/review_info/640d5903c88006391c0fa3209492168). The browser's taskbar shows the date 18/06/2022 and time 18:06.

Revisi mayor dari tiga reviewer

## Surat respon terhadap komentar reviewer dan revisi

Respon terhadap tiga reviewer

### Reviewer 1

Compared to other parts of the tropical world there is little information on secondary succession in Southeast Asia. Data based papers like this one therefore are welcome.

**RESPONSE: Thank you for appreciating the value of our study.**

The study evaluates plant richness, diversity and densities, and soil conditions, in 5 secondary forest (SF) locations and 1 primary forest (PF) location. In each of these locations 5 (SF) - 6 (PF) plots are installed. Plot size is quite small size, and increasingly smaller for the smaller size class plants. Additionally species are compared to lists of endemics, conservation value and invasives. Results are discussed in terms of how they fit into a swidden agriculture system, and in terms of conservation value. Plots have remnant trees and all kinds of planted species.

Although I like the topic and applaud that this has been done, I have a number of issues with the manuscript

1. The plots are very small. For instance in a secondary forest the seedlings are measured in 2x2 m per plot, giving a total of 5 times 4 = 20m<sup>2</sup> of seedlings per secondary forest location, and 24m<sup>2</sup> for the primary forests location.

**RESPONSE: The reviewer is correct that we sampled progressively smaller plots for smaller life-forms. Whilst the total area covered is small, we consider that our plots have value in being a much more**

extensive analysis of forest floristics than the majority of tropical forest studies that focus only on trees (usually  $\geq 10$  cm dbh).

2. The plots are clearly pseudoreplicated, as the figure. There are in total 6 locations and in every location (which I assume of one forest location with the same history and age), there are 5-6 small plots. This is fine to get a good view on these locations, but they cannot be used as replicates in an analysis. This means that some figures are okay (fig2), while others are not (fig4, fig 5). At least not if you would like to generalize the results.

**RESPONSE: Thank you for your comments on this important point. In order to attend to this, Figs. 2 and 3 remain unchanged. In response to Reviewer 2's comments, Fig 4 has now been removed. As Fig. 5 shows means for each of the plots (without error estimates), we consider it to be suitable and prefer to retain the table in order to facilitate comparisons between SF and PF as noted in in our response to point 6 below.**

3. Many plots have remnant trees, and planted crops of various kinds. This is unclear where it is and how it impacts the results. In such small plots the impact of an individual remnant tree can be very large.

**RESPONSE: Thank you for your comments on this important point. It can be seen from Fig. 4 that the contribution of large trees to the total density is very low. Generally, large trees ( $\geq 20$  cm dbh) increased in density with fallow age, however, the fact that 4-yr-old forests are not different from any other SF in terms of large trees shows that the presence of large trees in this forest age is more variable than the others. There appears to be no clear pattern in terms of the presence of crop/cultivated species and location seems to be a more important factor than fallow age (Appendix). We have now also added a photo of the forests to help with interpretation (Fig. 2).**

4. The units used and categories used are not clear in several figures (fig 2, fig 3, fig 4. Please adjust and include this in the figure headings.

**RESPONSE: We have altered the Figure headings accordingly to increase the clarity of what the Figures are showing. Particularly Figure 4 where we included that densities were multiplied accordingly so that the same area per lifeform is included – as this is an important point, we also included it in the Methods. Please inform us if further clarification is needed.**

5. Area of fig 4 is not correct. The mean is not per 0.3 or 0.36 ha. The mean value can be correct (for the whole) but then the error bars should not be there.

**RESPONSE: Thanks for noting these errors, However, In response to Reviewer 2's comments, Fig 4 has now been removed.**

6. All SF are very young. You could then use these four SF as replicates. Then you could test if PF would fall into or outside the category of the SF and that would be a good test. Of course you would have to correct for plot size differences.

**RESPONSE: We acknowledge the generally young age of our SF fallows and have added a sentence to the Discussion in this regard. In terms of comparison between PF and SF, we consider that the patterns show clear differences between these two classes in Fig. 3 (species accumulation curves), Fig. 4 (dendrogram) and Fig. 5 when looking at the table of Tukey test results.**

7. Fig 3 is using all the small and individual plots (maybe just the species presence? and including also all the smaller categories?) and because of the small size and remnant tree or planted tree will have a large impact and make that the small plots will be different. In which of these this is the case?

**RESPONSE: We have answered this under point 4 above.**

8. Soils are also pseudoreplicated, so be careful with interpretations other than that one location (one forest) is different from another one.

**RESPONSE: We acknowledge this useful point and have tried not to over-interpret our data.**

9. The pseudoreplication is mentioned somewhere in the discussion, but only slightly and between brackets. I think this is not correct as this is really a major issue in this study. As long as you describe the plots all is fine, but testing making it different.

**RESPONSE: Thank you for your clear recommendation. We have now included a penultimate paragraph in the Discussion where we note how our study could be improved including the concern of pseudo-replication and that we need to overcome this in future studies.**

10. The discussion has a lot of real-life comments on the forests and the local situation and that by itself is interesting. However, a bit more critical review of your own data results may be justified.

**RESPONSE: As in our response above, we have now included a penultimate paragraph in the Discussion where we note how our study could be improved including the concerns of pseudo-replication, small plots and young fallow ages.**

11. I also see that nearly all studies are from the region. If in the intro you mention that there is so much out there for other regions, maybe you could add a bit more discussion here of your or your region results compared to other regions.

**RESPONSE: We now include a paragraph comparing our results with those from other parts of New Guinea and also extending this, briefly, to other meta-analyses.**

## **Reviewer 2**

The article compares species richness and diversity between fallows and primary forests. These comparisons included different life forms such as trees, herbs, ferns, shrubs and lianas, and relatively young fallows (2-9 yrs old). I suggest that the authors consider the following commentaries:

1. Many studies compare primary vs. secondary forests, and consider that primary forests are really primary. However, since most of the forests of the world were disturbed at least once, these forests are really primary or are older secondary forests? What are the conditions or characteristics that these forests have to say they are primary? Older and bigger trees, high diversity, in inaccessible areas or unsuitable areas for agriculture? Maybe it would be useful in methods to say that these forests remained relatively undisturbed for decades, if this is the case.

**RESPONSE: We have added the following text to clarify the useful points raised by the reviewer: "These [secondary forests] were compared with forest that had been relatively undisturbed for decades due to its inaccessibility with no reports of ever being cultivation as it was in an inappropriate location; we hence call this primary forest."**

2. In the Intro, the authors say that "local people return to these re-growth forests to implement the next farming cycle..." Do you have information that the sites selected for this study were used more than once by indigenous people? This is important because this information can affect the results. In this case, density and diversity of plants may be influenced only to the fallows age but also to the number of times a forest was slashed and burned.

**RESPONSE: According to local informants, these fallow forests were only used once for cultivation. We have clarified this in the following text: "All secondary forests were in areas that had only been cultivated once (according to local informants)."**

3. Even though fallows were compared with primary forests, they will not necessary reach "primary structure" or a similar plant composition during succession. There are alternative pathways in succession due to the influence of different factors (for example, previous agriculture practices, species present in surrounding forests, climate and edaphic conditions, etc.). Additionally, primary forests do not necessary represent a climax phase, since its structure may be influenced by the intensity and frequency of natural and anthropogenic disturbances. Thus, I suggest the authors to discuss these aspects in the Discussion.

**RESPONSE: Thank you for these useful points. We have added a couple of sentences to the Discussion with an appropriate reference. TEXT**

4. In the last paragraph of the Intro, there are good predictions but explanations of the mechanisms that lead to those predictions are necessary. It was predicted that the density and species richness will increase during succession, but what are the processes involved? Plant facilitation, more time for plant recovery, competition or other species interactions?

**RESPONSE: We have now added that this is hypothesised to be “due to the greater amount of time for accumulation of species” and that the increase in soil fertility will be due to “nutrients are returned to the soil from regrowing vegetation.”**

5. Finally, I found the diversity analyses were redundant. For example, you can obtain relatively similar results in rarefaction and Shannon, but rarefaction is a more powerful analysis.

**RESPONSE: We have now removed the Shannon diversity analysis (Figure 4) as it is considered redundant by the Reviewer.**

### **Reviewer 3**

The authors' manuscript “Secondary succession after slash-and burn cultivation in Papuan lowland forest, Indonesia” clarified the change of community structure, composition, and plant diversity along secondary succession. It is important to understand the community changes and soil fertility during forest succession, which can provide positive suggestions for local forest managers and biodiversity conservation. However, this manuscript is still existing some problems. It needs a minor revision before publication.

line 17. “vegetation richness” should be “plant species richness”.

**RESPONSE: Changed as requested (and also at four other points in the manuscript for consistency).**

line 20. I want to know the vegetation types of primary forest in your manuscript, such tropical rainforest or tropical lower mountain evergreen forest.

**RESPONSE: In line 20, we have already written ‘lowland tropical forest’ but we have changed to ‘lowland evergreen tropical forest’ for clarity, and also changed this in the ‘Study area’ section.**

line 67. in this part, the authors need introduce more details about primary forest, such as vegetation, species composition.

**RESPONSE: We have referred readers to other studies by the team that outline typical species composition for primary forests in this region which we hope is suitable.**

line 81. I has a confusing about plot size in your study, such as same size between primary forest and fallow forests.

**RESPONSE: Plot size is identical between forests – but the number of replicates differs. We have added the text “In all forests,...” at the beginning of the relevant sentence to clarify this point.**

line 93. “as noted above”, and I don't find above life form classification, such as lianas, ferns, and herbs. Please add this content.

**RESPONSE: The classification according to lifeform has now been noted before the sampling scheme to clarify, and the sentence referred to in this comment has now been removed.**

line 138-141. I don't understand 0.3 ha. The authors mean that fallow forests and primary forest have different sampling plot size.

**RESPONSE: In response to Reviewer 2's comments, Fig 4 (and its legend) has now been removed.**

## Bentuk revisi

The screenshot displays a web browser window with several tabs open. The active tab shows a manuscript review page. The page content is organized into three main sections: Manuscript Information, Editor Decision, and Review Report. The Manuscript Information section lists various dates and counts. The Editor Decision section shows a decision to accept the manuscript in its current form. The Review Report section is currently empty.

Manuscript Information	
Received Date	29 December 2021
Revised Date	1 March 2022
Accepted Date	6 March 2022
Published Date	10 March 2022
Submission to First Decision (Days)	60
Submission to Publication (Days)	70
Round of Revision	2
Size of PDF	2207 KB
Word Count	4781
Page Count	14
Figure Count	5
Table Count	1
Reference Count	58

Editor Decision	
Decision	Accept in current form
Decision Date	4 March 2022

Review Report	
---------------	--

## Revisi dalam bentuk

# Secondary Succession after Slash-and-Burn Cultivation in Papuan Lowland Forest, Indonesia

Agustinus Murdjoko<sup>1,2\*</sup>, Francis Q. Brearley<sup>3</sup>, Antoni Ungirwalu<sup>1</sup>, Dony A. Djitmau<sup>1,2</sup> and Nithanel M. H. Benu<sup>4</sup>

<sup>1</sup> Fakultas Kehutanan, Universitas Papua, Jalan Gunung Salju Amban, Manokwari 98314, Papua Barat, Indonesia.

<sup>2</sup> Pusat Penelitian Keanekaragaman Hayati, Universitas Papua, Jalan Gunung Salju Amban, Manokwari 98314, Papua Barat, Indonesia.

<sup>3</sup> Department of Natural Sciences, Manchester Metropolitan University, Chester Street, Manchester M1 5GD, UK.

<sup>4</sup> Balai Penelitian dan Pengembangan Lingkungan Hidup dan Kehutanan (BP2LHK) Manokwari, Jalan Inamberi-Susweni, Manokwari 98301, Papua Barat, Indonesia.

\* Correspondance: agustinus.murdjoko.papua@gmail.com.

**Abstract:** Papuan forests have been subjected to shifting cultivation for centuries by indigenous people affecting the ecological processes therein; during secondary succession, fallow forests recover naturally. However, the information on ecological succession after swidden practices remains poorly understood in Papuan lowland forests. This study aimed to examine the plant species richness and density of different plant life-forms in fallows of increasing time after slash-and-burn cultivation along with basic edaphic factors. We performed data collection in the northern part of the lowland evergreen tropical forest near Manokwari, West Papua, Indonesia. The sampling consisted of 26 plots distributed in the primary forest ( $n = 6$ ) and in secondary/fallow forests 2-, 4-, 7-, and 9-years after cultivation ( $n = 5$  for each age class). The plant community in primary forest clearly differed from the secondary forests. The plant species richness was about twice as high in primary compared to secondary forests. The density of trees and shrubs increased during succession whereas that of lianas declined. The soil fertility declined in secondary forests, although soil organic matter was greatest two years after swidden and then decreased gradually over time. This research underlined that indigenous swidden practices alter ecological conditions and that secondary forests will take a long time to fully recover to resemble primary forest. Hence, the monitoring of vegetation during the process is necessary to inform conservation programs.

**Keywords:** lifeforms; New Guinea; swidden; tropical secondary forest; species richness

## 1. Introduction

Indonesian New Guinea is part of the largest tropical island containing some of the world's greatest floristic richness [1]. Forests of New Guinea have contributed to people's livelihoods and provided ecosystem services for many centuries [2-5]. However, the tropical forest area is being reduced over time as a result of anthropogenic factors such as agriculture, road expansion, and land-use conversion [6]. Of the human activities in tropical forests of this island, traditional agriculture has been conducted by indigenous people, and has been part of their culture, for generations [3,7,8]. This agricultural system is generally subsistence in nature and is mostly done by slashing-and-burning vegetation and subsequently cultivating the area [9-11]. The processes involved in this practice include: site selection, cutting, clearing, burning, planting, and harvesting, and the fields are generally only cultivated for one or a few years. The ex-cultivation areas are left to

**Citation:** Lastname, F.; Lastname, F.; Lastname, F. Title. *Forests* **2021**, *12*, x. <https://doi.org/10.3390/xxxxx>

Academic Editor: Firstname Lastname

Received: date  
Accepted: date  
Published: date

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2021 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Deleted: vegetation

Deleted: , diversity

Deleted: vegetation diversity and

Deleted: ere

Deleted: hree times higher

Deleted: vegetation



recuperate naturally through secondary succession, and, in many cases, local people return to these fallow forests to implement the next farming cycle after a given fallow period. They apply traditional indicators like the density of vegetation and the presence of certain species in the former areas of cultivation in order to determine when the area is ready to be recut [12]. Many researchers from around the world have shown the effect of shifting cultivation on species richness and diversity and the projection that recovery processes to reach mature forests would take decades or even centuries depending upon the disturbance intensity and other ecological conditions [13-16]. During slash-and-burn cultivation, the burning of vegetation adds nutrients to the soil via ash deposition which is used by the crops. Soil fertility then recovers during the fallow phase [17]. Some authors consider that shifting cultivation in New Guinea is less perturbing to soils due to the low intensity cultivation [18] when compared to other localities but there is little data to test this assertion.

Deleted: re-growth

Ecological studies related to the impact of slash-and-burn cultivation in Papua are infrequent although there are some studies on secondary forests [19,20,21] regrowing after cultivation. Thereby, we collected data in the western part of Papua to contribute to our understanding of the ecological changes post-slash-and-burn cultivation. Here, we hypothesize that plant species richness and density in fallow forests would differ from primary forests but would increase over time since cultivation due to the greater amount of time for the accumulation of species. Moreover, we hypothesize that soil properties would be also altered during the successional process with a general increase in soil fertility during secondary succession as nutrients are returned to the soil from regrowing vegetation.

