Gula Gula Food Forest Program – Ecosystem restoration in the Singkarak river basin, West Sumatra

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Submitted by
CO_2Operate BV
Woerden
The Netherlands
www.gulagula.org
www.co2operate.nl

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Executive Summary

According to the World Resource Institute, land degradation costs an estimated $6.3 trillion per year. This has a negative influence on 2.3 billion people's livelihoods worldwide. Addressing this scenario provides the greatest opportunity for climate action and global socio-economic improvement through earth repair. Traditionally land rehabilitation is considered high cost. The high expense is caused by conventional restoration efforts that work against or replace nature.

The *Gula Gula* Food Forest Program in West Sumatra, Indonesia, focuses on low tech ecosystem restoration approaches that work with nature. The *Gula Gula* Food Forest Program has integrated the ecologically-sound, cheap and easy to use Assisted Natural Regeneration (ANR) techniques with intercropping of economic valuable trees. It functions efficiently in rural settings where resources are severely limited. Even the most vulnerable farmers can implement and maintain the key elements of the ANR tools and techniques, since a wooden lodging board to press weeds and grasses is all that is needed.

The *Gula Gula* Food Forest Program in West Sumatra, Indonesia, is in a very rural setting where resources are scarce, and the people are impacted by poverty. In the *Gula Gula* Food Forest area, monthly incomes are around 50% of the official minimum wage for West Sumatra. For one, the carbon payments can (partly) bridge the gap between planting and the first harvest from the trees. From this moment onwards, tree products will provide good income sources above the minimum wage level of West Sumatra.

Established in 2008, and with over 25 years of grass-root level experience in agroforestry development in the tropics, both in Africa and Asia, the social enterprise CO_2Operate BV is the parent company behind the *Gula Gula* Food Forest Program. Its mission is to reverse poverty and climate change through farmer-based forest enterprises.

Through CO_2Operate BV, an increasing number of companies and non-profit organisations invest their carbon offsetting payments to reduce their ecological and environmental footprints in the *Gula Gula* Food Forest Program, and to build sustainable, biodiversity-rich supply chains, services and products (known as insetting). Although most income to finance ecosystem restoration comes from carbon off-setting contracts, biodiversity-rich product sales are also increasing, now that the forest and trees mature, and the area continues to extend.

At the start of 2020, 1,333 hectares of *Imperata cylindrica*-covered degraded lands have been brought back into productive food forest areas, providing direct support to 190 farmers and their families. In 2020, over 200 ha of new degraded land will be restored into productive food forests, from which over 300 new farming households will benefit. The off-setting of unavoidable emissions not only has significant potential to shift production beyond business-as-usual towards carbon neutrality. At the same time, it supports the achievement of various Global Goals (the Sustainable Development Goals or SDGs). For example, SDG 13 (climate action) is at the heart of all ecosystem restoration activities in the *Gula Gula* Food Forest Program.

Ecosystem restoration on degraded lands to build productive food forests gives a variety of benefits to farming households. Ecosystem restoration brings back all important environmental service functions. The farming households benefit from a combination of food security (SDG 2), CO_2 capture finance-structures and the sale of non-timber forest products (NTFP) at good prices (SDG 1).

Using Assisted Natural regeneration, means that the present and original vegetation is being protected and allowed to grow, including existing (small) indigenous trees, which are usually found in between the tall *Imperata cylindrica* grasses (*alang-alang* in Indonesian). This returns up to 35% - 40% of the original degraded forest to offer the original flora and fauna their homes support. The remaining percentages (the gaps) are used for planting economically valuable trees, from which the farming household can generate income through product sales. After 9 years of establishing the food forest area, biodiversity has increased tremendously, with representative fauna from all trophic levels of a food web being trapped on cameras (SDG15).

New agriculturally valuable land is created out of land that has been degraded and neglected for more than forty years. The areas increase in value naturally as tree and other vegetation growth occurs, and break the need to encroach into existing forests to open up new agricultural land.

West Sumatra province has a very specific socio-cultural environment, the matrilineal society of the Minangkabau. Land ownership and heritage follows the female lineage (matrilineal), and this is well defined in indigenous law, the *Adat* law system. Restoration activities take place in this context of the matrilineal, well-defined land ownership and land use structures. The Minangkabau matrilineal society makes us think differently about traditional gender family roles, as property, family name and land pass down from mother to daughter. Having control over land, women hold a high social position in the villages, and this leads to rather egalitarian social relationships between men and women.

Food security (rice cultivation and rice fields) is managed and controlled by the female lineage unit. The married man is traditionally considered the visitor in the wife's family and has the task to earn a decent income. One option is the management of an upland field (*kebun*) which are also mostly owned by the wife’s clan, where perennial cash crops can be cultivated. The upland areas are left in a degraded state and targeted for restoration activities.

Following the established community structures, public participation is rooted in the traditional values of the matrilineal Minangkabau community. Traditionally, official permission must be sought for any planned activity in the *nagari* (Village). They have a special term for this, *muryawah* (negotiation). Planned activities or projects can be implemented, but only through public participation, and only after reaching the phase of *mufakat* (public village consensus, including the opinion of women).

CO_2 Operate BV has blended the two approaches of Free, Prior and Informed Consent (FPIC) and local consensus building for project development and to build a strong sense of ownership among the local villagers/participants. This is also achieved by supporting the farmers to work as a performance-based cooperative farmer group, built on horizontal social relationships to enable open and free discussion of issues with each other for the benefit of the restoration activities. Various cooperative farmer groups (*kelompok tani*) have developed over the years. These are officially recognised by the local government, registered as cooperative farmer groups (*kelompok tani*) with their own bank accounts. With new carbon offsetting contracts, new participants either join existing groups, or if they prefer to establish their own, field staff of RPL will support them to become registered as *kelompok tani*.

Following the socio-cultural norms of the Minangkabau people has meant that the Minangkabau are responding positively to the program. They have also set up fire brigades to protect the forest that they are now understanding will deliver more income over time. They are the guardians of the forest, the harvest and their own future. This is proven by an increased natural regeneration of secondary forest on (former) *Imperata* grasslands in the area.

The program is coordinated by CO_2 Operate BV, with field implementation performed through the local NGO *Rimbo Pangan Lestari* (RPL) as the main partner in the field. To monitor and evaluate the KPIs of the mission of the social enterprise CO_2 Operate BV, local academic partners including the teacher's college STKIP and staff from various Departments of Andalas University support the program in conducting regular carbon assessments, biodiversity assessments, and socio-economic assessments. The program has built strong relationships with local government agencies such as Forestry and Agriculture. These relationships all add to the positive impact of the restoration activities. CO_2Operate BV with the EU-based clients are now ready to scale up the activities. We foresee that certified carbon credits are the crucial step to attract a larger segment of clients, and be able to scale up our reforestation efforts at a faster pace.

A Aims and objectives

A 1 Program Aims & Objectives

Tropical forests are important global climate regulators playing three crucial roles. Firstly, they sequester large amounts of carbon dioxide, store it, and give oxygen in return. Secondly, they house half the biodiversity on the planet. Thirdly, two billion people depend on tropical forests directly for their food, income, and medicines, and benefit indirectly from the ecosystem services that tropical forests provide.

Deforestation processes release carbon dioxide. This greenhouse gas (GHG) is one of the major contributors to global warming and climate change. Preventing deforestation and increasing reforestation & afforestation can support various Sustainable Development Goals simultaneously, including poverty reduction (SDG 1), climate action (SDG 13) and life on land (SDG 15).

Ultimate Goal and Objectives

In Indonesia, tropical forests are severely threatened by degradation and conversion into other land uses. Over 30 million hectares of tropical forest and associated biodiversity have disappeared in recent decades. Deforestation in Indonesia contributes to over 70% of the National GHG emissions. The high deforestation rates have negative effects on 60 million Indonesian people who directly depend on the forests for their survival. Deforested areas contribute to a loss of biodiversity, habitats and dysfunctional ecosystem services.

Increased erosion, reduced soil fertility and reduced water quality/ supply means that rural communities are struggling to live off their agricultural land. A recent study into deforestation in Indonesia by Austin et al. (2019) shows that, although conversion of forests into oil palm plantations remains the highest driver of deforestation (23%), small-scale agriculture and small-scale mixed plantations are second (22%), followed by the conversion of forests into grass/shrubland (20%).

Recurrent fires play an important role in the forest degradation into grassland establishment. The grassland areas are especially susceptible to fires, ultimately leaving a fire-climax, grassy vegetation known as *Imperata cylindrica* grasslands (*alang-alang* in Indonesian). The increased area of these grasslands poses an increased threat to rural livelihoods, through fires, and the increased difficulty grassland presents in carrying out agricultural activities on it. With an estimated 25 million ha of *Imperata* grasslands (Wicke et al., 2008), the conversion of new (forested) land into agricultural land is often one of few options for resource-poor people in rural areas for their own survival.

We see a significant opportunity in ecosystem restoration of these degraded grassland areas. Firstly, reforestation of *Imperata* grasslands contributes considerably to climate change mitigation by increasing the above & below-ground carbon fixation whilst posing less of a fire risk than the grasslands. Secondly, restoration of tree cover stabilises the immediate biodiversity environment, restoring habitat and ecosystem services, which are crucial elements for agricultural development. If restoration of degraded lands is planned well, rural livelihoods can be improved, which reduces the forest destruction needed to open new land for agricultural purposes. This is the goal of the Gula Gula Food Forest Program. The ultimate goal is:

“To combat poverty, climate change and biodiversity loss in an integrated manner by ecosystem restoration to restore productive forested landscapes.

We do so by converting grassy, tree-less land into productive, biodiverse food forests."

To achieve this, the objectives of the program are:

- To convert degraded (grassy) land into mixed food forests, thereby capturing and storing carbon and increasing biodiversity.
- To provide an effective, sustainable and ecologically-sound technique for ecosystem restoration. This is especially geared at low income regions, where resources are scarce, by combining Assisted Natural Regeneration (ANR) with tree planting.
- Empower and increase self-help of communities through community-based forest enterprise
- cooperatives. Improving incomes through wider (global) market access, profit sharing from carbon credit sales and the trade of sustainably produced food forest products.

To structure and achieve the goals and demonstrate impact, CO_2Operate BV has developed a Theory of Change. The Theory of Change is at the heart of the work and is a physical document. Whether the impact measurement results are good or show room for improvement, CO_2Operate BV and partners constantly strive to improve their services and the benefits for the people they serve. Figure 1 shows the Theory of Change Diagram.

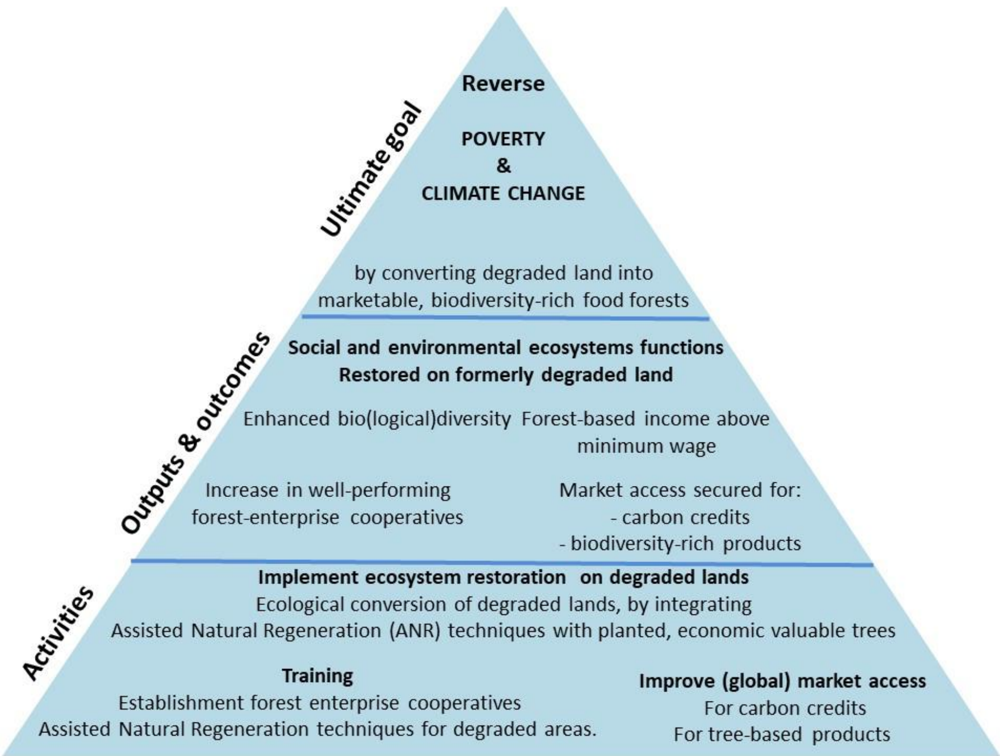

Figure 1: The Theory of Change

B Site Information

B1 Project location and boundaries

The *Singkarak-Ombilin* River Basin

Figure 2 shows that the *Gula Gula* Food Forest project has been implemented in two districts of West Sumatra, namely *Agam* district (35 ha) and *Solok* district (83 ha). The sites in Agam District and part of the restoration sites in Paninggahan started to be restored between 2009 - 2012, as part of the experimental project to develop a proof of concept for a carbon trade program (Figure 3). Although some private companies were willing to participate by offsetting their carbon emissions in this experimental phase, these areas will and cannot be included in the Plan Vivo certification process, as they began before 2014 (therefore exceeding the Plan Vivo Standard's limits on retroactive crediting). However, the many lessons learned from these initial experimental designs are taken along in this PDD where it helps to explain the set-up of the Gula Gula Food Forest Program. It is also still possible to sell the uncertified credits. The 35 ha *Agam* district and the initial 30 ha in Paninggahan (between 2009-2014) will, however, continue as carbon and biodiversity research sites. In addition, the food forest products from these areas are also included in the current product development phase. The baseline for the certification process for Plan Vivo is limited to restoration sites Paninggahan and Air Dingin, which started in or after 2014 (see **Error! Reference source not found.**). I n the *Singkarak* river basin, progress is currently being made in one of the largest sub-catchment areas, number 8 (*nagari Paninggahan*, see Figure 3). Since 2019, the activities have been extended the district Lembah Gumanti, where restoration activities in the *nagari* (village) Air Dingin have begun since late 2019. The project areas are located in the sub catchment 1 and 3 in Figure 3, where Air Dingin is located in the upper part of the river basin. The higher altitudes (around 1,400 metres abs) make it suitable for a mixture of (arabica) coffee and cinnamon trees, of which the products some of our clients wish to invest in.

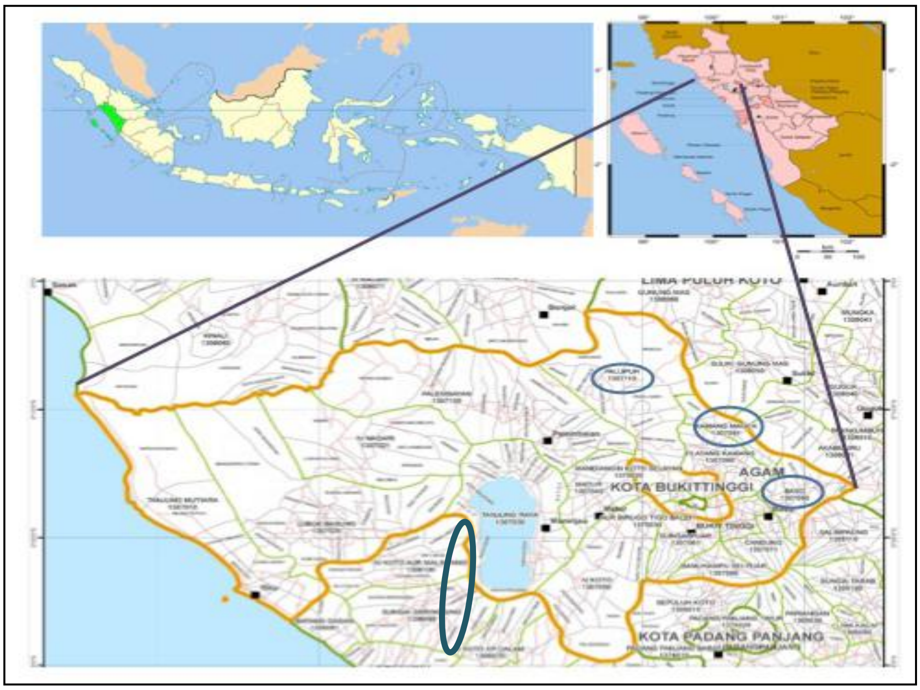

Figure 2: Current *Gula Gula* Food Forest Sites (blue circles) in West Sumatra province

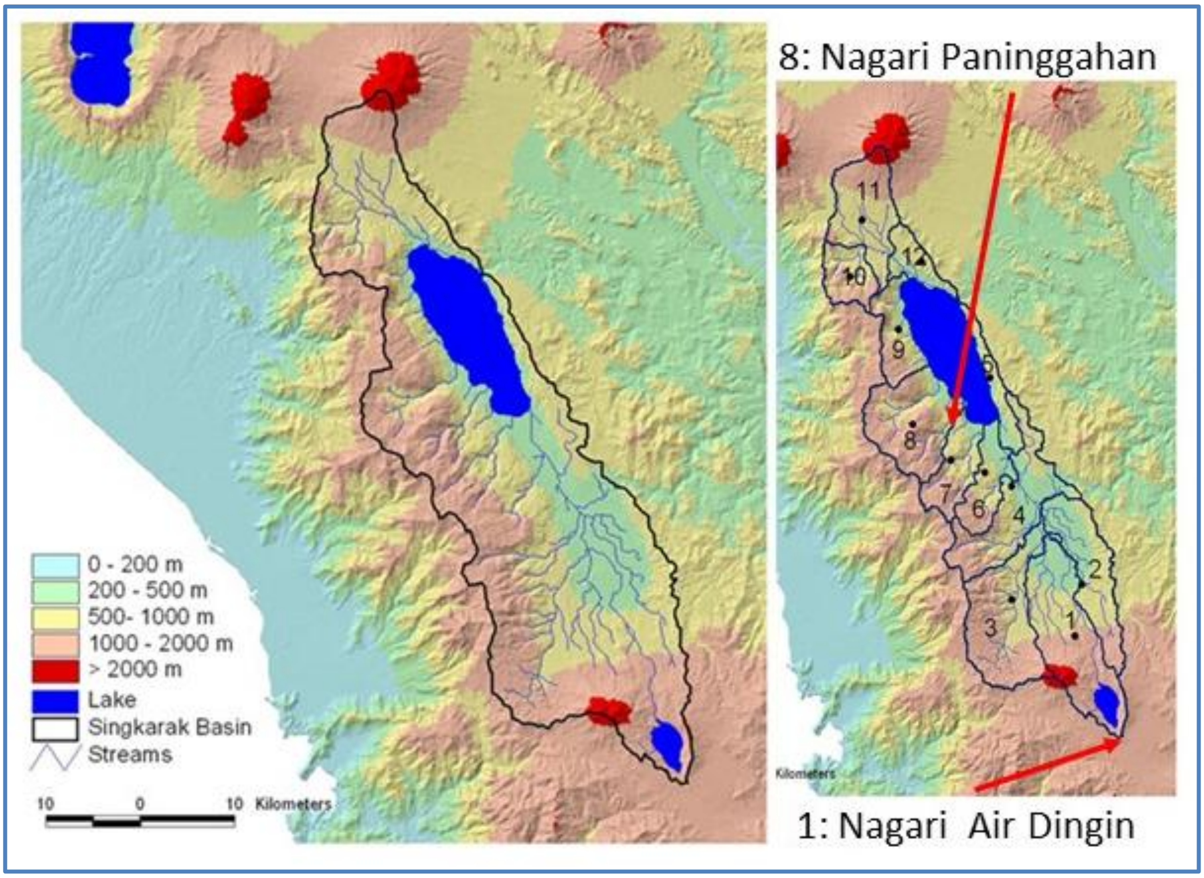

Figure 3: The boundaries of the *Singkarak* river basin and its 12 sub-catchment areas, showing the two project sites (right). Source: Digital Elevation Model using Landsat images, World Agroforestry Centre, Bogor.

