ASIAN JOURNAL OF AGRICULTURE
Volume 9, Number 2, December 2025 E-ISSN: 2580-4537
Pages: 671-682 DOI: 10.13057/asianjagric/g090235

Shifting cultivation and soil conservation strategies among Papuan communities, Indonesia

MAHMUD[1,♥], SRI ENDAYANI[2], ANDREW STEFANO[3], AMALIA LAKEHU[4], MUTAKIM[1], WAHYUDI[1], SUSILO BUDI HUSODO[1], SOETJIPTO MOELJONO[1]

[1]Faculty of Forestry, Universitas Papua. Jl. Gunung Salju, Amban, Manokwari 98314, West Papua, Indonesia.
Tel.: +62-986-211430, ♥email: mahmudalya6@gmail.com
[2]Department of Forestry, Faculty of Agriculture, Universitas 17 Agustus 1945 Samarinda. Jl. Ir. H. Juanda 80, Samarinda 75124, East Kalimantan, Indonesia
[3]Politeknik Pertanian Negeri Samarinda. Jl. Samratulangi, Samarinda 75131, East Kalimantan, Indonesia
[4]Faculty of Education and Teacher Training, Universitas Papua. Jl. Gunung Salju, Amban, Manokwari 98314, West Papua, Indonesia

Manuscript received: 18 August 2025. Revision accepted: 28 October 2025.

Abstract. *Mahmud, Endayani S, Stefano A, Lakehu A, Mutakim, Wahyudi, Husodo SB, Moeljono S. 2025. Shifting cultivation and soil conservation strategies among Papuan communities, Indonesia. Asian J Agric 9: 671-682.* Local Papuan communities in Indonesia, rely heavily on land resources for food security, yet shifting cultivation remains the dominant practice. This system, while traditional, often leads to soil nutrient depletion, reduced productivity, and increased deforestation. To understand the dynamics of local farming practices, this study applied interviews, surveys, and participatory approaches with farmers and community members. Findings reveal that short-term crops such as long beans, peanuts, cabbage, chilies, and sweet potatoes dominate cultivation, contributing to rapid soil fertility loss. In contrast, perennial crops such as *Areca catechu, Musa paradisiaca, Nephelium* lappaceum, and *Artocarpus altilis* are typically maintained in fixed plots without being shifted. To address soil degradation, the study proposes several conservation strategies. These include mulching to retain soil moisture, living fences and cover crops to minimize erosion, intercropping to diversify yields and improve nutrient cycling, and the integration of Multipurpose Tree Species (MPTS) and hedgerows to restore long-term soil fertility. Collectively, these measures can reduce the necessity for continuous land clearing and help communities move toward more sustainable sedentary agricultural systems. Beyond technical solutions, the research highlights the importance of strengthening community awareness about forest and soil conservation. Transitioning away from shifting cultivation not only improves land productivity but also contributes to broader ecological resilience. By adopting integrated conservation practices, Papuan farmers can secure food production, maintain forest ecosystems, and develop more sustainable livelihoods in harmony with their environment.

Keywords: Agroforestry, local communities, Papua, shifting cultivation, soil conservation

INTRODUCTION

Soil degradation is one of the most pressing global environmental challenges, threatening food security, ecosystem stability, and sustainable development (Borrelli et al. 2020). Across the world, unsustainable land use practices, deforestation, and climate variability accelerate soil erosion, reduce soil fertility, and impair water regulation (Steiner et al. 2023). These processes undermine agricultural productivity and contribute to broader issues, such as flooding, biodiversity loss, and climate change (Worman et al. 2017; Landu et al. 2025). Addressing soil degradation is therefore critical to achieving both ecological resilience and human well-being.

In Indonesia, particularly in Papua, soil degradation is closely tied to the practice of shifting cultivation and land clearing by burning (Murdjoko et al. 2022). While such practices are deeply rooted in local traditions, they have led to rapid forest loss and declining soil fertility. Between 2001 and 2019, Papua experienced deforestation of more than 660,000 hectares, with serious consequences for biodiversity, ecosystem services, and the livelihoods of local communities (Borrelli et al. 2020; Sonbait et al. 2021; Toansiba et al. 2021). In Manokwari and surrounding regions, traditional shifting cultivation often involves short-term crops that quickly exhaust soil nutrients, forcing farmers to abandon plots after only a few cycles (Villa et al. 2018; Bhuyan et al. 2019; Temjen et al. 2022). Although fallow periods were historically sufficient to restore fertility, increasing population pressure, reduced land availability, and shorter recovery cycles have intensified land degradation (Haregeweyn et al. 2017; Li et al. 2023; Tang et al. 2023; Wang et al. 2024).

Despite the urgency of this issue, knowledge gaps persist regarding how traditional farming systems in Papua can transition toward more sustainable forms of land use (Marhaento et al. 2018; Mahmud et al. 2021; Sagrim 2022). While local communities possess valuable ecological knowledge, systematic studies on how these practices can be adapted, improved, or combined with soil conservation strategies are still limited (Sumule et al. 2020; Hasannudin et al. 2022). Current research has largely focused on the ecological impacts of shifting cultivation; however, less attention has been given to practical, context-specific conservation models that balance productivity, cultural traditions, and environmental sustainability (Auliyani 2020; Triasary 2021).

Traditional agricultural practices, such as shifting cultivation, have been employed without considering long-term, sustainable solutions. These activities have led to massive deforestation and land degradation, resulting in the loss of forest resources in Indonesia. In Papua, for example, forest deforestation over the past two decades decreased by 663,443 hectares, with a 29% decline from 2001 to 2010 and a 71% decline from 2011 to 2019, resulting in an average annual loss of 34,918 hectares (Indonesian Coalition Monitors 2021). Forests, however, play a crucial role in mitigating floods, erosion, and landslides, underscoring the importance of sustainable forest management. Shifting cultivation, through the practice of burning, poses severe risks to forests and the land. Forests are increasingly damaged when cleared land is left unmanaged, with no conservation measures taken. The land normally remains fallow (resting) for 2-3 years before being overgrown with shrubs. According to studies, soil fertility in shifting cultivation systems is frequently replenished during the fallow periods.

In addition, this study addresses these gaps by identifying farming patterns among Papuan communities and proposing soil conservation designs tailored to local socio-ecological conditions. Specifically, it examines the transition from shifting cultivation to sedentary agriculture through the integration of practices such as mulching, living fences, cover crops, intercropping, and the maintenance of multipurpose tree species. By doing so, the research contributes to both scientific and practical discussions on sustainable land management in tropical regions. The findings are expected to inform agricultural policies and community-based strategies that restore soil fertility, reduce pressure on deforestation, and enhance the resilience of traditional farming systems in Papua New Guinea. Flooding, flash floods, and erosion are serious global issues today, posing significant challenges to the sustainable development of society, the environment, and the economy. This research will contribute to community-based soil conservation design, aiming to reduce deforestation, restore soil fertility quickly, and achieve sustainable agricultural development.

MATERIALS AND METHODS

Study area

The research was conducted in Manokwari District, West Papua, Indonesia (Figure 1), from May to October 2024. Tropical rainforests, high rainfall, and sloping land prone to erosion characterize this area. Farming activities in this region represent both shifting cultivation and permanent agriculture, making it a relevant location for studying agricultural patterns and soil conservation practices. A purposive sampling method was applied to select informants. A total of 35 respondents were chosen from 15 villages, representing diverse socio-demographic groups (residents, migrants, and mixed-marriage communities). This number was considered sufficient to ensure data saturation in both qualitative and quantitative descriptive analyses, while maintaining proportional representation of gender, age, ethnicity, and land-use practices.