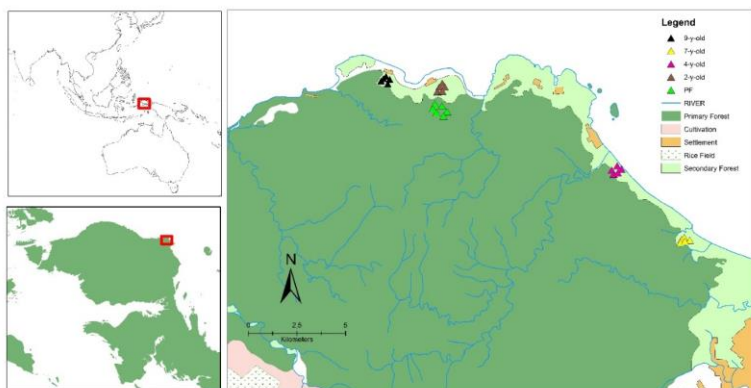
Deleted: vegetation

Deleted: .

## 2. Materials and Methods

### 2.1. Study area

The research was conducted in the northern part of lowland evergreen tropical forest in Manokwari, West Papua province, Indonesia (0°44' S and 133°54' E; Figure 1). While areas away from the coast are largely primary forest with species composition typical of the region [2,22,23], some areas relatively close to coastal villages are used for traditional farming, mainly shifting cultivation, by local communities. Most cultivated areas are found in flat areas with an elevation below 50 m a.s.l. (Figure 2). The annual precipitation is 2640 mm with 235 rainy days per year and at least 100 mm precipitation every month [24]. The soil types are characterized as Entisols, Inceptisols, and Ultisols. The soils in shifting cultivation areas have not had fertilizers applied, so the nutrient inputs are largely derived from decomposition of vegetation debris.



**Figure 1.** Location of the research in lowland evergreen primary forest (PF) and two- to nine-years-old post-swidden fallow forests in coastal areas of north Manokwari, West Papua, Indonesia.



**Figure 2.** Typical field used for swidden cultivation in coastal areas of north Manokwari, West Papua, Indonesia, with a four-year-old fallow forest in the background (Photo credit: Dony A. Djitmau).

## 2.2. Sampling and Data Collection

The secondary forest ages were identified by interviewing the local people who were directly engaged in the swidden practices and by checking satellite images via Google Earth Pro to analyze land cover changes by jumping backward in time through the Historical Imagery menu. All secondary forests were in areas that had only been cultivated once (according to local informants). These were compared with forest that had been relatively undisturbed for decades due to its inaccessibility with no reports of ever being under cultivation as it was in an inappropriate location; we hence call this primary forest. In all forests, we recorded the number of individuals and lifeforms of a range of plant taxa using a series of nested plots. The data on large trees ( $\geq 20$  cm dbh) were collected from 20 m x 30 m plots (plot A). Inside the plot A's, there were subplots of 10 m x 10 m (plot B) for tree poles ( $\geq 10$  cm dbh), of 5 m x 5 m for tree saplings ( $< 10$  cm dbh,  $\geq 1.5$  m tall),

Deleted: T

lianas, ferns, herbs, shrubs and palms/screw palms (plot C), and of 2 m x 2 m for tree seedlings (<1.5 m tall) (plot D) [20]. We placed the plots randomly in each forest type with a minimum distance among plots of at least 25 m. In the primary forest,  $n = 6$  plots; and in fallow forests cultivated 2, 4, 7, and 9 years before sampling,  $n = 5$  for each fallow age. The vouchers for identification were sent to Herbarium Papuaense of Balai Penelitian dan Pengembangan Lingkungan Hidup dan Kehutanan (BP2LHK) Manokwari and Herbarium Manokwariense (MAN) Pusat Penelitian Keanekaragaman Hayati Universitas Papua (PPKH-UNIPA), Manokwari. Conservation status of each species was based on The International Union for Conservation of Nature's Red List of Threatened Species (<https://www.iucnredlist.org/>). A soil sample was collected from each corner and the middle of each of the plot A's and those were mixed to create a composite sample. The soil analyses were conducted in the laboratory of Balai Pengkajian Teknologi Pertanian Yogyakarta, Indonesia where soil organic matter (SOM) was determined by loss-on-ignition and nitrogen (N) by the Kjeldahl method.

**Deleted:** We recorded the number of individuals and taxonomic identification for each taxa and then categorized them based on lifeform as noted above.

### 2.3. Data Analysis

We implemented a species abundance curve or Whittaker plot by plotting the abundance of each species (log-transformed) against its rank following a descending order. The species accumulation was analyzed using sample rarefaction (Mao's tau) [25]. These analyses were conducted using PAST (PAleontological STatistics) version 4.03 [26]. The dendrogram analysis was executed to compare the vegetation communities among contrasting forest ages using the 'vegan' package in R version 3.5.3 [27] in which all lifeforms were grouped together and data from smaller plots multiplied appropriately to give the equivalent area sampled for each lifeform. To determine differences between primary forest and fallow forests, analyses of variance (ANOVA) with subsequent Tukey's tests were performed with  $P < 0.05$  as the threshold using SPSS 16.0.

**Deleted:** To examine the species richness, we calculated the Shannon-Wiener diversity index using the formula  $H' = -\sum_{i=1}^S p_i \ln(p_i)$  where  $H'$  is the Shannon-Wiener index and  $p_i$  is the proportion that each species ( $i$ ) comprises of the total number of individuals in a plot (Shannon, 1948).

**Deleted:** and Diversity

## 3. Results

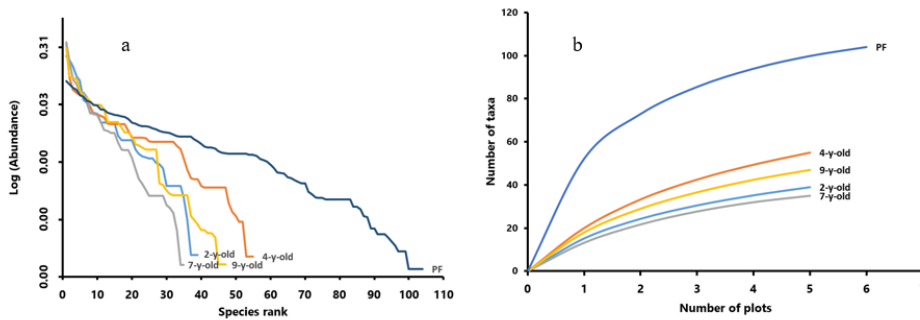
### Species Richness of Vegetation

We grouped the vegetation lifeforms (lianas, ferns, herbs, shrubs, palms/screw palms, tree seedlings, tree saplings, tree poles, and large trees) for the following analyses. In total, we recorded 152 taxa across all the plots that had an area of 1.84 ha. We analyzed species richness using rank-abundance (Figure 3a) and species accumulation (Figure 3b) curves which showed the species number per 0.30 ha (0.36 ha for primary forest) as 100 for the primary forest, 39 for two-year-old, 55 for four-year-old, 35 for seven-year-old, and 47 for nine-year-old fallow forests. Sixty-one species were only found in the primary forest (0.36 ha), 48 were only found in the fallow forests (1.5 ha), and 43 were shared between them. The results of vegetation classification revealed that there were two clear groups of plant communities based on the cluster dendrogram i.e. the primary forest and the fallow forests resulting from swidden activity (Figure 4).

**Deleted:** 2

**Deleted:** 2

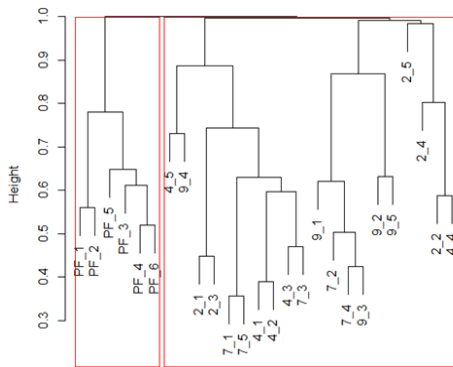
**Deleted:** 3



**Figure 3a.** The rank abundance curve or Whittaker plot implemented by plotting the log-transformed species abundance against species rank for all vegetation lifeforms. **Figure 3b.** Species accumulation curve for all vegetation lifeforms using sample rarefaction (Mao's tau) in fallow forests between two- and nine-years-old and primary forest (PF) in coastal areas of north Manokwari, West Papua, Indonesia.

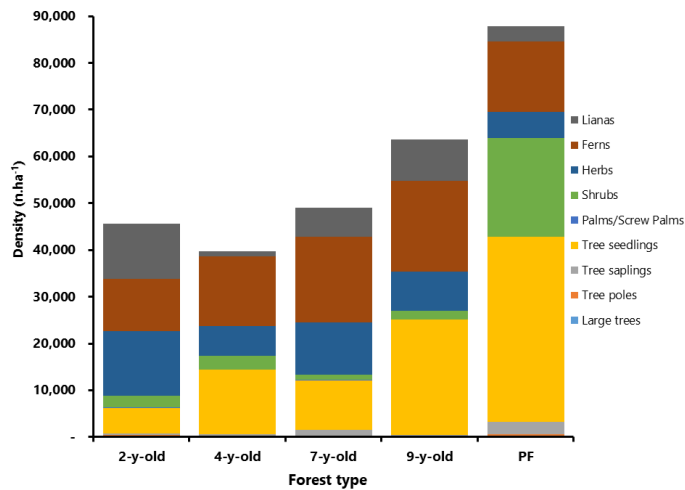
Deleted: 2  
Deleted: 2

The density of individuals of each lifeform was compared among the forest types. Tree seedlings were the most abundant life-form; their density was lowest after swidden agriculture, but then increased over time with increasing age of the fallow forest. The stem density of shrubs, seedlings, saplings, poles, and large trees in the primary forest was significantly greater than in fallow forests while lianas were more abundant in 2-y-old fallow forest than in most other forest ages. The density of herbs and palms/screw palms did not change during succession and that of ferns peaked in older fallows (Figure 5).



**Figure 4.** Grouping of plots in the primary forest (PF) and fallow forests between two- and nine-years-old in coastal areas of north Manokwari, West Papua, Indonesia. All vegetation lifeforms are grouped together and data from smaller plots is multiplied appropriately to give the equivalent area sampled for each lifeform. The number before the dash is the age of the fallow (2 for two-year-old, 4 for four-year-old, 7 for seven-year-old, and 9 for nine-year-old) while the number after the dash is a label for each plot.

Deleted: 3



Lifeform	2-y-old	4-y-old	7-y-old	9-y-old	PF	P-value
Lianas	c	b	ab	abc	ab	0.036
Ferns	ab	a	c	bc	a	0.015
Herbs	a	a	a	a	a	0.37
Shrubs	a	a	a	a	b	0.001
Palms/Screw Palms	a	a	a	a	a	0.40
Tree seedlings	a	a	a	a	b	<0.001
Tree saplings	a	a	a	a	b	<0.001
Tree poles	a	a	a	a	b	<0.001
Large trees	a	abc	ab	c	d	<0.001

**Figure 5.** The mean density of vegetation lifeforms in fallow forests between two- and nine-years-old and primary forest (PF) in coastal areas of north Manokwari, West Papua, Indonesia. For clarity, error bars are omitted. Different lowercase letters in the table show the differences according to ANOVAs and Tukey's tests with  $P < 0.05$ .

Two species were found with Near Threatened (NT) Red List status (*Cryptocarya massoy* and *Intsia bijuga*) and a further three species were classified as Vulnerable (VU) (*Aglaia brassii*, *Anisoptera thurifera* and *Neonauclea acuminata*). Seven species were found that were endemic to New Guinea (according to Cámara-Leret et al. [1]) along with a further three that were found in New Guinea and the Solomon Islands only (according to POWO [28]).

This study also compared the edaphic conditions among forest ages by means of soil organic matter (SOM) and nitrogen (N) as predictor of soil 'fertility'. The SOM was greatest in 2-y-old fallow forest and primary forest while the lowest SOM was found in the 9-y-old fallow forest. The total N showed a similar pattern and was greater in the primary forest than in fallow forests while the 9-y-old fallow forest had the lowest total N among the forest types.

**Table 1.** Mean ( $\pm$ standard error) soil organic matter (SOM) and total nitrogen (N) in fallow forests between two- and nine-years-old, and primary forest (PF) in coastal areas of north Manokwari, West Papua, Indonesia. Different lowercase letters show the differences according to Tukey's tests with  $P < 0.05$ .

Variable	Forest Type				
	2-y-old	4-y-old	7-y-old	9-y-old	PF
SOM (%)	18.40 $\pm$ 4.82 b	8.05 $\pm$ 3.15 ab	9.38 $\pm$ 2.77 ab	3.35 $\pm$ 0.36 a	10.00 $\pm$ 0.81 b

Total N (%)	0.47 ± 0.05 ab	0.41 ± 0.07 ab	0.54 ± 0.05 b	0.32 ± 0.03 a	0.84 ± 0.02 c
-------------	-------------------	-------------------	------------------	------------------	------------------

#### 4. Discussion

The swidden practice was conducted by local people in Papua where they allow forest recovery after cultivation during secondary succession as investigated in other studies in New Guinea [7,18,29,30] as well as numerous other tropical regions around the world [10,16,31-39]. In our study, the dendrogram revealed two main groups containing the primary forest plots in the first group and the fallow forest plots in the other group indicating the similarity of species composition among the fallows. We did not see a particularly clear pattern of change in the forests with age, perhaps due to the generally young age of the fallows. The forest fallows were more dynamic as the re-colonization of certain pioneer species was rapid due to the more open canopy increasing light availability. Increasing light and temperature will also increase the rate of seed germination in this area [38]. In addition, the fallow forests are very near, or surrounded by, either primary forest or older/denser fallow forests allowing colonization of individuals coming from both of these forest types [39,40]. Some ruderal species could be permanently present in the successional stages up to the climax phase, but others will be suppressed by the growth of other vegetation during succession [41-45]. Those species in this research such as *Piper* sp., *Macaranga* species, *Premna corymbosa*, and *Monstera* sp. tended to occupy fallow forests as early successional species.

The change in the vertical structure of the forest also leads to changes in the relative importance of certain life-forms. For example, lianas take advantage of the reduction of canopy layers, so they grow aggressively by overlaying other vegetation. For this reason, lianas were more abundant in the fallow forest, and particularly the youngest, most open forests, where this lifeform has the ability to grow not only in vertical but also horizontal directions. The increase in stem density during succession was largely comprised by trees, and larger trees at later stages of succession. The successional process in fallow forests is highly dynamic compared to primary forests in which the species composition and vertical structure are more static upon reaching the climax stage of succession. However, the time for fallow forests to reach a stable state resembling primary forest will take decades, if not longer [13,37,46]. It is also worth considering that there are alternative pathways in succession due to the influence of factors such as previous agriculture practices, the species present in surrounding forests, and edaphic conditions [47]. It is also important to study a large number of primary forest stands due to high heterogeneity in structure and diversity influenced, at least partly, by the intensity and frequency of disturbances.

The swidden practice changed the vertical structure of vegetation particularly the understory, but in some settings, large trees were left to grow ('remnant trees') because the cutting was conducted using traditional tools and usually by a single family that were not able to remove such large stems. Therefore, in some of the fallow forests, larger remnant trees were recorded, as found in other locations globally [13,48]. These remnant trees will contribute to species richness and carbon stocks in the fallows. The larger trees within fallow forest also play a significant role as putative parent trees to supply seeds which are important in the distribution of seeds into fallow areas [49]. The variety of crops could impact the size and type of area cleared as revealed in other studies [33,36] and, in this study, most local people planted agricultural products such as cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*) which do not require the forest to be totally cleared. Certain species growing in the fallow forests were from cultivation activity such as turmeric (*Curcuma zanthorrhiza*), bananas (*Musa* sp.) and pineapple (*Ananas comosus*) although these comprised only a small contribution as local people only

used certain cultivated plants. Additionally, fruit trees will have been planted in the fallows such as cempedak (*Artocarpus integer*), durian (*Durio zibethinus*), mango (*Mangifera indica*) and rambutan (*Nephelium lappaceum*). The fallows additionally contained introduced and potentially invasive species such as *Ageratum conyzoides* and *Imperata cylindrica* as well as *Piper aduncum* that was also found in primary forest from which it has rarely been reported before [42,50].