B2 Description of the program area

The main area for expansion is the *Singkarak* river basin. The basin covers two districts (*kabupaten* in the Indonesian language). These are *kabupaten Tanah Datar* in the northern part and *kabupaten Solok* in the southern part of the lake. The *Gula Gula* Food Forest Program in the river basin currently operates in Solok district, where the villages of Paninggahan and Air Dingin are located.

The lake is a deep depression in the rift valley of the *Bukit Barisan* mountain range. The *Singkarak* river basin is an elongated basin from *Mount Marapi* in the north and Lake *Danau Di Bawah* in the south. As can be seen from Figure 3, *Danau Di Bawah* in the South lies at an elevation between 1,000-2,000 meters, while other areas are as low as 200-500 meters. Lake *Singkarak* takes in water from five streams and rivers from surrounding slopes, while the river basin feeds into important connecting rivers.

Table 1: Location of the plots and their biophysical and geographical conditions

No	Location	Regency	No of plots	Altitude (msl)		Rainy days/year	Rainfall (mm)	Avg temp (°C)
				Lowest	Highest	2018	2018	
1	Paninggahan	Solok	133	297	369	162	2,946	22
2	Baso	Agam	23	500	1,000		3,500 - 4,000	22
3	Halalang	Agam	13	850	850		1,146 -2,662	22
4	Padang Kunyik	Agam	20	25	500		2,984	22
5	Air Dingin	Solok	101	1200	2000			
	Total		**189**					

The lake's natural outflow is via the *Ombilin* River. It is part of the depression of the *Semangko* faults, bound by mountainous area of the *Bukit Barisan* in the west, and tertiary fold in the east. The forests around *Danau Di Bawah* are part of the *Kerinci Seblat* National park area. The relatively flat depression area around and south of the lake is covered by alluvial deposits of clay, sand and gravel and andesite detritus from the volcanoes. The major underlying rocks in *Singkarak* Basin are volcanic rocks. Several parts in the western and north-western part of the basin are metamorphic rocks (limestones). The plain area to the south of the lake is alluvium. In the *Singkarak* Basin, the soils are mainly *Inceptisols* (*Dystropepts, Dystrandepts, Humitropepts and Tropaquepts*). However, a combination with *Ultisols* (*Paleudults, Hapludults, Haplohumults*), *Entisols* (*Troporthents, Tropofluvents*) and *Alfisols* (*Hapludalfs*) occur in some parts of the basin.

The relatively flat areas (< 10% slopes), covering 26% of the region, are mostly in the lower elevation (<500 m asl), around *Solok* town, and are mostly cultivated with rice. In higher elevation regions (>500 m asl), e.g. around *Padang Panjang*, vegetable crops are commonly planted as well. The major slopes in the *Singkarak* Basin are slopes of 10-30% (40% of the area). These slopes mostly occur in the foothills in the west, in the south (of Mount *Talang*), and in the north (of Mount *Merapi*). Agricultural lands like mixed gardens, where vegetables can be grown, are found in these areas below 1,000 m asl. A combination of steep slopes (30% up to 100%) appears as a dissected plateau in the west side of the basin. These very steep areas are covered by natural vegetation like forest, shrubs and grass, and mixed tree-crop gardens. The primary forests in the river basin are home to endangered species including the Sumatran tiger, elephant and rhinoceros.

The *Singkarak* river basin provides important environmental service functions, both locally as well as regionally. With an average rainfall of around 2,000 mm/year, hydrological service functions are important, especially since a 175 MW hydro-electricity power-plant was developed in the 1990s (Peranginangin et al, 2004). This power-plant adds to the importance of hydrological service functions. The presence of national parks also means that biodiversity protection is another important environmental service function. Environmental service functions are directly linked to the social and economic service functions of the river basin ecosystem (see Section C1). Many communities live in the river basin, which depend on supplies of water resources for their livelihoods, for example for irrigation and drinking water. In addition, a healthy ecosystem can also provide economic services such as forest products, and prevents soil losses and erosion which will support the sustainability of the agricultural systems.

The water inlet (left), leading into a 16,500 m long headrace tunnel to the PLN power station.

B3 Recent land use changes, the drivers, environment conditions

The *Singkarak* lake covers 129,000 ha in total (local people, a large-scale pine tree plantation project from the government has aggravated the degradation of the hill sides. They claim that pine trees cause soils to dry up (Leimona et al., 2015). Nowadays, about 32% of the area surrounding the lake (18,664 hectare) is considered critical land, covered by Imperata grassland, while rice paddy (21%), upland crops (17%) and other uses (30%) make up the rest. The satellite image of the lake's current conditions (Figure 4) shows many denuded grass-covered hills, especially on the Western part of the lake, where the majority of the people reside.

The main soil types on the slopes around the lake are *lithosols* and *Rendzina* (Laumonier, 1997). Developed on limestones, these soils are poor in organic matter and have high erosion risks. Forests on the slopes around lake *Singkarak* have been depleted since the colonial era to provide wood for coal mines. Local communities have since long used these deforested hills for mixed-tree cultivation, including clove trees, fruit trees and government-sponsored pine tree plantations. In addition, /Minangkabauu villages have for generations managed communal forest areas, called *hutan adat* or *hutan nagari* (village forest) usually to protect water sources. Here, encroachment and tree cutting is forbidden, but the harvesting of non-timber forest products is allowed. However, some individual trees may be cut down every now and then, after permission is granted from the village head and *Adat* council. This is limited to timber needs for house construction only, and usually is done in support of poor villagers not being able to purchase all construction materials to build a house. These forests have remained largely intact until today. From 2000 onwards, after political decentralisation was implemented, the West Suamtra government returned the management of the village forests to the villages (*nagari*). In January 2012, the governor of West Sumatra issued the official regulation, known as the PHBM program (Pengelolaan Hutan Berbasis Masyarakat) or in English the CBFM program (Community-based Forestry program). For one, this shows how forest protection and sustainable forest management is part of the culture of the Minangkabau people of West Sumatra.

In the 1970s, pests and diseases killed most of the productive and non-productive trees on these degraded hills. Tree-crop cultivation was abandoned, as it had left many people devastated without financial means or alternatives to rebuild this livelihood option. Ever since, recurrent fires have turned the abandoned and degrading hillsides into a grassland/fire climax dominated by *Imperata* grasslands. Once *Imperata* establishes, it becomes challenging for other plant and tree species to compete and regenerate, as *Imperata* outcompetes any other plant species, especially since it easily burns. Fires destroy the growth of tree seedlings, while it increases the rate of vigorous re-sprouting and regrowth of *Imperata* (Wibowo et al., 1997). It is generally assumed that the costs of replacing the original ecosystem goods and services, from the forest including timber products, fire stability and soil nutrients, rise sharply due to the *Imperata* grasses containment problem (Chaplin et al., 2000). In addition, the establishment of *Imperata* grasslands leads to significant decreases in biodiversity, which in turn reduces the resilience of the ecosystem to environmental change. According to the local people, a large-scale pine tree plantation project from the government has aggravated the degradation of the hill sides. They claim that pine trees cause soils to dry up (Leimona et al., 2015).

Nowadays, about 32% of the area surrounding the lake (18,664 hectare) is considered critical land, covered by *Imperata* grassland, while rice paddy (21%), upland crops (17%) and other uses (30%) make up the rest. The satellite image of the lake's current conditions (Figure 4**Error! Reference source not found.**) shows many denuded grass-covered hills, especially on the Western part of the lake, where the majority of the people reside.

Figure 4: Satellite image of the lake *Singkarak* basin, showing degraded hills on the western side

C Community and livelihood information

C1 The Minangkabau matrilineal socio-cultural life context

The *Singkarak* Watershed is situated in the heartland of the matrilineal *Minangkabau* society. The *Singkarak* water basin hosts over 900,000 people, of which around 400,000 live in the *nagaris (*villages*)* along the shores of the lake and the rivers. Traditionally, the *nagari* boundaries tend to coincide with hydrological sub-catchment areas, as depicted in Figure 3. The Indonesian government under Suharto's regime has imposed the "Java-based" *desa* concept as a political-administrative unit here. *Desa* is a political -administrative rural unit or village. This was laid out in the *UUPD* of 1979 (*Udang-Udang Pemerintahan Desa—Laws of Village Governance,* 1979) The *UUPD* sought a uniform structure of village government throughout the nation, called *desa* (Dix Grimes, 2006).A *Desa* has been defined as an area in which a number of inhabitants is located as a social and legal unit of society. It has the lowest governmental organization but has the right to organise its own households within the national unity of the Republic of Indonesia. However, s villages in West Sumatra already had developed their own village boundaries for centuries already, the *desa* boundaries developed by the Indonesian Government did not match the traditional *nagari* boundaries in West Sumatra. nagari boundaries were not developed as administrative units, but organised along ecological, sub-catchment boundaries. The *Minangkabau* have always continued to follow their *nagari* system, maintaining the pre-Suharto boundaries as their own "political-administrative unit" (see section C3 for details). The era of decentralization (starting in 2001) finally reinstalled the *nagari* as the official political-administrative unit, following sub-catchment areas as boundaries. To reinforce the *nagari* as the guardian of the customary law (*hukum Adat*) and to specify its jurisdiction, the Regional Government of West Sumatra enacted two laws between 2000 and 2008: Law No. 9/2000 repealed by Law No. 2/2007 and Law No. 6/2008 on communal land tenure (Tegnan, 2015).

Not only is the *nagari* system unique, the *Minangkabau* culture also blends a matrilineal society with Islam, entrepreneurship and a strong tradition of indigenous village government systems, known as *Adat (*Leimona et al, 2015*)*. Gender equality is an important concept and represents a very different picture of Muslim women. *Minangkabau* matriarchate is an established, rather complex social system in which women and men share power and control, based on the principle of interdependence and mutual responsibility. It appears to be drawn largely from the customary practice (*Adat*) that involves tracing inheritance through the matrilineal line and giving prominent roles to women.

Due to their culture that stresses the importance of learning, young men in particular are encouraged to leave their hometown to learn from schools or from experiences or to seek fortune as merchants out of their hometown. This is called *merantau*. When they are adults, men can return home wise and 'useful' for the society, after gaining sufficient skills to be (financially) productive men who can take care of the women (sisters, nieces, mother, aunts, grandmother, etc.). Usually, after me*rantau*, they are considered to be more desirable by the women and respected by the potential in-laws. Today, the modern Minangkabau women also aspire to wander out of their hometown because they want to earn their living by trade, have a career, or further their education.

Women hold central roles in community ceremonies and ownership of resources – land, water and rice fields. The ownership of property (such as land, house or livestock) passes from mother to daughter. As men should mainly take care of the income for the family, a father can pass earnings or ownership from a business or profession to sons.

A distinction is made between *harta pusaka tinggi*, which is property that follows *Adat law*, the inheritance lines of the female members of the clan (land, water, rice fields and house). *Harta pusaka rendah* or harta pusaka pencarian (acquired property) can be a business, or land situated beyond the village *Adat* law system. There usually follow Islamic law and can therefore be owned and inherited by men.

The female family members are responsible for the food security of the clan (called *suku*), as women manage and inherit the (irrigated) clan-owned rice fields. A *suku* consists of the female line from one ”mother”, so it could include a grandmother, mother, sisters, (grand)daughters. *Adat* regulations stipulate that it is not allowed to sell both the rice and the land from a communally owned rice field, called a *sawah giliran* or rotational rice fields. Instead of private ownership, access to rice fields can be secured by a female family member of the *suku* after the females have agreed on who will get the right to cultivate rice (known as *hak gilir*) during one cropping cycle. The female who is mostly in need of cultivating her own food crop rice will usually get the “*hak gilir*”. In this way, any female *suku* member can secure food needs in times of need. Their social and economic power in land ownership and food production gives women a high social status in the *nagari*. For upland fields, where dryland agriculture, or tree planting usually occurs, the land is usually owned by the clan females (*Adat* land). After seeking permission from the female owners, men usually work on these upland fields.

Tree covered uplands are important for the sustainability of rice cultivation in the flat areas near the villages.

The men often target the upland areas for cash crop cultivation. In general, land closest to the village is used for vegetable cultivation. The upland, harder to access land that is further away from the village, is used for economically valuable tree crop cultivation as it needs less attention.

C2 Socio-economic context

Fishing in lake Singkarak has always been an important income source

The livelihoods of the rural *Minangkabau* people in the river basin depend highly on the natural ecosystem. This can be observed in the traditional delineation of a *nagari* along sub-catchment areas, as a way to secure freshwater resources for people in the *nagari*.

In broader terms, important socio-economic functions of the *Singkarak* river basin consist of income from fishing in the lake and rivers, domestic water-use, and irrigation water for rice production.

As explained before, rice cultivation by the female members of a *suku* is an intrinsic part of *Minangkabu* socio-cultural life and crucial for food security. It is an important in-kind contribution to family wealth.

Fishing has always been an activity for men, as, historically, it could provide a major source of cash income. However, Figure 5 shows a sharp decline in fish stocks between 1996-2004. In 2019, CO_2Operate BV initiated an evaluation study, by the Belgian University of Leuven, about the impact of the *Gula Gula* Food Forest Program so far. For one, the responses from survey participants on fish stocks has shown that the fish (*ikan bilih* in particular) in the lake have largely disappeared. The CO_2Operate BV carbon payment scheme is therefore well received by the local people as it offers a potential alternative to vanishing incomes from *bilih* fish catches.

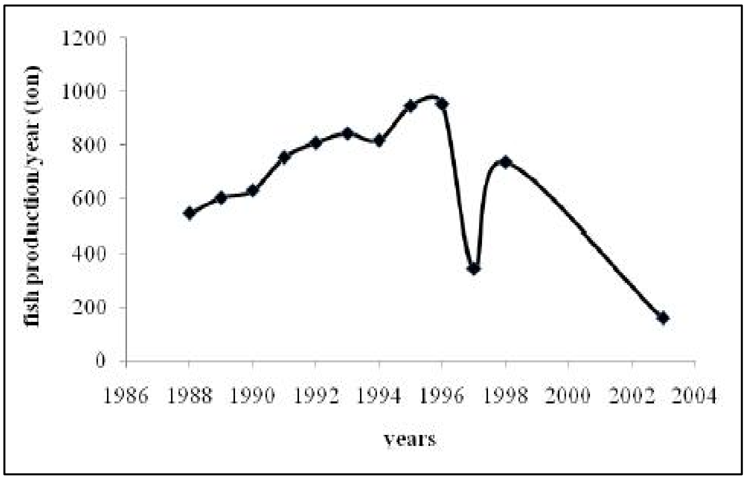

Figure 5: Fish production decline in Lake *Singkarak*, 1988-2004 (Source: Yuerlita & Perret, 2010)

A number of reasons for the decline in fish are mentioned. Increased sedimentation from increased soil erosion and eutrophication is regularly mentioned, which both cause the deterioration of the quality and quantity of the lake water. Inappropriate fishing techniques, which may result in over-fishing is another reason (Carolita et al., 2013). Local people partly blame the hydropower installation, as they believe that it has changed the water flows in the lake by dragging fish into the water tunnel of the inlet.

Besides deteriorating ecosystem functions of the lake itself, the reliability of the irrigation water has also been significantly reduced. This has negatively impacted rice yields. Samad (2001) showed for instance that yields dropped from an average of 4.2 tons/ha to 3.1 tons/ha in 1999. Figure 6 below from the Department of Agriculture, Solok, shows that this figure has increased a little bit over the years, thanks to efforts by the Department of Agriculture. However, despite efforts to increase yields, Fahmuddin Agus et al (2019) measured that rice production remains at 63% of its potential. This is in line with an earlier study by the FAO in 2000, where an estimated yield gap of 2.17 tons/ha in West Sumatra was calculated (Makarim, 2000). Parhusap et al (2020) show that the low use of fertilizers (low capital among small scale farmers), the type of varieties chosen and climate change are some of the causes for this continuing gap. A study done by Peng et al (2004) concludes that every one degree rise in night temperatures (global warming), leads to a 10% decline in rice yields. According to the older generation farmers in the villages, they all stated that when they were young, temperatures at night and during the day were much lower. Loss of tree cover was mentioned by the farmers to cause higher day and night temperatures.

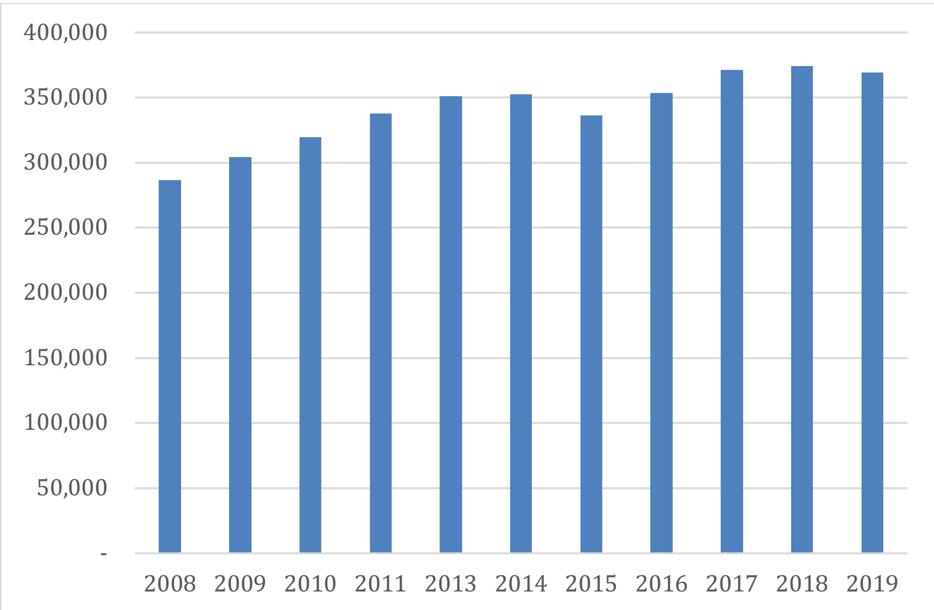

Figure 6: rice production in Solok district, 2008-2019 (Source: BPS Solok).

A combination of the decreasing ability of the barren hills to regulate water flows with more intense and irregular rainfall, caused by climate change, increases the risk of flooding, which has also negatively influenced rice yields. In 2016, for instance, almost the entire rice harvest was destroyed as rice fields were flooded after days of continuous rain in several *nagari* around the lake. The farmers often say that the rainy season can no longer be predicted, as rains show high variability. An evaluation study done by the University of Leuven, Belgium, about our program also highlighted the impact that pests can have on the rice crops. Respondents mentioned that, in 2017, mice destroyed most of the rice harvest, whilst in 2018, an insect plague destroyed most of the rice crop. The absence of natural enemies (e.g. snakes) could be one reason, why this occurs.