The selection of 35 respondents was based on the principle of representativeness and data saturation. This number ensured adequate coverage of socio-demographic diversity (gender, age groups, ethnicity, and farming practices) across 15 villages in Manokwari. According to methodological standards in qualitative-quantitative descriptive studies, a sample size of 30-40 respondents is sufficient to capture the heterogeneity of community knowledge and practices without redundancy. Thus, 35 informants were deemed appropriate to provide reliable insights into agricultural patterns and soil conservation strategies.

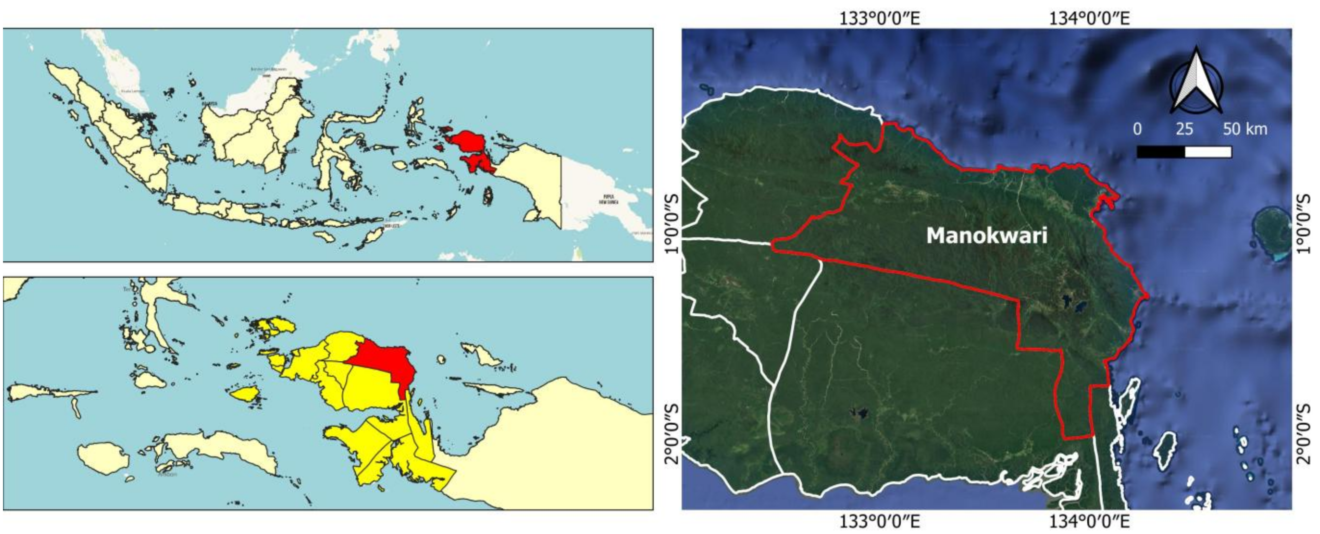

Figure 1. Map of research location in Manokwari District, West Papua, Indonesia

Data collection involved two approaches: (i) Interviews and structured questionnaires were used to gather information on farming systems, crop preferences, socio-demographic characteristics, and awareness of soil conservation from respondents. (ii) Field Observation - direct observations were conducted on agricultural land to record farming patterns, plant species cultivated, slope conditions, and conservation practices. Photovoice was also employed by taking photographs during farming activities to complement the narrative data.

Data analysis

This study was conducted for six months from May to October 2024, in Manokwari District. The materials used included structured questionnaires, regional maps of Manokwari, and soil samples. Tools, such as a GPS device, camera, measuring tape, machete, soil scope, computer, and stationery were employed. The study combined interviews and direct observation, with farmers serving as the primary subjects and their farming activities as the object of study. Interviews were conducted through the systemic data/information collection based on a set of pre-determined questions. The data were then analyzed using descriptive statistics by calculating the percentage (%) of traditional farmer parameters where the number of categories was divided by the number of respondents as follows:

$$Pi = \frac{ni}{N}$$

Where, Pi is the percentage (%) of socio-demographic characteristics (gender, education, occupation, and age group) in percent, ni is the number of socio-demographic characteristics (gender, education, occupation, and age group), and N is the total number of respondents.

Field observations focused on identifying agricultural trends, plant species, soil conservation measures, and land slope conditions. Interviews were performed to acquire information on agricultural systems, reasons for using various farming practices, farmers' age, and crop preferences. Purposive sampling was used to obtain data, with 35 male and female informants drawn from 15 villages in Manokwari. The respondents included local residents, migrant and mixed (intermarried) communities who actively utilize natural resources. A structured questionnaire was employed to collect comprehensive data on respondent backgrounds, including their identity, knowledge, experiences, level of education, ethnicity, age, length of residence and land conservation activities. This study also assessed the plantation community's perception of how they benefit from natural resources. Farmers' knowledge and awareness of farming were classified into social, ecological, economic, and energy-related advantages. Field photography was done using information supplied by respondents. The data were analysed using descriptive statistics, which presented the percentage (%) of social parameters associated with farming practices and photovoice by taking pictures during local activities. This study also combined analysis of conservation technique recommendations and qualitative descriptive analysis to formulate adaptive conservation strategies. This approach allowed for targeted, measurable, and sustainable conservation planning, with technical recommendations tailored to the physical characteristics of the area and the socio-economic conditions of the local community. The results of the analysis were then presented in the form of Figures.

RESULTS AND DISCUSSION

Socio-demographics

The study involved 35 respondents across 15 villages in Manokwari District. Most participants were men (60%), while women comprised 40%. Household sizes varied, with 64.90% consisting of 4-7 members, 24.10% fewer than four, and 11% more than six. The largest age group was 41-60 years (54.4%), followed by those under 40 (34.3%) and above 60 (11.30%). In terms of residence duration, 60.3% had lived in their villages for more than 26 years, demonstrating deep familiarity with local agro-ecological conditions. Meanwhile respondent's household displayed on Figure 2 and respondent's age Figure 3.

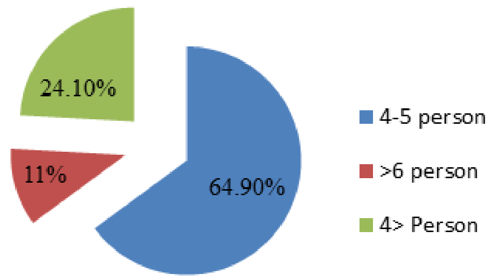

Figure 2. Respondent's household

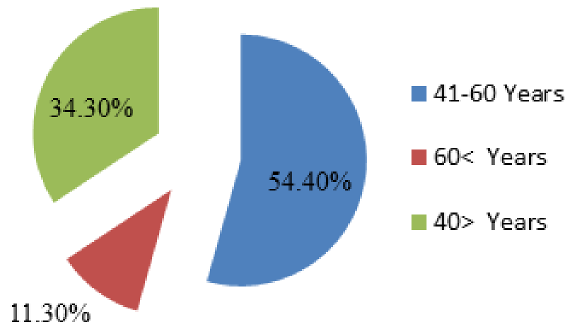

Figure 3. Respondent's age

Figure 2 shows that households are dominated by families of 4-5 people. Meanwhile, Figure 3 shows that farmers are predominantly aged 41-60 years. Most respondents were indigenous people who had lived in the region since birth, with just a small minority of outsiders who had moved to the villages through marriage. In terms of village residence duration, 39.7% of most respondents had lived there for less than 25 years, 40.2% for 26-46 years, and 20.1% for more than 47 years. This indicates that 60.3% of respondents had a thorough understanding of their village's socio-agricultural system, including the biophysical conditions in their region. For generations, the Papuan people have had a deep connection with the natural resources and surrounding forests.

