BIODIVERSITAS
Volume 19, Number 4, July 2018
Pages: 1334-1346

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d190421

Site selection and soil fertility management by the Outer Baduy People (Banten, Indonesia) in maintaining swidden cultivation productivity

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Manuscript received: 5 May 2018. Revision accepted: 21 June 2018.

Abstract. *Iskandar J, Iskandar BS, Partasasmita R. 2018. Site selection and soil fertility management by the Outer Baduy People (Banten, Indonesia) in maintaining swidden cultivation productivity. Biodiversitas 19: 1334-1346.* The Outer Baduy people heavily depend on swidden cultivation for subsistence. They grow rice in the uplands every year based on their calendar. The cropping calendar and calendar of social events are often closely interlinked. There is also traditional wisdom for conservation of land and forest such as the zonation for land use system. The Outer Baduy swidden land productivity is mainly determined by the time period of forest fallow relative to that of the crops. The long-term success of the Outer Baduy swidden cultivation depends on how well the fallow period restores or maintain soil fertility. The aim of this research was to study the local knowledge of Outer Baduy of soil categories and soil fertility and the management of soil fertility in their traditional practice of swidden cultivation. The method used in this study was the qualitative one, applying observation and in-depth interviews to collect the primary data. In addition, soil analysis was conducted by the Laboratory of Soil, Faculty of Agriculture, Padjadjaran University, Sumedang, Indonesia. The results of this study showed that the soils are classified by the Outer Baduy based on color, water content, stoniness or rock parent material, and humus content. To maintain soil fertility in the swidden cultivation, the Outer Baduy people have developed some strategies, such as determining appropriate fallow time period, applying zero tillage, and planting legume crops in both the swidden fields and the fallow land. Traditionally, because the Outer Baduy are forbidden to use inorganic fertilizers, the length of fallow period and kind of vegetation succession have an important role in maintaining soil fertility.

Keywords: Outer Baduy, soil categories, soil fertility, soil management, swidden cultivation

INTRODUCTION

Nowadays, the predominant means of subsistence among rural West Java and Banten is wet rice cultivation. The modern wet-rice farming introduced through the Green Revolution in early 1970s has been adopted by most farmers (Iskandar and Iskandar 2011; Amelia and Iskandar 2017). This modern wet rice farming depends heavily on artificial chemical fertilizers, synthetic pesticides, and rice hybrid seeds that must be purchased from the urban market (Iskandar and Iskandar 2016c). The Baduy community who resides in the Village of Kanekes, Lebak District of South Banten, however, has strongly rejected the Green Revolution program which is perceived as incompatible with the native ecosystems and the local culture. On the other hand, the swidden farming is considered as one of the religious obligations of the Baduy community (Iskandar 1998). Therefore, each household of the Baduy community must practice swidden farming every year. Although today's the population is increasing and the forest area is decreasing, the Baduy community wants to maintain the swidden farming system. Unlike the wet rice farming, the upland rice cultivation is only done once a year by the Baduy community. The management of swidden farming system is traditionally undertaken based on traditional ecological knowledge (TEK) and culturally embedded belief or cosmos (cf. Berkes 1999; Carlson and Maffi 2004). Each stage of the swidden farming system, namely selecting sites, preparing land (cutting underbrush, felling and pruning trees, drying debris, burning and reburning debris), planting rice, managing prepared swidden fields (weeding and providing medicinal rice), harvesting rice, storing and consuming rice, and leaving the land fallow must be done following the traditional Baduy calendar (Iskandar and Iskandar 2016b). In traditional management of swidden farming, hoeing of land (soil tillage), modern rice seeds, chemical fertilizer, and synthetic pesticide are prohibited (taboo). In addition, the swidden rice must not be sold, but it must be stored in traditional rice barns for a long time, more than 50 years (Iskandar and Ellen 1999; Iskandar and Iskandar 2017c). The swidden rice is mainly used for performing various stages of the rice farming and daily home consumption, particularly if they have enough money to buy hulled rice (*beras*) of wet-rice farming from village small shops. They obtain cash money to buy *beras* from selling non-rice crop products, such as fruits that are not prohibited for sale (Iskandar 2007). Because the hamlet forest, the swidden fields, and the fallow secondary forest are grown with various plants, such as fruits, some plant products can be harvested and sold to get cash household income.

The swidden farming system is different from the wet rice farming in that it does not use a permanent field. As a result, each year before the planting of upland rice, the site selection of secondary forest (*reuma*) must be done to practice swidden farming. The mature secondary forest which has been left fallow for more than 3 years must be selected and its vegetation is cut down for the planting of upland rice, and after the harvesting of rice, the land is left fallow which will develop into secondary forest by natural succession. The mature secondary forest can be recultivated after it is left fallow for more than 3 years and the soil fertility has been considered as recovery. Therefore, site selection and determination of land for the planting of upland rice during the first stage of swidden farming cycle are considered very important. In the past, when the population was small and forest area was still large, the selection of swidden fields was easily done. Nowadays, however, the selection of swidden fields has been difficult due to high population density and scarcity of the forest area. Consequently, some ecological strategies, such as introduction of commercial crops, crop diversification, petty trading, palm sugar industry, household handicrafts, and temporary migration, have been undertaken by the Outer Baduy community (Iskandar 1991, 2007; Iskandar and Ellen 2007; Iskandar and Iskandar 2016a; Iskandar et al. 2018). The temporary outmigration, however, has only been undertaken by the Outer Baduy because the Inner Baduy people are not allowed to practice swidden farming outside their territory. Some studies on Baduy knowledge of the local rice varieties, medicinal plants, traditional calendar, disaster mitigation, coping of drought disaster, animal hunting and children toys, have been carried out by scholars (Iskandar 2004; Iskandar and Iskandar 2005, 2017d; Permana et al. 2011; Alif et al. 2015). The study of Baduy local knowledge of soil, however, has rarely been undertaken.

The aim of this research was to study the local knowledge of the Outer Baduy (Banten, Indonesia) of soil categories and soil fertility and the management of soil fertility in their traditional practice of swidden cultivation. Three aspects are elucidated in this paper namely site selection, application of local knowledge of soil, and management of soil fertility by the Outer Baduy in managing the swidden farming.

MATERIALS AND METHODS

Study sites

This research was undertaken in the Outer Baduy area, namely hamlets of Kaduketug, Marengo, and Gajeboh, Kanekes Village, Leuwidamar Sub-district, Lebak District, Banten, Indonesia (Figure 1).

The Baduy area of Kanekes Village is located approximately between latitudes of 6^0 27’27” and 6^0 30’ North and between longitudes of 106^0 3’9” and 106^0 4’5” East. According to the bylaw of Lebak District No.32, 2001, the Baduy has a total area of about 5,136.58 hectares. About 5,136.58 hectares are allocated for forest protection area, while 2,136.58 hectares comprise land use for agriculture and settlement (Kurnia and Sahabudin 2010).

Based on the Baduy culture, Baduy territory may be divided into 3 groups, namely Inner Baduy area (*Daerah Baduy Dalam*), Outer Baduy area (*Daerah Baduy Luar*), and Dangka area (*Daerah Dangka*). The Inner Baduy area consists of 3 hamlets, namely Kampung Cibeo, Kampung Cikartawarna, and Cikeusik inhabited by the Inner Baduy People (*Urang Baduy Jero* or *Baduy Daleum*). The Outer Baduy area comprises more than 55 hamlets inhabited by the Outer Baduy people (*Urang Baduy Luar* or *Urang Panamping*). The Dangka area was initially composed of 7 hamlets, located in the Muslim territory areas. Today, however, because of the pressure from the Muslim people, two Dangka areas, namely Dangka Warega at Kamancing, and Dangka Cihandam have moved to Kampung Cipondoh and Kampung Kaduketug, respectively.