Livelihood vulnerability has increased significantly with poverty becoming widespread in the river basin. The area of the *Gula Gula* Food Forest Program in the *Singkarak* river basin, in subdistrict *junjung sirih*, where *nagari Paninggahan* is situated. Here, the average income is as low as 1 million Indonesian Rupiah (Rp) (about €70) per month, compared with the average monthly income at sub-district level of between 1.3 million and 1.5 million Rp per month, or around €91 on average (Tri Martial et al., 2012). However, the West Sumatra 2017 official legal minimum wage was set at 1,945,000 Rp per month (around €136 per month). This means that the incomes of the local people around the *Gula Gula* Food Forest site are nearly 50% of the West Sumatra legal minimum wage and 18% less than the sub district average income. This influences people migration towards the cities, which is often made easy because of the tradition of *Merantau* (see above). Strong social relationships exist with migrated Minangkabau all over Indonesia and Asia.

C3 Community profile for villages eligible for certification

Villages and sites eligible for carbon ceritification are Paninggahan and Air Dingin, both in Solok District. The reason being, that restoration activities have started from 2017 onwards, a requirement for carbon certification. Projects should not have started more than 5 years ago.

Table 2 Social services and land area in Paninggahan and Air Dingin

	Air dingin	Paninggahan
Total area (km2)	126,39	95,5
Primary schools	7	2
secondary	2	1
Puskesmas/poliklinik	0	1
Pustu (midwifery practice) clinique)	2	1
Market	Once a week	Once a week
Inhabitants	10770	10513
Inh /km2	85	110
Sawah (km2)	13,21	19,10

Sources: kecamatan junjung sirih dalam Angka, BPS 2020; kecamatan Lembah Gumanti dalam Angka (BPS, 2020)

Table 2 shows that both villages have around 10,000 inhabitants, In both villages, 99% of the people consider themselves as farmers. The remaining 1 % are non-farming households, usually shopkeepers, Both villages have primary schools, and secondary school facilities. Health clinics are limited to the lowest level of health provision in Indonesia, which are called *puskesma*s. Puskesmas provide preventive, promotive, and curative care at the sub-district level with a focus on both the community and the individual (2). The *puskesmas* network provides six essential services: 1) Health promotion, 2) Communicable disease control, 3) Ambulatory care, 4) Maternal and child health and family planning, 5) Community nutrition, and 6) Environmental health (*Indonesia: Puskesmas and the Road to Equity and Access | PHCPI (improvingphc.org))*

They also have a Pustu, a kind of midwifery practice. Irrigated ricefields can be found in the flat areas, with Paninggahan having the largest area. It must be noted that in Air Dingin the majority of sawah has been converted into vegetable gardens, as water for irrigation has become problematic due to

deforested upland areas. Where people still grow rice, production has generally increased over the past decade (Figure 6). This is mostly achieved not by extending the land under rice cultivation but by moving towards more intensive rice cultivation, with fast-growing varieties and other technological innovations. Rice is the main staple crop and with increasing number of young community members (Figure 7), food security through on farm cultivation remains important.
Both villages show typical population dynamics for remote, underdeveloped regions. A high representation of infants and young people, which usually means that population will continue to increase in the villages.

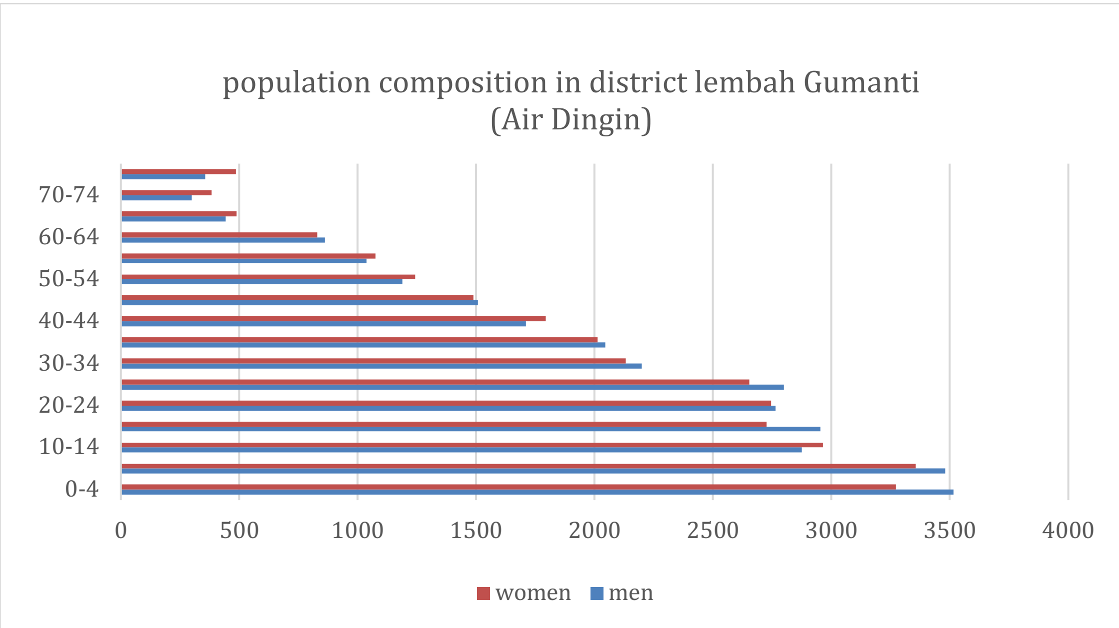

Figure 7 Population dynamics in Paninggahan and Air Dingin (2020)

Housing

Traditionally, houses are owned by the females of the family. Each house used to have various rooms where married men would stay with the wife. The research done by the Indoesian student in 2018 revealed that about 20% of all houses were still considered Adat houses (top right picture below). They are recognised by the typical roofs in the shape of a horn (minang) of the ox (kerbau). It is where the name Minangkabau comes from. Nowadays, married couple would still live close to the female family members, but they build separate houses close to each other, explaining the high percentage of ownership in Figure 8. Married men must ensure that he is able to build a good house for his wife, and therefore they often migrate to the big cities or even Malaysia to earn enough money to build a house made of bricks. Usually, once the savings are enough they come back, and start building the house for the family.

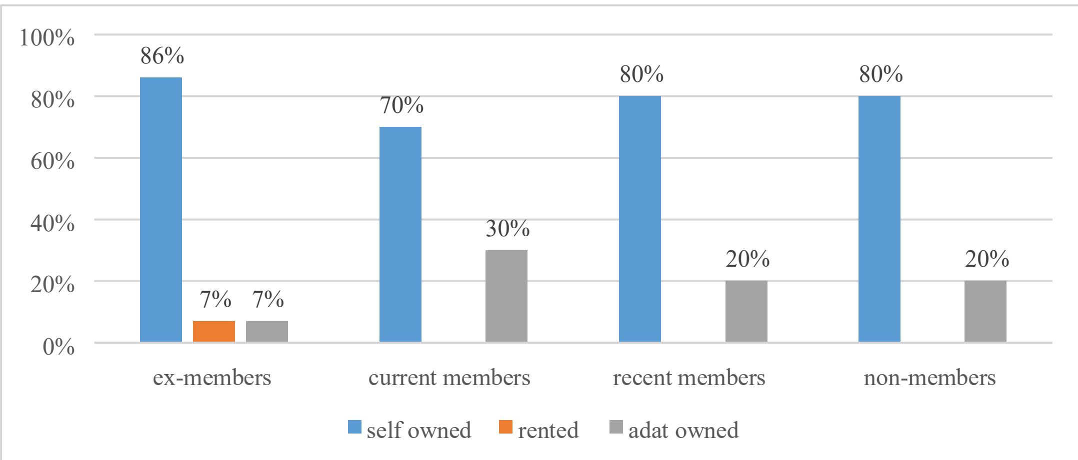

Figure 8 House ownership of all participants until 2018 (n =85).

Tolong menolong: Understanding (the absence of) marginalisation in Minang societies

The Minangkabau is very well known for its tradition to have a harmonious society, provide a sage and peaceful life in society for all. The customary provisions are based on a sense of togetherness, solidarity, tolerance which is believed to ensure harmony in daily life. This is rooted in their concept of mutual help (*Adaik hiduk tolong menolong).* It contains values that do not subscribe to individualistic thinking. Minangkabau people shall care for the natural and social environment, Helping the weak and poor is an important aspect in Minangkabau life, and those in need can count on support and help from the community.

Women hold a strong social position in the village, as land ownership passes through the female lineage (see section C1 for more detail). Instead, men could be considered marginalised, as they hold no land titles under Adat law They manage the land of the female clan members once they marry. However, managing the rice fields remains almost exclusively a task for women, although men will be asked to do the hard work on the ricefeld (ploughing, weeding) Cultivation of rice is based on the system of *giliran,* which means rotation. Before each new rice season, the female family members gather and will decide who is mostly in need of cultivation rice for her family. She will get the *hak gilir*, or the right to cultivate. This solidarity mechanism of mutual help still holds. Solidarity is also very common in relation to those in need or for outsiders who may seek land for survival or to build a better livelihood. Burgers (2004) for instance has done research on migration into *minangkabau* villages by outsiders (mostly non-Minangkabau people) during the economic crisis in the late 1990s, when especially on Java many rural people became marginalised. Javanese migrants settled in the villages, where they were given a piece of land to cultivate under sharecropping arrangements. The cultivator would get around 70% of the harvest. This kind of openness and traditional kind of hospitality toward those in need has helped many Javanese during the crisis to survive and even build up a better livelihood. The research also showed that migrants continue to migrate to Minang villages in West Sumatra on a temporary basis to work the land of the Minangkabau, as a way to build their livelihood. Earnings would be invested in their family on Java, to start a business or to construct a good house in their home village on Java. In order to find out whether certain community members would be (socially) excluded and marginalised in our program, we asked an Indonesian student from the university of Leuven, Belgium, to conduct an in depth evaluation of the impact of our program in 2018. In Paninggahan, where the evaluation study was conducted, it was found that 8% of members of the cooperative farmer groups in the first restoration activities did so under sharecropping arrangements, while this increased to 13% of recent members (joining 2017). Among recent members (starting in 2017), a substantial group of 28% rented land from others to be able to join the program. Gender and ethnic clearly has no link to marginalisation. She looked at various indicators, including age, educational level, main occupation and income. The main outcomes are included in this PDD, see below () Roughly speaking, all groups are represented, from young to old, various educational levels, income and main occupation. There may seem a low representation of members with low or no education, but the reason being that there are hardly any Minangkabau who have not attended school. This again is part of their culture of intellectual advancement (of which merantau is an important concept (section C1). In relation to income, it can be concluded that in particular people with low incomes are joining the program, which is positive. For main occupation most participants consider themselves as farmers, Off farm employment is also well represented, but these people usually combine off farm employment with being a farmer. These include teachers, middlemen, shopkeepers and drivers.

The study concluded that there are no specific people in the village which could be considered marginalised or excluded groups. There are poor people, but the cooperative farmer groups are open to anyone, including poor people. In fact, non-participants can be mainly found in the high income categories, with no specific need to obtain an additional income from ecosystem restoration or carbon payments. The program seems to be pro poor as well, as long as a participant has the motivation to work with the group on restoring degraded lands. The support members get from the project managers, field staff and cooperative farmer group members combined with the simple and very low cost technology of Assisted Natural regeneration means no hurdles exist for joining the program. The concept of mutual help is deeply rooted in Minangkabau society.

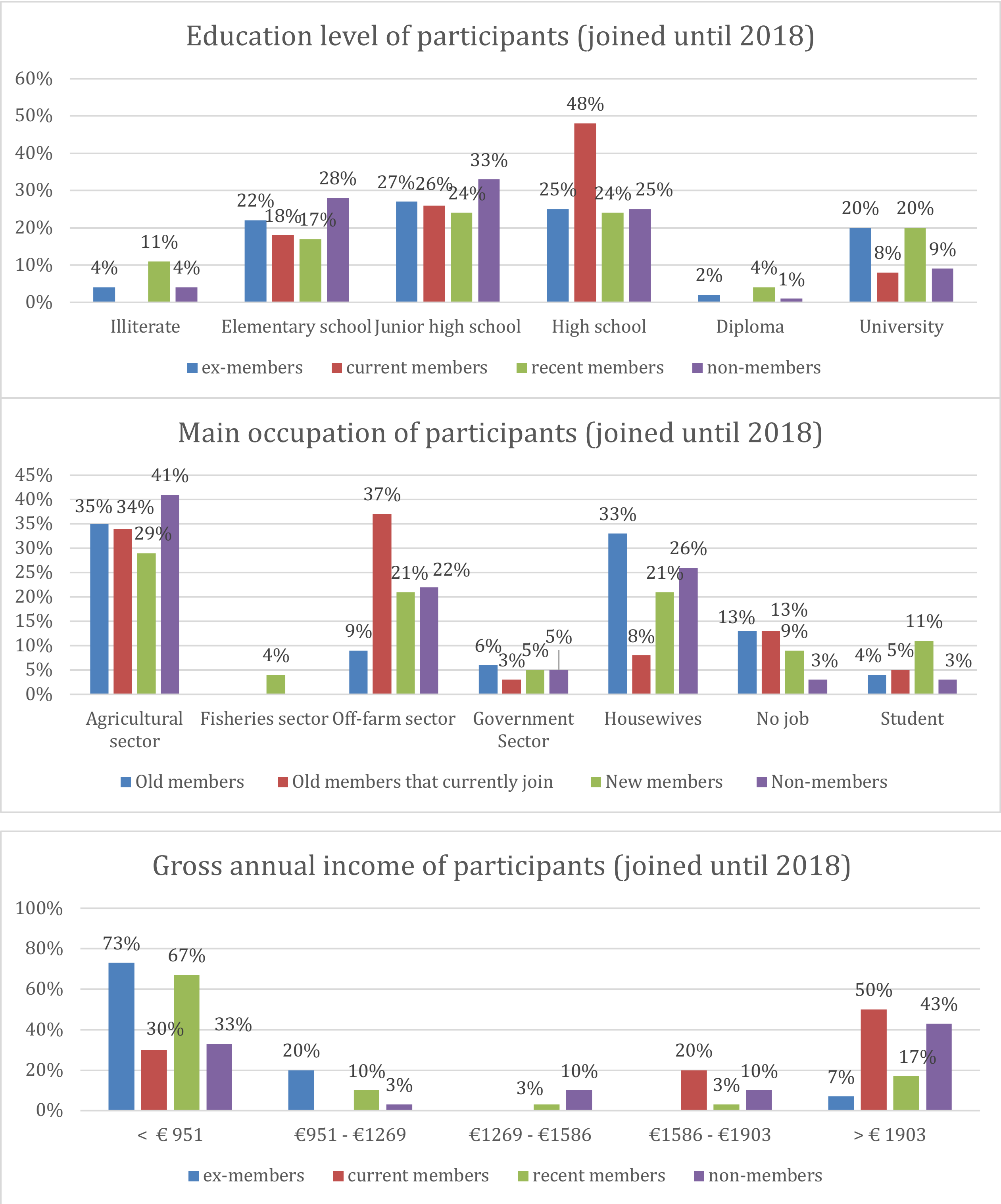

Figure 9 selected socio-economic characteristics of participants (2018).

Source: Dea Hasna Isadora, 2019

C4 land tenure & ownership of carbon rights

The governance system of villages (*desa*) was implemented across Indonesia since the rule of Suharto. West Sumatra is no exception. However, the Minangkabau have, over time, developed their own political-administrative units, called *nagari*.

The village and its territory: the *nagari*

The *nagari* is the pre-colonial, political unit for village in the Minangkabau society (Von Benda Beckmann, 2004). Usually, a *nagari* is organised around sub-water catchment areas (Figure 10:Village boundaries of nagari Paninggahan, which coincides with a sub-catchment area. and Figure 11), providing each *nagari* with their own water resources (Figure 3 shows all *nagari*/sub catchment areas in the Singkarak river basin). The decentralization processes from early 2000 onwards paved the way to change the system of governance in West Sumatra from 'village' (*desa*) into the original, pre-colonial governance structure in Minangkabau culture, the '*nagari*'. The *nagari* system recognises the traditional effectiveness of local communities in managing their natural resources, including the land.

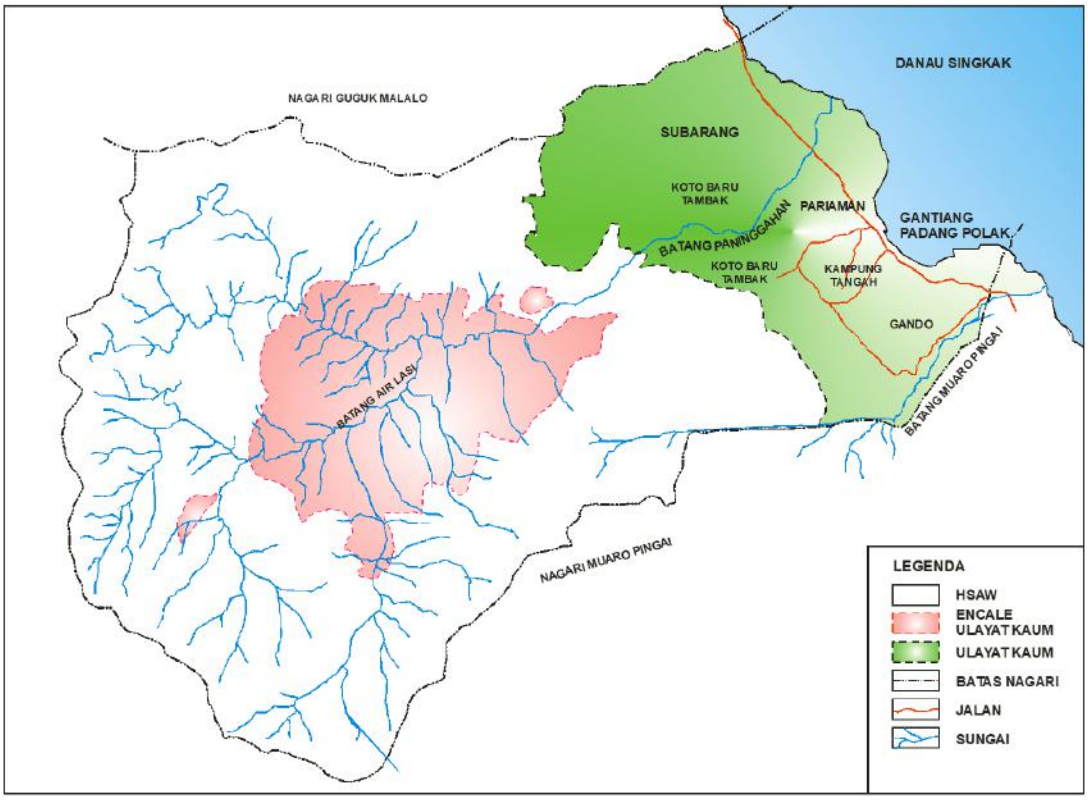

Figure 10:Village boundaries of nagari Paninggahan, which coincides with a sub-catchment area.