Some people consider agricultural land as the skin of a nurturing mother, providing nourishment, livelihoods, and food security. The community's dependence on and interaction with land and natural resources is deeply embedded in its cultural practices. As noted by Karous et al. (2021) and Martins and Shackleton (2021), this extended dependency and interaction have allowed local communities in Papua to develop traditional ecological knowledge that underpins sustainable farming practices. The local community's farming pattern is considered sustainable because unproductive land is rested for a designated fallow period. Sustainable agriculture can be developed by fostering and integrating local agricultural practices. However, notwithstanding this, the community's use of forest resources and agricultural land often ignores sustainability. To determine the extent of a more comprehensive agricultural pattern, it is necessary to establish a basic concept for analyzing the characteristics and typologies of farming communities.

Farming patterns

Two main agricultural systems were identified: shifting cultivation and permanent farming. Shifting cultivation was dominant (21 households, 60%), typically practiced by indigenous farmers with easier access to customary land. This system emphasized short-season crops-such as mustard greens, cabbage, corn, long beans, chilies, and tomatoes-without the application of inorganic fertilizers. Soil fertility was sustained only by ash and decomposing litter. In contrast, permanent farming (14 households, 40%) was practiced mainly by migrants and mixed-descent farmers. This system focused on perennial fruit crops (e.g., *Nephelium lappaceum*, *Artocarpus heterophyllus*, *Musa paradisiaca*, *Ananas comosus*), often within agroforestry systems that integrated food crops and multipurpose trees.

Traditional farming pattern

The study consisted more traditional farming with shifting cultivation carried out by local communities with limited formal education. As holders of customary land rights, these groups frequently clear new land, including forests, with ease and few constraints. Meanwhile, permanent agriculture is mostly carried out by immigrant and mixed-descendant communities who face limited access to land and must pay significant fees to clear new land (open forest). Humans' farming practices to meet food needs can be done through permanent agriculture and shifting cultivation systems. In general, permanent agriculture focuses on fruit crops.

Meanwhile, shifting cultivation includes plants such as mustard greens (*Brassica rapa*), cabbage (*Brassica oleracea*), corn (*Zea mays*), long beans (*Vigna cylindrica*), chilies (*Capsicum frutescens*), and tomatoes (*Solanum lycopersicum*). Farmers recognize that fruit plants have long, numerous, and extensive roots, which enable efficient nutrient absorption. In contrast, vegetable plants have shallow, fibrous roots that impede nutrient absorption. As a result, farmers have to move around while planting vegetables to restore soil fertility and boost agricultural production. Additionally, they do not use inorganic fertilizers. They use only natural inputs, such as decomposing litter and ash from burned organic litter, avoiding inorganic fertilizers. According to Sagrim (2022), local Papuan communities' agricultural activities so far do not include the use of fertilizers, either liquid or solid, on soil or leaves.

Shifting cultivation is an agricultural practice that involves clearing forests or land by burning, followed by the planting of food crops. This activity, which is routinely practiced by local populations, involves replanting following secondary succession, as demonstrated in research from Papua (Kukla et al. 2019) and other tropical regions worldwide (Hattori et al. 2019). This traditional system must be immediately prevented, and a transition to permanent agriculture must be prioritized. A lack of awareness among planters and a perception that educational forests and plant collections lacked utility resulted in the clearing of trees for crops such as corn and bananas (Figure 4.A). Meanwhile, in the shifting cultivation areas that were abandoned for a year, shrubs dominated by *Crotaria* sp. have begun to thrive (Figure 4.B). This farming system has caused the main environmental problems, such as the encroachment of forests and land in the Wosi and Rendani protected forests, which have been reduced to only 80 hectares due to clearing and burning (Mahmud 2021). Apart from that, there was also forest encroachment on the land of Gunung Meja Nutural Tourism Park (GMNTP), which has increased from 8.9 hectares to 30 hectares. For this reason, in Manokwari District, natural tourism parks remain the only certified nature conservation areas under the Regional Government's management.

In fact, if the land and remaining vegetation are not burned, several benefits can be obtained. These include the prevention of water pollution in rivers and air pollution, the retention of nutrients in the form of litter, which decompose gradually to release nutrients, and the continuous availability of nutrients thereby reducing the use of fertilizer (Mahmud 2023). Additionally, the growth of grass and weed is minimized, while branches and wood can be utilized to create various economically valuable products.

Figure 4. Trees felled in: A. The arboretum, B. Fallow land overgrown with *Crotaria* sp.

Contemporary agricultural patterns and agroforestry

Among the respondents, 14 planters (40%) adopted a permanent agricultural system incorporating modern practices and agroforestry. They plant crops, such as *N. lappaceum*, *A. heterophyllus*, *M. paradisiaca*, *A. comosus* and short-term crops like *Caladium* spp. (Figure 5.A). As population growth escalates while agricultural land remains static, it is important to maintain a stable agricultural system. These farmers apply measures to control soil erosion, maintain the integrity of the tillage layer, and ensure consistent nutrient availability. Such soil conservation methods that allow plant roots to absorb nutrients easily, keep the soil productive throughout the year and increase crop yields.

Fruit and tuber crops were cultivated without inorganic fertilizer, instead depending on compost, manure, and organic kitchen waste, including fruit peels, vegetable scraps, and different leftover foods. Organic kitchen waste was either composted in piles or spread onto the area where fruit and tuber plants were planted. Agroforestry methods were also used, with the main plant types including *Cocos nucifera* and *A. comosus*, as well as *Gliricidia sepium* as a shade tree (Figure 5.B). By staggering the cultivation phases of *A. comosus* and *C. nucifera*, allowed farmers to either use the harvested crops for their daily requirements or sell them to improve their revenue. According to Hasannudin et al. (2022) and Wattie and Sukendah (2023), highlight that communities near forests can benefit directly or indirectly from forest products, so boosting their livelihoods and wellbeing. *Gliricidia sepium* not only provides shade, but also improves soil fertility through its rapidly decomposing leaves, which release nutrients back into the soil.

A combination of soil conservation on 20% slopes was achieved using dead-end trenches and planting *A. comosus* in the holes. The trenches are 60-70 cm deep and surrounded solely by vegetable crops, ensuring that *A. comosus* receives adequate sunlight without being shadowed by surrounding plants. So far, dead-end trenches on plantation land have been used for disposing of organic waste such as fruit peels, fronds, palm kernel cake, leaves, and twigs. Planting *A. comosus* in these trenches helps utilize unused spaces, thereby increasing agricultural yields (Figure 6). However, if a dead-end trench with a diameter of 1.5 m is left without plants, it will not contribute to the improving agricultural yields and the farmer's economic well-being. Dead-end trenches provide multiple benefits, including increased water absorption (Wattie and Sukendah 2023), improved soil fertility (Mowidu and Endang 2022), habitat construction for various species of flora and fauna, as well as reduced water runoff, which help to prevent soil erosion (Mahmud 2023). To guarantee that *A. comosus* is not shaded, companion plants such as *C. frutescens, Cymbopogon citratus, Zingiber officinale* or other vegetable crops should be used since they do not interfere with the primary crops.