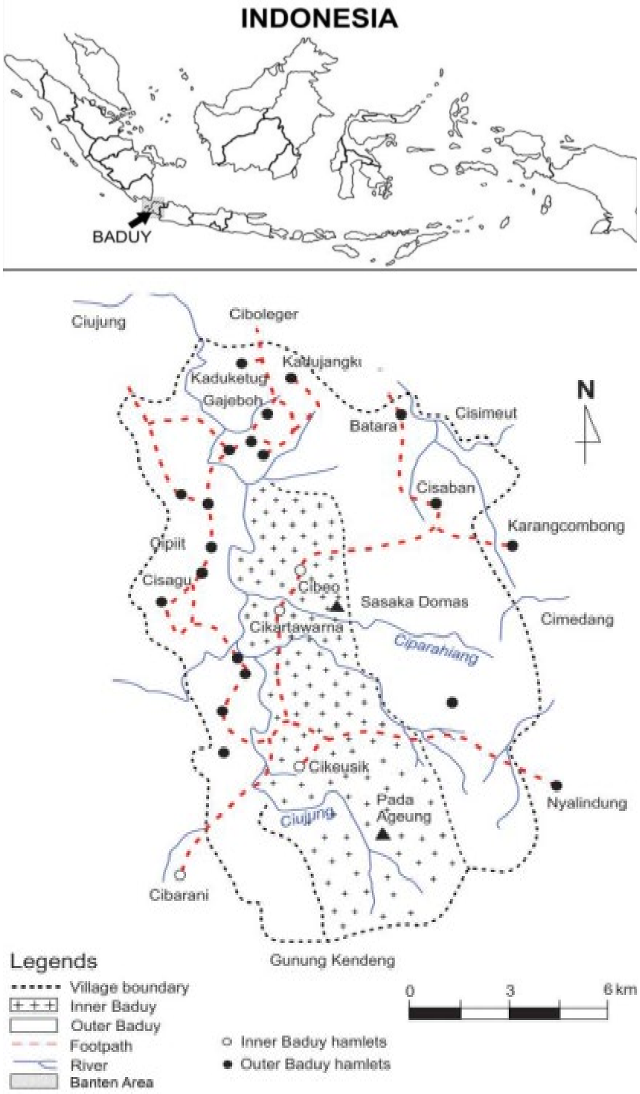

Figure 1. The study site of the Baduy area of Kanekes Village, Leuwi Damar Sub-district, Lebak District, Banten, Indonesia

The traditional agroforestry of Baduy consists of four types, namely swidden field (*huma* or *ladang*), fallow land of secondary forest (*reuma*), mixed-garden (*kebun campuran*), and hamlet forest (*dukuh lembur*). Unlike in hamlet forest and mixed garden, the most significant changes in the agroforestry system occur mainly in *reuma* and *ladang*. The mature secondary forest (*reuma kolot*) that is left fallow for 3 years or more is normally cultivated each year for practicing swidden cultivation, usually between 0.2 and 0.7 ha/family. Swidden fields (*huma*), after the harvesting of rice and other annual crops, are left fallow, which will develop into immature secondary forest (*reuma angora*) by natural succession. However, some fraction of the harvested swidden fields, before they are left fallow, can also be developed into monogardens, if the lands are planted by annual crops such as *mantang/ubi jalar* (*Ipomoea batatas* (L.) Lam.), *taleus/talas* (*Collocalia esculenta* (L.) Schott), *tiwu/ tebu* (*Sacharum officinarum* L.) and *cengek/cabe rawit* (*Capsicum frutescens* L.) (Figure 2). Meanwhile, the monogarden, after the harvesting of annual crops, can be developed either into immature secondary forest or into a mixed garden, particularly if the garden is planted with perennial crops, such as coffee, and fruits. Moreover, immature secondary forest (*reuma ngora*) will develop into mature secondary forest (*reuma kolot*) after the land is left fallow for enough time, such as more than 3 years (Figure 3). Some land use systems, such as the fallow land and monoculture gardens can also be developed into settlements (*kampung* or *lembur*) and hamlet forest (*dukuh lembur*), if the houses are constructed on those land use systems, particularly in the Outer Baduy area. Meanwhile, it is not traditionally allowed to build a new hamlet in the Inner Baduy area and the mount must remain three, namely Cibeo, Cikartawarna, and Cikeusik.

In 2017 the estimated total population of Baduy community was 11,699 people, consisting of 5,911 males and 5,788 females, representing 3,413 households. The population was dominated by the Outer Baduy people who constituted 89.6 percent of the total (10,488 people), with only 10.36 percent of the total population (1,211 people) from the Inner Baduy (Statistics of Kanekes village 2017). The Baduy community has a special religion called *Agama Baduy* or *Sunda Wiwitan* (original Sundanese). According to Garna (1987), *Sunda Wiwitan* is principally Buddhism influenced by Hinduism and Islam. Therefore, Baduy mythology can be shown to have influenced by both Hinduism and Islam. Based on the Baduy religion, the life is determined by god and staple food is provided by *Pohaci Sanghyang Asri* or *Nyi Pohaci*, considered as Goddess of rice. As a result, both swidden rice and the rice goddess are respected by Baduy community. The swidden cultivation must be undertaken by both swidden rice and rice goddess are deeply respected. Moreover, base on the Baduy tradition, the cultivation of wet-rice field (*nyawah*) is culturally prohibited (*teu wasa*). In addition, some modern inputs, including inorganic fertilizers, synthetic pesticides, and new rice varieties, are not allowed to use in the Baduy swidden farming system.

The main means of subsistence of the Baduy community is swidden farming (*ngahuma*). Their other activities are making handicraft, producing sugar palm (*gula kawung),* petty trading of non-rice crop productions, and working as laborers in the Muslim area. Unlike the Inner Baduy, the Outer Baduy community is allowed to practice swidden farming in neighboring non-Baduy area, the Muslim area, due to the lack of availability of mature secondary forest (*reuma kolot*). They obtain the swidden field in non-Baduy area by various means, including renting and share-cropping of non-Baduy land, while waiting for their own land during the fallow phase. They temporarily out-migrate to non-Baduy area (*nganjor*) and cultivate swidden farming in non-Baduy area for at least 3 years, depending on the readiness of their fallow land in their area to be recultivated (Iskandar et al. 2018).