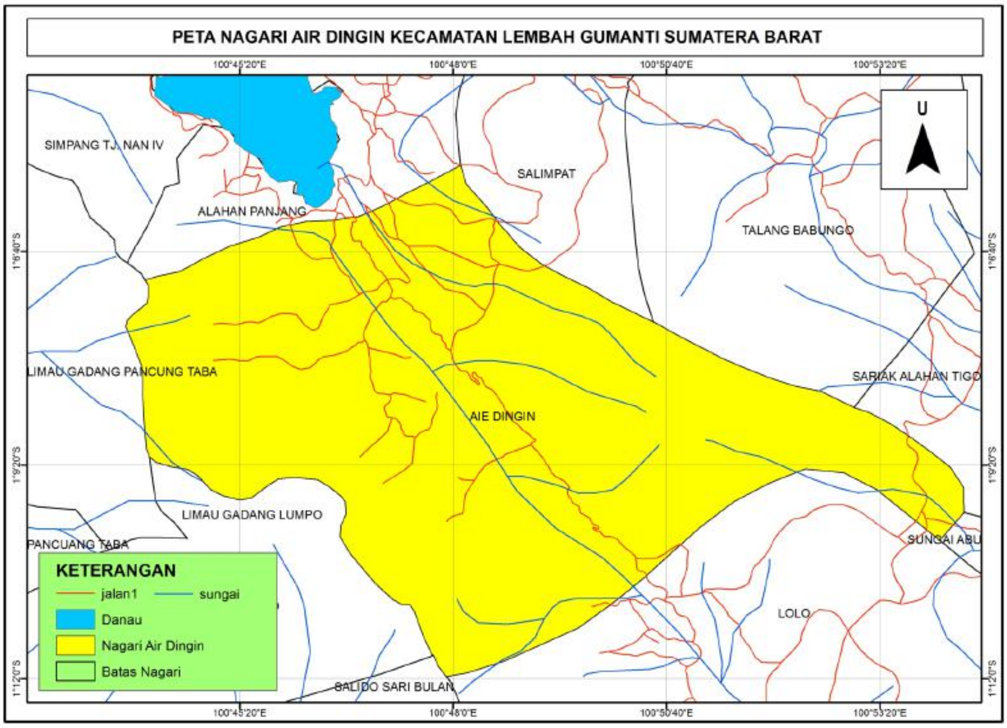

Figure 11: Village boundaries of *nagari Air Dingin, centred around the main rivers feeding into the lake (danau di atas)*

A *nagari* comprises of the village–territory and the agricultural land. Under *nagari*, land ownership–or more precisely the 'right to use' the land–is governed through the locally defined rules of the *Adat*. The *Adat* Council is the highest governmental body of the *nagari*. Every five years the village chief (*Wali Nagari*) is democratically voted in to be head of the *nagari*.

Where the rice fields are inherited by the female lines of a *suku* (clan), land of the surrounding hilly landscape is communally managed under rather complex agreements by both men and women. This involves either the (extended) families (*suku*) level or at the *nagari* level (*tanah ulayat nagari*). This usually concerns communal land for the benefit of the entire *nagari*, like mosques and schools, but also for specific forest areas called *Adat* forest (*hutan Adat)*. These are generally situated around crucial water sub-catchment areas. Forest products can be harvested, but timber can only be harvested for domestic purposes after permission from the *wali nagari* has been granted.

The hilly dryland agricultural areas are managed by the (extended) families and consist of two main types of land ownership under the *Adat* system. This 'tribal / clan land' (*Tanah Kaum/Suku)*, is owned by members of customary groups, the *suku*, (the female lineage, those with "blood" from one mother) operating under the matrilineal system. Open-access land, which is owned by whoever initially cultivated it; this land can be inherited, but is usually managed and controlled by the oldest man in the matrilineal lineage, or *Datuk*. This land is outside *Adat* law, but incorporated into the clan's land. One cannot sell land in either category. These informal rules are well-defined and enforced. The communities are also well-aware of the formal rules enforced by the state. For instance, state forest land, which is situated beyond the boundaries of *nagari* land, is respected as such by the communities as being government-owned land.

The *Gula Gula* Food Forest Program limits its interventions to the well-defined customary, *Adat*-controlled *tanah kaum.* Here, the government has no mandate or official control over the use of the land, hence the local people have full control over the land, including carbon rights.

However, over the past decade the Government of Indonesia is looking for ways to get more control over the carbon sequestered by carbon projects to reach the targets of their National Determined Commitment (NDC) to reduce GHG emissions. Since 2012, regulations began to develop to build carbon sequestration projects (Peratuan Menteri Kehutanan Republic Indonesia nomor: p.20/Menhut-II/2012). Activities were geared at forestry land, belonging to the ministry of Forestry. It limited to production forest, protection forest and conservation forest. Although community forests were mentioned, regulations for forestry activities in village areas were not included. Community forests are mainly defined as areas where local communities can manage the forest for the benefit of the village, but the area is designated as forestland under Government control. The *hutan desa* or *hutan nagari* concepts fall into this category. Carbon rights from these forests can be obtained by the local community, once they have successfully applied for a permit from the Government. This is more formally stated in the ministerial decrees of 2019; the Peraturan Menteri Lingkungan Hidup dan Kehutanan Republic Indonesia, nomor p.21/menkhk/setjen/kum.1/4/2019 on *hutan adat and hutan hak*. Again, most agricultural areas under village control were not targeted, hence carbon ownership rights on these lands solely belong to the local people. However, in order to achieve the NDC commitments, our contacts in the Ministry of Forestry explained to us that in May 2020, the Government of Indonesia has drafted new regulations for increasing carbon sequestration benefits from forestry projects which also implements carbon sales. The general direction seems to be that all carbon projects need to register officially, also those on non-government land, and a certain percentage of the generated carbon credits need to be sold to the government at a low price, in order to contribute to the NDC targets. We understand, that the regulations will not be implemented on existing and already sold carbon, but might be implemented on new activities. Double counting is therefore not a problem. The sales to the government will be registered. Plan Vivo credits are developed for the remaining carbon credits, and are supposed to be sold voluntarily by the community. For this, the community might need to apply for a permit to sell carbon credits in the future. According to our contacts in UNEP and the Ministry of Forestry, such a permit is not difficult to get for our cooperative farmer groups, since we have supported them to obtain an official status according to government regulations. The latest update is the debate which is still on-going about the percentage to be sold to the government, and whether or not relatively small community-based carbon projects (like the *Gula Gula* Food Forest program), should be included. So maybe initiatives like the *Gula Gula* Food Forest program might still be outside from these regulations. We are however constantly being informed about the progress in the Ministry, hence are able to anticipate to potential changes.

Only limited *adat* village land in West Sumatra falls under individual ownership (see, for instance, Tegnan (2015) for more background information. This land is outside of government land, belonging to and owned by the village. Carbon rights ownership follows carbon sequestration on these lands, and in many cases the cooperative farmer groups are organised along a *suku*.

The ownership and benefit-sharing mechanisms from selling carbon have been discussed in full detail during the FPIC process. The farmers considered the support from CO_2Operate BV important to apply for a formal (cooperative) status for each cooperative farmer group. This formal status allows them to open a cooperative bank account and enables each cooperative farmer group to monitor their own carbon income. Carbon payments are then transferred directly into the account of each cooperative farmer group. This gives them security to obtain the full income from the carbon credits they have produced. Furthermore, transferring money through direct payments reduces the risk of corruption emerging in the process. Currently, there are 4 official cooperative farmer groups in *Paninggahan* village, whereas in *Air Dingin* one large cooperative farmer group is established. These groups remain the basis for further expansion and inclusion of new members with access to the communal *Adat* land. Benefit-sharing mechanisms are discussed in detail in section E1.

D Project Interventions & Activities

D1 Project interventions

Several types of project intervention types are included in the project. These are:

• **Ecosystem rehabilitation**: Agroforestry development using Assisted Natural Regeneration (ANR) combined with tree planting.
• **Improved land management**: Diversification of (former) vegetable and degraded areas into agroforests.
• **Ecosystem restoration**: Natural Regeneration of secondary forests as a result of fire management.

Before the *Gula Gula* Food Forest Program introduced Assisted Natural Regeneration techniques in 2012, the normal farming rehabilitation practice has always been the uprooting of *Imperata* grasslands by slashing, hand-ploughing, and clean-weeding in order to grow crops or trees. This is labour-intensive, and often not rewarding, as *Imperata* grasses grow back vigorously. From the beginning of the project between 2009 and 2012, the *Gula Gula* Food Forest Program followed this method of reclaiming the land. However, it appeared to be damaging the ecosystem, as it promoted exposure of the soil to solar radiation which resulted in evaporation and the soils to dry out. This was aggravated by the drought period caused by El Niño in 2009-2010. The newly planted trees died under severe solar radiation, evapotranspiration and lack of rainfall.

Working against nature: The tradition of slashing, uprooting and clean-weeding before tree planting, proved to be ineffective for ecosystem restoration.

In early 2012, a collaboration with the Food and Agriculture Organisation (FAO) was set-up to organise field-testing using Assisted Natural Regeneration (ANR) as a low-cost method to restore ecosystems on degraded lands. By working with nature, the big advantage of Assisted Natural Regeneration is that *Imperata* grasslands no longer needed to be uprooted and removed. Instead, using a lodging board, grasses are simply pressed. Small, indigenous original rainforest tree seedlings, which are found in between the *Imperata* grasses, are marked with a bamboo stick before pressing, so that they are protected and allowed to grow, restoring part of the original forest ecosystem. It quickly became apparent that the technique of ANR is an easy to use, cheap and ecologically-sound technique of restoring trees in the landscape. It resulted in tree growth beyond expectations. The growth of the formerly suppressed indigenous species enabled quick gains in carbon stocks. It creates original ecosystem stability for the return of indigenous flora & fauna species.

The farmers became very enthusiastic about the ANR practices, especially in combination with the intercropping of economically-valuable agroforestry trees. The fast-growing indigenous trees provide favourable micro-climatic conditions for the planted economically-valuable trees. In addition, the pressed *Imperata* grasses form a thick isolation blanket, thereby reducing soil temperatures, conserving moisture and minimising soil moisture evaporation. Even after a 5-6 weeks during the dry period, the soils below the pressed *Imperata* remained moist. The decaying *Imperata* also provides additional carbon to the soil. The "trapped" moisture and absorbed carbon in the soil could explain the heightened accumulation of soil carbon and fast tree growth through improved soil quality.

With this knowledge, CO_2Operate BV began experimenting with the method to enable farmers to integrate ANR into the Voluntary Carbon Market (VCM) activities more effectively. It has now become one of the major interventions to rehabilitate ecosystem service functions within the project activities. However, if the land is predominantly covered with a ferny type of vegetation, ANR is difficult as ferns tend to bounce back after pressing. Here, the vegetation is slashed after marking useful existing seedlings and small trees. The slashed vegetation remains in the field, decays and the nutrients and carbon are taken up by the soils.

Pressed Imperata grasses provide isolation against evaporation, while decaying *Imperata* adds nutrients and carbon to the soil.

Another benefit of this ANR approach is that it is a zero-burning technique, which reduces the risk of fires. In combination with a fire prevention team, this is causing natural regeneration in those areas that have not been actively managed by CO_2Operate BV. Since the (young) trees present in the grasslands were no longer destroyed by fire, they could continue to regenerate and suppress the growth of *Imperata* grass by outcompeting it for light. The shade from the growing trees will ultimately significantly reduce the survival of *Imperata* grasses, as it is not shade-tolerant.
Finally, to highlight the benefits that the improved land management interventions caused, an increasing number of participants like to diversify their degraded lands or own vegetable land into a food forest. The reason being that degraded lands do not bring an income, and vegetable cultivation is practiced for cash only while it requires high input costs, and as farmers say, vegetable cultivation for cash is like gambling. You never know if it will be profitable, because of many diseases and high costs, while prices usually drop after harvesting, when the market is flooded with a certain type of vegetable. Therefore, more farmers prefer to plant trees as well, under a carbon contract. Trees normally require few/no external inputs, but can still generate food (fruits and spices) and cash. So far, 16 ha of vegetable land is being diversified into a mixed agroforestry system as part of the carbon contract. This further benefits biodiversity enhancement, as pesticides and insecticides are no longer being used, and flora and fauna is no longer affected. In addition, the wind no longer spreads remnants of these inputs in the area. These actions help to make the program a candidate for organic certification.

D2 Summarise the project activities for each intervention

Table 3: Description of activities

Description of activities				
Intervention type	**Project Activity**	**Description**	**Target group**	**Eligible for PV accreditation**
Ecosystem rehabilitation	Implementing Assisted Natural Regeneration (ANR) techniques combined with tree planting from village tree nurseries.	Agroforestry development through stimulation of natural regeneration of native species by pressing weeds & *Imperata* grasses. This brings back 30-40% of tree cover. Gap planting of economic valuable trees adds more trees.	Participating cooperative farmer groups (in *Paninggahan* and *Air Dingn*)	Yes
Improved land management	Planting a mixture of trees on degraded lands or abandoned cropland into agroforestry	Planting of agroforestry trees from village tree nurseries on former cropland, using zero tillage. Present vegetation is slashed instead of pressed, and left in the field to decay, with no burning.	Participating cooperative farmer groups (in specific areas of *Paninggahan*, and in all sites of *Air Dingin*)	Yes
Ecosystem restoration	Natural regeneration of secondary forest, caused by Fire management	The zero-burning techniques slows down/prevents fires. Farmer fire prevention teams were set up to stop burning for land clearing on fields not in the program. With no burning, tree seedlings in the *Imperata* can grow and outcompete *Imperata* grasses.	Participating cooperative farmer groups (in *Paninggahan*)	Yes

D3 Effects of activities on biodiversity and the environment

The project activities work on degraded *Imperata* grasslands and/or fern-dominated lands with low levels of biodiversity to bring back diverse (agro)forest cover. Recorded data show that, within 5 years, combining the growth of indigenous species with naturalised agroforestry trees enables the establishment of a biodiverse food forest. The local community benefits from improved food security and income. Besides providing better incomes and a more diverse food pattern, the forest-like structure provides increasing habitat and corridor functions for a growing number of flora and fauna. After 3-4 years, evidence points to increased animal activity in the *Gula Gula* food forest, as shown in the images below and those in Figure 12 . This ranges from animal tracks to animal-induced damage to the trees. The farmers see and hear an increasing sound of various types of birds and other animals. The farmers claim the birds divert their flying routes, using the food forest as shelter when flying from one patch of forest to another.

Signs of wildlife: tracks of wild boar, tree damage by deer and monkeys, and Sumatran tiger footprint

In order to find out what animals are (regularly) visiting the food forest, some camera traps were placed in the food forest. The photographic evidence indicates the presence of all trophic levels in the food web (an entire food chain, seeFigure 12). The most exciting species documented in these areas include the Sumatran tiger (evidence by footprint tracks) and the endangered *Langur* monkey. The Sumatran tiger roamed around the wooden hut in the food forest on several occasions whilst CO_2Operate BV staff and field staff were sleeping there.

Another remarkable development is the spread of a plant called *Curcuma zedoaria* (left) into the food forest. Farmers recognise it from the rainforest. This could indicate that environmental conditions in the food forest are beginning to replicate rainforest conditions. It appears that the interventions support, rather than deteriorate, the restoration of biodiversity and environmental conditions present in the original rainforest. This means that moisture is replacing the dry conditions present in *Imperata* grassland or fern-dominated lands. Figure 29 (in technical specifications) shows that the project interventions also increase the soil carbon. This is not only important for soil fertility; increased soil carbon is also said to improve the water retention capacity. These developments indicate a shift from degraded lands to rehabilitated fertile soils by means of ecosystem function restoration.

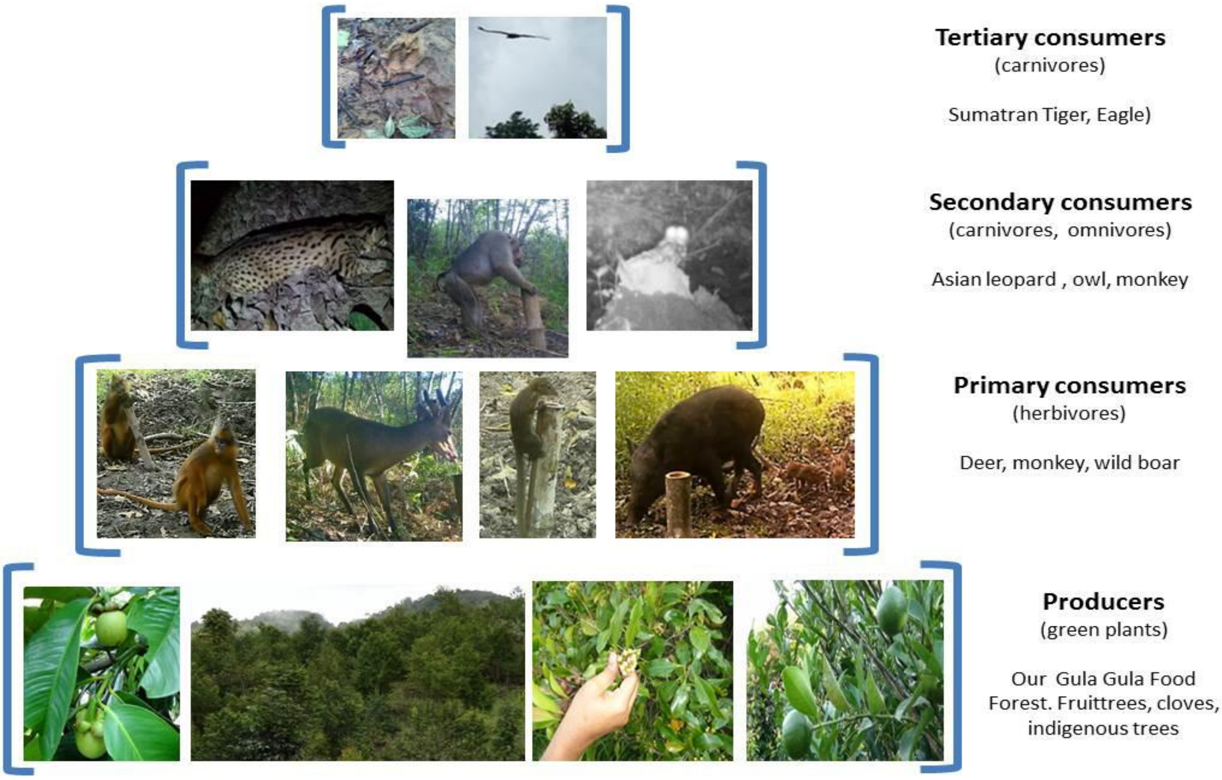

Figure 12: Food chain based on camera trap photos in the *Gula Gula* Food Forest

E Community participation

E1 Participatory project design

In the Minangkabau society, public participation is rooted in the traditional values of the matrilineal Minangkabau community, and must be followed for any planned activity in the *nagari* (village). They have a special term for this: *muryawarah.* Planned activities or projects can be implemented (including managing upland fields), but only through public participation, and only after reaching the phase of *mufakat* (public village consensus, including the opinion of women). One could say that this is a kind of indigenous FPIC process. CO_2Operate BV has blended the two FPIC ideologies to enable the success of the *Gula Gula* Food Forest program (Figure 13).