Soil conservation practices

Field observations revealed that traditional conservation practices were minimal. Farmers rarely received extension services and relied heavily on knowledge passed down through generations. However, several adaptive techniques were identified and designed for potential implementation (Figure/Table references as appropriate): (i) Mulching with organic waste to enhance soil fertility, water retention, and weed control. (ii) Living fences (e.g., *G. sepium*, *Moringa oleifera*) to reduce erosion and improve nutrient cycling. (iii) Cover crops (e.g., *Centrosema* sp., *Pueraria* sp., *Maranta arundinacea*) to maintain soil structure and fertility. (iv) Intercropping with *Artocarpus altilis* combined with annual crops to ensure continuous soil cover and higher yields. Maintenance of Multipurpose Tree Species (MPTS) and hedgerows on newly cleared land to mitigate runoff, conserve biodiversity, and provide economic benefits. Collectively, these practices aim to reduce land clearing, restore soil fertility, and support the transition from shifting to sedentary agriculture.

Figure 5. A. The sedentary agricultural pattern with consistent use of mulch, and B. Agroforestry of pineapple (*Ananas comosus*), coconut (*Cocos nucifera*) and *gamal* (*Gliricidia sepium*)

Figure 6. Pineapple plant in dead-end trench

The results of interviews with farmers revealed that they have almost never been provided with guidance on how to increase agricultural yields and conserve soil. Their farming knowledge has mostly been passed down through generations from their parents and ancestors. Overcoming agricultural, forestry, social, and economic problems, as well as flood and landslide disasters, requires applicable land-use strategies that balance productivity and ecological functions. Several soil conservation scenarios can be implemented to ensure agriculture is sustainable, easy for the community to adopt and still maintain environmental sustainability. These include using dead-end trenches inside a living fence, intercropping with *A. altilis* combination, and maintaining MPTS on newly farmed land. Dead-end trenches significantly reduce surface runoff, particularly on sloping terrain, and they can collect and retain rainwater, thereby increasing plant water availability (Faizin and Maghfiroh 2023). Aside from that, dead-end trenches are especially useful in locations with high rainfall, such as Papua, as they help prevent soil erosion (Maghfiroh and Putra 2024). Therefore, to achieve sustainable agriculture and prevent disaster, the following soil conservation techniques are recommended:

Utilization of mulch

The use of mulch can increase soil fertility by improving the availability of nutrients in the soil. It can be obtained from organic household waste, such as vegetable scraps, fruit peels and other unconsumed plant parts. Farmers must be able to select organic household waste and combine it with mulch, applying it to long-term crops, such as *N. lappaceum, A. heterophyllus* and *M. paradisiaca*. Over time, the mulch and organic waste will decompose, releasing nutrients essential for plant growth. However, during harvest, many nutrients are removed with the fruit, seeds, and leaves, requiring the renewal of the soil with manure, compost, or other organic materials to maintain soil fertility. Mulch and plant residues (litter) also enhance the soil's capacity to absorb water and help regulate its temperature (Asbur and Ariyanti 2017; Satriawan et al. 2017; Jayanti and Iswahyudi 2020).

The mulch, which is made from leaf midribs, stems, leaves, flowers, and grass, adds organic matter to the soil and can be spread evenly across the soil surface to inhibit weed growth and reduce runoff. When incorporated into soil or used as raised beds or banks on slopes, mulch reduces the kinetic energy of falling rain, thereby preventing soil aggregate damage and minimizing runoff. Therefore, soil erosion is diminished, and the organic content of the soil increases (Hasannudin et al. 2022; Moreau et al. 2022). On the other hand, burning mulch can lead to several adverse outcomes, including air and water pollution, nutrient leaching, an increased risk of uncontrolled fires, rapid nutrient loss, accelerated growth of grass and weeds, and a rapid decline in long-term soil fertility. Therefore, to ensure long-term soil health, farmers should refrain from burning mulch and instead adopt sustainable organic practices.

Farming inside a living fence

Farming within a living fence is an agricultural system where food crops are planted between rows of hedgerows. These hedgerows play very important role in reducing the rate of surface runoff, erosion, and sedimentation. When surface water flow carries sediment, the hedgerows act as natural barriers, trapping sediment and preventing it from being washed away. This system includes rows of main crops, with mulch or kitchen waste spread around the fence plants to enhance soil fertility (Figure 8). Cultivation within living fences can rehabilitate degraded land and promote environmentally sustainable farming systems. Farmers who do not have livestock can choose hedge plants such as *gedi* (*Abelmoschus manihot*), *kelor* (*M. oleifera*), and *katuk* (*Sauropus androgynus*). These three plants were chosen because they can be used as nutritious vegetables and if they are more, they can be sold. Meanwhile, those with cattle or goats may choose hedgerows, such as *gamal* (*G. sepium*), *kolonjono* (*Panicum muticum*) and *rumput gajah* (*Pennicetum purpureum*) as animal feed. *Gliricidia sepium* acts as an organic reserve of soil and nutrients, especially nitrogen, which benefits plants grown inside the fence. The alley cropping pattern on dry land, when designed to maximize economic value and opportunities, has great potential for agricultural development (Haerani 2017).

Gliricidia sepium requires regular pruning once it reaches 3-4 months of age or when its height begins to shade the main plants. Pruning ensures that the main crops receive enough sunlight, preventing competition for space and resources. If not pruned regularly, *G. sepium* can obstruct the growth of the main plant. The pruned branches, twigs and leaves can be used as animal feed and/or be spread on the ground as organic matter. Pruning is typically performed every 2-3 months, depending on the specific agricultural needs, types of plants and growth rate. In living fence systems, legume roots act as mineral pumps, drawing nutrients from deeper soil layers. Above the ground, their stems form part of an alley cropping system that effectively reduce surface runoff and soil erosion. Studies have shown that alley cropping on sloped land can reduce soil erosion from 96.9 tons ha^{-1} to just 0.8 tons ha^{-1} (Arsyad 2010). Furthermore, after three years of implementing this system, the soil nutrient balance becomes positive, meaning more nutrients are returned to the soil than are lost.

Matoa (*Pometia pinnata*) is chosen as an ideal tree species for agroforesty because of its multiple benefits. It provides shade, its wood can be used as building material for houses, and its fruit is both edible and marketable. As an endemic species in Papua, matoa is ecologically, physiologically and geographically well-suited to local condition, thriving naturally in the region. The fruit of matoa is highly valued for its unique taste and resemblance to longan, earing it the nickname Papuan longan.

Cover crops

Cover crops play a crucial role in maintaining the tillage layer against erosion and enhancing the soil's physical and chemical properties. Even if the land becomes unproductive, it should not be abandoned; instead, cover crops should be planted to sustain soil health. The roles of cover crops include reducing water runoff, minimizing the impact of falling raindrops that erode the soil, and adding organic material through the decomposition of plant residues. Leaf litter and plant stems that rot and decompose will add organic matter to the soil fertility, rejuvenating degraded land. Furthermore, the transpiration of cover crops helps to reduce soil water reserves, facilitating increased infiltration during rainfall. Land protected by mulch, plant residues, or cover crops experiences minimal loss of the tillage layer compared to relatively open land, which is more inclined to erosion (Pokorny et al. 2021; Seta et al. 2021).