Figure 2. A swidden field of Baduy before being left fallow, is developed into monogarden, planted by annual crops

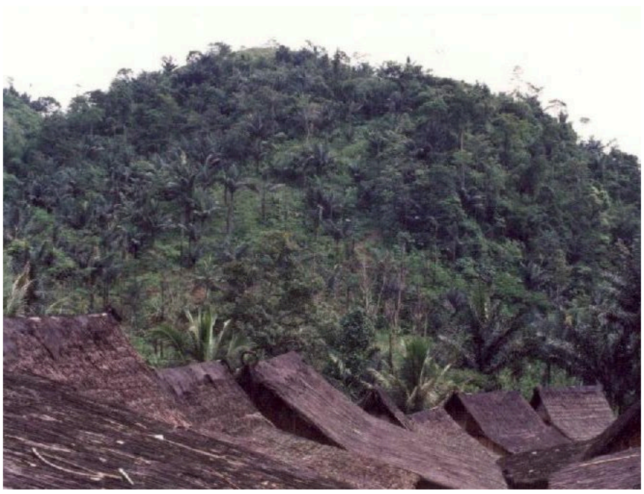

Figure 3. The fallow land in different fallow times that is predominantly grown with sugar palm trees (*Arenga pinnata* (Wurmb) Merr)

Research procedures

This study used qualitative methods based on ethnoecological approach (Martin 1995; Newing et al. 2011; Iskandar 2012; Albuquerque et al. 2014). Some techniques, namely observations, interviews and soil samplings were applied to collect primary data in the field. The observation was applied to obtain data of various local landscapes, land use zones, including settlement area, swidden fields, and fallow secondary forest land, and hilltop areas, and vegetation types of various traditional landscapes. The semi-structured interviews were undertaken with some informants considered competent and selectively chosen. In general, informants were chosen from the Outer Baduy who know most about local management of swidden farming and folk ecological knowledge of soils, vegetation, and land use zones. Some informants chosen in this study were administrative village leader (*Jaro Pamarentah*) and secretary of village leader (*carik desa*), hamlet informal leaders (*kokolot*), and old farmers in three hamlets of the Outer Baduy, namely Kaduketug, Marengo, and Gajeboh. Several informants were involved in soil sampling. Before soil sampling was done, some interviews about the soil as perceived by informants, such as the name of soil types, the characteristics of each soil type, the soil fertility, the site selection of secondary forest for swidden farming, and the management of soil fertility in both swidden and fallow lands were carried out. Moreover, to evaluate the local knowledge of soil that is considered fertile and poor, some soil samplings were done by purposively taking soil samples from two areas considered by informants as 'fertile' (*taneuh subur*) and 'poor' (*taneuh anggar*) in different fallow periods of secondary forest (*reuma*), namely 1 year, 2 years, 3 years, and 4 years, respectively.

Soil samples labelled by informants as 'poor ' and 'fertile 'were analyzed in the Soil Laboratory of the Agriculture Faculty of Padjadjaran University, Bandung. Fertile soil (type A) was taken from the Cihulu area, while poor soil (type B) was taken from Cicakal Muhara. In addition, some plants species of the secondary forests were collected and analyzed in the Herbarium Laboratory of Department Biology, Faculty of Mathematics and Natural Sciences, Padjadjaran University, Sumedang, Indonesia.

Data analyses

The data collected from different techniques, namely observation, semi-structured interviews, laboratory analyses, and literature study were analyzed by cross-checking, summarizing, synthesizing, and made narrative with evaluative and descriptive analyses (cf. Newing et al. 2011).

RESULTS AND DISCUSSION

Site selection

According to Baduy tradition, swidden farming activities and associated rituals must followed the Baduy agricultural calendar or Baduy calendar. There are 7 phases of the swidden farming activities, namely (i) selecting the site (*neangan pihumaeun*), (ii) preparing the land (*ngagawean pihumaeun)* including cutting underbrush (*nyacar*), felling trees (*nuar*) and pruning brunches of trees (*nutuh*), drying debris (*ngaganggang)*, burning debris (*ngahuru)*, reburning debris (*ngaduruk*) and weeding under piles of debris (*nyasap*), (iii) planting (*ngaseuk*), (iv) taking care of the rice and other annual plants (*ngarawat huma)*, particularly first weeding (*ngored munggaran)*, second weeding and providing medicinal rice (*ngubaran pare*), (v) harvesting rice (*dibuat* or *panen*), (vi) storing (*ngaleuitkeun*) and consuming rice (*nganyaran*), and (vii) leaving the land fallow (*ngareumakeun*). Traditionally, each phase of those activities must follow the Baduy calendar that is mainly arranged by informal leader (*Puun*) and his staff (Iskandar 1998; Iskandar and Iskandar 2016b).

Unlike wet-rice field farming, the swidden field is not permanently fixed in the same plot for cultivation each year, because the swidden field is usually planted with upland rice and other annual crops once and only occasionally, if the soil is still considered fertile. Moreover, after rice harvesting, the swidden field must be left fallow for at least 3 years or more, to regenerate soil fertility after the soil nutrients are intensively used by rice and other annual crops. As a result, each farmer has to find another appropriate special plot of mature secondary forest (*reuma kolot*) to be used for swidden farming for that year. According to ecological history, in the past swidden farmers did not have any problems finding new swidden plot because they owned large forest area and the population was still small. Therefore, the swidden farmers could freely explore the forest area to find an appropriate forest plot to be used for swidden farming. The farmer activity of surveying appropriate suitable forest location to be used for swidden farming is traditionally called *narawas*. If suitable forest location had been found, the forest area was marked by putting stones, whetstones, and turmeric rhizome/*rimpang kunir* (*Curcuma domestica* Vahl). The forest land that had been claimed by a farmer was owned by that person. In other words, the forest land was not free anymore because it had been claimed (*diaku*) by someone (Soepomo 1982). Moreover, the forest could be cultivated by the farmer who firstly claimed such forest. After rice harvesting, the fallow land was considered to be free. However, fruit trees planted by the farmer during the cultivating were considered as owned by the tree planters. During the first year of fallow period, the dry straws, called *jami*, were still commonly found in the land. The farmers who cultivated the *jami* was called *ngajami*. However, if the land was left fallow (*dipreikan* or *diperdeokan*) it would develop into immature secondary forest (*reuma ngora*) and mature secondary forest (*reuma kolot*) through natural vegetation succession process. During the fallow period, nutrient changes occurs in the soil because organic matter is added from litter and compost of the vegetation growing in the fallow land. As a result, the mature secondary forest with fallow time period of more than 7 years, which was called as *ngareuma,* could be recultivated. However, if the mature secondary forest was continuously abandoned and grown by tall trees, it was called *leuweung* instead of *reuma* (Soepomo 1982).

In the past, at the beginning of the agricultural cycle, secondary forest was surveyed by each household of the Outer Baduy to find an appropriate place for swidden fields. In addition, according to ecological history, share-cropping, land rental and mortgage agreement were not a recognized part of the swidden cultivation of the Outer Baduy (Iskandar 1998). Today, swidden fields on some hills of the Outer Baduy are owned by households living both in nearby and far away hamlets, and they even cultivate land in the neighboring Baduy area, in the Muslim territory, particularly during their temporary life in non-Baduy area (Iskandar et al. 2018). In addition, despite customary law which states that land of the Outer Baduy cannot be inherited or sold, in fact, it is commonly sold because of land shortage. In certain aspects, however, ownership rights to land (*hak garapan*) are still treated as it is still considered to be owned by their ancestors and must be managed properly (Iskandar 1998).

In the past, based on the Baduy customary law the fallow secondary forest had to be recultivated for swidden farming after having been left fallow for about 7 years or 9 years, which is usually odd number, and the land was considered fertile and good for swidden farming (Purnomohadi 1985; Iskandar 1982). Indeed, the Baduy's perception can be confirmed that after a plot of swidden field has been planted with rice, the soil nutrients are depleted, and when the plot has been left fallow appropriately, such as for 7 years or 9 years, the soil becomes fertile enough to grow rice again (cf. Chrisatanty 1986; Iskandar 1991; Miller 1992; Devi and Choudhury 2013). Therefore, unlike the sawah cultivation, the swidden field is not continuously cultivated for growing rice but the plot must be left fallow to restore the soil fertility by succession of secondary forest vegetation. A part of nutrient is stored in the vegetation and another part is returned to the soil surface in the form of litter and rain wash (Christanty 1986; Iskandar 1991). The native agricultural traditions in the tropics involve cutting down a small patch of forest, burning the slash after it has dried, planting the crops in the ashes that enrich the soil with nutrients and raise the pH of the very acidic forest soil. This produces one or two good food crops, but the yields decline rapidly, supposedly because the ash nutrients are soon leached away or are removed in the harvested food plants, and the pH of the soil declines towards its original value (Kimmins 1987). Thus, the long-term success of swidden cultivation depends on how well the fallow period restores or maintains soil fertility (Christanty 1986; Iskandar 1991).