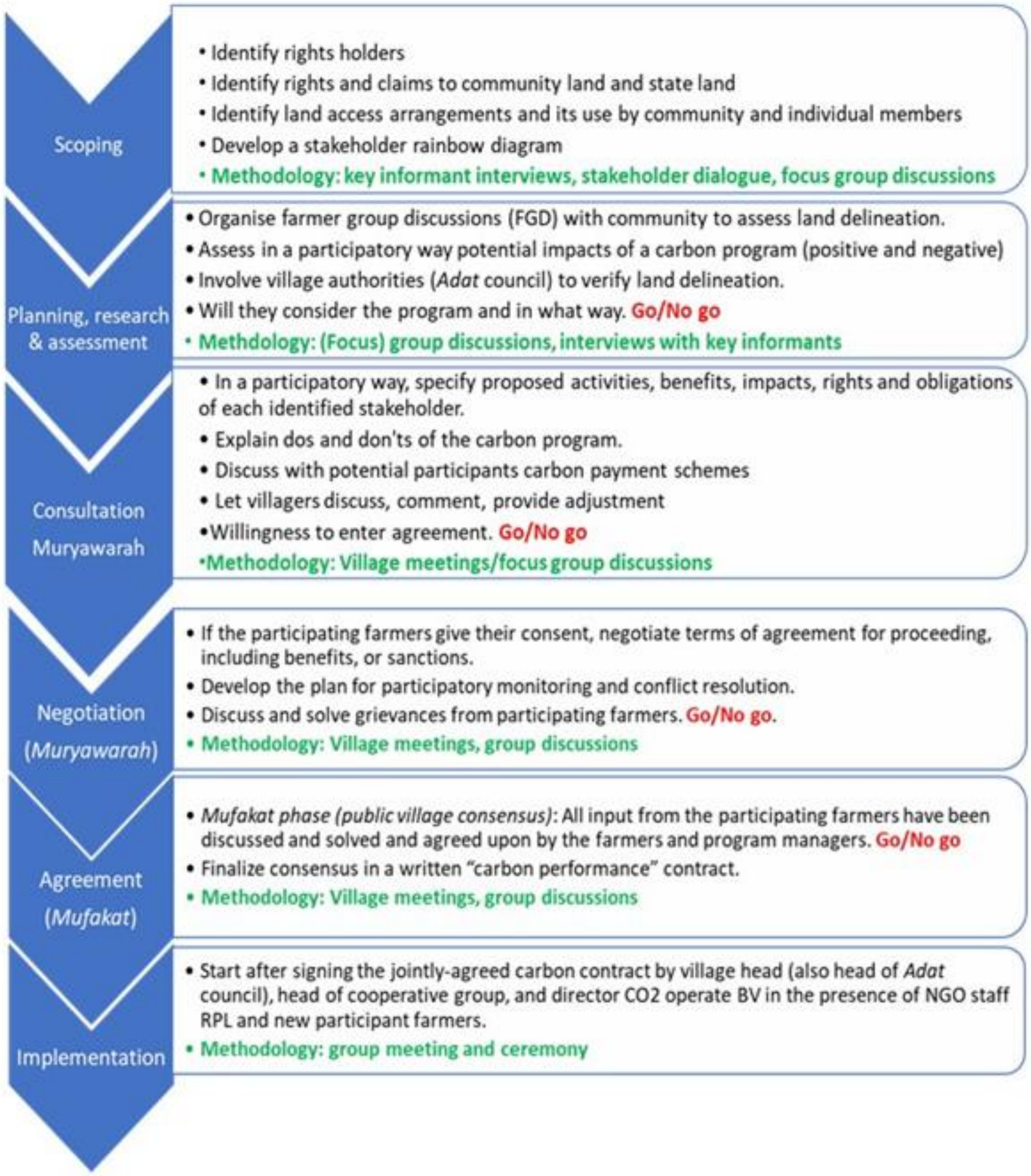

Figure 13: The FPIC process for ecosystem restoration in the *Gula Gula* Food Forest Program

Table 4: Activities and participatory approaches during the FPIC process

What	how	when	why	Who		Output
Project (Site) identification	FPIC, using farmer group meetings	Before the start of a new carbon contract	To get consent from new participants	CO2 Operate staff, RPL, potential new participants		Mutual agreement laid out in a performance-based carbon contract
Farmer participant selection	During farmer group meetings as part of the FPIC process.	At the start of FPIC process.	Discuss with farmers who is willing and able to manage the rehabilitation of a piece of land.	RPL as facilitator of farmer group discussions.		List of participants with a real interest in and capabilities for participation.
Land identification	GIS, using GPS for exact field measurements	Before signing carbon contract as part of FPIC process	Ensure clear land boundaries to avoid conflicts, and to ensure size of area needed for a carbon offsetting contract.	RPL, head of each cooperative farmer group, STKIP staff and students, participants.		Map showing plots, size and who manages it with trees present. All is uploaded in explorer.land online tool.
Tree selection	Counts of trees in the field, and a list of preferred species from each farmer.	Before carbon contract is signed	To develop carbon baseline and ensure planting needs from each farmer.	RPL, participants the head of the cooperative farmer groups.		List of existing trees to be protected and preferred agroforestry trees to be planted.

As in the Minangkabau culture, public participation is an important aspect. Due to the egalitarian social structures, and women possessing a high social position, it is not seen a necessary step to include a special target for women other than ensuring that men and women are represented in meetings or during FPIC processes. The ANR technology used is low cost and simple, making it accessible to even the poorest segments of the village. When funds become available for a new area of land restoration, interested community actors can join the planning process FPIC meetings. All families have access to land for consideration. From the beginning of the project with the experimental phase in 2009, various cooperative farmer groups (*kelompok tani*) have since been established. These are officially recognised by the local government and registered as a cooperative farmer group. With new carbon offsetting contracts, new participants will either join existing groups, or if they prefer to establish their own, field staff of RPL supports them to get registered as *kelompok tani*. Table 4 summarizes all steps and participatory approaches being done when funds become available for a new are to be restored into productive food forest.

E2 Community-Led Design Plan

After a testing phase, which started in 2009, the program has been running officially since 2012. When starting the activities, CO_2Operate BV identified local practices, culture, community priorities and needs (see section C for details). FPIC procedures were used to embed the philosophy of the project into their existing cultural habits. Harmonious agreements and understanding were sought for a respectful partnership. During the FPIC meetings, the village head (*wali nagari*) and interested, potential participants were present to discuss the carbon offsetting design plan.

After hearing the inputs from the community members, some changes to the initial performance-based carbon contract were made to fit the community's desires, needs and aspirations. For instance, the community members themselves requested the inclusion of a (financial) penalty system for those not meeting the targets and quality required for achieving the specific carbon offsetting quota in the contract. They insisted to include that any member in a group not performing well could be replaced. This already showed that the FPIC process gave a large sense of ownership to the community members since the beginning.

Another important change was made in the proposed payment schemes. The community members, the farmers, suggested that the equal distribution of funds over a 5-year period (each year 20%) should be adjusted towards a more stepwise approach. They highlighted the highest costs, such as input of labour, occur at the beginning when there is no income available from the harvest of the trees, while investment costs would be highest. The agreements were changed accordingly, where the participants suggested that 70% of the total carbon payments of the 5-year contract were done in the first two years (see section J1 for more details). In this way, the funds could act as bridging fund for the costs and maintenance of planting in the early years, where costs and management needs are highest. Until today, the "contract" remains largely intact, showing it fits the local community's reality.

All new participants become part of existing or new cooperative farmer groups. Monitoring the progress of participants against their targets is made easier by each group having a copy of the contract. Contracts are kept by the head of each cooperative farmer group and CO_2Operate BV/RPL field workers. Milestones and acceptable practices that deliver the farmer payments are defined within the contract.

Location, land, participants and all components of the contract are being discussed and agreed upon during the FPIC process before signing the contract, checked by and in the presence of the farmer participants.

E3 Community-led implementation of Plan Vivos

Preparation of a Plan Vivo at "contract -level" with all steps needed, is described above. Each contract includes a list of participants and what trees and area they will manage. The participants are selected by existing group members, or new groups are formed voluntarily. Usually, new groups come from one clan, are neighbours, friends or in any other way people close enough to each other to make restoration activities effective as a group, allowing effective communication among group members. Together with the participants and existing group members (but usually the head of the existing group and the finance person), staff from CO_2Operate BV/ RPL work in collaboration with staff and students from the teacher's college in Padang, STKIP. They discuss practical project issues and identify the land area for each participant to work on.

GPS points are made for all land areas, and for each individual participant (see Annex 6 for an example). These are mapped using google satellite images in collaboration with GIS staff at STKIP. These maps are made available and discussed with all participants during one of the monthly monitoring meetings. The meetings are organised by RPL staff together with each cooperative farmer group (See Annex 7 for an example of the maps).

In addition to including all names and land area managed in the offsetting contract, RPL staff keeps detailed records of the participant's name, area managed, number of indigenous

and planted trees (and what species). Since the participants are involved from the beginning of the negotiation process, they remain involved throughout the entire period of the contract. The accuracy of these records is regularly evaluated with the head of the cooperative group. Recently, all the information feeds into our project pages of the explorer.land project page of the German-based company Open Forests. See https://explorer.land/x/project/vcm/). This also allows for 100%

transparency of our work and progress at field level, while each client gets their own project page, showing the reforestation progress of their “own” carbon project.

Participatory monitoring and evaluation are crucial activities to ensure that all is done, according to the requirements in the contract and the fact, that participating farmers know they can speak regularly about progress, issues and challenges they face. It gives them a large sense of ownership, and feel they are supported by the program and can say whatever they want in order to ensure the success of the tree planting and tree growing.

Every month RPL staff members meet with each group to discuss progress, grievances and other matters. Issues are usually brought forward by the head of the farmer group (*ketua*) or the field coordinator (*koordinator lapangan*). Financial issues will be discussed with the treasurer (*bendahara*). These actions are carried out with the other members of the cooperative farmer group as witness, following the indigenous system of *muryawarah, where the negotiation processes reach consensus.* The cooperative farmer groups are organised along horizontal relationships, so that everyone feels free to discuss any issue within the group. Potential land disputes are minimised as all members discuss freely who will be able to manage what size of land. However, if a land dispute cannot be solved, the next step would be to send the issue to the *Adat* Council for adjudication. Figure 14provides an example of the organisational lay out at *nagari* level in Paninggahan. Variations in group size depends on the wishes of the participants. There is one large group in Air Dingin, but this group is subdivided into smaller groups for regular meetings, for one because the fields and houses per subgroup are quite scattered.

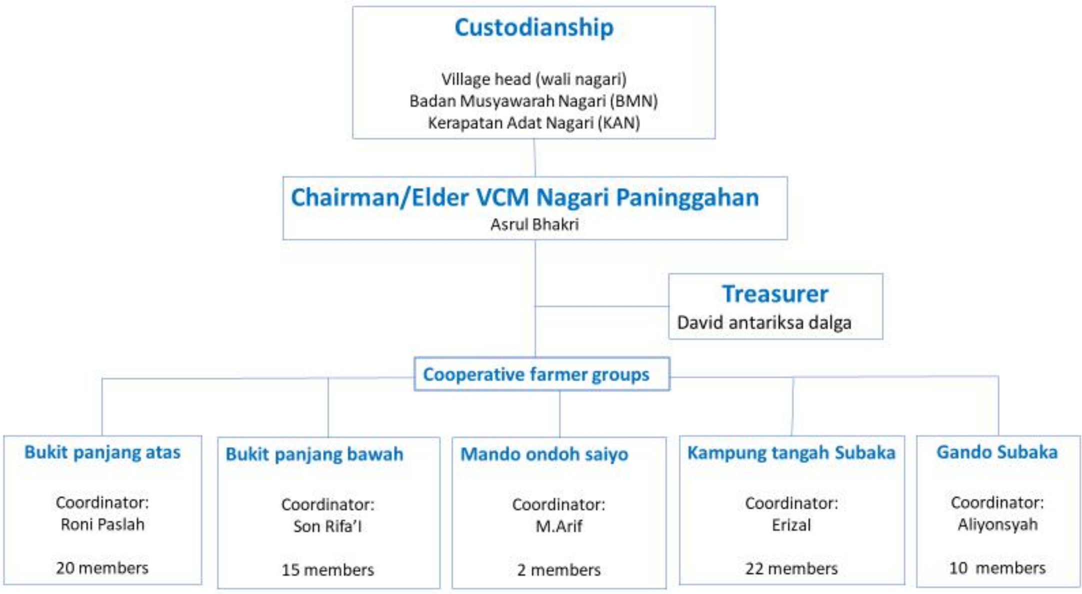

Figure 14: Example of the program organisation at *nagari Paninggahan*.

Although the project coordinators are in regular contact with each other and RPL staff using skype, WA calls or WhatsApp (several times a week), the project coordinators visit the project area at least two times a year. Farmer group discussions are then organised to discuss any issue with the project coordinators, where the project coordinator answers all kinds of questions.

Once a year the cooperative farmer group representatives, RPL and the project coordinator conduct a
participatory evaluation exercise to see if the targets for that particular year have been achieved. Once this process is finished, and the cooperative farmer group members also give their consent on
the conclusions made from the measurements and meetings, carbon payments are transferred directly into the group's or individual members' bank account(s) for that year. Where milestones are not achieved, payments will be on hold until all is finished according to the contract. There are pre-agreed allocated time periods for the cooperative farmer groups to address, improve and make good any shortcomings in the field work if the targets were not met.

FPIC meetings and regular monitoring meetings in the field where both men and women are present, always lead to lively discussions in the Minangkabau society.

E4 Farmer-initiated grievance mechanisms

The concept of mutual help and village consensus (*Mufakat*) is also important when it comes to managing the program. This became clear in the early stages of the program, when the initial set up hampered free discussion among participants caused a serious conflict. The Box below describes how the conflict evolved, was solved by the members themselves and suggested a new set up of cooperative farmer groups with horizontal social relations, so that grievances can be raised and discussed among members in an open and transparent way. This grievance mechanism still holds today and is verry effective. Cooperative farmer groups have thus far been able to solve their own grievances, with or without the input of the wali nagari (Box 1). It has formed an example for the other villages we work in. New participants always give their consent about the set-up of the grievance mechanisms once consent of the set up of the cooperative farmer group has been given as well.

Participants can raise issues or grievances about anything related to the project, the project management (RPL, CO2 Operate BV), about their own group members, including the group leaders and potential land disputes. Reporting pests are normally also reported through this mechanism, sometimes directly to RPL, as they have direct contact to experts on pests and its management at Andalas University in Padang. When they can wait, grievances are raised during monthly meetings of the cooperative farmer group (the *kelompok tani*). Non-members can also raise grievances, either direct to the *kelompok* leaders or through the wali nagari. In most cases, the kelompok is able to solve the issues ad grievances internally. If it concerns a member, for instance someone not performing as agreed

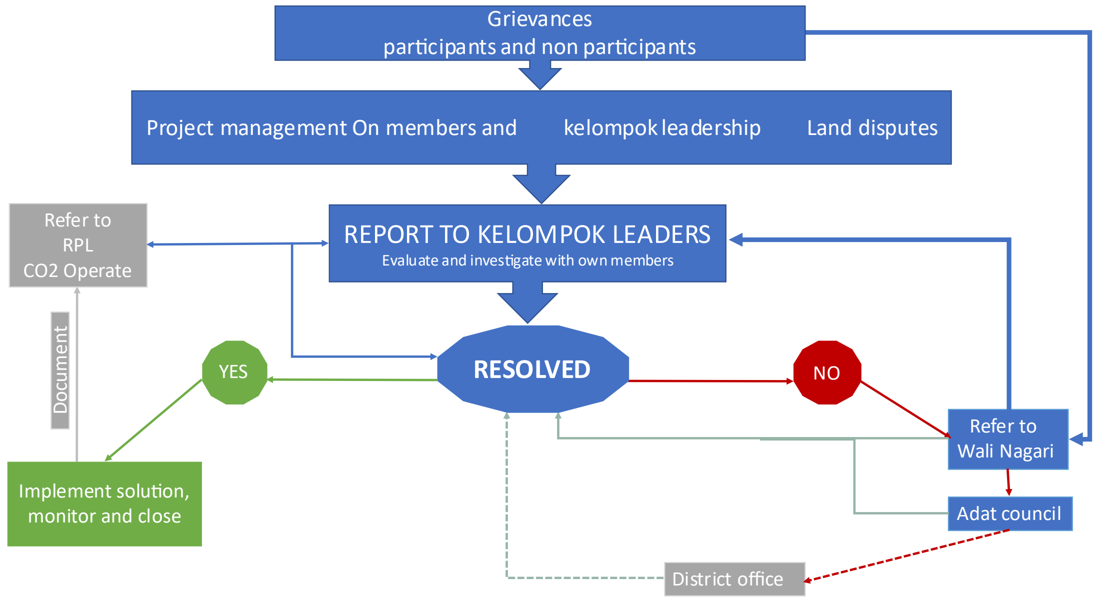

Figure 15 Grievance mechanisms for individuals in the gula gula food forest villages

upon with the kelompok, the situation is evaluated first. If the person is ill, or worse, may pass away, other (family) members may take over as long as needed. Benefits will usually remain with the initial member, as usually men do the hard work of ecosystem restoration. Men live with the entire family of the wife or mother, hence if sisters or daughters have married already, there will be men around who takes over the work for wife's family. A group decision may also result in replacing a person who, after several warnings, does not want to do the work. Changes are documented and shared with RPL staff. Since the start of corona in 2020, we have monthly update meetings, using zoom, using powerpoint presentations with specific slides summarizing potential issues/ grievances. Any grievances raised, and how they are resolved, are all presented in the powerpoint presentations of the monthly update meetings. At the end of the year, we will collect and summarize them into a table as part of the annual report process to Plan Vivo.

Box 1: How initial grievances went as far as the district office in 2010.

The VCM institutional set-up was also discussed during the FPIC phase. Cooperative Farmer groups were set up and coordinated by members of the Adat council. During the implementation phase, it emerged that the strong, hierarchical Adat chieftaincy has made individual farmers reluctant to discuss their growing discontent with the performance of the VCM scheme. This is in conflict with the Minangkabau socio-cultural norms of *muryawarah* and *mufakat* (Figure 13). One year later, discontent turned into open conflict with the Adat authorities and the wali nagari, who is the head of the *Adat* council. It was ignited by the fact that seedlings, which were given by the Forestry Department for free for the participants, were not distributed by the Adat council to the farmers, because of the growing disagreements. A lack of maintenance caused all seedlings to die in the compound of the office of '*Wali Nagari*'.
In a very emotional village meeting, the farmer-participants forced the council members to resign from the VCM scheme. The conflict even made the farmers to go to the district office to protest and to force the resignation of the *Wali Nagari* from his position. This was successfully done. Obviously, they were not working for the overall prosperity and harmony of the *nagari*. The farmer participant took charge of their own development and they suggested a democratic and transparent agreement with CO_2 Operate only. The *Adat* council and the new *Wali Nagari* were taken out as a direct beneficiaries of the VCM program. However, it was agreed that they would continue to play their role as "village court" to solve potential land tenure issues or other issues that would go against Adat regulations or could not be solved at the level of the cooperative farmer group. The cooperative farmer group members reorganized themselves with people they would select as a group to enable strong horizontal social relations . The leader of each group was chosen by the group members for a period of 5 years. This has turned into active participation of all members and allows them to freely discuss any subject with each other.

These slides are used by CO2 Operate staff to document and monitor solutions.
If an issue cannot be resolved internally, the next step is to involve the village head (wali nagari). If needed, the adat council will get involved and exercise its jurisdiction, as the council acts as the indigenous court in the village. It mostly concerns land disputes, an important responsibility of the adat council as guardians of the indigenous *Adat* law system, which includes land boundaries. The involvement of the district office is very rare. However, Box 1 shows that it can be an important and ultimate solution during a serious conflict situation.