The use of cover crops offers numerous benefits, including stabilizing or improving soil structure, increasing water supplies, enhancing soil nutrient availability, maintaining productive soil, and supporting farmers' economic stability. Recommended cover crops should have root systems that do not compete with main plants and be adaptable to less fertile soils. Ideal cover crops grow fast, produce young leaves quickly, allow regular pruning, and decompose easily to enrich the soil. They should also resist drought, disease, and pests, suppress weed growth, and remain non-toxic to main crops. Key benefits of cover crops include decreasing surface runoff, reducing erosion, ensuring a steady supply of organic matter, increasing infiltration, and retaining rainwater characteristics, as seen in crops like arrowroot tubers (Figure 7). Several types of cover crops that are usually used in agriculture, namely: (i) *Centrosema* sp., *Calopogonium mucunoides*, *Pueraria* sp., and *Ageratum conyzoides*. This plant is classified as a climbing or low-growing types. (ii) *Acacia villosa* and *Crotaria* sp. (iii) *Albizia falcataria* (*kemlandingan*), *Leucaena glauca* (local *lamtoro*), *Leucaena leucocephala* (giant *lamtoro*). (iv) *M. arundinacea* (arrowroot) and *Arachis hypogaea* (peanut).

Figure 7. *Maranta arundinacea* is a shade-tolerant ground cover crop

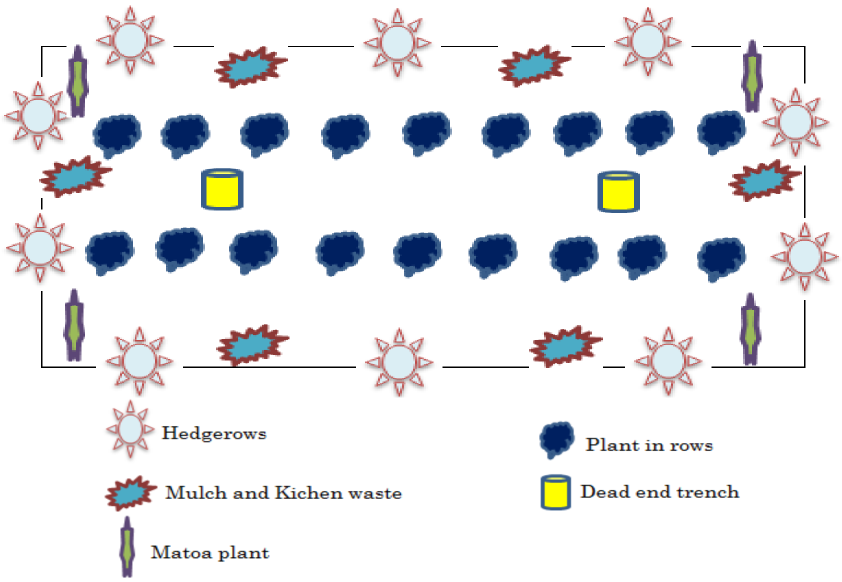

Figure 8. Planting design in the matoa combination living fence

Intercropping with Artocarpus altilis

Intercropping with *A. altilis* includes cultivating multiple types of plants on the similar land simultaneously, by arranging plants of relatively similar ages in stips. This linear planting, which combines trees and vegetable crops, provides various advantages. In addition to improving crop production and providing animal feed, it increases human welfare by contributing to environmental protection and sustainability (Mulu et al. 2020; Nandini et al. 2023).

Artocarpus altilis is combined into intercropping systems by alternating rows with combinations, such as mustard greens and corn, corn and peanuts, legumes and chilies, or corn and cowpeas. *Artocarpus altilis* is typically planted in the corners of the land and inside the living fence (Figure 10). Choosing suitable main plant is important because each plant has allelopathic properties that can inhibit or suppress the growth of neighbouring plants. Important factors to consider in selecting plants include planting time, canopy width, root distribution area, and particular chemical compounds released by plants, which may reduce or accelerate the growth of other types because they are related to the compounds released (Subedi et al. 2018). Furthermore, agricultural yields, crop growth, and nitrogen uptake can be significantly influenced by intercropping patterns of legume and non-legume crops (Bahabol et al. 2021; Sudomo et al. 2021; Chamkhi et al. 2022).

Sometimes, intercropping systems involve plants of varying ages, typically two to three species. On slightly sloping land, raised beds are arranged to reduce the slope. Meanwhile, on flat land, the orientation of the rows of beds depends on the land's layout. During the early planting of the rainy season, *Ipomoea batatas* are planted simultaneously with *Z. mays*. In the next planting season, corn is intercropped with *A. hypogaea* and *Manihot esculenta* without resting the land. This farming system offers several benefits, involving increased agricultural yields, reduced surface runoff, and the return of plant residues to the soil, which helps to maintain its physical and chemical properties. It also diminishes the growth of weeds and other invasive species. By maintaining the land remains constantly covered with vegetation, this farming system prevents shifting cultivation. The land is consistently covered by vegetation with the main crops in this system include horticultural plants. Furthermore, *A. altilis* serves as both protective plant and a means of soil conservation. Some people consider *A. altilis* to be a highly valuable type of fruit because of its year-round availability (Figure 9).

Some Papuans classify *A. altilis* as a staple food, serving as a local alternative to rice and an important source of carbohydrates. Its wide leaves and dense plant crowns effectively intercept raindrops, reducing their impact on the soil surface and preventing soil erosion.

Figure 9. People sell *Artocarpus altilis* in front of their houses

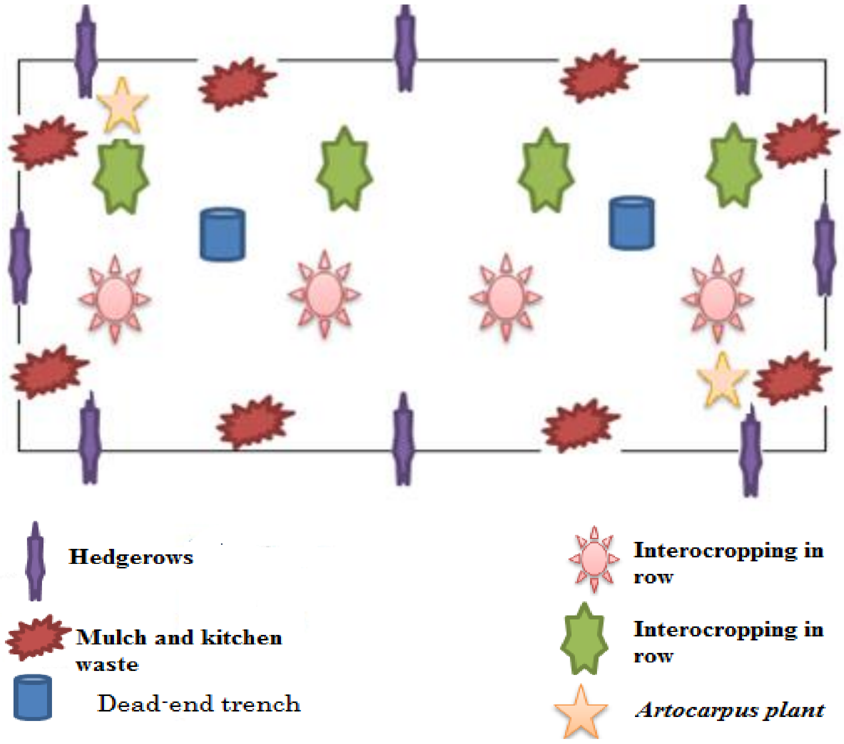

Figure 10. Design of *Artocarpus altilis* combination intercropping in the fence

Maintain MPTS and hedge rows on new land

Land selected for farming is generally located near the areas that are to be abandoned. In the case where all should be cleared without know there are useful species. However, if the land is cleared and contains MPTS that offer noticeable environmental and economic benefits, the community will be driven to care for, maintain the land, and avoid burning it entirely. Burning the land can harm the MPTS and fence plants, and reduce the capacity of soil's water absorption, and increase surface runoff, which may trigger environmental degradation. As noticed by (Sukmawardhono and Nugroho 2020) reducing the availability of land for water absorption has serious environmental effects, increasing surface runoff and the risk of disasters such as floods and landslides. To diminish these effects, clearing new land need to include preserving MPTS and hedge plants, while shrubs, herbs, grasses, and tree saplings are completely cleared (Figure 11).