Today, in general, swidden land productivity of the Outer Baduy has tended to be maintained because of many factors, including appropriate site selection of secondary forest (*reuma*) to be cultivated for swidden farming. According to Baduy people, there are some traditional ways that can be used to determine whether a *reuma* considered appropriate to be cultivated for swidden farming. For example, it is based on characteristic of soils, consisting of color, water, stone, and humus content, topography, and plant species.

Local knowledge of soil

Soil is locally named by the Outer Baduy people as *taneuh* or *tanah* in the Indonesian language. Moreover, soil can be classified by the Outer Baduy people based on color, water content, stoniness or rock parent material, and humus content and vegetation (Table 1).

Soil color

In term of color, soil can be divided into three types, namely 'red soil' (*taneuh beureum*), 'clay soil' (*taneuh bodas*), and 'black soil' (*taneuh hideung*). Among the three types of soil, 'the black soil' is considered good for practicing swidden farming, because 'the black soil' is considered fertile (*taneuh subur*), containing humus (*surubuk*). On the contrary, the other soil types are regarded as poor (*taneuh anggar*) and are not rich in humus.

The Outer Baduy's soil classification, based on global cross culture, is similar to that of Dayak community of the Lun Dayeh, the Sub-district of Kerayan, the District of Bulungan, East Kalimantan, in which soil is classified into 4 types based on color, namely 'white' (*mebuda*), 'black' (*mitem*), 'red' (*masia*), and 'yellow' (*mebira*). 'The black soil' is considered more fertile than the other soil types (Padoch 1986). Like the Outer Baduy and the Lun Dayeh, the traditional community who resides in the Pachmarhi Biosphere Reserve (PBR) of India, has traditional ecological knowledge that classifies soil based on color, namely 'black' (*teloala*), 'red' (*lalmiiti*), and 'whitish' (*chhnimiiti*), and 'the black soil' is considered fertile (Kala 2013).

Table 1. Classification of soil according to the Outer Baduy people, Banten, Indonesia (Iskandar 1998)

Main criteria	Vernacular names	English terms	Characteristics
Color	*Taneuh beureum*	Red soil	Visual appearance is red; considered poor
	Taneuh bodas	Clay soil	Visual appearance is white; considered poor
	Taneuh hideung	Black soil	Visual appearance is black; considered fertile
Water content/ Stickiness	*Taneuh liket*	Sticky soil	Poor aerial saturation; fertility is low
	Taneuh bear	Non-sticky soil	Good aerial saturation; fertility is high
Stoniness/ Smoothness	*Taneuh karang*	Stony soil	Consisting of many stones; considered fertile soil
	Taneuh euweuh karang	Non-stony soil	No stones; fertility is high
	Taneuh keusik	Sandy soil	High sand content; fertility is moderate
Humus content	*Taneuh loba surubuk*	Rich humus soil	High humus soil content; fertility is high
	Taneuh kurang surubuk	Poor humus soil	Lack of humus; fertility is low

Water and stone content

On the basis of water and air content in the soil, the soil can be divided by the Outer Baduy community into two categories, namely 'sticky soil' (*taneuh liket*) and 'non-sticky soil' (*taneuh bear*), because the sticky soil is regarded as having poor aeration. This soil is traditionally considered not good for growing crops in swidden farming compared to the other soil type. On the contrary, the non-sticky soil is perceived as good for swidden farming, since it is considered as having good aeration and is therefore good for growing crops in the swidden fields. The Baduy's perception on soil is rational, considering that many factors, including sunlight, water, and soil conditions can influence plant growth. The good soil for growing crops must have fine cavities in the form of soil pores containing water and air which are important for enabling crop roots to penetrate the soil and branch in it, and take up nutrients with the assistance of water (Heddy 2010).

In addition, the soil can be traditionally classified into 3 categories based on stoniness/smoothness, namely 'stony soil' (*taneuh karang*), 'non-stony soil' (*taneuh euweuh karang*), and 'sandy soil' (*taneuh keusik*). Of the three categories of soil, the non-stony soil is considered by the Outer Baduy as fertile and good for swidden farming. This perception is considered rational because soil consisting of many stones, in general, does not have much litter and humus, does not hold much water and air. So, it is difficult for crop roots, and for living organisms to grow in this type of soil (cf. Kimmins 1987; Kala 2013).

Humus and vegetation

The Outer Baduy community recognizes humus well. The humus is traditionally called *surubuk,* while litter consisting of dry leaves and twigs is called *koleang*. According to the Outer Baduy's perception, the secondary forest (*reuma*) is considered good for swidden farming, if such land has a lot of *koleang* and *humus*. This local knowledge is considered reasonable because *koleang* and *surubuk* are sources of organic fertilizer that provide macro and micronutrients for the growing crops in the swidden farming. Indeed, this role of litter and humus is important because the Outer Baduy community is prohibited to use inorganic fertilizers. According to the Outer Baduy's perception, the soil can have a lot of the litter and humus if the land has been left fallow for a long time. The Outer Baduy's perception is regarded as very rational, because it has been mentioned by scholars that along with the increasing length of fallow period of the secondary forest, the amount of vegetation biomass, litter and humus increases and the sufficient time period of fallow can sustain the long-term success of swidden farming (Christanty 1986; Kuyuma and Pirintra 1983; Nye and Greenland 1969; Okigbo 1984; Sanchez 1976). More recently, Christanty (1989) also mentions that branch and foliage biomass of bamboo garden (*talun bambu*) of Selaawi hamlet, Soreang District, West Java, per ha increased with the increasing field age. The branch biomass increased from 0.1 ha^{-1} at 16 months to 6.0 t ha^{-1} at 72 months. The foliage biomass increased from 2.6 t ha^{-1} to 4.7 ha-1 between 36 and 72 months. Moreover, litterfall is an important source of the majority of the nutrients taken up annually by plants (Kimmins 1987)

According to the Baduy community, apart from the amount of humus on the topsoil, the presence of certain plant species in the secondary forest can be used as indicator of soil condition and fertility. For example, the presence of *babakoan* (*Flemingia lineata* (L) Aiton), *bintinu* (*Kleinhovia hospita* L), *mardelan* (*Macaranga*) and *kiseureuh* (*Piper aduncum* L) in the secondary forest (*reuma*) are indicators of good and fertile soil. Conversely, the secondary forest soil that is grown by *reungkay* (*Eugenia linesta*), *seuhang* (*Ficus grossularioides* Burm.f.), *peuris* (*Symplocos cochinchinensis* (Lour) S.Moore) and *hamirung* (*Vernonia arborea* Schreb Ham) is considered poor (Table 2).

The use of these indicators can be considered rational because various plants of *Myrtaceae* Family and *Ficus* spp. predominantly grow in dry land of secondary forest. Conversely, some plants, including *kiseureuh* (*Piper aduncum* L) normally grows in the moist and relatively fertile soil.