Deleted: "

In addition to vegetation changes, soil properties were also impacted by the agricultural practices. The soil nutrients two years after swidden activity were generally similar to primary forest but differed from the rest of the fallow forests. This is likely due to the minimal impact of agricultural practices that conserved soil organic matter and the low-intensity fires (due to moist conditions) prior to agriculture with some cultivators not using fire [21]. The high C:N ratio of the soils in the youngest fallows (38 vs. 16 as mean of all other ages) suggests this was likely due to input of incompletely burned decomposing wood/logs into the soils. The decline in SOM in the 9-year-old fallows also supports this as this wood will have more fully decomposed but the forest has not grown back sufficiently for large inputs of carbon via leaf litter production. Soil nutrient loss could also occur from surface runoff because the fallow forests have less dense canopies, and the forest floor vegetation was not as developed. As reported by many studies, the vegetation cover has an inverse relationship with surface runoff whereby the amount of nutrient loss would be removed from the fallow forests over time [51].

Deleted: and vegetation diversity

Species richness declined in fallows compared to primary forest in line with other studies conducted in New Guinea and more broadly. We found that there were about twice as many species (all taxa) in primary forest as compared to secondary forests. This is similar to other studies in New Guinea [30] that showed there were two to three times more tree species in primary forest than younger (< 9-yr-old) secondary forest. The difference in diversity between the two forest types with respect to tree size was greater for the larger trees. When we re-examined our data for trees  $\geq 10$  cm dbh only then the pattern was more marked that for all taxa together, with about four times as many tree species in primary forest compared to secondary forests (data not shown). Supporting this, another study [21] showed greater richness of trees in primary forest sites compared to formerly cultivated sites but not of non-tree plant life-forms. It is also important to bear in mind that species richness recovers more rapidly than species composition [35] due to the slow growth of many late-successional primary forest specialist trees.

Deleted: ,

Deleted: but the

Although species richness in fallow forests is lower than primary forests, they play a crucial role in local livelihoods. Local people applied the traditional techniques and tools, and the main purpose of their cultivation was to supply food for themselves. This traditional swidden practice has been performed for centuries around the world including in New Guinea [9,52]. Local people also implemented their traditional knowledge that supports the sustainability of the swidden practice, for example, swiddens are not placed close to rivers. They only clear dense forest for cultivation, but the density of vegetation especially larger trees and presence of particular species are traditional indicators of an area ready for recultivation. Furthermore, there are certain areas of primary forests that were purposefully left to grow naturally without disturbance because local people hold the traditional belief that if these primary forests are disturbed, some disaster will happen in this area, therefore they have traditional zones reserved especially for livelihood activities including their swidden practice.

Among Red-Listed plant species, four were only found in primary forest and two were found in both primary forest and fallows. Five out of the seven species endemic to New Guinea (and seven out of the ten endemic to New Guinea and the Solomon Islands) were only found in the primary forest. Therefore, although primary forests are more valuable in terms of species richness and also contain

Deleted: The number of fallow forests would predictably increase with increasing demand for food supply. The re-growth forests would reach a stable condition resembling primary forests, but some researchers uncovered that the species composition of vegetation would not be similar while the vegetation density, basal area, and canopy layers would predictably reach similarity to the primary forest [16,42]. Improved and extended sampling (avoiding pseudo-replication as done here) would help explore this further.



rarer species, fallow forests have some role to play in conservation as some Red-Listed species and endemic species are still found within them. Overall, of the taxa we identified to species level, only 55 % have been assessed for the IUCN Red List indicating that there is still considerable work to be done here.

We recognize that our sampling design is pseudo-replicated, thereby limiting the conclusions that can be drawn. Nevertheless, our study has value in presenting data from a very understudied tropical region that is coming under increasing pressure [1,6,53]. Furthermore, the inclusion of lifeforms that are less often included in traditional inventories of tropical forests (e.g. herbs, ferns) is of value. Generally, the fallows studied here are of a younger age (< 10-years-old) and incorporation of mid- to late-age fallows across a broader landscape (avoiding pseudo-replication) and in larger plots would allow us to determine the trajectory of succession at later stages more effectively.

Government intervention is necessary to support the implementation of traditional knowledge in sustainable forest management [2,54] and the local government should legally concede the traditional zones designed by local people for livelihood activity and delineate customary forests [55]. Whilst the farming method in this area disturbs small areas of forest, these disturbed forests will recuperate over time, but at least they are still covered by vegetation and the land is not converted to other functions such as settlements. Moreover, it is crucial to carry out further anthropological research to document the swidden practice in the context of local traditions. It is also essential to monitor the vegetation in the disturbed forests to record the species diversity and recovery in permanent plots [56] Both of these would clearly support conservation programs in tropical forests of Papua.

**Author Contributions:** Conceptualization, Agustinus Murdjoko; Data curation, Agustinus Murdjoko; Formal analysis, Agustinus Murdjoko and Francis Brearley; Investigation, Agustinus Murdjoko, Antoni Ungirwalu, Dony A Djitmau and Nithanel M H Benu; Methodology, Agustinus Murdjoko, Antoni Ungirwalu and Dony A Djitmau; Project administration, Agustinus Murdjoko; Resources, Agustinus Murdjoko; Supervision, Agustinus Murdjoko and Francis Brearley; Validation, Agustinus Murdjoko and Francis Brearley; Visualization, Agustinus Murdjoko; Writing – original draft, Agustinus Murdjoko and Francis Brearley; Writing – review & editing, Antoni Ungirwalu, Dony A Djitmau and Nithanel M H Benu.

**Funding:** Fakultas Kehutanan, Universitas Papua.

**Acknowledgments:** We thank Fakultas Kehutanan, Universitas Papua and Pemerintah Provinsi Papua Barat for issuing permits.

**Conflicts of Interest:** The authors declare no conflicts of interest.

**Appendix 1.** Plant species list in fallow forests between two- and nine-years-old and primary forest (PF) in coastal areas of north Manokwari, West Papua, Indonesia. The presence of species is symbolized using √. The seven species in bold text are endemic to New Guinea according to Cámara-Leret et al. [1].

Species	Forest type				
	2-y-old	4-y-old	7-y-old	9-y-old	PF
<i>Actinodaphne nitida</i> Teschner					√
<i>Ageratum conyzoides</i> (L.) L.	√				
<i>Aglaia spectabilis</i> (Miq.) S.S.Jain & S.Bennet					√
<i>Aglaia brassii</i> Merr. & L.M.Perry		√			√
<i>Alpinia galanga</i> (L.) Willd.		√	√		

Deleted:



<i>Alpinia</i> sp.					√
<i>Alstonia scholaris</i> (L.) R.Br.	√	√	√	√	√
<i>Ananas comosus</i> (L.) Merr.			√		
<i>Anisoptera thurifera</i> (Blanco) Blume					√
<i>Antiaris toxicaria</i> (J.F.Gmel.) Lesch.					√
<b>Archidendron pachycarpum (Warb.) Dewit</b>					√
<b>Archidendron parviflorum Pulle</b>		√		√	√
<i>Archidendron</i> sp.					√
<i>Areca catechu</i> L.		√		√	
<i>Artocarpus altilis</i> (Parkinson ex F.A.Zorn) Fosberg	√	√	√		√
<i>Artocarpus integer</i> (Thunb.) Merr.				√	
<i>Baccaurea</i> sp.					√
<i>Bidens pilosa</i> L.	√				
<i>Blechnum patersonii</i> (R.Br.) Mett.				√	
<i>Bubbia</i> sp.		√			
<i>Buchanania arborescens</i> (Blume) Blume					√
<i>Calophyllum inophyllum</i> L.					√
<i>Campnosperma coriaceum</i> (Jack) Hallier f.					√
<i>Cananga odorata</i> (Lam.) Hook.f. & Thomson		√	√	√	√
<i>Canarium hirsutum</i> Willd.					√
<i>Celtis latifolia</i> (Blume) Planch.					√
<i>Ceodes umbellifera</i> J.R.Forst. & G.Forst.					√
<i>Cerbera floribunda</i> K.Schum.					√
<i>Chionanthus</i> aff. <i>macrocarpus</i> Blume	√				
<i>Chionanthus</i> sp.					√
<i>Chisocheton ceramicus</i> (Miq.) C.DC.					√
<i>Cocos nucifera</i> L.	√		√		
<i>Coffea</i> sp.					√
<b>Cryptocarya massoy (Oken) Kosterm.</b>					√
<i>Curcuma zanthorrhiza</i> Roxb.				√	
<b>Cynometra browneoides (Harms) Rados.</b>		√			√
<i>Diospyros discolor</i> Willd.			√		√
<i>Dracontomelon dao</i> (Blanco) Merr. & Rolfe	√	√		√	√
<i>Durio zibethinus</i> L.		√		√	
<i>Dysoxylum mollissimum</i> Blume	√	√	√	√	√
<i>Dysoxylum parasiticum</i> (Osbeck) Kosterm.		√			√
<i>Elaeocarpus angustifolius</i> Blume					√
<i>Endospermum moluccanum</i> (Teijsm. & Binn.) Kurz		√		√	√
<i>Falcataria falcata</i> (L.) Greuter & R.Rankin					√
<i>Ficus</i> aff. <i>annulata</i> Blume	√				
<i>Ficus benjamina</i> L.					√
<i>Ficus drupacea</i> Thunb.					√
<i>Ficus macrothyrsa</i> Corner	√	√	√	√	
<i>Ficus racemifera</i> Roxb.					√
<i>Ficus septica</i> Burm.f.		√	√	√	
<i>Ficus variegata</i> Blume		√	√	√	
<i>Ficus</i> sp. 1	√	√	√	√	
<i>Ficus</i> sp. 2		√			√
<i>Ficus</i> sp. 3		√			√
<i>Ficus</i> sp. 4					√
<i>Ficus</i> sp. 5					√

<i>Garcinia</i> sp.					√
<i>Gmelina</i> sp.					√
<i>Gnetum gnemon</i> L.		√	√	√	√
<i>Gonocaryum littorale</i> (Blume) Sleumer					√
Grass A	√	√		√	
<i>Gymnacranthera farquhariana</i> (Wall ex. Hook.f. & Thomson) Warb.	√				√
<i>Harpullia</i> sp.					√
<i>Hibiscus tiliaceus</i> L.	√				
<i>Hibiscus</i> sp.			√		√
<i>Homalium foetidum</i> (Roxb.) Benth.					√
<i>Hopea</i> sp.					√
<i>Horsfieldia irya</i> (Gaertn.) Warb.		√		√	√
<i>Hylodesmum repandum</i> (Vahl) H. Ohashi & R.R. Mill		√		√	
<i>Imperata cylindrica</i> (L.) Raeusch.	√	√	√	√	
<i>Intsia bijuga</i> (Colebr.) Kuntze		√	√		√
<i>Koordersiodendron pinnatum</i> (Blanco) Merr.		√	√	√	√
Lauraceae sp.	√				
<i>Leea aculeata</i> Blume ex Spreng.			√		√
<i>Lepiniopsis ternatensis</i> Valetton	√			√	√
<i>Leucaena leucocephala</i> (Lam.) de Wit		√			
Liana A	√			√	
Liana B				√	
Liana C	√				
Liana D				√	
<i>Litsea ledermannii</i> Teschner					√
<i>Litsea timoriana</i> Span.		√		√	√
<i>Litsea tuberculata</i> (Blume) Boerl.					√
<i>Litsea</i> sp.					√
<i>Lunasia amara</i> Blanco		√			√
<i>Maasia glauca</i> (Hassk.) Mols, Kessler & Rogstad					√
<i>Macaranga</i> sp. 1	√	√	√	√	
<i>Macaranga</i> sp. 2	√	√	√	√	√
<i>Mallotus floribundus</i> (Blume) Müll. Arg.					√
<i>Mangifera indica</i> L.				√	
<i>Maniltoa</i> sp.					√
<i>Mastixiodendron pachyclados</i> (K. Schum.) Melch.		√	√	√	√
<i>Medusanthera laxiflora</i> (Miers) R.A. Howard		√			√
<i>Melicope elleryana</i> (F. Muell.) T.G. Hartley				√	√
<i>Merremia</i> sp.				√	
<i>Mimusops elengi</i> L.					√
<b><i>Monoon polycarpum</i> (Burck) B.Xue &amp; R.M.K.Saunders</b>					√
<i>Monstera</i> sp.	√	√	√	√	
<i>Mucuna novo-guineensis</i> Scheff.	√				√
<i>Musa</i> sp.	√			√	
<i>Myristica fatua</i> Houtt.					√
<i>Myristica</i> aff. <i>gigantea</i> King		√			
<i>Myristica</i> sp.					√
<i>Neolamarckia cadamba</i> (Roxb.) Bosser				√	√
<b><i>Neonauclea acuminata</i> Ridsdale</b>					√

<i>Neonauclea</i> sp.					√
<i>Nepheleum lappaceum</i> L.			√	√	
<i>Nephrolepis</i> sp.	√	√	√	√	√
<i>Ochrosia</i> sp.					√
<i>Octomeles sumatrana</i> Miq.	√		√	√	√
Orchidaceae sp.		√			
<i>Ormosia calavensis</i> Azaola					√
<i>Ormosia</i> sp.					√
<i>Osmoxylon</i> aff. <i>globulare</i> Philipson	√	√			
<i>Palaquium amboinense</i> Burck		√			√
<i>Palaquium</i> sp.		√	√	√	
<i>Pandanus tectorius</i> Parkinson ex Du Roi	√				
<i>Pimelodendron amboinicum</i> Hassk.		√			√
<i>Piper aduncum</i> L.	√	√	√	√	√
<i>Piper</i> sp.	√				
<i>Pipturus argenteus</i> (G.Forst.) Wedd.					√
<i>Polyalthia</i> sp. 1					√
<i>Polyalthia</i> sp. 2					√
<i>Pometia pinnata</i> J.R.Forst. & G.Forst.		√		√	√
<i>Premna corymbosa</i> Rottler & Willd.	√	√	√	√	
<i>Prunus arborea</i> (Blume) Kalkman		√			√
<i>Pterygota horsfieldii</i> (R.Br.) Kosterm.				√	√
<i>Pterygota</i> sp.					√
<i>Rhus taiensis</i> Guill.		√			√
<i>Rhus</i> sp.					√
Sapindaceae sp.					√
<b><i>Semecarpus papuanus</i> Lauterb.</b>					√
<i>Spathiostemon javensis</i> Blume		√	√		√
<i>Spondias dulcis</i> Parkinson	√	√	√		
<i>Stachytarpheta jamaicensis</i> (L.) Vahl	√				
<i>Sterculia</i> aff. <i>elongata</i> Ridl.		√	√		
<i>Sterculia macrophylla</i> Vent.		√		√	√
<i>Sterculia parkinsonii</i> F.Muell.					√
<i>Sterculia urceolata</i> Sm.		√	√		√
<i>Syzygium</i> sp.		√			√
<i>Tectaria</i> aff. <i>zollingeri</i> (Kurz) Holttum	√				√
<i>Teijsmanniodendron bogoriense</i> Koord.					√
Thelypteridiaceae sp.	√	√	√	√	
<i>Timonius timon</i> (Spreng.) Merr.					√
<i>Timonius</i> sp.					√
Tree A	√				
Tree B	√	√	√		
<i>Uncaria</i> sp. 1					√
<i>Uncaria</i> sp. 2					√
<i>Vigna trilobata</i> L. (Verdc.)				√	
<i>Vitex</i> sp.		√	√	√	
<i>Ziziphus</i> sp.					√

## References

1. Cámara-Leret, R.; Frodin, D.G.; Adema, F.; Anderson, C.; Appelhans, M.S.; Argent, G.; Guerrero, S.A.; Ashton, P.S.; Baker, W.J.; Barfod, A.S.; Barrington, D.; Borosova, R.; Bramley, G.L.C.; Briggs, M.; Buerki, S.; Cahen, D.; Callmander, M.W.; Cheek, M.R.; Chen, C.-W.; Conn, B.J.; Coode, M.J.E.; Darbyshire, I.; Dawson, S.; Dransfield, J.; Drinkell, C.;