If MPTS such as *C. nucifera*, *P. pinnata*, *A. altilis*, *Psidium guajava*, *Syzygium aqueum*, and *Aleurites moluccanus* are found on the land chosen for clearing, they need to be preserved, because they have economic and ecological benefits. Economically, these species are useful for harvesting valuable fruits, either for family consumption or for sale. Ecologically, preserving these trees ensures continued land cover, which will prevent surface runoff. Furthermore, border vegetation, such as *G. sepium*, *A. manihot*, *M. oleifera*, and other types of plants that are useful for gardeners needs to be maintained (not cut down). If planters clear land by cutting down everything on the surface of the land, the land will be opened, making it highly vulnerable to surface runoff. Increation rainfall intensity on opened land worsens surface runoff, resulting in erosion, landslides and even flooding (Nasiry 2023). According to Tarigan (2022), surface runoff on a large scale can damage the soil and reduces its fertility, as erosion removes necessary nutrients. Therefore, it is important to always educate farmers on the need to maintain new land if there are MPTS and border vegetation. These plants have an important function in strengthening the soil structure, reducing surface runoff, and averting erosion risks.

If planters had applied appropriate methods to maintain MPTS and hedgerows during new land clearing, the situation depicted in Figure 12 would not have occurred. This figure shows scattered logs, standing wood stumps, and a thin layer of ash (indicated by the slightly blackened soil surface), suggesting the burning of litter, shrubs, and remaining trees. While it is generally believed that ash from burned litter, twigs, branches, limbs, and trunks can help improve the level of soil fertility and agricultural yields, the habit of clearing new land through cutting and burning has long-standing roots in traditional farming methods passed down through generations for a long time. However, because the land is located on sloped terrain with gradients of up to 30% (Figure 12), surface runoff gradually removes ash from the soil surface, lessening its potential benefits. This emphasizes the necessity of practicing sustainable land management that maintains MPTS and hedgerows to avoid surface runoff and preserve soil fertility.

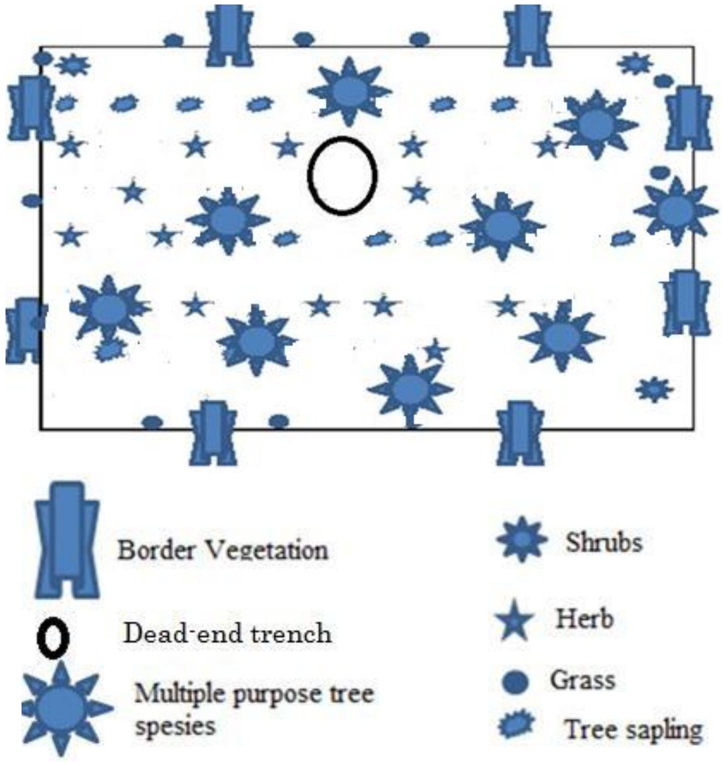

Figure 11. Land clearing design with the implementation of soil conservation practices

Figure 12. Land clearing by removing all vegetation

Discussion

The findings confirm that shifting cultivation remains the dominant farming practice in Papua, as reported in earlier studies across tropical regions (Kukla et al. 2019). However, its reliance on burning and short fallow cycles accelerates nutrient depletion and forest degradation, consistent with studies linking shifting agriculture to biodiversity loss and erosion (Bhuyan 2019; Temjen et al. 2022). In contrast, the permanent agroforestry systems observed in this study mirror global trends that integrate ecological functions with food production (Hasannudin et al. 2022; Wattie and Sukendah 2023).

A key novelty lies in documenting how Papuan farmers integrate *A. altilis* as both a staple food and a conservation mechanism. Unlike previous reports that focus mainly on annual cropping, this study demonstrates how perennial and multipurpose species can simultaneously underpin soil conservation and food security. Similarly, the design of dead-end trenches combined with *A. comosus* represents a locally adapted solution to high-rainfall erosion, which has been less emphasized in prior literature.

The results highlight both opportunities and challenges for transforming Papuan agriculture. On one hand, traditional knowledge of resting land and avoiding fertilizers shows ecological awareness. On the other hand, continued dependence on burning and shifting systems risks worsening deforestation, erosion, and reduced crop productivity. Integrating soil conservation methods-such as mulching, living fences, cover crops, and intercropping-into local practices can enhance soil fertility, improve yields, and reduce pressure on protected forests.

For sustainable land-use transitions, the active role of agricultural extension services, NGOs, and local government is crucial. Programs must be community-based, recognizing customary land tenure and farmers' ecological knowledge while introducing practical conservation methods. Policies promoting the cultivation of MPTS, the adoption of agroforestry practices, and the avoidance of burning are crucial for mitigating climate change and ensuring long-term food security in Papua New Guinea.

In conclusion, this study highlights that Papuan farming communities still rely predominantly on shifting cultivation, cultivating short-term crops such as beans, peanuts, cabbage, chilies, and sweet potatoes, which rapidly deplete soil nutrients and lower productivity upon replanting. At the same time, perennial crops-including *Areca catechu*, *M. paradisiaca*, and *A. altilis* are typically planted without relocation, reflecting a mixed but fragile agricultural system. The key findings demonstrate that five soil conservation strategies -mulching, farming within living fences, ground cover crops, intercropping, and the preservation of MPTS and hedgerows- offer practical and culturally appropriate methods to restore soil fertility, reduce land clearing, and support the transition from nomadic to sedentary agriculture. This research contributes to the growing body of literature on sustainable agriculture by providing an empirical case study from Papua. In this region, traditional ecological knowledge and conservation practices can be integrated with modern approaches. The proposed strategies are not only relevant to Papua but also applicable to other tropical regions facing similar challenges, including forest loss, shifting cultivation, and climate vulnerability. By documenting locally adapted soil conservation designs, this work underscores the importance of context-specific strategies for strengthening food security, preventing land degradation, and aligning agricultural development with biodiversity protection. From a policy and practical perspective, the findings suggest that promoting soil conservation through extension services, farmer training, and participatory planning can help mitigate deforestation, enhance local awareness of environmental stewardship, and strengthen resilience against erosion and flooding.