Like the Outer Baduy community, the Lun Dayeh cultivators of East Kalimantan, also use some plants as indicators to determine soil fertile and suitability for practicing the swidden farming. For example, the presence of some plants, such as *Piper* sp. aff. *caninum* Blume, *Rubus moluccensis* L and *Curculigo borneensis* Merr in the forest can become indicators of good soil conditions. Conversely, the presence of some plants, including *Lycopodium cernuum* L, *Timonius finlaysonianus* Hook f. and *Curculigo villosa* Wall can become indicators of poor soil (Table 3).

Table 2. Some plant species commonly used by the Outer Baduy, Banten, Indonesia as indicators of soil condition and fertility (Iskandar 1998)

Species	Family	Outer Baduy name	Soil condition indicator
Syzigium sp.	Myrtaceae	Reungkay	Poor
Ficus grossularioides Burm.f.	Moraceae	Seuhang	Poor
Flemingia lineata (L) Aiton	Fabaceae	Babakoan	Good
Kleinhovia hospita L	Sterculiaceae	Bintinu	Good
Macaranga triloba Muell	Euphorbiaceae	Mardelan	Good
Macaranga rhizinoides Muell	Euphorbiaceae	Mara	Good
Piper aduncum L	Piperaceae	Kiseureuh	Good
Symplocos cochinchinensis (Lour) S.Moore	Symplocaceae	Peuris	Poor
Vernonia arborea Schreb Ham	Asteraceae	Hamirung	Poor

Table 3. Common plant species indicating agricultural potential according to Lun Dayeh farmers of East Kalimantan, Indonesia (Padoch 1986)

Species	Family	Lun Dayeh name	Condition indicator
Rubus moluccensis L	Rosaceae	Serinit	Good
Selaginella sp. aff. *brevipes* Fee	Selaginaceae	Gugor	Good
Piper sp. aff. *caninum* Blume	Piperaceae	Buyu' berek	Good
Curculigo borneensis Merr	Hypoxidaceae	Lapa'	Good
Cyrtanda trisepala C.B.L	Gesneriaceae	Taneb luba'	Average
Lycopodium cernuum L	Lycopodiaceae	Lio fade	Poor
Curculigo villosa Wall	Hypoxidaceae	Tamar	Poor
Timonius finlaysonianus Hook f.	Rubiaceae	Anur sia'	Poor
Clethra lonspicata J.J.Sm	Clethraceae	Anur ferian	Poor

The local knowledge of Lun Dayeh farmers (emic perception) is similar to that of Dr. Paul Chai, Forest Botanist of Sarawak (ethic perception), who identified the plant specimens. Based on his study of local vegetation ecology, he made ratings of plant species as an indicator of agricultural potential. His ratings were exactly the same as those of the Lun Dayeh informants of East Kalimantan (Padoh 1986). Therefore, biological components, including plant species are traditionally used as indicators of soil fertility (cf. Saito et al. 2006; Lima and Brussaard 2010; Vourlitis et al. 2012).

Topography

Topographically, the Baduy area consists of moderately steep to very steep hill and mountain, and forms a ridge and valley complex. Based on the Baduy classification (folk classification), the topography of the fallow secondary forest (*reuma*) can be divided into two categories, mainly steep slope (*lahan gedeng*) and flat area (*lahan cepak*). The topsoil on flat or non-steep land of the secondary forest is traditionally considered not seriously eroded by run-off during rainy season. As a result, the secondary forest that is located in non-steep slope is considered good for the practice of swidden farming. In addition, the land can be cultivated for two consecutive years. Conversely, because the topsoil of secondary forest as well swidden land is considered vulnerable to serious soil erosion (*taneuh dadas kabawa cai*), the steep slope land can be considered not good for the practice of swidden farming. Indeed, it can be cultivated only one time and after rice harvesting, it is directly left fallow for several years. The Outer Baduy's perception on land suitability for the practice of swidden farming is in accordance with the statement of Kimmins (1987). According to Kimmins much of the really fertile soils on moderate topography in areas with climate that are suitable for high-production forestry have already been sequestered by agriculture, while steeper slopes and ridge tops undergo more rapid erosion and consequently often have thinner soils with a coarser texture than the more gentle slopes. Water drains rapidly from such sites and therefore the soils are drier.

Soil fertility

Based on scientific knowledge (*ethic perception*), from the soil samples taken from different areas of Baduy, it can be seen that the soil in Baduy area is predominantly brown latosol (*latosol coklat*). In general, the Baduy areas, including Kaduketug, Kaduketer, and Gajeboh have soil fertility variation, having clay texture comprising clay particles (56.9%), silt (32.2%) and sand (10.9%) (Purnomohadi 1985).

Similarly, according to the Outer Baduy informants, soil fertility in the Baduy areas varies from place to place. In the Outer Baduy areas, for example, some areas of Kaduketug and Kadujangkung are recognized as fertile (*tanah subur*), while in the south between Cicakal Hilir and Cicakal Girang the soil is thought to be poor (*taneuh anggar*). In some parts of neighboring areas, such as Kaduheulang near Cihandam, the northern part of the Baduy area, the soil is also recognized as fertile (Iskandar 1999). To analyze soil conditions particularly regarding soil reaction (pH), cation exchange capacity, saturated aluminum, dry bulk density, water availability, and permeability, some soil samples were taken from different areas of the Outer Baduy areas, classified by informants as 'poor (*taneuh anggar*) and 'fertile' (*taneuh subur*). Fertile soil (type A) and poor soil samples (type B) were taken from the Cihulu and Cicakal Muhara area, respectively. This soil samples were analyzed in the soil laboratory of the Agriculture Faculty of Padjadjaran University, Sumedang, Indonesia.

From the Soil Laboratory analysis, it can be inferred that the quality of the 'fertile' soil (type A) tended to be better that of the 'poor' soil (type B). For example, the type B soil was highly acidic, particularly in the land left fallow for 2 to 3 years. Soil type A, however, was only very acidic when the sample was taken from the land left fallow for 1 and 2 years (Table 4) (Iskandar 1998).

The cation exchange capacity of soil type A was higher than that of soil type B, which means that soil type A has a higher capacity to maintain its fertility than soil type B (Table 5). The saturated aluminum content, which can poison crops if it is in excess, was higher in soil type B. In type B samples, high percentage of saturated aluminum was recorded for soil from the land left fallow for 1 to 4 years, while in soil type A it was found only in the land left fallow for 1 and 2 years (Table 6).

Dry bulk density of topsoil of type A was slightly better than that of B. This is probably because the decrease of bulk density has occurred faster in type A soils than in type

B, may be due to the faster rate of organic material decomposition in type A than in type B (Table 7). For other characteristics, water availability and permeability, soil type A was also relatively better than type B (Tables 8 and 9).

Overall, the Baduy's perceptions on poor soil (*taneuh anggar*) are confirmed by the results of laboratory analyses, particularly with respect to pH, cation exchange capacity, based saturation, saturated aluminum, dry bulk density, water availability and permeability (Iskandar 1998).

Today, because traditional Baduy is forbidden to use artificial chemical fertilizers, the duration of fallow period and the kind of vegetation succession have an important role in maintaining soil fertility. The transfer of nutrients between soil and vegetation in swidden farm has 3 aspects: uptake by vegetation, removal from the vegetation and return to soil. The nutrients are returned to soil in litter, in rain wash and in ashes from the burning of biomass, roots excretions, and mineralization of organic matter. Nutrient losses can be caused by soil erosion (Nye and Greenland 1960; Christanty 1986).