- Duyffes, B.; Ebihara, A.; Ezedin, Z.; Fu, L.-F.; Gideon, O.; Girmansyah, D.; Govaerts, R.; Fortune-Hopkins, H.; Hassemer, G.; Hay, A.; Heatubun, C.D.; Hind, D.J.N.; Hoch, P.; Homot, P.; Hovenkamp, P.; Hughes, M.; Jebb, M.H.P.; Jennings, L.; Jimbo, T.; Kessler, M.; Kiew, R.; Knapp, S.; Lamei, P.; Lehnert, M.; Lewis, G.P.; Linder, H.P.; Lindsay, S.; Low, Y.W.; Lucas, E.; Mancera, J.P.; Monro, A.K.; Moore, A.; Middleton, D.J.; Nagamasu, H.; Newman, M.F.; Nic Lughadha, E.; Melo, P.H.A.; Ohlsen, D.J.; Pannell, C.M.; Parris, B.; Pearce, L.; Penneys, D.S.; Perrie, L.R.; Petoe, P.; Poulsen, A.D.; Prance, G.T.; Quakenbush, J.P.; Raes, N.; Rodda, M.; Rogers, Z.S.; Schuitman, A.; Schwartsburd, P.; Scotland, R.W.; Simmons, M.P.; Simpson, D.A.; Stevens, P.; Sundue, M.; Testo, W.; Trias-Blasi, A.; Turner, I.M.; Utteridge, T.M.A.; Walsingham, L.; Webber, B.L.; Wei, R.; Weiblen, G.D.; Weigend, M.; Weston, P.; de Wilde, W.; Wilkie, P.; Wilmot-Dear, C.M.; Wilson, H.P.; Wood, J.R.L.; Zhang, L.-B.; van Welzen, P.C. New Guinea has the world's richest island flora. *Nature* **2020**, *584*, 579–583.
2. Murdjoko, A.; Ungirwalu, A.; Mardiyadi, Z.; Tokede, M.J.; Djitmau, D.A.; Benu, N.M.H. Floristic composition of Buah Hitam habitats in lowland tropical mixed forest of West Papua, Indonesia. *Florest. Ambient.* **2021**, *28*, e20210042.
  3. Ungirwalu, A.; Awang, S.A.; Murdjoko, A. Model aplikasi agroforestri tumbuhan Buah Hitam (*Haplolobus monticola* Husson) berbasis pengetahuan lokal etnis Wandamen-Papua: prospek pengembangan perhutanan sosial di Papua. In *Prosiding Seminar Nasional Silvikultur II: Pembaruan Silvikultur untuk Mendukung Pemulihan Fungsi Hutan menuju Ekonomi Hijau, Universitas Gadjah Mada, Yogyakarta, 28 Agustus 2014*; Prehaten, D.; Syahbudin, A.; Andiyani, R.D., Eds.; 2014; pp. 268–274.
  4. Vallet, A.; Locatelli, B.; Levrel, H.; Brenes Pérez, C.; Imbach, P.; Estrada Carmona, N.; Manlay, R.; Oszwald, J., 2016. Dynamics of ecosystem services during forest transitions in Reventazón, Costa Rica. *PLoS One* **2016**, *11*, e0158615.
  5. Wakhidah, A.Z.; Chikmawati, T.; Purwanto, Y. Homegarden ethnobotany of two Saibatin villages in Lampung, Indonesia: species diversity, uses, and values. *For. Soc.* **2020**, *4*, 338–357. <https://doi.org/10.24259/fs.v4i2.9720>
  6. Gaveau, D.L.A.; Santos, L.; Locatelli, B.; Salim, M.A.; Husnayaen, H.; Meijaard, E.; Heatubun, C.D.; Sheil, D. Forest loss in Indonesian New Guinea (2001–2019): trends, drivers and outlook. *Biol. Conserv.* **2021**, *261*, 109225.
  7. Manner, H.I. Ecological succession in new and old swiddens of montane Papua New Guinea. *Hum. Ecol.* **1981**, *9*, 359–377.
  8. Ungirwalu, A.; Awang, S.A.; Suryanto, P.; Maryudi, A. The ethno-techno-conservation approach in the utilization of Black Fruit (*Haplolobus* sp.) by the Wandamen ethnic of Papua, Indonesia. *Biodiversitas* **2017**, *18*, 1336–1343.
  9. Heinemann, A.; Mertz, O.; Frolking, S.; Christensen, A.E.; Hurni, K.; Sedano, F.; Chini, L.P.; Sahajpal, R.; Hansen, M.; Hurtt, G. A global view of shifting cultivation: recent, current, and future extent. *PLoS One* **2017**, *12*, e0184479.
  10. Mukul, S.A.; Herbohn, J. The impacts of shifting cultivation on secondary forests dynamics in tropics: a synthesis of the key findings and spatio temporal distribution of research. *Environ. Sci. Policy* **2016**, *55*, 167–177.
  11. Schmidt-Vogt, D.; Leisz, S.J.; Mertz, O.; Heinemann, A.; Thiha, T.; Messerli, P.; Epprecht, M.; Cu, P.V.; Chi, V.K.; Hardiono, M.; Dao, T.M. 2009. An assessment of trends in the extent of swidden in Southeast Asia. *Hum. Ecol.* **2009**, *37*, 269–280.
  12. Angelsen, A. Shifting cultivation and “deforestation”: a study from Indonesia. *World Dev.* **1995**, *23*, 1713–1729.
  13. Brearley, F.Q.; Prajadinata, S.; Kidd, P.S.; Proctor, J.; Suriantata. Structure and floristics of an old secondary rain forest in Central Kalimantan, Indonesia, and a comparison with adjacent primary forest. *For. Ecol. Manage.* **2004**, *195*, 385–397.
  14. Ding, Y.; Zang, R.; Liu, S.; He, F.; Letcher, S.G. Recovery of woody plant diversity in tropical rain forests in southern China after logging and shifting cultivation. *Biol. Conserv.* **2012**, *145*, 225–233.
  15. Fujiki, S.; Nishio, S.; Okada, K.-i.; Nais, J.; Kitayama, K. Plant communities and ecosystem processes in a succession-altitude matrix after shifting cultivation in the tropical montane forest zone of northern Borneo. *J. Trop. Ecol.* **2017**, *33*, 33–49.
  16. Villa, P.M.; Martins, S.V.; Nolasco de Oliveira Neto, S.; Rodrigues, A.C.; Martorano, L.G.; Delgado Monsanto, L.; Cancio, N.M.; Gastauer, M. Intensification of shifting cultivation reduces forest resilience in the northern Amazon. *For. Ecol. Manage.* **2018**, *430*, 312–320.
  17. Ribeiro Filho, A. A.; Adams, C.; Murrieta, R. S. S. 2013. The impacts of shifting cultivation on tropical forest soil: a review. *Bol. Mus. Para. Emílio Goeldi Cienc. Hum. Belém* **2013**, *8*, 693–727.
  18. Kukla, J.; Whitfield, T.J.S.; Cajthaml, T.; Baldrian, P.; Veselá-Šimáčková, H.; Novotný, V.; Frouz, J. The effect of traditional slash-and-burn agriculture on soil organic matter, nutrient content, and microbiota in tropical ecosystems of Papua New Guinea. *Land. Degrad. Dev.* **2019**, *30*, 166–177.
  19. Polak, M. The botanical diversity in the Ayawasi area, Irian Jaya, Indonesia. *Biodivers. Conserv.* **2000**, *9*, 1345–1375.
  20. Sheil, D.; Boissière, M.; van Heist, M.; Rachman, I.; Basuki, I.; Wan, M.; Watopa, Y. The floodplain forests of the Mamberamo Basin, Papua, Indonesia (western New Guinea): vegetation, soils, and local use. *Forests* **2021**, *12*, 1790.
  21. van Heist, M.; Sheil, D.; Rachman, I.; Gusbager, P.; Raweyai, C.; Yoteni, H. The forests and related vegetation of Kwerba, on the Foja foothills, Mamberamo, Papua (Indonesian New Guinea). *Blumea* **2010**, *55*, 153–161.
  22. Robiansyah, I. Diversity and biomass of tree species in Tambrau, West Papua, Indonesia. *Biodiversitas* **2018**, *19*, 377–386.

23. Tawer, P.; Maturbongs, R.; Murdjoko, A.; Jitmau, M.; Djitmau, D.; Siburian, R.; Ungirwalu, A.; Wanma, A.; Mardiyadi, Z.; Wanma, I.; Rumatora, A.; Mofu, W.; Sinery, A.; Fatem, S.; Benu, N.; Kuswandi, R.; Lekitoo, K.; Khayati, L.; Tambing, J. 2021. Vegetation dynamic post-disturbance in tropical rain forest of Bird's Head Peninsula of West Papua, Indonesia. *Ann. Silvic. Res.* **2021**, *46*, 48–58.
24. Badan Pusat Statistik Kabupaten Manokwari. *Kabupaten Manokwari Dalam Angka 2021*; Badan Pusat Statistik Kabupaten Manokwari; Manokwari, Indonesia, 2021; p 13.
25. Colwell, R.K.; Mao, C.X.; Chang, J. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology* **2004**, *85*, 2717–2727.
26. Hammer, Ø.; Harper, D.A.; Ryan, P.D. 2001. PAST: paleontological statistics software package for education and data analysis. *Palaeontol. Electron.* **4**, 4.
27. Oksanen, A. J.; Blanchet, F.G.; Friendly, M.; Kindt, R.; Legendre, P.; McGlinn, D.; Minchin, P.R.; O'Hara, R.B.; Simpson, G.L.; Solymos, P.; Stevens, M.H.H.; Szoecs, E. Package 'vegan' Community ecology package. Version 2.5-6. **2019**. Available online: <https://cran.r-project.org/web/packages/vegan/index.html>.
28. Plants of the World Online. Available online: <http://www.plantsoftheworldonline.org/> (accessed on 11 October 2020).
29. Sillitoe, P.; Shiel, R.S. Soil fertility under shifting and semi-continuous cultivation in the Southern Highlands of Papua New Guinea. *Soil Use Manag.* **1999**, *15*, 49–55.
30. Whitfield, T.J.S.; Lasky, J.R.; Damas, K.; Sosanika, G.; Molem, K.; Montgomery, R.A. Species richness, forest structure, and functional diversity during succession in the New Guinea lowlands. *Biotropica* **2014**, *46*, 538–548.
31. Hattori, D.; Kenzo, T.; Shirahama, T.; Harada, Y.; Kendawang, J.J.; Ninomiya, I.; Sakurai, K. Degradation of soil nutrients and slow recovery of biomass following shifting cultivation in the heath forests of Sarawak, Malaysia. *For. Ecol. Manage.* **2019**, *432*, 467–477.
32. Klanderud, K.; Mbolatiana, H.Z.H.; Vololomboahangy, M.N.; Radimbison, M.A.; Roger, E.; Totland, Ø.; Rajeriarison, C. Recovery of plant species richness and composition after slash-and-burn agriculture in a tropical rainforest in Madagascar. *Biodivers. Conserv.* **2010**, *19*, 187–204.
33. Pereira Cabral Gomes, E.; Sugiyama, M.; Fernandes de Oliveira Junior, C.J.; Medeiros Prado, H.; Ribeiro Filho, A.A.; Adams, C. Post-agricultural succession in the fallow swiddens of southeastern Brazil. *For. Ecol. Manage.* **2020**, *475*, 118398.
34. Siahaya, M.E.; Hutauruk, T.R.; Aponno, H.S.E.S.; Hatulesila, J.W.; Mardhanie, A.B. Traditional ecological knowledge on shifting cultivation and forest management in east Borneo, Indonesia. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manage.* **2016**, *12*, 14–23.
35. Rozendaal, D.M.A.; Bongers, F.; Aide, T.M.; Alvarez-Dávila, E.; Ascarrunz, N.; Balvanera, P.; Becknell, J.M.; Bentos, T. V.; Brancalion, P.H.S.; Cabral, G.A.L.; Calvo-Rodríguez, S.; Chave, J.; César, R.G.; Chazdon, R.L.; Condit, R.; Dallinga, J.S.; de Almeida-Cortez, J.S.; de Jong, B.; de Oliveira, A.; Denslow, J.S.; Dent, D.H.; DeWalt, S.J.; Dupuy, J.M.; Durán, S.M.; Dutrieux, L.P.; Espirito-Santo, M.M.; Fandino, M.C.; Fernandes, G.W.; Finegan, B.; García, H.; Gonzalez, N.; Moser, V.G.; Hall, J.S.; Hernández-Stefanoni, J.L.; Hubbell, S.P.; Jakovac, C.C.; Hernández, A.J.; Junqueira, A.B.; Kennard, D.; Larpin, D.; Letcher, S.G.; Licona, J.C.; Lebrija-Trejos, E.; Marín-Spiotta, E.; Martínez-Ramos, M.; Massoca, P.E.S.; Meave, J.A.; Mesquita, R.C.G.; Mora, F.; Müller, S.C.; Muñoz, R.; Nolasco de Oliveira Neto, S.; Norden, N.; Nunes, Y.R.F.; Ochoa-Gaona, S.; Ortiz-Malavassi, E.; Ostertag, R.; Peña-Claros, M.; Pérez-García, E.A.; Piotta, D.; Powers, J.S.; Aguilar-Cano, J.; Rodríguez-Buritica, S.; Rodríguez-Velázquez, J.; Romero-Romero, M.A.; Ruiz, J.; Sanchez-Azofeifa, A.; Silva de Almeida, A.; Silver, W.L.; Schwartz, N.B.; Thomas, W.W.; Toledo, M.; Uriarte, M.; de Sá Sampaio, E.V.; van Breugel, M.; van Der Wal, H.; Martins, S.V.; Veloso, M.D.M.; Vester, H.F.M.; Vicentini, A.; Vieira, I.C.G.; Villa, P.M.; Williamson, G.B.; Zanini, K.J.; Zimmerman, J.; Poorter, L. 2019. Biodiversity recovery of Neotropical secondary forests. *Sci. Adv.* **2019**, *5*, eaau3114.
36. Tongkoom, K.; Marohn, C.; Piepho, H.P.; Cadisch, G. Ecosystem recovery indicators as decision criteria on potential reduction of fallow periods in swidden systems of northern Thailand. *Ecol. Indic.* **2018**, *95*, 554–567.
37. Villa, P.M.; Martins, S.V.; Nolasco de Oliveira Neto, S.; Rodrigues, A.C.; Safar, N.V.H.; Delgado Monsanto, L.; Cancio, N.M.; Ali, A. Woody species diversity as an indicator of the forest recovery after shifting cultivation disturbance in the northern Amazon. *Ecol. Indic.* **2018**, *95*, 687–694.
38. Lu, X.; Zang, R.; Ding, Y.; Letcher, S.G.; Long, W.; Huang, Y. Variations and trade-offs in functional traits of tree seedlings during secondary succession in a tropical lowland rain forest. *Biotropica* **2014**, *46*, 404–414.
39. Hawes, J.E.; Vieira, I.C.G.; Magnago, L.F.S.; Berenguer, E.; Ferreira, J.; Aragão, L.E.O.C.; Cardoso, A.; Lees, A.C.; Lennox, G.D.; Tobias, J.A.; Waldron, A.; Barlow, J. A large-scale assessment of plant dispersal mode and seed traits across human-modified Amazonian forests. *J. Ecol.* **2020**, *108*, 1373–1385.
40. Murdjoko, A.; Jitmau, M.M.; Djitmau, D.A.; Siburian, R.H.S.; Ungirwalu, A.; Wanma, A.O.; Mardiyadi, Z.; Rumatora, A.; Mofu, W.Y.; Sineri, A.S.; Fatem, S.M.; Worabai, D.; May, N.L.; Tokede, M.J.; Warmetan, H.; Wanggai, C.B.; Wanma, J.F.; Sirami, E.V.; Paembonan, J.B.; Unenor, E.; Kuswandi, R.; Lekitoo, K.; Khayati, L.; Benu, N.M.H.; Tambing, J.; Saragih, A.B.S. Heterospecific and conspecific associations of trees in lowland tropical forest of New Guinea. *Biodiversitas* **2020**,

Deleted: <#>¶

21, 4405–4418.