F Ecosystem Services & Other Project Benefits

F1 Carbon benefits

The time-averaged net carbon benefits expressed in t CO_2e/ha over the project period (30 years) are expressed in **Error! Reference source not found.**. The carbon pools accounted for in the carbon e stimations are: the total tree biomass, the root biomass (assuming roots contain 25% of the biomass of the shoot, based on Mokany et al., 2006), the soil organic carbon and necromass (set equal to the biomass of the decaying baseline), and the understorey/undergrowth (20% of the aboveground biomass) (see further section G2).

Three baseline systems were considered, consisting of a) *Imperata* grasslands, b) ferns and c) shrubs (semak/belukar). *Imperata* grasslands are assumed to have a time-averaged carbon stock of 5 t/ha (belowground & aboveground), based on the study by Syahrinudin et al. (2020) on *Imperata* grasslands in Sumatra and assuming recurrent fire under a Business as Usual scenario without the interventions (see further G3). Ferns are assumed to have a total biomass stock (aboveground and belowground) of 35 t/ha (Agus et al., 2009), and shrub (semak/belukar) of 25 t/ha in total (Yassir et al, 2010).

Because of the varying interventions and planting times of the trees and plants in the plots, now and in the future, we have chosen to classify the agroforestry plots based on the type of intervention (i.e. ecosystem rehabilitation (EH), improved land management (ILM) and ecosystem restoration (ER)), the location of the plot, and the year of planting of the trees/plants. In total, 17 types of tree and plant species have been selected and planted by the farmers in the agroforestry plots. These are shown in

. In total, 12 dominant tree and plant species in terms of number of trees and plants planted and thus in carbon stock accumulation have been selected for the calculations. These species are avocado (*Persea americana Mill.*), cinnamon (*Cinnamomum zeylanicum Blume*), clove (*Syzygium aromaticum (L.) Merr. & L.M.Perry*), cocoa (*Theobroma cacao L.*), coffee (*Coffea arabica L.*), jengkol (*Archidendron jiringa (Jack) I.C.Nielsen*), jirak (*Eurya Acuminata*), lamtoro (*Leucaena leucocephala (Lam.) de Wit*), mahogany (*Swietenia macrophylla King*), petai (*Parkia speciosa Hassk.*) and surian (*Toona sureni (Blume) Merr.*). We made basic assumptions for the remaining tree and plant species.

The carbon accumulation rates over time (see section G4/5 for the carbon stock accumulation graphs per dominant tree species) are based on tree characteristics, diameter and breast height (DBH) (if applicable) and specific allometric models derived from the literature. See section G4/G5 and the attached Excel file for further details.

Table 5: Net carbon benefits per ha in the *Gula Gula* Food Forest Program.

Carbon benefits					
	1	2	3	4	2-(1+3+4)
Intervention type (technical specification)	Baseline carbon uptake / emissions i.e. without project (t CO_2e/ha)	Carbon uptake/emissions reductions with project (t CO_2e/ha)	Expected losses from leakage (t CO_2e/ha)	Deduction of risk buffer (t CO_2e/ha): 16%	Net carbon benefit (t CO_2e/ha)
Paninggahan (2017)	18.7	244.5	0	36.1	189.7
Paninggahan (Subaka, 2017)	18.7	208.2	0	30.3	159.1
Air Dingin (2020)	31.5	389.4	0	57.3	300.6
FMO 1a	18.7	304.9	0	45.8	240.4
FMO 1b	18.7	317.3	0	47.8	250.8
FMO 2a	43.9	272.8	0	36.6	192.3
FMO 2b	43.9	289.0	0	39.2	205.9
FMO3	43.9	305.4	0	41.8	219.7
FMO4	31.5	379.4	0	55.7	292.2
FMO 5 a	43.9	309.5	0	42.5	223.1
FMO 5 b	43.9	316.1	0	43.6	228.7
Note that the underlying calculations can be found in the Excel file provided and partly in Section G.					

F2 Livelihoods benefits

Table 6: Schematic overview of the livelihood benefits

Food and agricultural production	Financial assets and incomes	Environmental services (water, soil, etc.)	Timber & non-timber forest products (incl. forest food)	Land & tenure security	Use-rights to natural resources	Social and cultural assets
Cloves and clove essential oil production	Assets in the form of clove trees, with income above official minimum wage West Sumatra. Distilling units.	Reduction of soil erosion Reduction of floods. Water retention capacity improved. Improved soil fertility through carbon uptake in the soil. Carbon sequestration.	Cloves, Essential oils	Secured through *Adat*/ clan land (suku).	Improved rights as degraded lands are taken back into production after more than 40 years.	Improved family income, for one used for education of children. Stronger collaboration within the village.
Fruit production from planted fruit trees	Productive trees are an asset, providing good incomes.	Reduction of soil erosion Reduction of floods as water retention capacity increases. Improved soil fertility through carbon uptake in the soil. Carbon sequestration.	Fruits, including durian, avocado, petai, pinang & mango	Already secure through *Adat*/ clan land (suku).	Improved rights as degraded lands are taken back into production after more than 40 years.	Improved and more diverse food supplies in local market. Improved family income. And mostly for education of children.
Timber from harvest of timber trees	Timber is an asset (acting as their savings account).	Reduction of soil erosion and floods. Improved soil fertility through carbon uptake in the soil. Improved balance of water supplies. Carbon sequestration.	Timber	Already secured through clans (*Adat*).	Improved rights as degraded lands are taken back into production after more than 40 years.	Timber is planted as saving for (grand)children or as a pension scheme.
Coffee harvest	Coffee is added on degraded land, providing an important asset and income	Reducing soil erosion on former degraded land. Improved carbon recycling between trees and soil.	Coffee berries	Secured through Adat	Improved access to tree products, land.	New farmer groups are being formed, which increases social cohesion. Increased income especially used

Food and agricultural production	Financial assets and incomes	Environmental services (water, soil, etc.)	Timber & non-timber forest products (incl. forest food)	Land & tenure security	Use-rights to natural resources	Social and cultural assets
	earner for farmers. Incomes					for education children.
Cinnamon production	Cinnamon trees are a financial asset, and provides income	Reduction of soil erosion, food forest will improve water retention capacity.	Cinnamon bark	Secure land access exists through Adat	Improved rights, as land is being planted with tree crops	Reduced vulnerability as cinnamon bark provides petty cash as well as a savings for large expenses, such as funeral or wedding.

F3 Ecosystem & biodiversity benefits

Table 7: Ecosystem impacts of project interventions

Ecosystem impacts				
Intervention type (technical specification)	**Biodiversity impacts**	**Water/watershed impacts**	**Soil productivity/ conservation impacts**	**Other impacts**
Ecosystem rehabilitation	Protection of existing indigenous trees combined with tree planting. Ultimately, food forests provide habitat functions and fruits for wide variety of fauna and flora. Original vegetation returns to a certain degree.	Bringing back tree cover on degraded lands will reduce fast and intense water run-off. Water retention capacity of area will be improved. Ultimately, balanced water levels in the lake.	ANR provides good soil cover from flattened grasses, acting as isolation blanket. Erosion is thus minimised. Soil carbon is improved (due to decaying weeds & grasses). Increase in soil carbon improves water holding capacity of the soil.	Fire prevention as flattened grass forms a moist blanket, providing little oxygen for potential fires to spread. Flattened grass prevents evapotranspiration.
Improved land management	Useful trees like fruit trees attract animals, which increases on-site biodiversity. Enriching into diverse agroforests combined with no/low external input use enables the harbouring of higher levels of (associated) biodiversity.	Enriching towards agroforestry slows down run off compared to open field vegetable cultivation, leading to an improved water balance in the area.	Above and below ground carbon is improved as trees increase. Soil carbon is important for plant growth and soil water retention capacity. Increase biomass and tree growth could bring back Ph to "normal" levels.	No/low use of pesticides and insecticides improves health situation for the people. These areas were high external input vegetable areas. Soil Ph has changed, and microorganisms decreased, leading to thriving ferny types of vegetation here.
Ecosystem restoration	Project activities on the hills combined with fire prevention measures has proven to stop fires. Adjacent state forest areas also no longer burn.	Tree cover on degraded land is naturally restored which will Improve water retention capacity of area and reduce high run off. Ultimately, balanced water levels in the lake.	Natural regeneration leads to increased biomass production, which benefits carbon sequestration above and belowground.	Natural regeneration allows for enrichment planting, in gaps, of economic valuable trees. This improves productivity of secondary forest.

G Technical Specifications

G1 Project intervention, Additionality and Environmental Integrity

This technical specification has been developed to cover the wide range of farmer-designed and farmer-led food forest restoration activities. The technical specifications focus on the ongoing restoration activities in West Sumatra. These technical specifications will also serve as a guideline for future activities in other islands of Indonesia, where we aim to implement similar methodologies for landscape restoration. The aim is to produce long-term, verifiable voluntary emission reductions and carbon sequestration by combining rural livelihood improvements with biodiversity enhancement.

Table 8: Applicability criteria for inclusion in the Gula Gula Food Forest Program

Relevant section of PDD with more information	Environmental	Socio-economic
Soils (Section B2)	Inceptisols, ultisols, entisols	
Geography (Section B2)	1 Altitude between 300-2000 masl 2 Rainfall 1500-2500 mm/yr	
Land cover (Section G1)	1. Unused degraded sites, covered with *Imperata* grasslands in various configurations with ferns and/or shrubby vegetation. 2. Degraded (secondary) forests 3. Abandoned commercial food crop area.	
Land management (to take place after joined project)	1. Pressing/slashing 2. Pressed/slashed vegetation left to decay in the field. 3. Zero burning	Land preparation including tree planting is taken up as a group activity or individually (report to head of farmer group).
Land status (Section C3)		1 Land access clearly defined under village *Adat* law system 2 Individual ownership
PES agreement (section I, J)		All participants are willing to sign PES agreement, which includes grievance mechanisms, after consent has been achieved.
Farmer organisations (Section E3)		All participating farmers are/become member of the established VCM cooperative farmer groups.

The activities proposed here are implemented on unused degraded and treeless communal farm areas. However, recently, farmers have also expressed their wish to develop an agroforestry system on abandoned land, formerly used for cash crop cultivation, mostly vegetables. This intervention has been included as a separate intervention, namely improved land management.
Before explaining more into detail what the applicability criteria entail, Table 8 summarizes the applicability criteria.

Description of the Land-Use System

The agroforestry systems in these technical specifications are built on a combination of Assisted Natural Regeneration with gap filling of economic valuable agroforestry trees. It allows existing tree seedlings of native species to grow in synergy with planted economic valuable trees. The aim is to bring back tree cover in landscapes seriously affected by processes of deforestation and degradation, and to provide multiple benefits such as timber, food and marketable tree products, at minimal cost by letting nature work. The combinations of trees have also proven to enhance biodiversity by providing a home and shelter, and corridor functions for flora and fauna. The technical specifications comprise of a more holistic approach to landscape restoration. To bring back productive tree systems within the *Gula Gula* Food Forest Program, three main approaches can be distinguished to kick start landscape restoration:

- Assisted Natural Regeneration
- Weeding and slashing
- Natural Regeneration with enrichment planting

Assisted Natural Regeneration

Where there is availability of seed inputs from nearby forested areas, ANR is very effective in bringing back tree cover. This is even more so when combined with the planting of economic valuable tree species, which can fill gaps in the returning forest. Where *Imperata* grassland is the main vegetation type, the use of a lodging board to press the grasses, while allowing present tree seedlings to grow, speeds up forest restoration. Pressing the grasses forms a thick isolation blanket, thereby reducing soil temperatures and conserving moisture. The Imperata grasses decay from below, thereby adding significant amounts of nutrients and carbon to the soil. The majority of the land we work on has been restored using ANR techniques. Lessons learned from our collaboration with the Food and Agriculture Organisation (FAO) on field testing ANR provided various inputs for the practical manual "Restoring forest landscapes through Assisted natural Regeneration (ANR)" (FAO, 2019). We make use of this manual during farmer training sessions.

Weeding and slashing and zero tillage

With growing distance from the forested area, the impact of seeds dispersed by wind, and seeds in droppings from wild animals and birds decreases the amount of naturally regenerating trees. However, pressing can still be done when *Imperata* is the climax vegetation in these areas, although existing tree seedlings may be low or absent. Here, more trees need to be planted. Obviously, isolated trees and tree seedlings that may be present are protected.

Where ferns are the dominant vegetation, slashing is most common. Our experience showed, that pressing ferns is not very effective, as ferns have proven to bounce back after pressing. The slashed vegetation is not burnt or taken out, but left in the field to decay to support nutrient cycling. In this way, soils are protected against the impact of solar radiation, while nutrients and carbon are added to the soil once ferns decay, similar to pressed *Imperata* grasses.

Natural regeneration as a result of fire prevention management

Before the program started, about one third of the degraded hills covered with *Imperata* and/or ferns would burn at least once a year. Each year, a different area would burn, meaning that on average all sites would burn once every three years. This is accounted for in the carbon estimations of the baseline system. The regular fires in these landscapes can also be seen from the natural vegetation, as there are no indigenous trees older than 8 years; since the *Gula Gula* Food Forest program started. The fires stopped when the program was implemented because of the following reasons:

- Villagers became more cautious or even stopped using fire as a land management tool, knowing trees were planted in the hills.
- More farmers started practicing ANR. ANR significantly decreases the danger of fires, as it is a zero-burning technique, while the pressed grasses hold little oxygen, which makes the spread of fires difficult.
- The pressed grasses work as an isolation blanket against evaporation. Hence, the soils remain very moist, which further limits the fires to spread easily.
- Finally, one of the farmer groups established an informal fire brigade. In particular, the fire brigade would monitor people from outside the village moving into the upland areas for hunting. Quite often, a hunter would set fire to the *Imperata* grasslands so that wild animals would run away from the fire and could be shot easily. The group chases the outsiders away, and hunting-related fires have ceased to exist as well.

In the absence of fires, existing trees and tree seedlings no longer burn, and they can continue to grow to outgrow *Imperata* grasslands. Significantly large grassland areas are now showing processes of natural forest succession. In Annex 9, the letter of the *wali nagari* (village head) also states that fires have stopped once the program was implemented.

Fire prevention by the *Gula Gula* Food Forest Program has caused an entire hill to regenerate naturally in 7 years (2010 left, 2017 right).

Main (dominant) Tree Species

Farmers in the project region have decided themselves which tree species they wanted to plant in their agroforestry plot, also taking account of the suitability of the species for the geophysical and biophysical conditions. As an example, whenever slopes are steep, farmers requested a larger amount of timber trees to be planted in these areas, as these hold good options to reduce soil erosion. As a result, most of the plots have been planted with a different composition of tree species.

summarizes the type and number of tree species planted during the project interventions are shown.

Table 9: Summary of tree composition in plots for Agam, Air Dingin, Paninggahan, Paninjawan, Selayo and Sirukam.

No	General name of the species	Latin name	Location	Total number of trees planted
1	Avocado	*Persea americana Mill.*	Air Dingin/ Paninggahan/ Paninjawan/ Selayo/ Sirukam	14,764
2	Areca*	*Areca catechu L.*	Paninggahan	3,033
3	Bayur*	*Pterospermum javanicum Jungh.*	Agam/ Paninjawan	1,712
4	Cinnamon	*Cinnamomum zeylanicum Blume*	Agam/ Air Dingin/ Sirukam	62,997
5	Clove	*Syzygium aromaticum (L.) Merr. & L.M.Perry*	Agam/ Paninggahan/ Selayo	29,599
6	Cocoa	*Theobroma cacao L.*	Agam	2,489
7	Coffee Arabica	*Coffea arabica L.*	Air dingin/ Sirukam	125,720
8	Coffee Robusta	*Coffea canephora (syn. Coffea robusta)*	Paninggahan/ Paninjawan/ Selayo	52,871
9	Durian*	*Durio zibethinus L.*	Agam/ Paninggahan	2,695
10	Jengkol	*Archidendron jiringa (Jack) I.C.Nielsen*	Paninggahan/ Paninjawan/ Selayo	7,016
11	Jirak	*Eurya Acuminata*	Agam/ Paninggahan	13,037
12	Lamtoro	*Leucaena leucocephala (Lam.) de Wit*	Air Dingin/ Paninggahan/ Paninjawan/ Selayo/ Sirukam	44,619
13	Mahogany	*Swietenia macrophylla King*	Agam/ Air Dingin/ Paninggahan	26,541
14	Mangosteen*	*Garcinia mangostana Gaertn.*	Agam/ Paninggahan	1,320
15	Petai	*Parkia speciosa Hassk.*	Agam/ Paninggahan/ Selayo	6,853
16	Shorea*	*Shorea spp. (meranti)*	Agam	1,015
17	Soursop*	*Annona muricata L.*	Agam	7
18	Surian	*Toona sureni (Blume) Merr.*	Agam/ Paninggahan/ Paninjawan/ Selayo/ Sirukam	26,320

* these tree species were not accounted for in the biomass estimations. Instead, the percentage of the number of these trees relative to the total number of trees has been included in the biomass estimations.

Additionally, the type of main tree species also depends on whether ANR was applied, as this would define the number of indigenous species in one hectare of land. In most cases, the tree locally known as jirak (*Eurya Acuminata* DC.) is said to be useful to the farmers for erosion control, to provide shade for crop growth (for example, very beneficial for clove trees) and as a source of timber. Economically valuable species which are planted by the participating farmers may differ for each farmer, depending on their individual needs and preferences. Looking at the so-called "planvivos" (the individual carbon plots of the participating farmers) in Paninggahan and/or Air Dingin have all planted timber species as a saving for their (grand)children. These are mahogany (*Swietenia macrophylla* King Swietenia macrophylla King) and a local forest species known as surian (*Toona sureni* (Blume) Merr). The most common economic-valuable non-timber trees that can be found on the farmer's lands are clove trees, petai trees, cengkol trees and durian trees. These trees also provide good options for carbon sequestration as their wood densities are relatively high.

In total, 18 types of tree and plant species have been selected and planted by the farmers in the agroforestry plots. The 12 main or dominant tree and plant species in terms of number of trees and plants planted and thus in carbon stock accumulation have been selected for the calculations. These species are avocado, cinnamon, clove, cocoa, , coffee, jengkol, jirak, lamtoro, mahogany, petai and surian.

Some relevant characteristics of the dominant tree species (in terms of number of species) planted in the project region are described in more detail in the next sections. The remaining (non-dominant) tree species, namely areca, durian, bayur, shorea, mangosteen and soursop, are not described since these make up a relatively small proportion of the total tree composition in the project region.

Avocado: ***Persea americana Mill***.