Nutrient inputs from vegetation after swidden fields have been left fallow can be very rapid, depending upon the health and extent of coppiced vegetation and the remaining seed bank on the site. According to Kalpage (1976), the rate of accumulation of nutrients in forest vegetation is high in the early years of the fallow when most of the vegetative growth takes places. Therefore, the effects of fallow period in swidden cultivation are critical (cf. Devi and Choudhury 2013). Soil fertility can be maintained by inputs of nutrients during the fallow period, and soil fertility decreases through nutrient use by crops and soil loss due to erosion which occurs mainly during the cropping period. Nutrients are usually taken up by annual crops, such as rice, and the land surface is not necessary densely covered by vegetation, so the nutrients in the soil decrease. However, erosion usually decreases after rice harvesting when vegetation well covers the land surface during the fallow period (Wiersum 1984).

Management of soil fertility

Some efforts, including applying zero tillage, planting various legume plants, and improving fallow period have been undertaken by the Outer Baduy community to maintain soil fertility in the management of their traditional swidden farming system.

Table 4. The pH of composite soil samples from the Outer Baduy area, Banten, Indonesia at depths of 0-20 cm (Iskandar 1998)

Fallow period (year)	Soil reaction (pH)	
	Fertile soil (*taneuh subur*) [Type A]	Poor soil (*taneuh anggar*) [Type B]
4	5.00 (acidic)	4.46 (acidic)
3	4.70 (acidic)	4.39 (highly acidic)
2	4.24 (highly acidic)	4.21 (highly acidic)
1	4.41 (highly acidic)	4.30 (highly acidic)

Table 5. The cation exchange capacity (CEC) of composite soil samples from the Outer Baduy area, Banten, Indonesia at depths of 0-30 cm (Iskandar 1998)

Fallow period (year)	Cation exchange capacity (me/100 g)	
	Fertile soil (*taneuh subur*)	Poor soil (*taneuh anggar*)
4	25.58 (high)	14.29 (low)
3	37.52 (high)	14.77 (low)
2	21.38 (medium)	15.26 (low)
1	25.56 (high)	14.87 (low)

Table 6. The saturated aluminum of composite soil samples from the Outer Baduy, Banten, Indonesia area at depths 0-30 cm (Iskandar 1998)

Fallow period (year)	Saturated aluminum (%)	
	Fertile soil (*taneuh subur*)	Poor soil (*taneuh anggar*)
4	12.91 (low)	41.75 (high)
3	18.03 (low)	52.92 (high)
2	45.87 (high)	49.92 (high)
1	80.95 (high)	50.51 (high)

Table 7. The dry bulk density of topsoil of soil samples from the Outer Baduy area, Banten, Indonesia (Iskandar 1998)

Fallow period (year)	Dry bulk density (g/cm^3)	
	Fertile soil (*taneuh subur*)	Poor soil (*taneuh anggar*)
4	0.78	0.81
3	0.83	0.82
2	0.91	0.82
1	1.08	1.04

Table 8. The water availability of composite soil samples from the Outer Baduy area, Banten, Indonesia (Iskandar 1998)

Fallow period (year)	Wa (2.42% of volume)		Wa (4.20% of volume)	
	Fertile soil (*taneuh subur*)	Poor soil (*taneuh anggar*)	Fertile soil (*taneuh subur*)	Poor soil (*taneuh anggar*)
4	52.51	48.44	35.78	33.91
3	50.46	47.88	33.22	33.04
2	48.54	45.29	34.38	32.27
1	46.84	42.68	27.46	30.73

Table 9. The permeability of composite soil samples from the Outer Baduy area, Banten, Indonesia (Iskandar 1998)

Fallow period (year)	Permeability (cm/hour)	
	Fertile soil (*taneuh subur*)	Poor soil (*taneuh anggar*)
4	2.44 (moderate)	1.07 (somewhat poor)
3	2.40 (moderate)	1.88 (somewhat poor)
2	2.43 (moderate)	0.84 (somewhat poor)
1	2.33 (moderate)	0.71 (somewhat poor)

Zero tillage

Traditionally, the land use systems in the Outer Baduy can be divided into three zones (Iskandar and Iskandar 2017 d). The first zone is flat area, near water sources, mainly used for settlement and hamlet forest (*dukuh lembur*). The second zone is located in the upper part of settlement area on hillsides. The third zone is located on top of the hills, traditionally allocated for mature forest and never cleared for swidden farming. The swidden farming is predominantly done in the second zone (Iskandar 1998). Therefore, the second zone is composed of overlapping swidden fields (*huma*) and the secondary forest (*reuma*) at different ages. Reuma left fallow for less than one year, between two and three years, and more than 3 years is called *jami*, *reuma ngora*, *reuma kolot*, respectively.

In term of topography, the Outer Baduy swidden fields are predominantly located in steep slopes. For example, the direct measurement of topography of swidden fields from 15 samples showed that the swidden fields are located on the topography between 20^0 (36%) and 35^0 (70%) (Table 10) (Iskandar 1985).

The swidden fields of Outer Baduy are located in various altitudes and topographical variations. Two main categories of slope based on the Outer Baduy perception, mainly non-steep slope or flat area (*lahan cepak*) and steep slope area (*lahan gedeng*). The non-steep lands are considered good for practicing the swidden farming, better than the steep slope, because the humus on the topsoil is not eroded during the rainy season (*humus henteu kabawa cai hujan*). Conversely, the steep slope lands are considered not good for practicing swidden farming because the humus on the topsoil of the steep slope is seriously eroded during the rainy season (*humus kabawa cai hujan di lahan gedeng*). Therefore, the zero tillage is normally applied in preparing swidden field, before rice planting, to avoid soil erosion, particularly during the rainy season. Based on the Baduy's culture, the Baduy community is prohibited to hoe ground. Consequently, soil structure and soil erosion can be minimized. The tillage can affect positively and negatively on soil condition. The positive effects of tillage on soil conditions are improvement of aeration and infiltration capacity, heat reduction and capillary connection breaking down in the soil, creating favorable conditions for seed germination. However, the tillage can also have negative effects on soil organisms and increase mineralization of organic matter. If not undertaken well, it can also increase erosion (Reijntjes et al. 1992). In addition, the Outer Baduy community is prohibited from applying synthetic chemical fertilizers. Therefore, the soil fertility of the swidden fields is determined by the dead vegetation biomass in the forms of leaf litter and necromass which eventually become humus. During the fallow period, the swidden land regenerates and becomes immature secondary forest and then mature secondary forest by natural succession process. In addition, soil fertility of swidden field is determined by nutrients from ashes resulting of vegetation burning during land preparation.

Table 10. The swidden plots of the Outer Baduy (Banten, Indonesia) swidden farming (Iskandar 1998)

No.	Size (hectares)	Amount of paddy seeds (bundles)	Slope of swidden sites in degree (°) and percent (%)
1	0.24	2	27 (51)
2	0.97	9	35 (70)
3	1.31	13	25 (46)
4	0.66	6	27 (51)
5	043	4	27 (51)
6	0.11	1	27 (51)
7	0.49	4	27 (51)
8	0.24	2	17 (30)
9	0.34	3	25 (46)
10	0.21	2	21 (38)
11	1.38	13	10 (17)
12	0.85	8	25 (46)
13	0.21	2	21 (38)
14	1.84	18	30 (57)
15	2.34	23	20 (36)

The swidden activities of the Outer Baduy are predominantly undertaken in the steep slope area. However, landslide has rarely occurred because the Outer Baduy community has managed the swidden farming based on traditional ecological knowledge embedded in the local culture. The soil erosion and landslide are avoided by some mitigating efforts. For example, during the land preparation of cutting trees on steep slopes, the branches of trees of *kawung* (*Arenga pinnata* (Wurmb) Merr), *bambu* (*Gigantochloa apus* (Shult. F.) Kurz, and *ki sereuh* (*Piper aduncum* L) are placed across on the ground of the hill that constructs a terrace or soil embankment. Therefore, soil eroded from the topsoil can be retained by the traditional terraces. Moreover, the soil along the embankments can be grown with various annual crops which grow well because the soil is fertile due to sedimentation of eroded soil from topsoil.