41. Chong, K.Y.; Corlett, R.T.; Nuñez, M.A.; Chiu, J.H.; Courchamp, F.; Dawson, W.; Kuebbing, S.; Liebhold, A.M.; Padmanaba, M.; Souza, L.; Andersen, K.M.; Fei, S.; Lee, B.P.Y.-H.; Lum, S.; Luskin, M.S.; Ngo, K.M.; Wardle, D.A. Are terrestrial biological invasions different in the tropics? *Annu. Rev. Ecol. Evol. Syst.* **2020**, *52*, 291–314.
42. Hartemink, A.E. The invasive shrub *Piper aduncum* in Papua New Guinea: a review. *J. Trop. For. Sci.* **2010**, *22*, 202–213.
43. Kuswandi, R.; Murdjoko, A. Population structures of four tree species in logged-over tropical forest in south Papua, Indonesia: an integral projection model approach. *Indones. J. For. Res.* **2015**, *2*, 93–101.
44. Murdjoko, A. Recuperation of non-commercial trees in logged forest in southern Papua, Indonesia. *J. Manaj. Hutan Trop.* **2013**, *19*, 94–102.
45. Murdjoko, A.; Marsono, D.; Sadono, R.; Hadisusanto, S. Population dynamics of *Pometia* for the period of post-selective logging in tropical rainforest, southern Papua, Indonesia. *Biosaintifika* **2016**, *8*, 321–330.
46. McNamara, S.; Erskine, P.D.; Lamb, D.; Chantalangsy, L.; Boyle, S. Primary tree species diversity in secondary fallow forests of Laos. *For. Ecol. Manage.* **2012**, *281*, 93–99.
47. [Jakovac, C.C.; Junqueira, A.B.; Crouzeilles, R.; Peña-Claros, M.; Mesquita, R.C.G.; Bongers, F. The role of land-use history in driving successional pathways and its implications for the restoration of tropical forests \*Biol. Rev.\* \*\*2021\*\*, \*96\*, 1114–11134.](#)
48. Cuni Sanchez, A.; Lindsell, J.A. The role of remnant trees in carbon sequestration, vegetation structure and tree diversity of early succession regrowing fallows in eastern Sierra Leone. *Afr. J. Ecol.* **2017**, *55*, 188–197.
49. Sandor, M.E.; Chazdon, R.L. Remnant trees affect species composition but not structure of tropical second-growth forest. *PLoS One* **2014**, *9*, e83284.
50. Lepš, J.; Novotný, V.; Čížek, L.; Molem, K.; Isua, B.; Boen, W.; Kutil, R.; Auga, J.; Kasbal, M.; Manumbor, M.; Hiuk, S. Successful invasion of the Neotropical species *Piper aduncum* in rain forests in Papua New Guinea. *Appl. Veg. Sci.* **2002**, *5*, 255–262.
51. Labrière, N.; Locatelli, B.; Laumonier, Y.; Freycon, V.; Bernoux, M., 2015. Soil erosion in the humid tropics: a systematic quantitative review. *Agric. Ecosyst. Environ.* **2015**, *203*, 127–139.
52. Li, P.; Feng, Z.; Jiang, L.; Liao, C.; Zhang, J. A review of swidden agriculture in Southeast Asia. *Remote Sens.* **2014**, *6*, 1654–1683.
53. [Rochmyaningsih, D. Massive road project threatens New Guinea's biodiversity. \*Science\* \*\*2021\*\*, \*374\*, 246–247.](#)
54. Cámara-Leret, R.; Dennehy, Z. Indigenous knowledge of New Guinea's useful plants: a review. *Econ. Bot.* **2019**, *73*, 405–415.
55. [Ungirwalu, A.; Awang, S.A.; Runtuboi, Y.Y.; Peday, M.Y.; Marwa, I.; Maitar, B.; Murdjoko, A.; Fatem, S.M. Customary forests in West Papua: contestation of desires or needs? \*For. Soc.\* \*\*2021\*\*, \*5\*, 365–375.](#)
56. [Brearley, F.O.; Adinugroho, W.C.; Cámara-Leret, R.; Krisnawati, H.; Ledo, A.; Oie, L.; Smith, T.E.L.; Aini, F.; Garnier, F.; Lestari, N.S.; Mansur, M.; Murdjoko, A.; Oktarita, S.; Soraya, E.; Tata, H.L.; Tiryana, T.; Trethowan, L.A.; Wheeler, C.E.; Abdullah, M.; Aswandi; Buckley, B.I.W.; Cantarello, E.; Dunggio, L.; Gunawan, H.; Heatubun, C.D.; Dwi Arini, D.I.; Istomo; Komar, T.E.; Kuswandi, R.; Mutaqien, Z.; Pangala, S.R.; Ramadhanil; Prayoto; Puspanti, A.; Oirom, M.A.; Rozak, A.H.; Sadili, A.; Samsuodin, I.; Sulistyawati, E.; Sundari, S.; Sutomo; Tampubolon, A.P.; Webb, C.O. Opportunities and challenges for an Indonesian forest monitoring network \*Ann. For. Sci.\* \*\*2019\*\*, \*76\*, 54.](#)

1.

**Deleted:** <#>Shannon, C.E., 1948. A mathematical theory of communication. *Bell Syst. Tech. J.* **27**, 623–656. <https://doi.org/10.1145/584091.584093>

**Deleted:** <#>¶

# Keputusan akhir journal

The screenshot displays a web interface for a journal submission system. The browser's address bar shows the URL: `suay.mdpk.com/user/manuscripts/review_info/640a5903c88006391c0fa3209492168`. The page content is organized into several sections:

- Submission Details:** A list of key dates and metrics including Received Date (29 December 2021), Revised Date (1 March 2022), Accepted Date (6 March 2022), and Published Date (10 March 2022). It also lists counts for Submission to First Decision (60), Submission to Publication (70), Round of Revision (2), Size of PDF (2207 KB), Word Count (4781), Page Count (14), Figure Count (5), Table Count (1), and Reference Count (58).
- Editor Decision:** A section with a dark header containing the text "Decision: [Accept on cleared form](#)" and "Decision Date: 4 March 2022".
- Reviewer Report:** A section with a dark header listing three reviewers, each with a link to their report: "Reviewer 1: [Review Report \(Round 1\)](#)", "Reviewer 2: [Review Report \(Round 1\)](#)", and "Reviewer 3: [Review Report \(Round 1\)](#)".

The interface includes a taskbar at the bottom with several open PDF files (e.g., "forests-13-00434 (6).pdf") and a system tray showing the date and time as 18:23 on 20/12/2022.

Hasil revisi diterima

Article

## Secondary Succession after Slash-and-Burn Cultivation in Papuan Lowland Forest, Indonesia

Agustinus Murdjoko<sup>1,2,\*</sup>, Francis Q. Brearley<sup>3</sup>, Antoni Ungirwalu<sup>1</sup>, Dony A. Djitmau<sup>1,2</sup> and Nithanel M. H. Benu<sup>4</sup>

<sup>1</sup> Fakultas Kehutanan, Universitas Papua, Jalan Gunung Salju Amban, Manokwari 98314, Papua Barat, Indonesia.

<sup>2</sup> Pusat Penelitian Keanekaragaman Hayati, Universitas Papua, Jalan Gunung Salju Amban, Manokwari 98314, Papua Barat, Indonesia.

<sup>3</sup> Department of Natural Sciences, Manchester Metropolitan University, Chester Street, Manchester M1 5GD, UK.

<sup>4</sup> Balai Penelitian dan Pengembangan Lingkungan Hidup dan Kehutanan (BP2LHK) Manokwari, Jalan Inamberi-Susweni, Manokwari 98301, Papua Barat, Indonesia.

\*Correspondence: agustinus.murdjoko.papua@gmail.com.

**Abstract:** Papuan forests have been subjected to shifting cultivation for centuries by indigenous people affecting the ecological processes therein; during secondary succession, fallow forests recover naturally. However, the information on ecological succession after swidden practices remains poorly understood in Papuan lowland forests. This study aimed to examine the plant species richness and density of different plant life-forms in fallows of increasing time after slash-and-burn cultivation along with basic edaphic factors. We performed data collection in the northern part of the lowland evergreen tropical forest near Manokwari, West Papua, Indonesia. The sampling consisted of 26 plots distributed in the primary forest ( $n = 6$ ) and in secondary/fallow forests 2-, 4-, 7-, and 9-years after cultivation ( $n = 5$  for each age class). The plant community in primary forest clearly differed from the secondary forests. The plant species richness was about twice as high in primary compared to secondary forests. The density of trees and shrubs increased during succession whereas that of lianas declined. The soil fertility declined in secondary forests, although soil organic matter was greatest two years after swidden and then decreased gradually over time. This research underlined that indigenous swidden practices alter ecological conditions and that secondary forests will take a long time to fully recover to resemble primary forest. Hence, the monitoring of vegetation during the process is necessary to inform conservation programs.

**Keywords:** lifeforms; New Guinea; swidden; tropical secondary forest; species richness

**Citation:** Lastname, F.; Lastname, F.; Lastname, F. Title. *Forests* **2021**, *12*, x. <https://doi.org/10.3390/xxxxx>

Academic Editor: Firstname Lastname

Received: date  
Accepted: date  
Published: date

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2021 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

### 1. Introduction

Indonesian New Guinea is part of the largest tropical island containing some of the world's greatest floristic richness [1]. Forests of New Guinea have contributed to people's livelihoods and provided ecosystem services for many centuries [2-5]. However, the tropical forest area is being reduced over time as a result of anthropogenic factors such as agriculture, road expansion, and land-use conversion [6]. Of the human activities in tropical forests of this island, traditional agriculture has been conducted by indigenous people, and has been part of their culture, for generations [3,7,8]. This agricultural system is generally subsistence in nature and is mostly done by slashing-and-burning vegetation and subsequently



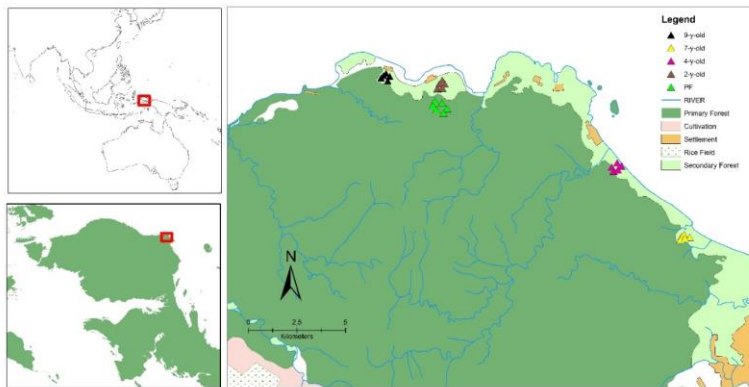
cultivating the area [9-11]. The processes involved in this practice include: site selection, cutting, clearing, burning, planting, and harvesting, and the fields are generally only cultivated for one or a few years. The ex-cultivation areas are left to recuperate naturally through secondary succession, and, in many cases, local people return to these fallow forests to implement the next farming cycle after a given fallow period. They apply traditional indicators like the density of vegetation and the presence of certain species in the former areas of cultivation in order to determine when the area is ready to be recut [12]. Many researchers from around the world have shown the effect of shifting cultivation on species richness and diversity and the projection that recovery processes to reach mature forests would take decades or even centuries depending upon the disturbance intensity and other ecological conditions [13-16]. During slash-and-burn cultivation, the burning of vegetation adds nutrients to the soil via ash deposition which is used by the crops. Soil fertility then recovers during the fallow phase [17]. Some authors consider that shifting cultivation in New Guinea is less perturbing to soils due to the low intensity cultivation [18] when compared to other localities but there is little data to test this assertion.

Ecological studies related to the impact of slash-and-burn cultivation in Papua are infrequent although there are some studies on secondary forests [19,20,21] regrowing after cultivation. Thereby, we collected data in the western part of Papua to contribute to our understanding of the ecological changes post-slash-and-burn cultivation. Here, we hypothesize that plant species richness and density in fallow forests would differ from primary forests but would increase over time since cultivation due to the greater amount of time for the accumulation of species. Moreover, we hypothesize that soil properties would be also altered during the successional process with a general increase in soil fertility during secondary succession as nutrients are returned to the soil from regrowing vegetation.

## **2. Materials and Methods**

### *2.1. Study area*

The research was conducted in the northern part of lowland evergreen tropical forest in Manokwari, West Papua province, Indonesia (0°44' S and 133°54' E; Figure 1). While areas away from the coast are largely primary forest with species composition typical of the region [2,22,23], some areas relatively close to coastal villages are used for traditional farming, mainly shifting cultivation, by local communities. Most cultivated areas are found in flat areas with an elevation below 50 m a.s.l. (Figure 2). The annual precipitation is 2640 mm with 235 rainy days per year and at least 100 mm precipitation every month [24]. The soil types are characterized as Entisols, Inceptisols, and Ultisols. The soils in shifting cultivation areas have not had fertilizers applied, so the nutrient inputs are largely derived from decomposition of vegetation debris.



**Figure 1.** Location of the research in lowland evergreen primary forest (PF) and two- to nine-years-old post-swidden fallow forests in coastal areas of north Manokwari, West Papua, Indonesia.



**Figure 2.** Typical field used for swidden cultivation in coastal areas of north Manokwari, West Papua, Indonesia, with a four-year-old fallow forest in the background (Photo credit: Dony A. Djitmau).

## 2.2. Sampling and Data Collection

The secondary forest ages were identified by interviewing the local people who were directly engaged in the swidden practices and by checking satellite images via Google Earth Pro to analyze land cover changes by jumping backward in time through the Historical Imagery menu. All secondary forests were in areas that had only been cultivated once (according to local informants). These were compared with forest that had been relatively undisturbed for decades due to its inaccessibility with no reports of ever being under cultivation as it was in an inappropriate location; we hence call this primary forest. In all forests, we recorded the number of individuals and lifeforms of a range of plant taxa using a series of nested plots. The data on large trees ( $\geq 20$  cm dbh) were collected from 20 m x 30 m plots (plot A). Inside the plot A's, there were subplots of 10 m x 10 m (plot B) for tree poles ( $\geq 10$  cm dbh), of 5 m x 5 m for tree saplings ( $< 10$  cm dbh,  $\geq 1.5$  m tall),

lianas, ferns, herbs, shrubs and palms/screw palms (plot C), and of 2 m x 2 m for tree seedlings (<1.5 m tall) (plot D) [20]. We placed the plots randomly in each forest type with a minimum distance among plots of at least 25 m. In the primary forest,  $n = 6$  plots; and in fallow forests cultivated 2, 4, 7, and 9 years before sampling,  $n = 5$  for each fallow age. The vouchers for identification were sent to Herbarium Papuaense of Balai Penelitian dan Pengembangan Lingkungan Hidup dan Kehutanan (BP2LHK) Manokwari and Herbarium Manokwariense (MAN) Pusat Penelitian Keanekaragaman Hayati Universitas Papua (PPKH-UNIPA), Manokwari. Conservation status of each species was based on The International Union for Conservation of Nature's Red List of Threatened Species (<https://www.iucnredlist.org/>). A soil sample was collected from each corner and the middle of each of the plot A's and those were mixed to create a composite sample. The soil analyses were conducted in the laboratory of Balai Pengkajian Teknologi Pertanian Yogyakarta, Indonesia where soil organic matter (SOM) was determined by loss-on-ignition and nitrogen (N) by the Kjeldahl method.