Nevertheless, this study has several limitations. The research relied on descriptive surveys and interviews within a limited sample of farming households, which may have resulted in the underrepresentation of broader ecological and socio-economic dynamics. Future research should therefore combine longitudinal ecological monitoring with socio-economic assessments to evaluate the long-term effectiveness and adoption of soil conservation practices.

ACKNOWLEDGEMENTS

The author would like to thank friends who helped in collecting data and the farming community who were willing to be interviewed.

REFERENCES

Arsyad S. 2010. Konservasi Tanah dan Air. Bogor, IPB Press. [Indonesian]

Asbur Y, Ariyanti M. 2017. Peran konservasi tanah terhadap cadangan karbon tanah, bahan organik, dan pertumbuhan kelapa sawit (*Elaeis guineensis* Jacq.). Jurnal Kultivasi 16 (3): 402-411. DOI: 10.24198/kltv.v16i3.14446. [Indonesian]

Auliyani D. 2020. Upaya konservasi tanah dan air pada daerah pertanian dataran tinggi di Sub-Daerah Aliran Sungai Gandul. Jurnal Ilmu Pertanian Indonesia 25 (3): 382-387. DOI: 10.18343/jipi.25.3.382. [Indonesian]

Bahabol S, Sagrim M, Suwardi I. 2021. Kajian pengembangan pertanian pola tanam campuran pada masyarakat Suku Meyah di Kampung Wariki Distrik Sidey Kabupaten Manokwari. Jurnal Sosio Agri Papua 10 (1): 68-76. DOI: 10.30862/sap.v10i1.110. [Indonesian]

Bhuyan R. 2019. A review note on shifting cultivation in northeast India amidst changing perceptions. Dhaulagiri J Sociol Anthropol 13: 90-95. DOI: 10.3126/dsaj.v13i0.24252.

Borrelli P, Robinson DA, Panagos P, Lugato E, Yang JE, Alewell C, Wuepper D, Montanarella L, Ballabio C. 2020. Land use and climate change impacts on global soil erosion by water (2015-2070). Proc Natl Acad Sci 117: 21994-22001. DOI: 10.1073/pnas.2001403117.

Chamkhi I, Cheto S, Geistlinger J, Zeroual Y, Kouisni L, Bargaz A, Ghoulam C. 2022. Legume-based intercropping systems promote beneficial rhizobacterial community and crop yield under stressing conditions. Ind Crops Prod 183: 114958. DOI: 10.1016/j.indcrop.2022.114958.

Faizin A, Maghfiroh CN. 2023. Pengaruh rorak terhadap serangan hama pada tanaman kopi robusta (*Coffea robusta* L.). Agrosaintifika J Ilmu-Ilmu Pertanian 5 (2): 54-66. DOI: 10.32764/agrosaintifika.v5i2.3638. [Indonesian]

Haerani N. 2017. Alley cropping increases the resilience of agricultural production on dry land (A review). Agrovital J Agric Sci Al Asyariah Univ 2 (2): 72-82. DOI: 10.35329/agrovital.v2i2.132.

Haregeweyn N, Tsunekawa A, Poesen J, Tsubo M, Meshesha DT, Fenta AA, Nyssen J, Adgo E. 2017. Comprehensive assessment of soil erosion risk for better land use planning in river basins: Case study of the Upper Blue Nile River. Sci Total Environ 574: 95-108. DOI: 10.1016/j.scitotenv.2016.09.019.

Hasannudin DAL, Nurrochmat D, Ekayani M. 2022. Agroforestry management systems through landscape-life scape integration: A case study in Gowa, Indonesia. Biodiversitas 23 (4): 1864-1874. DOI: 10.13057/biodiv/d230420.

Hattori D, Kenzo T, Shirahama T, Harada Y, Kendawang JJ, Ninomiya I, Sakurai K. 2019. Degradation of soil nutrients and slow recovery of biomass following shifting cultivation in the heath forests of Sarawak, Malaysia. For Ecol Manag 432: 467-477. DOI: 10.1016/j.foreco.2018.09.051.

Indonesian Coalition Monitors. 2021. Looking East: Deforestation and Release of Forest Areas in Papua. Jakarta. [Indonesian]

Jayanti ND, Iswahyudi H. 2020. Soil conservation on oil palm plantations of mature in PT. Citra Putra Kebun Asri Jorong Tanah Laut. Agrisains J Budidaya Tanam Perkebunan Politeknik Hasnur 6 (1): 18-23. DOI: 10.46365/agrs.v6i01.368.

Karous O, Jilani IBH, Ghrabi-Gammar Z. 2021. Ethnobotanical study on plants used by semi-nomad descendants' community in Ouled Dabbeb - Southern Tunisia. Plants 10 (4): 642. DOI: 10.3390/plants10040642.

Kukla J, Whitfeld T, Cajthaml T, Baldrian P, Simackova HV, Novotný V, Frouz J. 2019. The effects of traditional slash-and-burn agriculture on soil organic matter, nutrient content, and microbiota in tropical ecosystems of Papua New Guinea. Land Degrad Dev 30: 166-177. DOI: 10.1002/ldr.3203.

Landu EL, Mawe GI, Imwangana FM, Bielders C, Dewitte O, Poesen J, Hubert A, Vanmaercke M. 2025. The potential of runoff retention structures as a strategy to control urban gullying in tropical cities. Intl Soil Water Conserv Res 13: 217-234. DOI: 10.1016/j.iswcr.2024.11.002.

Li KH, Zhang Y, Shen C, Zhang JB, Liang YR, Wang JX. 2023. Distribution characteristics and influencing factors of gully density on cropland in the Songnen typical black soil region. Trans Chin Soc Agric Eng 39: 130-138. DOI: 10.11975/j.issn.1002-6819.202301116.

Maghfiroh CN, Putra ETS. 2024. Pengaruh Rorak terhadap Karakteristik Tanah di Perkebunan Kakao (Theobroma cacao L.). Kultiva 1 (1): 1-5. DOI: 10.57251/kultiva.v1i1.1463. [Indonesian]

Mahmud, Wahyudi, Bataradewa S, Budirianto HJ, Mutakim, Muhlis LO. 2021. The relationship of rainfall on surface runoff and sediments on various land uses in the Arui Watershed, Manokwari Regency. Jurnal Ilmu Tanah dan Lingkungan 23 (2): 85-92. DOI: 10.29244/jitl.23.2.85-92.

Mahmud. 2021. Deadlock in maintaining Wosi Rendani Protected Forest in Manokwari Regency, West Papua. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (JPSL) 11 (2): 261-275. DOI: 10.29244/jpsl.11.2.261-275.

Mahmud. 2023. Skenario konservasi tanah pada perkebunan sawit sebagai upaya mitigasi limpasan permukaan pada DAS Arui, Kabupaten Manokwari, Papua Barat. Jurnal Ilmu Pertanian Indonesia 28 (1): 129-139. DOI: 10.18343/jipi.28.1.129. [Indonesian]

Marhaento H, Booij MJ, Hoekstra AY. 2018. Hydrological response to future land-use change and climate change in a tropical catchment.