Planting various legume plants

Each household of Outer Baduy community has swidden field varying in sizes from small (0.11 ha) to large (2.34 ha) (Table 10). After the burning of biomass from slashed shrubs and tree branches, before the beginning of rainy season, on the month of *Kasalapan* (September-October), the rice seeds and other annual crops are planted. Non-rice crops, such as banana (*Musa x paradisiaca* L), are planted early in the swidden fields, namely during the drying of vegetation biomass from slashed shrubs and tree branches (*ngaganggang*) at the month of *Kadalapan* (August-September). Young banana plants are buried when the vegetation is burned, and covered in soil and humus. Therefore, although the leaves are sometimes scorched, the plants will grow well because the roots are encased in humus (Iskandar 1998). The distance among banana trees is relatively close, if the field will be cultivated with rice one time or will not be recultivated in the following season.

However, if the field will be planted with rice for two consecutive years, the banana trees are planted at a longer distance, so the the canopy of banana trees does not shade the rice.

At the time of rice planting, on the month of *Kasalapan* (September-October), various non-rice crops, such as *kacang penyut* (*Vigna sinensis* L), *hiris* (*Cajanus cajan* (L) Millsp), *cengek* (*Capsicum frutescens* L), *hanjeli* (*Coix lacryma-jobi* L), *kunyit* (*Curcuma domestica* Val), *wijen* (*Sesamum indicum* L), *terong* (*Solanum melongena* L), *jagung* (*Zea mays* L), *bonteng gede* (*Cucumis* sp.) , *kepes* (*Dolichos* sp.), *kacang jerami* (*Vigna* sp.), *kacang belendung* (*Phaseolus vulgaris*), *roay* (*Dolichos lablab*), *hui* (*Dioscorea alata* L), *talas* (*Colocasia esculenta* (L) Schott), *emes* (*Luffa acutangula* (L) Roxb), *jaat* (*Psopocarpus tetragonolobus* (L) DC), and *waluh* (*Cucurbita moschata* Durch) are planted in the swidden fields (Table 11). Traditionally, the swidden fields are planted with high diversity of plants. Therefore, the swidden fields are important for conservation of biodiversity and managing them properly can become an appropriate strategy to mitigate various risks of crop failure harvest due to unpredictable environmental changes, including drought and pests (cf. Aryal and Choudhury 2015).

Hiris (*Cajanus cajan* (L) Millsp) and *kacang penyut* (*Vigna sinensis* L) are planted in one hole with rice seeds. Some liana crops are planted near trees because they need the trees to creep on. *Hanjeli* (*Coix lacryma-jobi* L) trees are planted on the edges of the swidden fields at the same time with the planting of rice. *Trubus/tiwu endog* (*Saccharum edule* Hasskarl) and *kumili* ((*Plectranthus rotundifolius* (Poiret) Sprengel) are grown at the same time with the first weeding at the month of *Kasapupuh* (October-November). *Dangdeur/singkong* (*Manihot esculenta* Crantz) is grown at the same time with the second weeding in the month of *Hapit Lemah* (November-December). *Tiwu endog*, *ubi jalar/mantang* (*Ipomoea batatas* (L) Lam), and *singkong* are also planted after the harvesting of rice, before the land is left fallow.

Among various annual crops jointly grown with rice, many are categorized as legume crops (Family *Fabaceae*), such as *hiris*, *roay*, and *kacang penyut* (Table 11). In addition, perennial trees of legumes, including *jeujing* (*Albizzia chinensis* (Osb)), *kihiang* (*Albizzia procera* (Roxb) Bth), *kitoke* (*Albizia lebbeck* (L), *peuteuy* (*Parkia speciosa* Hassk), and *jengkol* (*Archidendron pauciflorum* (Benth) I.C. Nielen) are commonly found in the swidden fields. Since these trees grew in the secondary forest (*reuma*) are not cut but only pruned during the land preparation, these perennial trees and annual crops of legumes play an important role in improving soil fertility due to their ability to live in symbiotic relationship with rhizobia that can fix atmospheric nitrogen (Reijnthes et al. 1992).

Table 11. Cropping calendar of the Outer Baduy, Banten, Indonesia (Iskandar 1998)

Local names of crops	**Months (P planting, harvesting; .. cropping period; fr=fruiting)**												
	Sa	**Ka**	**Kn**	**Kp**	**Kd**	**Ks**	**Kh**	**Hl**	**Hk**	**Ks**	**Kr**	**Kt**	**Sa**
Pare (*Oryza sativa* L)						P	..	..	..	..	..	H	
Kacang penyut (*Vigna sinensis* L)*						P	..	..	..	..	..	H	
Hiris (*Cajanus cajan* (L) Millsp)*						P	..	..	..	..	..	..	H
Cengek (*Capsicum frutescens* L)						P	..	..	..	..	..	..	H
Hanjeli (*Coix lacryma-jobi* L)						P	..	..	..	..	..	H	
Kunyit (*Curcuma domestica* Val)						P	..	..	..	..	..	H	
Wijen (*Sesamum indicum* L)						P	..	..	H				
Tiwu endog (*Saccharum edule* Hasskarl)	P	..	..	H			P	..	H				
Mantang (*Ipomoea batatas* (L) Lam)	P	..	..	H					P	..	..	H	
Dangdeur (*Manihot esculenta* Crantz)								P	..	…	…	…	H
Cau (*Musa x paradisiaca* L)	P	..	..	..	..	..	..	..	..	..	..	..	H
Terong (*Solanum melongena* L)						P	..	..	H				
Jagong (*Zea mays* L)	P	..	..	H									
Bonteng gede (*Cucumis* sp.)						P	..	H					
Kepes (*Dolichos* sp.)*						P	..	..	..	..	..	..	H
Kacang jarami (*Vigna* sp.)*						P	..	..	..	..	..	..	H
Kacang belendung (*Phaseolus vulgaris* L)*						P	..	..	..	..	..	H	
Roay (*Dolichos lablab*)*						P	..	..	..	..	..	H	
Hui manis (*Dioscorea alata* L)						P	..	..	..	..	..	..	H
Taleus (*Colocasia esculenta* (L) Schott)	..	H				P	..	..	..	..	..	..	..
Emes (*Luffa acutangula* (L) Roxb)						P	..	..	..	..	..	..	H
Jaat (*Psopocarpus tetragonolobus* (L) DC)*						P	..	..	..	..	..	..	H
Waluh (*Cucurbita moschata* Durch)						P	..	..	H				
Kumili (*Plectranthus rotundifolius* (Poiret) Sprengel)							P	..	..	..	..	..	..
Durian (*Durio zibetinus* Murr) and other fruits		Fr	Fr	Fr	Fr	Fr	Fr	Fr					

Note: Sa=*Sapar* (April-May); Ka=*Kalima* (May-June); Kn=*Kanem* (June-July); Kp=*Kapitu* (July-August); Kd=*Kadalapan* (August-Sept); Ks=*Kasalapan* (Sept-Oct); Kh=*Kasapuluh* (Oct-Nov); Hl=*Hapit Lemah* (Nov-Dec); Hk=*Hapit Kayu* (Dec-Jan); Ks=*Kasa* (Jan-Feb); Kr=*Karo* (Feb-March); Kt=*Katiga* (March-April); P=Planting; H=Harvesting; Fr=Fruiting