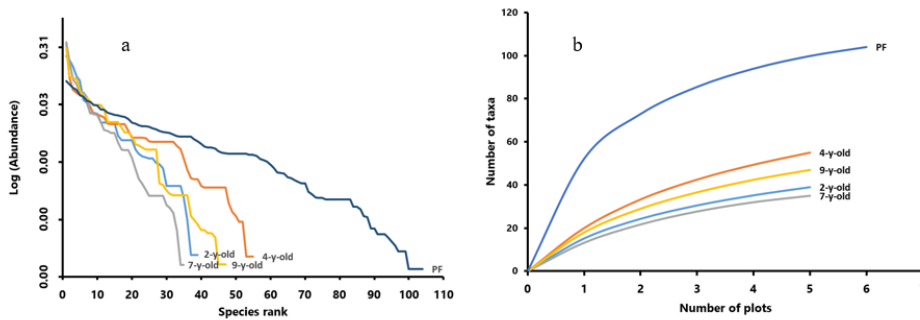
### 2.3. Data Analysis

We implemented a species abundance curve or Whittaker plot by plotting the abundance of each species (log-transformed) against its rank following a descending order. The species accumulation was analyzed using sample rarefaction (Mao's tau) [25]. These analyses were conducted using PAST (PAleontological STatistics) version 4.03 [26]. The dendrogram analysis was executed to compare the vegetation communities among contrasting forest ages using the 'vegan' package in R version 3.5.3 [27] in which all lifeforms were grouped together and data from smaller plots multiplied appropriately to give the equivalent area sampled for each lifeform. To determine differences between primary forest and fallow forests, analyses of variance (ANOVA) with subsequent Tukey's tests were performed with  $P < 0.05$  as the threshold using SPSS 16.0.

## 3. Results

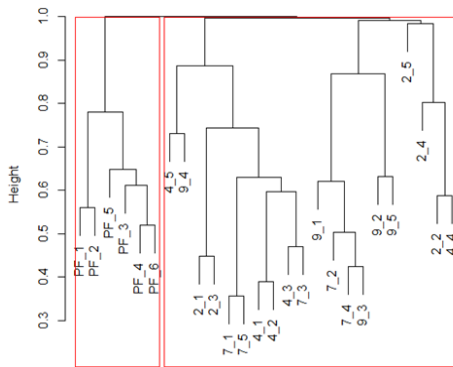
### *Species Richness of Vegetation*

We grouped the vegetation lifeforms (lianas, ferns, herbs, shrubs, palms/screw palms, tree seedlings, tree saplings, tree poles, and large trees) for the following analyses. In total, we recorded 152 taxa across all the plots that had an area of 1.84 ha. We analyzed species richness using rank-abundance (Figure 3a) and species accumulation (Figure 3b) curves which showed the species number per 0.30 ha (0.36 ha for primary forest) as 100 for the primary forest, 39 for two-year-old, 55 for four-year-old, 35 for seven-year-old, and 47 for nine-year-old fallow forests. Sixty-one species were only found in the primary forest (0.36 ha), 48 were only found in the fallow forests (1.5 ha), and 43 were shared between them. The results of vegetation classification revealed that there were two clear groups of plant communities based on the cluster dendrogram i.e. the primary forest and the fallow forests resulting from swidden activity (Figure 4).

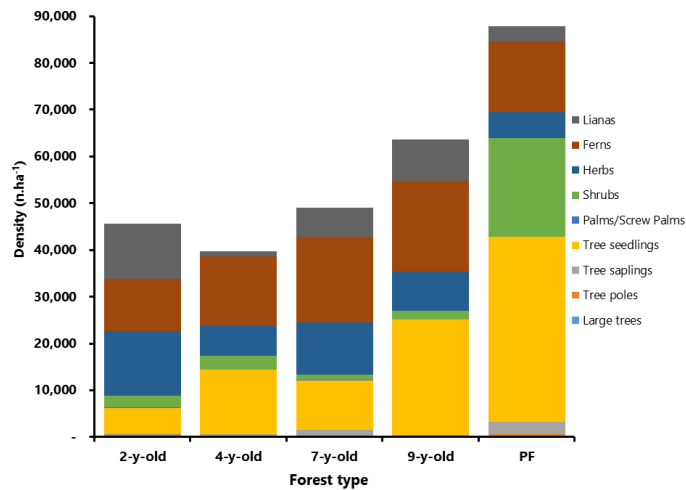


**Figure 3a.** The rank abundance curve or Whittaker plot implemented by plotting the log-transformed species abundance against species rank for all vegetation lifeforms. **Figure 3b.** Species accumulation curve for all vegetation lifeforms using sample rarefaction (Mao's tau) in fallow forests between two- and nine-years-old and primary forest (PF) in coastal areas of north Manokwari, West Papua, Indonesia.

The density of individuals of each lifeform was compared among the forest types. Tree seedlings were the most abundant life-form; their density was lowest after swidden agriculture, but then increased over time with increasing age of the fallow forest. The stem density of shrubs, seedlings, saplings, poles, and large trees in the primary forest was significantly greater than in fallow forests while lianas were more abundant in 2-y-old fallow forest than in most other forest ages. The density of herbs and palms/screw palms did not change during succession and that of ferns peaked in older fallows (Figure 5).



**Figure 4.** Grouping of plots in the primary forest (PF) and fallow forests between two- and nine-years-old in coastal areas of north Manokwari, West Papua, Indonesia. All vegetation lifeforms are grouped together and data from smaller plots is multiplied appropriately to give the equivalent area sampled for each lifeform. The number before the dash is the age of the fallow (2 for two-year-old, 4 for four-year-old, 7 for seven-year-old, and 9 for nine-year-old) while the number after the dash is a label for each plot.



Lifeform	2-y-old	4-y-old	7-y-old	9-y-old	PF	P-value
Lianas	c	b	ab	abc	ab	0.036
Ferns	ab	a	c	bc	a	0.015
Herbs	a	a	a	a	a	0.37
Shrubs	a	a	a	a	b	0.001
Palms/Screw Palms	a	a	a	a	a	0.40
Tree seedlings	a	a	a	a	b	<0.001
Tree saplings	a	a	a	a	b	<0.001
Tree poles	a	a	a	a	b	<0.001
Large trees	a	abc	ab	c	d	<0.001

**Figure 5.** The mean density of vegetation lifeforms in fallow forests between two- and nine-years-old and primary forest (PF) in coastal areas of north Manokwari, West Papua, Indonesia. For clarity, error bars are omitted. Different lowercase letters in the table show the differences according to ANOVAs and Tukey's tests with  $P < 0.05$ .

Two species were found with Near Threatened (NT) Red List status (*Cryptocarya massoy* and *Intsia bijuga*) and a further three species were classified as Vulnerable (VU) (*Aglaia brassii*, *Anisoptera thurifera* and *Neonauclea acuminata*). Seven species were found that were endemic to New Guinea (according to Cámara-Leret et al. [1]) along with a further three that were found in New Guinea and the Solomon Islands only (according to POWO [28]).

This study also compared the edaphic conditions among forest ages by means of soil organic matter (SOM) and nitrogen (N) as predictor of soil 'fertility'. The SOM was greatest in 2-y-old fallow forest and primary forest while the lowest SOM was found in the 9-y-old fallow forest. The total N showed a similar pattern and was greater in the primary forest than in fallow forests while the 9-y-old fallow forest had the lowest total N among the forest types.

**Table 1.** Mean ( $\pm$ standard error) soil organic matter (SOM) and total nitrogen (N) in fallow forests between two- and nine-years-old, and primary forest (PF) in coastal areas of north Manokwari, West Papua, Indonesia. Different lowercase letters show the differences according to Tukey's tests with  $P < 0.05$ .

Variable	Forest Type				
	2-y-old	4-y-old	7-y-old	9-y-old	PF
SOM (%)	18.40 $\pm$ 4.82 b	8.05 $\pm$ 3.15 ab	9.38 $\pm$ 2.77 ab	3.35 $\pm$ 0.36 a	10.00 $\pm$ 0.81 b

Total N (%)	0.47 ± 0.05 ab	0.41 ± 0.07 ab	0.54 ± 0.05 b	0.32 ± 0.03 a	0.84 ± 0.02 c
-------------	-------------------	-------------------	------------------	------------------	------------------

#### 4. Discussion

The swidden practice was conducted by local people in Papua where they allow forest recovery after cultivation during secondary succession as investigated in other studies in New Guinea [7,18,29,30] as well as numerous other tropical regions around the world [10,16,31-39]. In our study, the dendrogram revealed two main groups containing the primary forest plots in the first group and the fallow forest plots in the other group indicating the similarity of species composition among the fallows. We did not see a particularly clear pattern of change in the forests with age, perhaps due to the generally young age of the fallows. The forest fallows were more dynamic as the re-colonization of certain pioneer species was rapid due to the more open canopy increasing light availability. Increasing light and temperature will also increase the rate of seed germination in this area [38]. In addition, the fallow forests are very near, or surrounded by, either primary forest or older/denser fallow forests allowing colonization of individuals coming from both of these forest types [39,40]. Some ruderal species could be permanently present in the successional stages up to the climax phase, but others will be suppressed by the growth of other vegetation during succession [41-45]. Those species in this research such as *Piper* sp., *Macaranga* species, *Premna corymbosa*, and *Monstera* sp. tended to occupy fallow forests as early successional species.

The change in the vertical structure of the forest also leads to changes in the relative importance of certain life-forms. For example, lianas take advantage of the reduction of canopy layers, so they grow aggressively by overlaying other vegetation. For this reason, lianas were more abundant in the fallow forest, and particularly the youngest, most open forests, where this lifeform has the ability to grow not only in vertical but also horizontal directions. The increase in stem density during succession was largely comprised by trees, and larger trees at later stages of succession. The successional process in fallow forests is highly dynamic compared to primary forests in which the species composition and vertical structure are more static upon reaching the climax stage of succession. However, the time for fallow forests to reach a stable state resembling primary forest will take decades, if not longer [13,37,46]. It is also worth considering that there are alternative pathways in succession due to the influence of factors such as previous agriculture practices, the species present in surrounding forests, and edaphic conditions [47]. It is also important to study a large number of primary forest stands due to high heterogeneity in structure and diversity influenced, at least partly, by the intensity and frequency of disturbances.

The swidden practice changed the vertical structure of vegetation particularly the understory, but in some settings, large trees were left to grow ('remnant trees') because the cutting was conducted using traditional tools and usually by a single family that were not able to remove such large stems. Therefore, in some of the fallow forests, larger remnant trees were recorded, as found in other locations globally [13,48]. These remnant trees will contribute to species richness and carbon stocks in the fallows. The larger trees within fallow forest also play a significant role as putative parent trees to supply seeds which are important in the distribution of seeds into fallow areas [49]. The variety of crops could impact the size and type of area cleared as revealed in other studies [33,36] and, in this study, most local people planted agricultural products such as cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*) which do not require the forest to be totally cleared. Certain species growing in the fallow forests were from cultivation activity such as turmeric (*Curcuma zanthorrhiza*), bananas (*Musa* sp.) and pineapple (*Ananas comosus*) although these comprised only a small contribution as local people only

used certain cultivated plants. Additionally, fruit trees will have been planted in the fallows such as cempedak (*Artocarpus integer*), durian (*Durio zibethinus*), mango (*Mangifera indica*) and rambutan (*Nephelium lappaceum*). The fallows additionally contained introduced and potentially invasive species such as *Ageratum conyzoides* and *Imperata cylindrica* as well as *Piper aduncum* that was also found in primary forest from which it has rarely been reported before [42,50].

In addition to vegetation changes, soil properties were also impacted by the agricultural practices. The soil nutrients two years after swidden activity were generally similar to primary forest but differed from the rest of the fallow forests. This is likely due to the minimal impact of agricultural practices that conserved soil organic matter and the low-intensity fires (due to moist conditions) prior to agriculture with some cultivators not using fire [21]. The high C:N ratio of the soils in the youngest fallows (38 vs. 16 as mean of all other ages) suggests this was likely due to input of incompletely burned decomposing wood/logs into the soils. The decline in SOM in the 9-year-old fallows also supports this as this wood will have more fully decomposed but the forest has not grown back sufficiently for large inputs of carbon via leaf litter production. Soil nutrient loss could also occur from surface runoff because the fallow forests have less dense canopies, and the forest floor vegetation was not as developed. As reported by many studies, the vegetation cover has an inverse relationship with surface runoff whereby the amount of nutrient loss would be removed from the fallow forests over time [51].

Species richness declined in fallows compared to primary forest in line with other studies conducted in New Guinea and more broadly. We found that there were about twice as many species (all taxa) in primary forest as compared to secondary forests. This is similar to other studies in New Guinea [30] that showed there were two to three times more tree species in primary forest than younger (< 9-yr-old) secondary forest. The difference in diversity between the two forest types with respect to tree size was greater for the larger trees. When we re-examined our data for trees  $\geq 10$  cm dbh only then the pattern was more marked that for all taxa together, with about four times as many tree species in primary forest compared to secondary forests (data not shown). Supporting this, another study [21] showed greater richness of trees in primary forest sites compared to formerly cultivated sites but not of non-tree plant life-forms. It is also important to bear in mind that species richness recovers more rapidly than species composition [35] due to the slow growth of many late-successional primary forest specialist trees.

Although species richness in fallow forests is lower than primary forests, they play a crucial role in local livelihoods. Local people applied the traditional techniques and tools, and the main purpose of their cultivation was to supply food for themselves. This traditional swidden practice has been performed for centuries around the world including in New Guinea [9,52]. Local people also implemented their traditional knowledge that supports the sustainability of the swidden practice, for example, swiddens are not placed close to rivers. They only clear dense forest for cultivation, but the density of vegetation especially larger trees and presence of particular species are traditional indicators of an area ready for re-cultivation. Furthermore, there are certain areas of primary forests that were purposefully left to grow naturally without disturbance because local people hold the traditional belief that if these primary forests are disturbed, some disaster will happen in this area, therefore they have traditional zones reserved especially for livelihood activities including their swidden practice.

Among Red-Listed plant species, four were only found in primary forest and two were found in both primary forest and fallows. Five out of the seven species endemic to New Guinea (and seven out of the ten endemic to New Guinea and the Solomon Islands) were only found in the primary forest. Therefore, although primary forests are more valuable in terms of species richness and also contain

rarer species, fallow forests have some role to play in conservation as some Red-Listed species and endemic species are still found within them. Overall, of the taxa we identified to species level, only 55 % have been assessed for the IUCN Red List indicating that there is still considerable work to be done here.

We recognize that our sampling design is pseudo-replicated, thereby limiting the conclusions that can be drawn. Nevertheless, our study has value in presenting data from a very understudied tropical region that is coming under increasing pressure [1,6,53]. Furthermore, the inclusion of lifeforms that are less often included in traditional inventories of tropical forests (e.g. herbs, ferns) is of value. Generally, the fallows studied here are of a younger age (< 10-years-old) and incorporation of mid- to late-age fallows across a broader landscape (avoiding pseudo-replication) and in larger plots would allow us to determine the trajectory of succession at later stages more effectively.

Government intervention is necessary to support the implementation of traditional knowledge in sustainable forest management [2,54] and the local government should legally concede the traditional zones designed by local people for livelihood activity and delineate customary forests [55]. Whilst the farming method in this area disturbs small areas of forest, these disturbed forests will recuperate over time, but at least they are still covered by vegetation and the land is not converted to other functions such as settlements. Moreover, it is crucial to carry out further anthropological research to document the swidden practice in the context of local traditions. It is also essential to monitor the vegetation in the disturbed forests to record the species diversity and recovery in permanent plots [56] Both of these would clearly support conservation programs in tropical forests of Papua.

**Author Contributions:** PLEASE CHECK AND ADD FOR ANTONI, DONY & THANEL Conceptualization, Agustinus Murdjoko; Data curation, Agustinus Murdjoko; Formal analysis, Agustinus Murdjoko and Francis Brearley; Investigation, Agustinus Murdjoko, Antoni Ungirwalu, Dony A Djitmau and Nithanel M H Benu; Methodology, Agustinus Murdjoko, Antoni Ungirwalu and Dony A Djitmau; Project administration, Agustinus Murdjoko; Resources, Agustinus Murdjoko; Supervision, Agustinus Murdjoko and Francis Brearley; Validation, Agustinus Murdjoko and Francis Brearley; Visualization, Agustinus Murdjoko; Writing – original draft, Agustinus Murdjoko and Francis Brearley; Writing – review & editing, Antoni Ungirwalu, Dony A Djitmau and Nithanel M H Benu.