Avocado or *Persea americana Mill*. is a member of the flowering plant family Lauraceae. The subtropical almost evergreen tree is likely originating from southcentral Mexico (and is still the World's largest producer), and is currently being cultivated in many countries across tropical and Mediterranean climates. Avocado trees are partially self-pollinating because of dichogamy in its flowering. (Wikipedia.org). Avocado needs a climate without frost and little wind, and sufficient spacing (particularly in deep, rich soil). The tree needs well-aerated and well-drained soils of various types (red clay, sand, volcanic loam, lateritic soils, or limestone) with an optimal pH of 6-7 and soils ideally more than 1 m deep. (Wikipedia.org)

The avocado tree grows quite fast and up to 2-9 m in height (sometimes up to 18m or higher). The trunk can be 30-60 cm in diameter (greater in very old trees). The trunk can also be short and spreading with branches close to the ground. (https://hort.purdue.edu/newcrop/morton/avocado_ars.html#:~:text=The%20avocado%20tree%20may%20be,beginning%20close%20to%20the%20ground)

Cinnamon: ***Cinnamomum zeylanicum Blume***

The Cinnamomum zeylanicum Blume tree belongs to the family of Lauraceae. The true cinnamon tree grows originally in moist, well drained soils from sea level to about 700 meters, but for commercial harvesting purposes it grows best up to about 500 m. It is widely cultivated across the tropics. Optimal rainfall is between 2,000 and 2,500 mm/year. It grows semi-shade or no shade and it prefers moist soil. Cinnamon is a slow-growing small evergreen tree of about 10-15 meters tall. (https://pfaf.org/user/Plant.aspx?LatinName=Cinnamomum+zeylanicum)

Clove: ***Syzygium aromaticum (L.) Merr. & L.M.Perry***

Clove or *Syzygium aromaticum (L.) Merr. & L.M.Perry* is a bushy, evergreen tree-shaped species of the genus *Syzygium Gaertn* and in the Family Myrtaceae Juss. Clove was originally found only on (thus: native to) the lower forests of the Maluku/Moluccas islands of Indonesia. It is now growing in various places throughout the tropics. Clove trees grow best on tropical mountain slopes at lower elevations (up to 900 m) as part of a mixed forest (powo.science.kew.org). Clove is a tree-shaped species with a medium-sized crown and a DBH of 15-20 cm (Ariyanti et al., 2012) and a height of about 8-20 m (powo.science.kew.org; sciencepress.mnhn.fr). It has much potential to be a carbon sink plant as it grows relatively fast with large morphological sizes (Hariyadi et al., 2019). Okubo et al., 2010 analysed various agroforestry systems and found that the systems dominated with cloves had the highest income potential.

Cocoa: *Theobroma cacao L.*

Cocoa *or Theobroma cacao* is a small evergreen tree (4-8 m, exceptionally 20 m) in the family Malvaceae. Cocoa is native to the deep tropical regions of Mesoamerica as an understorey plant, and is now cultivated all across the lowland tropics. Cocoa is usually found below 300m, but occasionally as high as 900 m (tropical.theferns.info/Cacao). It grows best with temperatures between 18-28.5 degrees Celsius, with a maximum temperature of 30-33.5 degrees Celsius. Optimal rainfall is between 1,500-2,000 mm per/year (and max. 3,000 mm/year) evenly distributed throughout the year (tropical.theferns.info/Cacao).

Cocoa has a short bole of about 20-30 cm in diameter. The growth rate of cocoa is medium: rarely growing more than 1.5 m tall after 2 years (tropical.theferns.info/Cacao) up to a maximum of 8 m tall. Pruning should be carried out to maintain the required shape.

Coffee: ***Coffee arabica L.***

Wild *Coffee arabica* plants grow between 9 and 12 m tall. *C. arabica* has an open branching system and matures in about seven years. *C. arabica* grows best between 1,200-1,800 m above sea level, and it requires about 1,800 mm of rain, evenly distributed throughout the year. *C. arabica* prefers light shade and temperatures between 15 and 24 degrees Celsius (Nair, 2010).

Commercial cultivars mostly grow to about 5 m; often trimmed up to a maximum of 2 m tall to facilitate harvesting. Pruning can prevent over-flowering of the tree: this is important as the plant tend to produce too many berries and favours ripening the berries to the detriment of its own health. Trees can produce from 0.5 to 5 kg of dried beans, about 2-3 years after planting. (Wikipedia.org)

Jengkol: *Archidendron jiringa* (Jack) I.C. Nielsen

Archidendron pauciflorum, commonly known as Djenkol or Jengkol is a flowering tree in the pea family, Fabaceae. The tree is native to Southeast Asia. The seeds from Jengkol are consumed mainly in Thailand, Malaysia and Indonesia. (Wikipedia.org)

The tree is indigenous to primary and secondary forests in humid, mountainous and undulating areas from sea level up to altitudes of 1,600 m. They grow best in well-drained sandy, lateritic or sandy clay soils, and need high levels of rainfall (2,000-3,000 mm (and tolerates: 1,000-4,000 mm)). (Wikipedia) The tree can grow in semi-shade or no shade.
(https://pfaf.org/user/Plant.aspx?LatinName=Archidendron+jiringa)

Jirak: *Eurya acuminata*

Jirak or *Eurya acuminata* is a fast-growing evergreen shrub or tree with a maximum of about 5 to 12/14 meters tall (indiabiodiversity.org), and can be used for its wood (tropical.theferns.info/Eurya). The species is often found in hill forests at elevations of about 1,500-2,400 m and in open places at about 1,000-3,000 m (tropical.theferns.info/Eurya). It is a typical successional tree that is one of the first to establish naturally in forest gaps or in this case treeless, degraded areas. The aboveground carbon biomass is about 26.5 kg/tree (eol.org) (at a diameter of=12.4 cm).

Lamtoro: *Leucaena leucocephala* (Lam.) de Wit

Lamtoro (*Leucaena leucocephala* (Lam.) de Wit) is a long-lived fast-growing medium to small-sized tree (up to ~20 m) also known as wild tamarind (in English) and lamtoro (in Hindi/Indonesian). The stem is generally short with a diameter of about 10-50 cm. Lamtoro belongs to the genus *Leucaena* and the family *Leguminosae*. It is native to southern Mexico and the northern Central America, and is now commonly planted throughout the tropics, often as a pioneer species for restoring grasslands to forests, or as a shade tree over cocoa or coffee.

Lamtoro adapts easily to various ecological conditions and is very suitable to tropical environments. The tree can grow at temperatures of 25-30 degrees Celsius, 650-3,000 mm of mean annual rainfall, and at altitudes up to 1,500 m-2,100 m and is thriving on steep slopes. It prefers well-drained soils in full sun and it is drought tolerant (tropical.theferns.info/Leucaena). The relatively small tree re-sprouts after fire or cutting and fixes nitrogen, and is therefore found suitable in reforestation and soil improvement activities (Savale et al., 2007). Lamtoro has a high biomass productivity (Feria et al., 2011).

Mahogany: *Swietenia macrophylla King*

Mahogany is a tropical hardwood species of the genus *Swietenia* in the family Meliaceae. Mahogany grows well with 1,400 and 2,500(-3,500) mm of rainfall, 23 and 36 degrees Celsius of temperature and 50 to 1,400 m of altitude. Mahogany is a moderate-fast growing species which is very suitable for agroforestry, a.o. because of the deep rooting system and because partial shade in the early stages of the seedling results in faster growth (Kumar et al., 2015; In Kumar, 2016). Adinugroho and Sidiyasa (2006) (in Krisnawati et al., 2011) developed allometric equations using a sample of 30 *S. macrophylla* trees (DBH range: 14.3-36.9 cm) grown in plantations in West Java.

Petai: *Parkia speciosa Hassk*.

Petai, or Parkia speciosa, is an evergreen medium-sized leguminous tree belonging to the genus Parkia in the family Fabaceae. Petai is very popular in the highlands of Java and Sumatra for culinary ingredients. (Wikipedia.org, https://rimbakita.com/pohon-petai/).

Petai trees grow best in an open environment with sufficient sunlight intensity and a wet or slightly wet climate, and can be found in the lowlands to the highlands at a maximum altitude of 1,500 m above sea level. The soil needs to be well-drained loamy or clay-loamy and have a fine texture and a pH range of 5.5-6.5. (https://rimbakita.com/pohon-petai/)

Petai is an umbrella-shaped N2-fixing tree that can grow to about 15-45 m tall, but grows usually only to about 5-20 m. The tree has a straight trunk and can form buttress roots. The trunk can grow up to 1 m (100 cm) in diameter. The growth rate of the tree is slow. Petai reaches maturity after 7 years (https://www.nparks.gov.sg/florafaunaweb/flora/3/0/3052)

Surian: *Toona sureni (Blume) Merr*.
Surian, or *Toona sureni (Blume) Merr,* is also known as the Indonesian mahogany species, although it is not a true mahogany with genus *Swietenia*. Surian is a medium-sized to large tropical hardwood tree of the genus *Toona* in the family Meliaceae. *Toona sureni* is native to many countries and regions, including Indonesia, and trees are usually found in primary forests and sometimes in secondary forests on hillsides, slopes and river banks at altitudes of 1,200-2,700 m above sea level (Orwa et al., 2009). Surian requires 20-30 degrees Celsius in temperature, 1,120-4,000 mm annual rainfall and fertile loamy soil. *T. sureni* is fast-growing and light-demanding (Orwa et al., 2009). Surian is often planted as a shade tree and protective stand (shelter) in intercropping or agroforestry systems. Surian can reach a maximum height of 40-60m and a DBH of 100-300 cm, and is valued for timber production (Orwa et al., 2009).

Inputs

Seedlings
Whenever a site is close enough to a forested area, seedlings may exist in between the climax vegetation of *Imperata* grasslands, ferns or a combination of the various vegetation types. Seeds are dispersed by wind or through droppings from birds or from wild animals. By using ANR competition for light and space is reduced and existing seedlings can grow relatively fast, as they already have developed quite a good root system. The density of existing seedlings is such, that economic valuable trees can be planted to fill the gaps. Seedlings for planted trees are obtained through different resources. The collaboration with local Forestry agencies allows to either get seeds and have seedlings develop from the village nurseries which are set up and managed by the farmer groups. We also collaborate with BPDAS, the local forestry agency providing seedlings for improving tree cover in river basin management activities. Coffee seeds are planted in the village nursery, with technical support from our partner Solok Radjo, the coffee processing unit in Air Dingin. Cinnamon seedlings are usually collected from the wild, as seeds or certified seedlings are in very short supply.

Maintenance

Weeding and weed control
In all cases, weeds will not be removed after slashing or pressing. If ANR is applied, pressing the *Imperata* is done 2-3 times in the first year. The pressed Imperata grasses decay from below, and our experience showed that after one year, the large majority of Imperata grasses have died off. The nutrients and carbon in the decaying biomass is then taken up by the soil. From this moment onwards, a more diverse, low vegetation takes over, which appears to be very useful. Not only does it provide good ground cover and said to improve soil fertility (nitrogen fixing), farmers also use it as forage for their chicken and livestock. It is easy to maintain, using a big knife, called parang, although more farmers now are using a diesel-powered cutter.

Where ferns are the dominant baseline groundcover, like in Air Dingin, slashing and cutting is done. Pressing ferns has proven not to be successful, as the ferns bounce back after pressing. In all cases, the slashed or cut biomass is left on the field to decay and to serve as isolation blanket, similar to pressed Imperata grasses. This saves labour, reduces soil temperatures, reduces weeds to re-establish, and decaying weeds provide nutrients and carbon to the soil. Both in Imperata and fern vegetation, after the initial full weeding, farmers practice ring weeding around the trees. This is usually done 2-3 times a year.

The slashed weeds are put back in the ring to reduce the impact of solar radiation, and as a green manure. Weeding of the non-planted areas may be done 1-2 times a year, depending on the growth of the remaining vegetation. Once trees start to provide shade (usually after 2 years), the shade intolerant weeds will disappear.

Tree replacement

In order to achieve carbon sequestration targets, the performance-based contract has included criteria on replacing dead trees. If it is caused by mismanagement the farmer must replace the trees at his/her own costs. If drought or other external factors (force majeure including pests) caused the death of trees, CO_2 Operate and the Forestry agencies will support the farmers in getting replacement trees. However, usually, the village nursery has more seedlings than needed, to serve as a buffer against potential tree deaths. From our experience, we know that on average up to 5% of the trees need to be replaced, due to force majeure.

Pruning

Except for the coffee and cocoa systems, pruning is not done. Coffee and cocoa plants are pruned, and some branches of *leuceana* may be cut if needed. The branches are left in the field as a green manure. Leaves and green branches of *leuceana* may also be used as an animal fodder, but since the area for tree planting is quite far from the village, not many farmers may want to do that, especially as forages can still be found close to the village. Individual branches of cinnamon trees may be cut, as the harvested bark from twigs and branches provide a cash income to purchase daily needs, including rice, tea or cigarettes.

Thinning and cyclical harvest

Thinning is done on a small scale, often restricted to cutting branches to reduce physical competition with other trees. In Paninggahan (and Agam), there are relatively few trees on one hectare, hence no thinning has been done. Harvest times vary widely. Cinnamon trees are often planted as a saving, and are cut down whenever large sums of cash are needed, such as funerals, weddings or costs for higher education of the children. We assume that cinnamon trees are cut down after 12-15 years once the bard reaches AA quality. A small percentage (around 20%) is cut after 8 years, to provide for intermediate cash needs.

Pest control

So far, no pest control measures have been taken. Farmers have learned from their parents, that monoculture stands are highly susceptible to pests and diseases. They now judge, that using a mixture of trees, pests and diseases do not spread significantly. As farmers jokingly say, the pests get lost in the agroforest. Some pests and diseases found on a small scale are termite attacks and the stemborer. Termite attacks seem to occur on places where there is still biomass of former big trees in the soil. Stemborer attacks on clove trees are rare, often leads to the cutting of the infected branch, and burn it in the field to kill the insect. An expert from the Gadjah Mada university, who joined to the field a few times, explained to the farmers that it would be best to take away ground cover under the tree, or to put lime (Calcium) on the first 50-60 cm of the tree. This prevents the stemborer to get in. Another nature-friendly solution is fermented cassava. Putting this in a bottle and hang it in the tree, will attract stemborer, and kill it once it gets into the fluid of the fermented cassava. As stemborer was mainly affecting some clove trees, the production of essential oils from fallen clove leaves seems a win-win situation. Famers take the leaves under the tree and sell it, while this clean area prevents the stemborer from getting into the trees.

Fire and drought management

Ever since the programme started, fires have ceased to exist. People have become careful with using fires a tool for land management. The use of ANR is easier, while pressed Imperata grasses serve as firebreak by itself. Pressed grasses hardly burn, through lack of oxygen. This has become a fire management tool in itself. This is also caused by the pressed grasses, which form an isolation blanket against the penetration of solar radiation, or evapotranspiration. The soil remains very moist under the grasses, further reducing fire to spread. Fern dominated areas are now slashed only, and again leaving it on the field keeps the soil moist, which reduces the spread of fire. These interventions also prevent drought conditions of exposed soils.

G2 Additionality and environmental Integrity

Additionality and climate benefits include benefits that would not occur under a Business as Usual scenario. In the *Gula Gula* Food Forest Program we distinguish between four types of additionality:

- **Financial additionality**: evidence that project activities are stimulated by investments or funding beyond that not normally available; the carbon off setting contracts.
- **Technological additionality:** evidence that project activities have resulted from the removal of technological barriers; the use of assisted natural regeneration techniques.
- **Institutional additionality:** evidence that project activities go beyond the scope of national programs or regulations; see below.
- **Carbon additionality**: evidence of GHGs 'emissions additional' reductions by the project activities, compared to what they would have been in the absence of the project (see sections G3-G5).

Financial additionality

The program has been running entirely on funds from the private sector for carbon off setting. Without these funds no activities would have taken place, as the area has been left unused for more than 15 years in Air Dingin, and over 40 years in Paninggahan (see

). Recently, investment funds are secured to continue restoration activities. Funds will be returned by selling carbon credits from the area under the investment contract. Such innovative finance mechanisms for ecosystem restoration would never have occurred without the project activities.

Institutional additionality

Institutional additionality in the program focuses on the project taking place on degraded lands not owned by the state, so it is additional to already existing (mainly governmental) programs. The term 'degraded' has been used in multiple contexts in Indonesian law and policy. Indonesian policies generally denotes land that contains less than 35 Mg of carbon per hectare, or land that is legally designated as degraded (Republic of Indonesia, 2015; Gingold et al. 2012). Land degradation assessments in Indonesia reveal 15.5 million ha in two high-priority rehabilitation categories: i.e. 7.0 million ha abandoned land and highly critical ("*tanah terlantar yang kondisinya sangat kritis*") and 8.5 M ha of "*alang alang*" grassland *(or Imperata cylindrica* gasslands), (Forestry Department of FAO, 2010). In line with national policies, West Sumatra has implemented policies to mitigate climate change. Mitigation is key in these policies and the forest sector plays an important role. In West Sumatra, land and forest rehabilitation programs are carried out as part of a community empowerment strategy which includes:

- Regional strategic planning for middle term development (RPJMD)
- Regional Action Plan Policies to reduce Greenhouse Gases (RAD-GRK West Sumatra)
- Provincial Strategy Action Plan (SRAP) Policy for REDD+ in West Sumatra
- Provincial Policy Priorities for Forest Plan (PCTR) in West Sumatra

However, all these programs are geared at forests and forest land under the official control ("ownership") of the provincial and district authorities in West Sumatra. This means that these policies and programs cannot and do not include the village *Adat* land of local (Minangkabau) communities, despite it being particularly mentioned in the 2016 NDC (Nationally Determined Contribution) that *Adat* communities should actively participate. Participation in this context means that communities should actively participate in restoring degraded state-owned lands, not the community's own *Adat* village land. It is here, where CO_2Operate BV can play an important role, as these activities go beyond the scope of national programs or the regulations of provincial or district governments. Our activities complement (and are additional to) government programs and regulations, since any government program in state (forest) land can only be successful if the buffer zone around these areas, the village territories, are managed sustainably (e.g. because slash and burn activities regularly cause fires which spread into state-owned forest areas).

Technological additionality

The degraded land in Paninggahan has been left idle since the 1970s, when a disease destroyed the mono-culture clove plantations on the hills. Many villagers lost their investments and options to earn an income from clove sales. The tree-cropping area became neglected. Recurrent fires on these lands have caused *Imperata* grasslands to establish. In Air Dingin, lands were left idle since 2000, when another disease killed their maracuja plantations. Here, ferns established ever since.

The common technology of rehabilitating *Imperata* grasslands has always been uprooting and (hand) ploughing the land, after an initial burn. Often this also involves the use of the herbicide *round-up*, since long viewed as the only possibility to destroy the *Imperata* grasses. These high investment costs are considered a serious risk for a resource-poor farmer, as the soils lack healthy biomass and fires could easily destroy individual restoration investments. In the absence of government support, individual restoration efforts by resource-poor villagers are severely limited or non-existent.

The method of combining Assisted Natural Regeneration (ANR), zero tillage techniques combined with tree planting provides a sustainable, zero burning and resource-efficient way to restore these degraded lands, based on natural processes of forest regeneration. ANR is a low-cost, labor-extensive and simple technology to restore degraded areas by letting nature work. Figure 16 shows the responses of participants when asking about the labor requirements in using ANR compared to the practice of uprooting and ploughing. In particular, the time and need for less hired labor makes ANR and zero tillage techniques a very effective method according to the participant farmers.