In addition, the legume trees, particularly albizia trees (*Falcataria moluccana* (Miq.) Barneby & J.W. Grimes, syn.: *Paraserianthes falcataria* (L) Nielsen) are not only important for improving soil fertility but can also be sold to provide cash income for the households (Iskandar and Ellen 2000). The planting of albizia trees in the swidden fields is similar to that of *hiris* trees in that the trees are jointly grown with rice seeds or grown between rows of rice crops. After the planting of rice, the albizia trees are allowed to grow in the fallow land of secondary forest. When a farmer of the Outer Baduy wants to recultivate the land that has been left fallow for more than 3 years, the mature albizia trees are cut. Moreover, the albizia timbers are sawed to make logs and sold by volume in cubic meter. Therefore, planting albizia trees in the secondary forest that it has been left fallow has an important to provide cash income. According to informants, the secondary forest of size approximately 0.5 hectares and planted by albizia trees between 350 and 400 individual. About 4 years the mature albizia trees can be harvested and may provide about between 10,500,000 and 12,000,000 rupiahs in 2007.

Improving fallow land

According to environmental history, after the harvesting of rice, the land of the Outer Baduy was left fallow for a long time. Traditionally, the land was left fallow for 7 years or 9 years, using odd numbers (Purnomohadi 1985; Iskandar 200; 2007). However, nowadays because the population increases and the secondary forest area decreases due to conversion of land into swidden fields, the land is left fallow for approximately 3 to 4 years. Moreover, the Outer Baduy have tried to cope with the shortage of mature secondary forest by developing some strategies. For example, they have involved in temporary migration to neighboring area of the Muslim territory to practice swidden farming by renting land and sharing crops (Iskandar and Iskandar 2018). The Outer Baduy have also tried to select and introduce new cash crops, which bring more benefits to the swidden farmers, including albizia and coffee. In addition, they have tried to maintain the soil fertility and accelerate the recovery of soil fertility in the fallow land. Normally after rice harvesting, the land is left fallow to develop into secondary forest through vegetation succession. The fallow land that is still predominantly covered with straws (*jami*) is cultivated by annual crops such as *ubi jalar/mantang*, *singkong/dangdeur*, *trubus/tiwu endog*, and *jagong* to make it a garden or it is directly abandoned. For the land which is directly left fallow, the straws and legume crops are left to decompose into humus. Moreover, the fallow land is grown by shrubs, including *kaso* (*Saccharum spontaneum* L), *babakoan* (*Flemingia lineata* (L) Aiton), *ki seureuh* (*Piper aduncum* L), *beunying* (*Ficus brevicuspis* Mq), and *mardelan* (*Macaranga triloba* Muell). The land left fallow for 2 years is called as *reuma ngora* and the land left fallow for more than 2 years is called *reuma kolot.*

To accelerate the recovery of soil fertility of the fallow land, the Outer Baduy community has planted albizia trees (*F. moluccana*). Initially, the albizia seedlings are planted in the swidden fields during the rice planting. When the rice is harvested, the young albizia trees are allowed to continue growing. The straws and grasses around the albizia trees are cleared by machetes and the remaining biomass are piled surrounding trees, functioning as organic fertilizers in the secondary forest that has been felt fallow. So at that time, the swidden farmer can obtain land ready to recultivate and can harvest albizia timbers to sell to middleman to get cash money. According to our informants, the albizia tree seedlings with a height of 0.5 meters are purchased at a price of a thousand rupiah per seedling in 2017, while the albizia timber can be sold at a price of 250.000 rupiahs per cubic meter. The 0.5 ha swidden plot is grown with about 350 trees. As a result, cultivating the albizia trees mixed with rice in the swidden field provide both ecological and socio-economic benefits (Iskandar and Ellen 2000). In term of ecological benefits, planting albizia has improved soil fertility both in the *huma* and *reuma* (Figure 4).

Figure 4. Albizia (*Falcataria moluccana* (Miq.) Barneby & J.W. Grimes) trees and *kawung* (*Arenga pinnata* (Wurmb) Merr) are grown in fallow land (*reuma*)

Figure 5. A boy of the Outer Baduy (Banten, Indonesia) is harvesting fruits of *rindu* (*Piper rindu* C.DC.) at the fallow land

Another attempt to improve soil fertility of fallow land, is planting another legume tree, *dadap* (*Erythrina variegata*), which plays an important role in improving soil fertility. In addition, this tree is also used by a creeping plant, *rindu* (*Piper rindu* C.DC.) to creep on. Dry seeds of *rindu* are commonly sold to middleman at a price of 120,000 rupiahs/kg in 2007. Indeed, the integration of *dadap* (*Erythrin*a *variegata* L) trees with the *rindu* not only improves soil fertility but also provides money (Figure 5).

Another commercial crop, coffee (*Coffea arabica* L) is also commonly grown in the fallow swidden land. Initially, it was prohibited to plant coffee trees in the past. However, nowadays, coffee trees have been introduced by the Outer Baduy. Unlike the albizia, coffees are not planted in the swidden fields but the fallow land. As a result, the coffee trees have not disturbed the swidden farming systems, but can be integrated into the more permanent fallow land which is not regularly cut for swidden farming rotation. The production of coffee is predominantly used for home consumption and some surpluses are also sold to middleman. In the Outer Baduy area, the dry coffee beans are locally sold at a price of 25,000 rupiahs/kg in 2017. The coffee trees are usually grown in mixture with *dadap* and albizia whose functions are to provide shading for the crops and to improve soil fertility. Therefore, the fallow secondary forest (*reuma*) can be considered very important both for restoring soil fertility and for providing productions of non-rice crops to be used for the household consumption and cash income (cf. Iskandar 2007; Weinstock 2015; Partey et al 2017). Undoubtedly, planting legume trees as a nitrogen-fixing plant, mixed with other cash-crops in the fallow land can become a strategy for sustainable soil fertility management (cf. Bunch 2015; Garrity 2015; Ramakrishnan 2015; Partley et al. 2016).

To sum up, it can be concluded that to maintain soil fertility in the swidden cultivation, the Outer Baduy people have developed some strategies, such as implementing appropriate fallow time period, applying zero tillage, and planting legume crops in both the swidden field and the fallow land. Traditionally, because the Outer Baduy are forbidden to use inorganic fertilizers, the time period of fallow and kind of vegetation succession have an important role in maintaining soil fertility. Thus, we suggest that the traditional ecological knowledge (TEK) of the farmers and Western scientific knowledge be integrated to support sustainable agriculture development program in Indonesia for the future, which is ecologically sound, economically viable, and adaptable to various ecological and economic changes.

ACKNOWLEDGEMENTS

The data on this paper were initially collected by the first author when he was conducted research for a dissertation in the University of Kent at Canterbury funded by the ESCDI (Environmental Studies Centre for Development in Indonesia) project. The field work and updating were funded by the ALG (Academic Leadership Grant) of Padjadjaran University. Iskandar would like to acknowledge the support of funding of the ESDI and ALG Program of Padjadjaran University. He would like to express special appreciation and thanks to his supervisor Prof. Roy Ellen for his invaluable knowledge and enthusiasm. Undoubtedly, we express our sincere gratitude to the Baduy people, especially the village leader of Kanekes village, village secretary, and our informants in Kaduketug, Cihulu, Gajeboh, and Babakan Marengo, whom we visited frequently during our fieldwork. Not only did they cooperate willingly, but they also offered unlimited hospitality.

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