**Funding:** ANY FUNDING TO REPORT???

**Acknowledgments:** We thank Fakultas Kehutanan Universitas Papua and Pemerintah Provinsi Papua Barat for issuing permits.

**Conflicts of Interest:** The authors declare no conflicts of interest.

**Appendix 1.** Plant species list in fallow forests between two- and nine-years-old and primary forest (PF) in coastal areas of north Manokwari, West Papua, Indonesia. The presence of species is symbolized using √. The seven species in bold text are endemic to New Guinea according to Cámara-Leret et al. [1].

Species	Forest type				
	2-y-old	4-y-old	7-y-old	9-y-old	PF
<i>Actinodaphne nitida</i> Teschner					√
<i>Ageratum conyzoides</i> (L.) L.	√				



<i>Aglaiia spectabilis</i> (Miq.) S.S.Jain & S.Bennet					√
<i>Aglaiia brassii</i> Merr. & L.M.Perry		√			√
<i>Alpinia galanga</i> (L.) Willd.		√	√		
<i>Alpinia</i> sp.					√
<i>Alstonia scholaris</i> (L.) R.Br.	√	√	√	√	√
<i>Ananas comosus</i> (L.) Merr.			√		
<i>Anisoptera thurifera</i> (Blanco) Blume					√
<i>Antiaris toxicaria</i> (J.F.Gmel.) Lesch.					√
<b>Archidendron pachycarpum (Warb.) Dewit</b>					√
<b>Archidendron parviflorum Pulle</b>		√		√	√
<i>Archidendron</i> sp.					√
<i>Areca catechu</i> L.		√		√	
<i>Artocarpus altilis</i> (Parkinson ex F.A.Zorn) Fosberg	√	√	√		√
<i>Artocarpus integer</i> (Thunb.) Merr.				√	
<i>Baccaurea</i> sp.					√
<i>Bidens pilosa</i> L.	√				
<i>Blechnum patersonii</i> (R.Br.) Mett.				√	
<i>Bubbia</i> sp.		√			
<i>Buchanania arborescens</i> (Blume) Blume					√
<i>Calophyllum inophyllum</i> L.					√
<i>Campnosperma coriaceum</i> (Jack) Hallier f.					√
<i>Cananga odorata</i> (Lam.) Hook.f. & Thomson		√	√	√	√
<i>Canarium hirsutum</i> Willd.					√
<i>Celtis latifolia</i> (Blume) Planch.					√
<i>Ceodes umbellifera</i> J.R.Forst. & G.Forst.					√
<i>Cerbera floribunda</i> K.Schum.					√
<i>Chionanthus</i> aff. <i>macrocarpus</i> Blume	√				
<i>Chionanthus</i> sp.					√
<i>Chisocheton ceramicus</i> (Miq.) C.DC.					√
<i>Cocos nucifera</i> L.	√		√		
<i>Coffea</i> sp.					√
<b>Cryptocarya massoy (Oken) Kosterm.</b>					√
<i>Curcuma zanthorrhiza</i> Roxb.				√	
<b>Cynometra browneoides (Harms) Rados.</b>		√			√
<i>Diospyros discolor</i> Willd.			√		√
<i>Dracontomelon dao</i> (Blanco) Merr. & Rolfe	√	√		√	√
<i>Durio zibethinus</i> L.		√		√	
<i>Dysoxylum mollissimum</i> Blume	√	√	√	√	√
<i>Dysoxylum parasiticum</i> (Osbeck) Kosterm.		√			√
<i>Elaeocarpus angustifolius</i> Blume					√
<i>Endospermum moluccanum</i> (Teijsm. & Binn.) Kurz		√		√	√
<i>Falcataria falcata</i> (L.) Greuter & R.Rankin					√
<i>Ficus</i> aff. <i>annulata</i> Blume	√				
<i>Ficus benjamina</i> L.					√
<i>Ficus drupacea</i> Thunb.					√
<i>Ficus macrothyrsa</i> Corner	√	√	√	√	
<i>Ficus racemifera</i> Roxb.					√
<i>Ficus septica</i> Burm.f.		√	√	√	
<i>Ficus variegata</i> Blume		√	√	√	
<i>Ficus</i> sp. 1	√	√	√	√	
<i>Ficus</i> sp. 2		√			√

<i>Ficus</i> sp. 3		√			√
<i>Ficus</i> sp. 4					√
<i>Ficus</i> sp. 5					√
<i>Garcinia</i> sp.					√
<i>Gmelina</i> sp.					√
<i>Gnetum gnemon</i> L.		√	√	√	√
<i>Gonocaryum littorale</i> (Blume) Sleumer					√
Grass A	√	√		√	
<i>Gymnacranthera farquhariana</i> (Wall ex. Hook.f. & Thomson) Warb.	√				√
<i>Harpullia</i> sp.					√
<i>Hibiscus tiliaceus</i> L.	√				
<i>Hibiscus</i> sp.			√		√
<i>Homalium foetidum</i> (Roxb.) Benth.					√
<i>Hopea</i> sp.					√
<i>Horsfieldia irya</i> (Gaertn.) Warb.		√		√	√
<i>Hylodesmum repandum</i> (Vahl) H. Ohashi & R.R. Mill		√		√	
<i>Imperata cylindrica</i> (L.) Raeusch.	√	√	√	√	
<i>Intsia bijuga</i> (Colebr.) Kuntze		√	√		√
<i>Koordersiodendron pinnatum</i> (Blanco) Merr.		√	√	√	√
Lauraceae sp.	√				
<i>Leea aculeata</i> Blume ex Spreng.			√		√
<i>Lepiniopsis ternatensis</i> Valetton	√			√	√
<i>Leucaena leucocephala</i> (Lam.) de Wit		√			
Liana A	√			√	
Liana B				√	
Liana C	√				
Liana D				√	
<i>Litsea ledermannii</i> Teschner					√
<i>Litsea timoriana</i> Span.		√		√	√
<i>Litsea tuberculata</i> (Blume) Boerl.					√
<i>Litsea</i> sp.					√
<i>Lunasia amara</i> Blanco		√			√
<i>Maasia glauca</i> (Hassk.) Mols, Kessler & Rogstad					√
<i>Macaranga</i> sp. 1	√	√	√	√	
<i>Macaranga</i> sp. 2	√	√	√	√	√
<i>Mallotus floribundus</i> (Blume) Müll. Arg.					√
<i>Mangifera indica</i> L.				√	
<i>Maniltoa</i> sp.					√
<i>Mastixiodendron pachyclados</i> (K. Schum.) Melch.		√	√	√	√
<i>Medusanthera laxiflora</i> (Miers) R.A. Howard		√			√
<i>Melicope elleryana</i> (F. Muell.) T.G. Hartley				√	√
<i>Merremia</i> sp.				√	
<i>Mimusops elengi</i> L.					√
<b><i>Monoon polycarpum</i> (Burck) B.Xue &amp; R.M.K.Saunders</b>					√
<i>Monstera</i> sp.	√	√	√	√	
<i>Mucuna novo-guineensis</i> Scheff.	√				√
<i>Musa</i> sp.	√			√	
<i>Myristica fatua</i> Houtt.					√
<i>Myristica</i> aff. <i>gigantea</i> King		√			

<i>Myristica</i> sp.					√
<i>Neolamarckia cadamba</i> (Roxb.) Bosser				√	√
<b><i>Neonauclea acuminata</i> Ridsdale</b>					√
<i>Neonauclea</i> sp.					√
<i>Nephranium lappaceum</i> L.			√	√	√
<i>Nephranium</i> sp.	√	√	√	√	√
<i>Ochromolaena</i> sp.					√
<i>Octomeles sumatrana</i> Miq.	√		√	√	√
Orchidaceae sp.		√			
<i>Ormosia calavensis</i> Azaola					√
<i>Ormosia</i> sp.					√
<i>Osmoxylon</i> aff. <i>globulare</i> Philipson	√	√			
<i>Palaquium amboinense</i> Burck		√			√
<i>Palaquium</i> sp.		√	√	√	
<i>Pandanus tectorius</i> Parkinson ex Du Roi	√				
<i>Pimelodendron amboinicum</i> Hassk.		√			√
<i>Piper aduncum</i> L.	√	√	√	√	√
<i>Piper</i> sp.	√				
<i>Pipturus argenteus</i> (G.Forst.) Wedd.					√
<i>Polyalthia</i> sp. 1					√
<i>Polyalthia</i> sp. 2					√
<i>Pometia pinnata</i> J.R.Forst. & G.Forst.		√		√	√
<i>Premna corymbosa</i> Rottler & Willd.	√	√	√	√	
<i>Prunus arborea</i> (Blume) Kalkman		√			√
<i>Pterygota horsfieldii</i> (R.Br.) Kosterm.				√	√
<i>Pterygota</i> sp.					√
<i>Rhus taiensis</i> Guill.		√			√
<i>Rhus</i> sp.					√
Sapindaceae sp.					√
<b><i>Semecarpus papuanus</i> Lauterb.</b>					√
<i>Spathiostemon javensis</i> Blume		√	√		√
<i>Spondias dulcis</i> Parkinson	√	√	√		
<i>Stachytarpheta jamaicensis</i> (L.) Vahl	√				
<i>Sterculia</i> aff. <i>elongata</i> Ridl.		√	√		
<i>Sterculia macrophylla</i> Vent.		√		√	√
<i>Sterculia parkinsonii</i> F.Muell.					√
<i>Sterculia urceolata</i> Sm.	√	√	√		√
<i>Syzygium</i> sp.	√				√
<i>Tectaria</i> aff. <i>zollingeri</i> (Kurz) Holttum	√				√
<i>Teijsmanniodendron bogoriense</i> Koord.					√
Thelypteridiaceae sp.	√	√	√	√	
<i>Timonius timon</i> (Spreng.) Merr.					√
<i>Timonius</i> sp.					√
Tree A	√				
Tree B	√	√	√		
<i>Uncaria</i> sp. 1					√
<i>Uncaria</i> sp. 2					√
<i>Vigna trilobata</i> L. (Verdc.)				√	
<i>Viridula surinamensis</i> (Rol. ex Rottb.) Warb.					√
<i>Ziziphus</i> sp.					√

## References

57. Cámara-Leret, R.; Frodin, D.G.; Adema, F.; Anderson, C.; Appelhans, M.S.; Argent, G.; Guerrero, S.A.; Ashton, P.S.; Baker, W.J.; Barford, A.S.; Barrington, D.; Borosova, R.; Bramley, G.L.C.; Briggs, M.; Buerki, S.; Cahen, D.; Callmander, M.W.; Cheek, M.R.; Chen, C.-W.; Conn, B.J.; Coode, M.J.E.; Darbyshire, I.; Dawson, S.; Dransfield, J.; Drinkell, C.; Duyfjes, B.; Ebihara, A.; Ezedin, Z.; Fu, L.-F.; Gideon, O.; Girmansyah, D.; Govaerts, R.; Fortune-Hopkins, H.; Hassemer, G.; Hay, A.; Heatubun, C.D.; Hind, D.J.N.; Hoch, P.; Homot, P.; Hovenkamp, P.; Hughes, M.; Jebb, M.H.P.; Jennings, L.; Jimbo, T.; Kessler, M.; Kiew, R.; Knapp, S.; Lamei, P.; Lehnert, M.; Lewis, G.P.; Linder, H.P.; Lindsay, S.; Low, Y.W.; Lucas, E.; Mancera, J.P.; Monro, A.K.; Moore, A.; Middleton, D.J.; Nagamasu, H.; Newman, M.F.; Nic Lughadha, E.; Melo, P.H.A.; Ohlsen, D.J.; Pannell, C.M.; Parris, B.; Pearce, L.; Penneys, D.S.; Perrie, L.R.; Petoe, P.; Poulsen, A.D.; Prance, G.T.; Quakenbush, J.P.; Raes, N.; Rodda, M.; Rogers, Z.S.; Schuiteman, A.; Schwartsburd, P.; Scotland, R.W.; Simmons, M.P.; Simpson, D.A.; Stevens, P.; Sundue, M.; Testo, W.; Trias-Blasi, A.; Turner, I.M.; Utteridge, T.M.A.; Walsingham, L.; Webber, B.L.; Wei, R.; Weiblen, G.D.; Weigend, M.; Weston, P.; de Wilde, W.; Wilkie, P.; Wilmot-Dear, C.M.; Wilson, H.P.; Wood, J.R.I.; Zhang, L.-B.; van Welzen, P.C. New Guinea has the world's richest island flora. *Nature* **2020**, *584*, 579–583.
58. Murdjoko, A.; Ungirwalu, A.; Mardiyadi, Z.; Tokede, M.J.; Djitmau, D.A.; Benu, N.M.H. Floristic composition of Buah Hitam habitats in lowland tropical mixed forest of West Papua, Indonesia. *Florest. Ambient.* **2021**, *28*, e20210042.
59. Ungirwalu, A.; Awang, S.A.; Murdjoko, A. Model aplikasi agroforestri tumbuhan Buah Hitam (*Haplolobus monticola* Husson) berbasis pengetahuan lokal etnis Wandamen-Papua: prospek pengembangan perhutanan sosial di Papua. In *Prosiding Seminar Nasional Silvikultur II: Pembaruan Silvikultur untuk Mendukung Pemulihan Fungsi Hutan menuju Ekonomi Hijau, Universitas Gadjah Mada, Yogyakarta, 28 Agustus 2014*; Prehaten, D.; Syahbudin, A.; Andiyani, R.D., Eds.; 2014; pp. 268–274.
60. Vallet, A.; Locatelli, B.; Levrel, H.; Brenes Pérez, C.; Imbach, P.; Estrada Carmona, N.; Manlay, R.; Oszwald, J., 2016. Dynamics of ecosystem services during forest transitions in Reventazón, Costa Rica. *PLoS One* **2016**, *11*, e0158615.
61. Wakhidah, A.Z.; Chikmawati, T.; Purwanto, Y. Homegarden ethnobotany of two Saibatin villages in Lampung, Indonesia: species diversity, uses, and values. *For. Soc.* **2020**, *4*, 338–357. <https://doi.org/10.24259/fs.v4i2.9720>
62. Gaveau, D.L.A.; Santos, L.; Locatelli, B.; Salim, M.A.; Husnayaen, H.; Meijaard, E.; Heatubun, C.D.; Sheil, D. Forest loss in Indonesian New Guinea (2001–2019): trends, drivers and outlook. *Biol. Conserv.* **2021**, *261*, 109225.
63. Manner, H.I. Ecological succession in new and old swiddens of montane Papua New Guinea. *Hum. Ecol.* **1981**, *9*, 359–377.
64. Ungirwalu, A.; Awang, S.A.; Suryanto, P.; Maryudi, A. The ethno-techno-conservation approach in the utilization of Black Fruit (*Haplolobus* sp.) by the Wandamen ethnic of Papua, Indonesia. *Biodiversitas* **2017**, *18*, 1336–1343.
65. Heinemann, A.; Mertz, O.; Frohling, S.; Christensen, A.E.; Hurni, K.; Sedano, F.; Chini, L.P.; Sahajpal, R.; Hansen, M.; Hurr, G. A global view of shifting cultivation: recent, current, and future extent. *PLoS One* **2017**, *12*, e0184479.
66. Mukul, S.A.; Herbohn, J. The impacts of shifting cultivation on secondary forests dynamics in tropics: a synthesis of the key findings and spatio temporal distribution of research. *Environ. Sci. Policy* **2016**, *55*, 167–177.
67. Schmidt-Vogt, D.; Leisz, S.J.; Mertz, O.; Heinemann, A.; Thiha, T.; Messerli, P.; Epprecht, M.; Cu, P.V.; Chi, V.K.; Hardiono, M.; Dao, T.M. 2009. An assessment of trends in the extent of swidden in Southeast Asia. *Hum. Ecol.* **2009**, *37*, 269–280.
68. Angelsen, A. Shifting cultivation and “deforestation”: a study from Indonesia. *World Dev.* **1995**, *23*, 1713–1729.
69. Brearley, F.Q.; Prajadinata, S.; Kidd, P.S.; Proctor, J.; Suriantata. Structure and floristics of an old secondary rain forest in Central Kalimantan, Indonesia, and a comparison with adjacent primary forest. *For. Ecol. Manage.* **2004**, *195*, 385–397.
70. Ding, Y.; Zang, R.; Liu, S.; He, F.; Letcher, S.G. Recovery of woody plant diversity in tropical rain forests in southern China after logging and shifting cultivation. *Biol. Conserv.* **2012**, *145*, 225–233.
71. Fujiki, S.; Nishio, S.; Okada, K.-i.; Nais, J.; Kitayama, K. Plant communities and ecosystem processes in a succession-altitude matrix after shifting cultivation in the tropical montane forest zone of northern Borneo. *J. Trop. Ecol.* **2017**, *33*, 33–49.
72. Villa, P.M.; Martins, S.V.; Nolasco de Oliveira Neto, S.; Rodrigues, A.C.; Martorano, L.G.; Delgado Monsanto, L.; Cancio, N.M.; Gastauer, M. Intensification of shifting cultivation reduces forest resilience in the northern Amazon. *For. Ecol. Manage.* **2018**, *430*, 312–320.
73. Ribeiro Filho, A. A.; Adams, C.; Murrieta, R. S. S. 2013. The impacts of shifting cultivation on tropical forest soil: a review. *Bol. Mus. Para. Emílio Goeldi Cienc. Hum. Belém* **2013**, *8*, 693–727.
74. Kukla, J.; Whitfield, T.J.S.; Cajthaml, T.; Baldrian, P.; Veselá-Šimáčková, H.; Novotný, V.; Frouz, J. The effect of traditional slash-and-burn agriculture on soil organic matter, nutrient content, and microbiota in tropical ecosystems of Papua New Guinea. *Land. Degrad. Dev.* **2019**, *30*, 166–177.
75. Polak, M. The botanical diversity in the Ayawasi area, Irian Jaya, Indonesia. *Biodivers. Conserv.* **2000**, *9*, 1345–1375.
76. Sheil, D.; Boissière, M.; van Heist, M.; Rachman, I.; Basuki, I.; Wan, M.; Watopa, Y. The floodplain forests of the Mamberamo Basin, Papua, Indonesia (western New Guinea): vegetation, soils, and local use. *Forests* **2021**, *12*, 1790.