Hydrol Sci J 63 (9): 1368-1385. DOI: 10.1080/02626667.2018.1511054.
Martins ARO, Shackleton CM. 2021. Local use and knowledge of *Hyphaene coriacea* and *Phoenix reclinata* in Zitundo area, Southern Mozambique. South Afr J Bot 138: 65-75. DOI: 10.1016/j.sajb.2020.12.011.
Moreau G, Chagnon C, Achim A, Caspeísen J, D'Orangeville I, Sánchez-Pinillos M, Thiffault N. 2022. Opportunities and limitations of thinning to increase resistance and resilience of trees and forests to global change. Forestry 95 (5): 595-615. DOI: 10.1093/forestry/cpac010.
Mowidu I, Endang SDHS. 2022. Rekayasa lingkungan perakaran melalui sistem rorak untuk meningkatkan serapan hara pada tanaman kakao. Agropet 19 (1): 9-15. DOI: 10.32764/agropet.v19i1.1844. [Indonesian]
Mulu M, Ngalu R, Lazar FL. 2020. Pola Tanam Tumpang Sari di Desa Satar Punda Barat, Kabupaten Manggarai Timur, Provinsi Nusa Tenggara Timur. Agrokreatif 6 (1): 72-78. DOI: 10.29244/agrokreatif.6.1.72-78. [Indonesian]
Murdjoko A, Brearley FQ, Ungirwalu A, Djitmau DA, Benu NMH. 2022. Secondary succession after slash-and-burn cultivation in Papuan lowland forest, Indonesia. Forests 13 (3): 434. DOI: 10.3390/f13030434.
Nandini R, Susila IWW, Agustarini R, Samawandana G. 2023. Evaluating agroforestry patterns to increase land productivity of *Falcataria moluccana* private forests in Central Lombok Regency, West Nusa Tenggara. For Soc 7 (2): 247-262. DOI: 10.24259/fs.v7i2.25752.
Nasiry MK, Said S, Ansari SA. 2023. Analysis of surface runoff and sediment yield under simulated rainfall. Model Earth Syst Environ 9 (1): 157-173. DOI: 10.1007/s40808-022-01471-x.
Pokorny B, Robiglio V, Reyes M, Vargas R, Carrera CFP. 2021. The potential of agroforestry concessions to stabilize Amazonian forest frontiers: A case study on the economic and environmental robustness of informally settled small-scale cocoa farmers in Peru. Land Use Policy 102: 105242. DOI: 10.1016/j.landusepol.2020.105242.
Sagrim M. 2022. Traditional knowledge of land management in Maybrat District, West Papua Province, Indonesia: Implications for agricultural development. Biodiversitas 23 (8): 4144-4151. DOI: 10.13057/biodiv/d230836.
Satriawan H, Fuady, Agusni. 2017. Soil conservation techniques in palm oil cultivation for sustainable agriculture. J Nat Resour Environ Manag 7 (2): 178-183. DOI: 10.29244/jpsl.7.2.178-183.
Seta GW, Widiyanto, Hidayati F, Na'im M. 2021. Impact of thinning and pruning on tree growth, stress wave velocity, and Pilodyn plantation response of clonal teak (*Tectona grandis*) plantation. For Sci Technol 17 (2): 57-66. DOI: 10.1080/21580103.2021.1911865.
Sonbait LY, Manik H, Warmetan H, Wambrauw YLD, Sagrim M, Djitmau DA, Wanggai J, Rettob BB, Murdjoko A. 2021. The natural resource management to support tourism: A traditional knowledge approach in Pegunungan Arfak Nature Reserve, West Papua, Indonesia. Biodiversitas 22 (10): 4466-4474. DOI: 10.13057/biodiv/d221040.
Steiner JL, Lin X, Cavallaro N, Basso G, Sassenrat G. 2023. Climate change impacts on soil, water, and biodiversity conservation. J Soil Water Conserv 78 (2): 27A-32A. DOI: 10.2489/jswc.2023.0208A.
Subedi YR, Mulia R, Cedamon E, Lusiana B, Shíestha K, Nuberg I. 2018. local Knowledge on Factoís leading to Agroforestry Diversification in Mid-hills of Nepal. J For Livelihood 15 (2): 31-51.
Sudomo A, Mahaíani D, Swestiani D, Sabastian GE, Roshetko JM, Peidana A, Fambayun RA. 2021. Intercropping short rotation timber species with teak: Enabling smallholder silviculture practices. Forests 12 (12): 1761. DOI: 10.3390/f12121761.
Sukmawardhono NA, Nugroho P. 2020. Pengaruh perubahan guna lahan terhadap infiltrasi di Hulu Das Beringin. Jurnal Pembangunan Wilayah dan Kota 16 (4): 253-262. DOI: 10.14710/pwk.v16i4.31931. [Indonesian]
Sumule A, Baransano M, Sagrim M, Pattiasina T. 2020. Mencapai pembangunan pertanian berkelanjutan di Kabupaten Mamberamo Raya, Provinsi Papua. J Sosio Agri Papua 9 (2): 160-173. DOI: 10.30862/sap.v9i2.121. [Indonesian]
Tang J, Xie Y, Wu YQ, Liu G. 2023. Influence of precipitation change and topography characteristics on the development of farmland gully in the black soil region of Northeast China. Catena 224: 106999. DOI: 10.1016/j.catena.2023.106999.
Tarigan RA. 2022. Impact of climate change on soil erosion. Agrotekma J Agroteknologi Ilmu Pertanian 7 (1): 28-35. DOI: 10.31289/agr.v7i1.9427.
Temjen W, Singh MR, Ajungla T. 2022. Effect of shifting cultivation and fallow on soil quality index in Mokokchung district, Nagaland, India. Ecol Process 11: 42. DOI: 10.1186/s13717-022-00386-w.
Toansiba M, Katmo ETR, Krisnawati, Wambrauw YLD. 2021. Pengelolaan tanah dalam pengetahuan lokal dan praktik pertanian berkelanjutan pada masyarakat Arfak, Papua Barat. Jurnal Ilmu Pertanian Indonesia 26 (3): 370-378. DOI: 10.18343/jipi.26.3.37. [Indonesian]
Triasary K, Purwanto MYJ, Tarigan SD. 2021. Land use scenarios for hydrological conditions improvement in Cidurian Watershed. Jurnal Penelitian Pengelolaan Daerah Aliran Sungai 5 (2): 121-140. DOI: 10.20886/jppdas.2021.5.2.121-140.
Villa PM, Martins SV, Neto SNDO, Rodrigues AC, Martorano LG, Monsanto LD, Cancio NM, Gastauer M. 2018. Intensification of shifting cultivation reduces forest resilience in the Northern Amazon. For Ecol Manag 430: 312-320. DOI: 10.1016/j.foreco.2018.08.014.
Wang K, Zhou J, Tan ML, Lu P, Xue Z, Liu M, Wang X. 2024. Impacts of vegetation restoration on soil erosion in the Yellow River Basin, China. Catena 234: 107547. DOI: 10.1016/j.catena.2023.107547.
Wattie GGRW, Sukendah. 2023. Peran penting agroforestri sebagai sistem pertanian berkelanjutan. Jurnal Ilmu Pertanian dan Perkebunan 5 (1): 30-38. DOI: 10.55542/jipp.v5i1. [Indonesian]
Worman A, Lindstrom G, Riml J. 2017. The power of runoff. J Hydrol 548: 784-793. DOI: 10.1016/j.jhydrol.2017.03.041.