77. van Heist, M.; Sheil, D.; Rachman, I.; Gusbager, P.; Raweyai, C.; Yoteni, H. The forests and related vegetation of Kwerba, on the Foja foothills, Mamberamo, Papua (Indonesian New Guinea). *Blumea* **2010**, *55*, 153–161.
78. Robiansyah, I. Diversity and biomass of tree species in Tambrau, West Papua, Indonesia. *Biodiversitas* **2018**, *19*, 377–386.
79. Tawer, P.; Maturbongs, R.; Murdjoko, A.; Jitmau, M.; Djitmau, D.; Siburian, R.; Ungirwalu, A.; Wanma, A.; Mardiyadi, Z.; Wanma, J.; Rumatora, A.; Mofu, W.; Sinery, A.; Fatem, S.; Benu, N.; Kuswandi, R.; Lekitoo, K.; Khayati, L.; Taming, J. 2021. Vegetation dynamic post-disturbance in tropical rain forest of Bird's Head Peninsula of West Papua, Indonesia. *Ann. Silvic. Res.* **2021**, *46*, 48–58.
80. **Badan Pusat Statistik Kabupaten Manokwari, 2021. Kabupaten Manokwari Dalam Angka 2021.**
81. Colwell, R.K.; Mao, C.X.; Chang, J. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology* **2004**, *85*, 2717–2727.
82. Hammer, Ø.; Harper, D.A.; Ryan, P.D. 2001. PAST: paleontological statistics software package for education and data analysis. *Palaeontol. Electron.* **4**, 4.
83. Oksanen, A. J.; Blanchet, F.G.; Friendly, M.; Kindt, R.; Legendre, P.; McGlinn, D.; Minchin, P.R.; O'Hara, R.B.; Simpson, G.L.; Solymos, P.; Stevens, M.H.H.; Szoecs, E. Package 'vegan' Community ecology package. Version 2.5-6. **2019**. Available online: <https://cran.r-project.org/web/packages/vegan/index.html>.
84. Plants of the World Online. Available online: <http://www.plantsoftheworldonline.org/> (accessed on 11 October 2020).
85. Sillitoe, P.; Shiel, R.S. Soil fertility under shifting and semi-continuous cultivation in the Southern Highlands of Papua New Guinea. *Soil Use Manag.* **1999**, *15*, 49–55.
86. Whitfield, T.J.S.; Lasky, J.R.; Damas, K.; Sosanika, G.; Molem, K.; Montgomery, R.A. Species richness, forest structure, and functional diversity during succession in the New Guinea lowlands. *Biotropica* **2014**, *46*, 538–548.
87. Hattori, D.; Kenzo, T.; Shirahama, T.; Harada, Y.; Kendawang, J.J.; Ninomiya, I.; Sakurai, K. Degradation of soil nutrients and slow recovery of biomass following shifting cultivation in the heath forests of Sarawak, Malaysia. *For. Ecol. Manage.* **2019**, *432*, 467–477.
88. Klanderud, K.; Mbolatiana, H.Z.H.; Vololomboahangy, M.N.; Radimbison, M.A.; Roger, E.; Totland, Ø.; Rajeriarison, C. Recovery of plant species richness and composition after slash-and-burn agriculture in a tropical rainforest in Madagascar. *Biodivers. Conserv.* **2010**, *19*, 187–204.
89. Pereira Cabral Gomes, E.; Sugiyama, M.; Fernandes de Oliveira Junior, C.J.; Medeiros Prado, H.; Ribeiro Filho, A.A.; Adams, C. Post-agricultural succession in the fallow swiddens of southeastern Brazil. *For. Ecol. Manage.* **2020**, *475*, 118398.
90. Siahaya, M.E.; Hutauruk, T.R.; Aponno, H.S.E.S.; Hatulesila, J.W.; Mardhanie, A.B. Traditional ecological knowledge on shifting cultivation and forest management in east Borneo, Indonesia. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manage.* **2016**, *12*, 14–23.
91. Rozendaal, D.M.A.; Bongers, F.; Aide, T.M.; Alvarez-Dávila, E.; Ascarrunz, N.; Balvanera, P.; Becknell, J.M.; Bentos, T. V.; Brancalion, P.H.S.; Cabral, G.A.L.; Calvo-Rodríguez, S.; Chave, J.; César, R.G.; Chazdon, R.L.; Condit, R.; Dalling, J.S.; de Almeida-Cortez, J.S.; de Jong, B.; de Oliveira, A.; Denslow, J.S.; Dent, D.H.; DeWalt, S.J.; Dupuy, J.M.; Durán, S.M.; Dutrieux, L.P.; Espirito-Santo, M.M.; Fandino, M.C.; Fernandes, G.W.; Finegan, B.; García, H.; Gonzalez, N.; Moser, V.G.; Hall, J.S.; Hernández-Stefanoni, J.L.; Hubbell, S.P.; Jakovac, C.C.; Hernández, A.J.; Junqueira, A.B.; Kennard, D.; Larpin, D.; Letcher, S.G.; Licona, J.C.; Lebrija-Trejos, E.; Marín-Spiotta, E.; Martínez-Ramos, M.; Massoca, P.E.S.; Meave, J.A.; Mesquita, R.C.G.; Mora, F.; Müller, S.C.; Muñoz, R.; Nolasco de Oliveira Neto, S.; Norden, N.; Nunes, Y.R.F.; Ochoa-Gaona, S.; Ortiz-Malavassi, E.; Ostertag, R.; Peña-Claros, M.; Pérez-García, E.A.; Piotta, D.; Powers, J.S.; Aguilar-Cano, J.; Rodríguez-Buritica, S.; Rodríguez-Velázquez, J.; Romero-Romero, M.A.; Ruiz, J.; Sanchez-Azofeifa, A.; Silva de Almeida, A.; Silver, W.L.; Schwartz, N.B.; Thomas, W.W.; Toledo, M.; Uriarte, M.; de Sá Sampaio, E.V.; van Breugel, M.; van Der Wal, H.; Martins, S.V.; Veloso, M.D.M.; Vester, H.F.M.; Vicentini, A.; Vieira, I.C.G.; Villa, P.M.; Williamson, G.B.; Zanini, K.J.; Zimmerman, J.; Poorter, L. 2019. Biodiversity recovery of Neotropical secondary forests. *Sci. Adv.* **2019**, *5*, eaau3114.
92. Tongkoom, K.; Marohn, C.; Piepho, H.P.; Cadisch, G. Ecosystem recovery indicators as decision criteria on potential reduction of fallow periods in swidden systems of northern Thailand. *Ecol. Indic.* **2018**, *95*, 554–567.
93. Villa, P.M.; Martins, S.V.; Nolasco de Oliveira Neto, S.; Rodrigues, A.C.; Safar, N.V.H.; Delgado Monsanto, L.; Cancio, N.M.; Ali, A. Woody species diversity as an indicator of the forest recovery after shifting cultivation disturbance in the northern Amazon. *Ecol. Indic.* **2018**, *95*, 687–694.
94. Lu, X.; Zang, R.; Ding, Y.; Letcher, S.G.; Long, W.; Huang, Y. Variations and trade-offs in functional traits of tree seedlings during secondary succession in a tropical lowland rain forest. *Biotropica* **2014**, *46*, 404–414.
95. Hawes, J.E.; Vieira, I.C.G.; Magnago, L.F.S.; Berenguer, E.; Ferreira, J.; Aragão, L.E.O.C.; Cardoso, A.; Lees, A.C.; Lennox, G.D.; Tobias, J.A.; Waldron, A.; Barlow, J. A large-scale assessment of plant dispersal mode and seed traits across human-modified Amazonian forests. *J. Ecol.* **2020**, *108*, 1373–1385.
96. Murdjoko, A.; Jitmau, M.M.; Djitmau, D.A.; Siburian, R.H.S.; Ungirwalu, A.; Wanma, A.O.; Mardiyadi, Z.; Rumatora,

- A.; Mofu, W.Y.; Sineri, A.S.; Fatem, S.M.; Worabai, D.; May, N.L.; Tokede, M.J.; Warmetan, H.; Wanggai, C.B.; Wanma, J.F.; Sirami, E.V.; Paembonan, J.B.; Unenor, E.; Kuswandi, R.; Lekitoo, K.; Khayati, L.; Benu, N.M.H.; Tambing, J.; Saragih, A.B.S. Heterospecific and conspecific associations of trees in lowland tropical forest of New Guinea. *Biodiversitas* **2020**, *21*, 4405–4418.
97. Chong, K.Y.; Corlett, R.T.; Nuñez, M.A.; Chiu, J.H.; Courchamp, F.; Dawson, W.; Kuebbing, S.; Liebhold, A.M.; Padmanaba, M.; Souza, L.; Andersen, K.M.; Fei, S.; Lee, B.P.Y.-H.; Lum, S.; Luskin, M.S.; Ngo, K.M.; Wardle, D.A. Are terrestrial biological invasions different in the tropics? *Annu. Rev. Ecol. Syst.* **2020**, *52*, 291–314.
98. Hartemink, A.E. The invasive shrub *Piper aduncum* in Papua New Guinea: a review. *J. Trop. For. Sci.* **2010**, *22*, 202–213.
99. Kuswandi, R.; Murdjoko, A. Population structures of four tree species in logged-over tropical forest in south Papua, Indonesia: an integral projection model approach. *Indones. J. For. Res.* **2015**, *2*, 93–101.
100. Murdjoko, A. Recuperation of non-commercial trees in logged forest in southern Papua, Indonesia. *J. Manaj. Hutan Trop.* **2013**, *19*, 94–102.
101. Murdjoko, A.; Marsono, D.; Sadono, R.; Hadisusanto, S. Population dynamics of *Pometia* for the period of post-selective logging in tropical rainforest, southern Papua, Indonesia. *Biosaintifika* **2016**, *8*, 321–330.
102. McNamara, S.; Erskine, P.D.; Lamb, D.; Chantalangsy, L.; Boyle, S. Primary tree species diversity in secondary fallow forests of Laos. *For. Ecol. Manage.* **2012**, *281*, 93–99.
103. Jakovac, C.C.; Junqueira, A.B.; Crouzeilles, R.; Peña-Claros, M.; Mesquita, R.C.G.; Bongers, F. The role of land-use history in driving successional pathways and its implications for the restoration of tropical forests *Biol. Rev.* **2021**, *96*, 1114–11134.
104. Cuni Sanchez, A.; Lindsell, J.A. The role of remnant trees in carbon sequestration, vegetation structure and tree diversity of early succession regrowing fallows in eastern Sierra Leone. *Afr. J. Ecol.* **2017**, *55*, 188–197.
105. Sandor, M.E.; Chazdon, R.L. Remnant trees affect species composition but not structure of tropical second-growth forest. *PLoS One* **2014**, *9*, e83284.
106. Lepš, J.; Novotný, V.; Čížek, L.; Molem, K.; Isua, B.; Boen, W.; Kutil, R.; Auga, J.; Kasbal, M.; Manumbor, M.; Hiuk, S. Successful invasion of the Neotropical species *Piper aduncum* in rain forests in Papua New Guinea. *Appl. Veg. Sci.* **2002**, *5*, 255–262.
107. Labrière, N.; Locatelli, B.; Laumonier, Y.; Freycon, V.; Bernoux, M., 2015. Soil erosion in the humid tropics: a systematic quantitative review. *Agric. Ecosyst. Environ.* **2015**, *203*, 127–139.
108. Li, P.; Feng, Z.; Jiang, L.; Liao, C.; Zhang, J. A review of swidden agriculture in Southeast Asia. *Remote Sens.* **2014**, *6*, 1654–1683.
109. Rochmyaningsih, D. Massive road project threatens New Guinea's biodiversity. *Science* **2021**, *374*, 246–247.
110. Cámara-Leret, R.; Dennehy, Z. Indigenous knowledge of New Guinea's useful plants: a review. *Econ. Bot.* **2019**, *73*, 405–415.
111. Ungirwalu, A.; Awang, S.A.; Runtuboi, Y.Y.; Peday, M.Y.; Marwa, J.; Maitar, B.; Murdjoko, A.; Fatem, S.M. Customary forests in West Papua: contestation of desires or needs? *For. Soc.* **2021**, *5*, 365–375.
112. Brearley, F.Q.; Adinugroho, W.C.; Cámara-Leret, R.; Krisnawati, H.; Ledo, A.; Qie, L.; Smith, T.E.L.; Aini, F.; Garnier, F.; Lestari, N.S.; Mansur, M.; Murdjoko, A.; Oktarita, S.; Soraya, E.; Tata, H.L.; Tiryan, T.; Trethowan, L.A.; Wheeler, C.E.; Abdullah, M.; Aswandi; Buckley, B.J.W.; Cantarello, E.; Dunggjo, I.; Gunawan, H.; Heatubun, C.D.; Dwi Arini, D.I.; Istomo; Komar, T.E.; Kuswandi, R.; Mutaqien, Z.; Pangala, S.R.; Ramadhanil; Prayoto; Puspanti, A.; Qirom, M.A.; Rozak, A.H.; Sadili, A.; Samsuodin, I.; Sulistyawati, E.; Sundari, S.; Sutomo; Tampubolon, A.P.; Webb, C.O. Opportunities and challenges for an Indonesian forest monitoring network *Ann. For. Sci.* **2019**, *76*, 54.