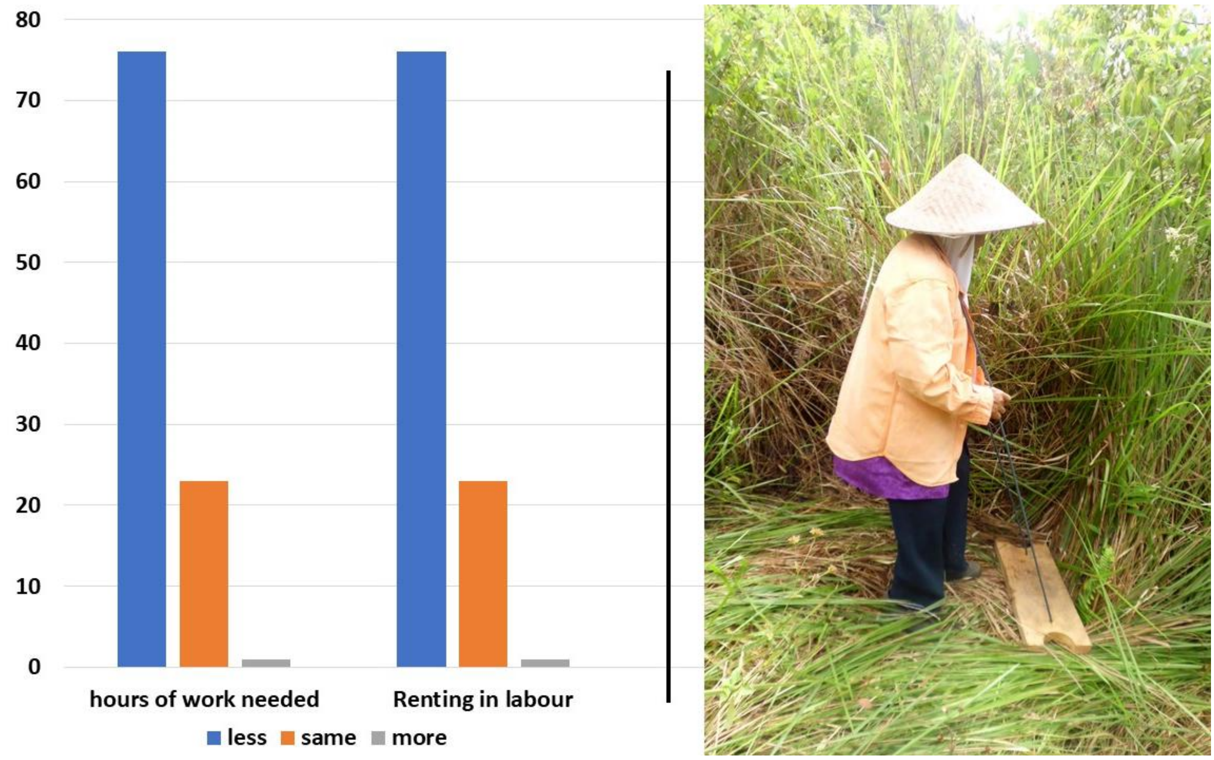

Figure 16: Labour requirements (%) when using ANR compared to usual practice (n=25)

Source: field research 2014 CO_2Operate BV/STKIP

ANR enables the original rainforest to restore and speeds up the forest restoration processes, not altering the vegetation, such as occurs with tree-cutting techniques. It fits well with the resource-poor villagers, protecting naturally occurring original rainforest trees in the land to provide habitat for the original flora and fauna. No clearance techniques are completed.

ANR is particularly effective in *Imperata* grasslands. Pressing the grass instead of burning, not only is it proved to be an effective fire-break (fire does not spread through pressed

Imperata grasses because of lack of oxygen and captured moisture), but the grasses decay and add organic material to the soils. The decaying biomass also forms an isolation blanket against evapotranspiration, keeping the soil moist throughout the year. In addition, the originally present (small) trees are allowed to grow. The flattening of the grass allows sunlight to reach the original trees easily after years of being out-competed. Since the original trees already have a well-developed root system, it enables these trees to grow fast. The trees add additional biomass through litter, while the increasing shade from the trees helps to suppress the grasses. Since nature does most of the work, the only work needed by the farmers is pressing the grasses. The only inputs needed are (family) labour and a wooden lodging board (see picture above). In many cases, farmers use a piece of wood that they can find in the forest, or whatever they have at home. A piece of rope may be the only cost. On average, three pressing events in one year is enough to stifle the grasses into decay as the new tree cover outcompetes the grasses for sunlight, stopping the *Imperata* from re-establishing. These naturally occurring trees provide a favourable microclimate for other selected trees to be incorporated. These trees are usually economically valuable trees, for which a good market (potential) exists. For example, clove trees, fruit-trees (lemon, durian, mango, avocado, *jengkol*), timber trees, cinnamon trees or coffee trees. The direct benefit of the zero-burning technique, combined with an increased awareness of restoration activities, has resulted in the prevention of fires. This has had a direct positive effect on natural forest regeneration within the surrounding *Imperata* grasslands. In recent years, new participants have also requested to plant trees on (former) vegetable areas, changing intensive, high input vegetable cultivation into low-input tree farming practices.

Sometimes economic valuable trees are already present in between the *Imperata* grasses, like these cinnamon trees.

Carbon additionality

Imperata grasslands are known for their low biodiversity and carbon stock levels. The ANR and improved land management applied in this project allows the degraded lands to regenerate and the tree and plant species to (re)grow. The regeneration of the tree and plant species already present and the growth of the trees and plants that have been planted in the agroforestry plots add much carbon to accumulate aboveground and in the soils (see section F1).

Carbon on mineral land is stored in the aboveground plant biomass (shoot), necromass (all dead non-decomposed plant parts) and belowground root or soil biomass (Agus et al., 2009). The total amount of stored carbon & biomass depends on soil fertility, local climate (rainfall, temperature, altitude) and land use types. We have selected the following carbon pools since these carbon pools substantially increase compared to the baseline.

1. **The total tree biomass**, which includes the biomass of the:
    - dominant tree species
    - non-dominant tree species (as a percentage of the dominant tree species biomass)

2. **The root biomass**, based on Makony et al. (2006) for forests and plantations), set to 25% of the total aboveground tree biomass.

3. **The soil organic carbon/necromass**, assuming the nutrients and carbon of the baseline vegetation (pressed and decaying *Imperata* grasses) at the start of the intervention(s) is fully taken up by the soil. Biomass in the necromass and in the soil are accounted for in the estimations as similar to the decaying biomass of the *Imperata* at the start of the intervention. This means that the soil biomass/necromass is set equal to the biomass of the *Imperata* baseline at t = 0 years, just before the *Imperata* was pressed. For the duration of the project, we assumed that the soil biomass/necromass remains equal due to a balance between decay and uptake of nutrients and carbon.

4. **The understorey/undergrowth**, including *Imperata* grasses, and litter (based on a default value from the literature: 20% of aboveground biomass (van Noordwijk et al., 2002)

G3 Project Period

The carbon project started in 2009. However, in 2009-2010, El Niño events caused droughts and killed most of the trees (around 80%). Thankfully, the provincial Forestry Department supported the replanting of all the dead trees. In 2012, the collaboration with FAO on implementing Assisted Natural Regeneration (ANR) as an ecologically-sound and climate-proof intervention has significantly increased the success of the project. The ANR method has been adapted and improved to fit local circumstances and priorities of the participants since its introduction. The total quantification period is estimated to be 30 years, the time timber trees in the system may be harvested. It takes about 5 years before cloves and other economic tree products can be harvested with large enough quantities. The local community judged that, from this point onwards, they can live from the income of the trees. Therefore, carbon off setting contracts are set up for 5 years. The value from tree products in a standing food forest encourages farmers to keep protecting the trees. They become the guardians of the forest.

G4 Baseline scenario

The farmers have explained that the hilly upland areas under *Adat* law around lake *Singkarak* have been left idle since the mid-1970s. Many stories exist where farmers explain that their parents were traumatised when pests and diseases killed their (productive) trees during this period. Many families went bankrupt, as they were still waiting for their first harvest. This collective trauma left the slopes unmanaged ever since, allowing *Imperata* grasslands to spread and conquer the hilly uplands on a massive scale. This was strengthened by recurrent fires.

Some of the degraded upland areas in *nagari Paninggahan*, where the *Gula Gula* Food Forest Program is implemented.

The results from participatory timeline exercises that CO_2Operate BV, RPL and STKIP staff have conducted coincide with data from a study by Jeanes (2015). Jeanes completed a historical land cover analysis of secondary sources from the 1700s onwards in the *Singkarak* river basin (Table 10).

Especially data from the lake basin, where *nagari Paninggahan* is situated, together with the *Lembang* area show the occurrence and spread of *Imperata* grasslands since the 1970s. Since the start-up phase of the *Gula Gula* Food Forest Program, these degraded hills as part of the Adat village area have been targeted for ecosystem restoration. Their long term state of degradation show that additionality is secured, as no efforts would take place without the program. The lack of intervention on these village lands is further strengthened by the fact that reforestation programs of the forestry department cannot be implemented on village areas, as forestry interventions are limited to State Forest Land only. The degraded areas are under full responsibility of the *nagari* institutions, including the local Adat regulations.

This distinct separation of government land (green, purple areas) and *Adat* land (white/no colour) is illustrated in maps from the Ministry of Forestry (Figure 17). The coloured areas on the map are under Forestry department control or on State forest land. The areas are classified as *hutan lindung*, or protection forest. Protection means it has important functions in water retention and soil protection. Around lake *Singkarak*, there is a large purple area in Figure 17. This is idle farmland, covered with *semak (scrubland)*. *Semak* is an Indonesian word for land covered with a mixture of shrubby vegetation, ferns and/or *Imperata.* A few scattered trees may still exist (less than 5%) and some shrubs (also less than 5% in one ha).

Table 10: History of Land cover change in the *Singkarak*-Ombilin river basin.

Time Line	Data source / Reference		Sub-catchment or Sub-basin / Forested Areas				
			Ombilin Sub-Basin	Lake Basin	Lembang	Sumani	Selo
			Mt. Marapi & Malintang volcanoes Eastern watershed hills	Mt. Marapi, Singgalang & Talang volcanoes Bukit Barisan slopes	Mt. Talang volcano	Mt. Talang volcano Bukit Barisan slopes	Mt. Marapi & Malintang volcanoes Eastern watershed hills
1700's	Marsden (1783)	upland	forest	forest	forest	forest	forest
		lowland	agriculture ?	agriculture?	forest	agriculture ?	agriculture ?
1930's	van Steenis (1935)	upland	forest (upper to mid slopes)	forest (43%) (upper to mid slopes)	forest (25%) (upper slopes) scrubland (mid slopes)	forest (42%) (upper to mid slopes)	forest (15%) (upper to mid slopes)
		lowland	agriculture	agriculture	agriculture	agriculture	agriculture
1950's	Hannibal (1952)	upland	forest (upper to mid slopes)	forest (29%) (upper to mid slopes)	forest (11%) (upper slopes) scrubland (mid slopes)	forest (21%) (upper to mid slopes)	forest (26%) (upper to mid slopes)
		lowland	agriculture grasslands	agriculture ricefields	agriculture ricefields	agriculture ricefields	agriculture ricefields
1970's	BLKT Sumatera Barat (1995) Laumonier et.al. (1986)	upland	forest (upper slopes) grassland / scrubland (mid-slopes)	forest (23 - 34%) (upper slopes) grassland / scrubland (mid-slopes)	forest (5 - 10%) (upper slopes) grassland / scrubland (mid slopes)	forest (24%) (upper slopes) grassland / scrubland (mid-slopes)	forest (16 - 26%) (upper slopes) agriculture (mid-slopes)
		lowland	agriculture tree gardens grassland / scrubland	agriculture (5 - 7%) ricefields (22 - 26%) tree gardens (15 - 17%)	agriculture (5%) ricefields (13%) tree gardens (13%)	agriculture (7 - 9%) ricefields (14%) tree gardens (7 - 10%)	agriculture (12%) ricefields (21 - 27%) tree gardens (9%)
1980's	RePPProt (1988) Peranginangin et.al. (2004)	upland	forest (20%) (upper-mid slopes) agriculture / grassland (mid-slopes)	forest (30 - 32%) (upper slopes) scrubland / agriculture (mid-slopes)	forest (15%) (upper slopes) agriculture (mid-slopes)	forest (23 - 39%) (upper slopes) grassland / scrubland (mid-slopes)	forest (39%) (upper-mid slopes) agriculture (mid-slopes)
		lowland	agriculture (18%) ricefields (13%) tree gardens (10%)	agriculture (12% -21%) ricefields (22 - 19%) tree gardens (6 - 14%)	agriculture (15%) ricefields (46%)	agriculture (9 - 14%) ricefields (16 - 41%) tree gardens (4%)	agriculture tree gardens (46%) grassland (12%)
1990's	Ministy of Forestry (1996) Ministry of Forestry (1999) Helmi (2001) Peranginangin et.al. (2004)	upland	forest (14%) (upper slopes) grassland / scrubland (mid-slopes)	forest (25%) (upper slopes) grassland / scrubland (mid-slopes)	forest (36%) (upper slopes) agriculture (mid slopes)	forest (36%) (upper slopes) grassland / scrubland (mid-slopes)	forest (32%) (upper slopes) agriculture (mid slopes)
		lowland	agriculture (25%) ricefields (11%) tree gardens (13%)	agriculture (15%) ricefields (15%) tree gardens (7%)	agriculture (19%) ricefields (43%)	agriculture (15%) ricefields (41%)	agriculture (12%) ricefields (51%)
2000's	PSDA Sumatera Barat (2004d) Farida et.al. (2005) - ICRAF	upland	forest (18%) (upper slopes) grassland / scrubland (mid-slopes)	forest (21%) (upper slopes) grassland / scrubland (mid-slopes)	forest (4%) (upper slopes) scrubland (mid-slopes)	forest (14%) (upper slopes) grassland / scrubland (mid-slopes)	forest (32%) (upper slopes) agriculture (mid slopes)
		lowland	agriculture (30%) ricefields (10%) tree gardens (29%)	agriculture (18%) ricefields (17%) tree gardens (17%)	agriculture (18%) ricefields (35%) tree gardens (12%)	agriculture (24%) ricefields (24%) tree gardens (18%)	agriculture (27%) ricefields (14%) tree gardens (23%)

Source: Jeanes, 2015

Main types of vegetation in the degraded lands, Ferns, *Imperata*, shrubs or a mixture.

Fires regularly occur in areas covered with *Imperata* or *semak*, making this type of vegetation the climax vegetation in these areas, as trees cannot develop when the vegetation is burned regularly. The dark green colours on the map indicate the remaining primary forest outside the National park. Once *Imperata* grasses establish, low levels of biodiversity are the result. By reducing environmental disaster risks, like fires, the *Gula Gula* food forests restores these degraded areas, reducing fires and bringing back tree cover.

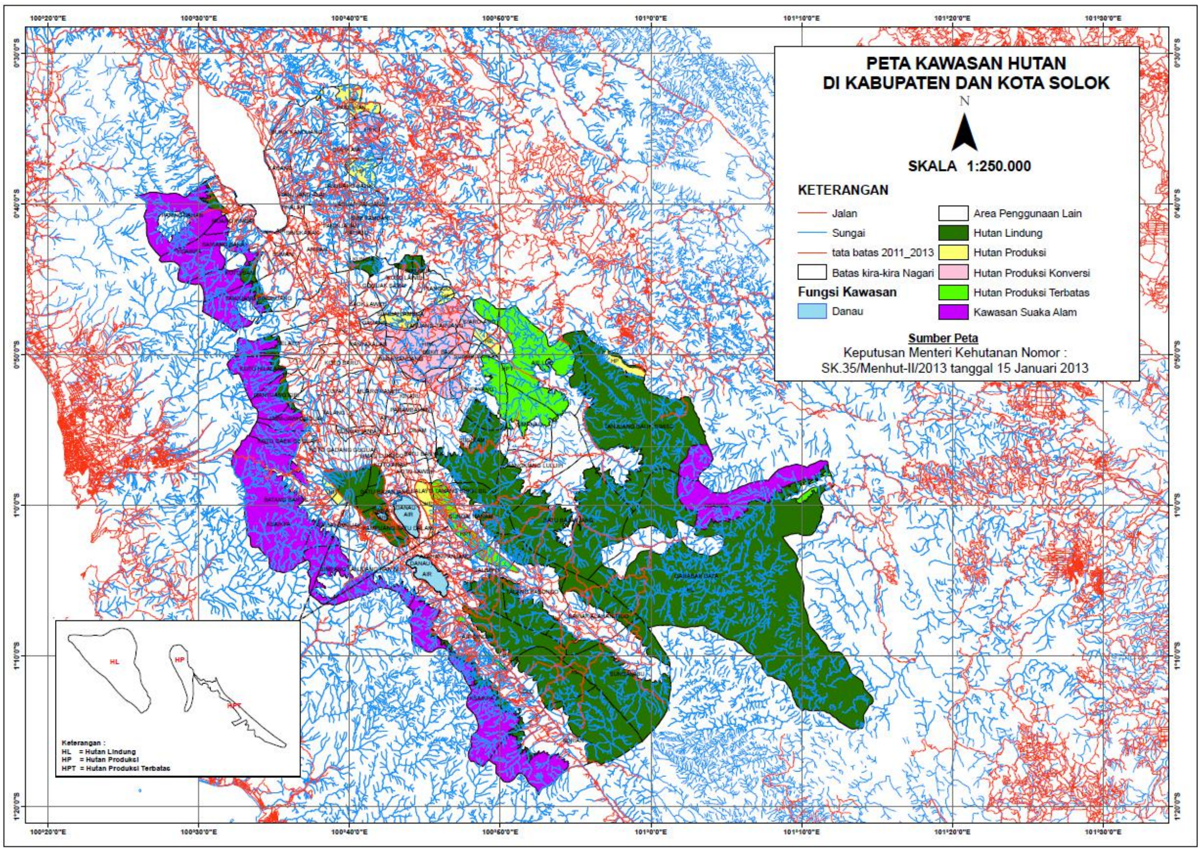

Figure 17: Map showing protected forest areas in the *Singkarak* river basin.

Source: Provincial Forestry Department, Padang, West Sumatra.

Carbon stocks of the baseline land cover under the Business as Usual scenario

For practical reasons, the baseline land cover under the Business as Usual scenario has been assumed to be predominantly *Imperata* grasslands (with or without some shrubs), ferns or shrubs (semak/belukar). The carbon stocks of the baselines have been defined using secondary sources of scientific research papers on carbon stocks in Sumatra. In addition, land use maps were derived from Landsat Images with resolution 30 x 30m. More recently, maps were downloaded from the Indonesia Geoportal for One Map Policy. The village land use maps were downloaded from http://tanahair.indonesia.go.id/portal-web. The combination of these information sources gives a sound basis for the baseline scenario in the program area.

For *Imperata* grasslands, we applied the biomass and carbon stock data provided by the study of Syahrinudin et al., (2020) as this was the only source of data that provided shoot biomass and root biomass. According to this study, the shoot biomass is 7.4 tonnes/ha and the root biomass is 9.1 tonnes/ha, resulting in a total time-averaged biomass of 16.5 tonnes/ha. For ferns, we applied the biomass data from Agus et al. (2009) showing a total biomass stock (aboveground and belowground) of 35 t/ha. For shrub (semak/belukar), we applied the data from Yassir et al (2010) showing a biomass stock of 25 t/ha in total.

Fires occurred regularly before the start of the project(s) in all project sites, partly due to the sensitivity of *Imperata* grasslands. It is therefore assumed that without project intervention, fire occurrence would continue on a regular basis, assuming that every plot could burn once every three years under the Business as Usual scenario. As a result, we assumed that all locations remain covered with *Imperata* grasses under the Business as Usual scenario.

Due to the expected presence of (mostly) *Imperata* grasslands and the continuous occurrence of fire under the Business as Usual scenario, it is expected that the total biomass stock remains more or less similar over time. In Figure 18, the total baseline biomass stock under the Business as Usual scenario is shown, assuming regular occurrence of fire.

We assumed that the *Imperata* grasslands reach a maximum total biomass of 12.1 tonnes/ha or 5.6 tonnes carbon/ha. The time-averaged baseline carbon stock over 30 years would be 5.1 tonnes carbon/ha, including 4.1 tonnes belowground carbon/ha and 0.9 tonnes aboveground carbon/ha.

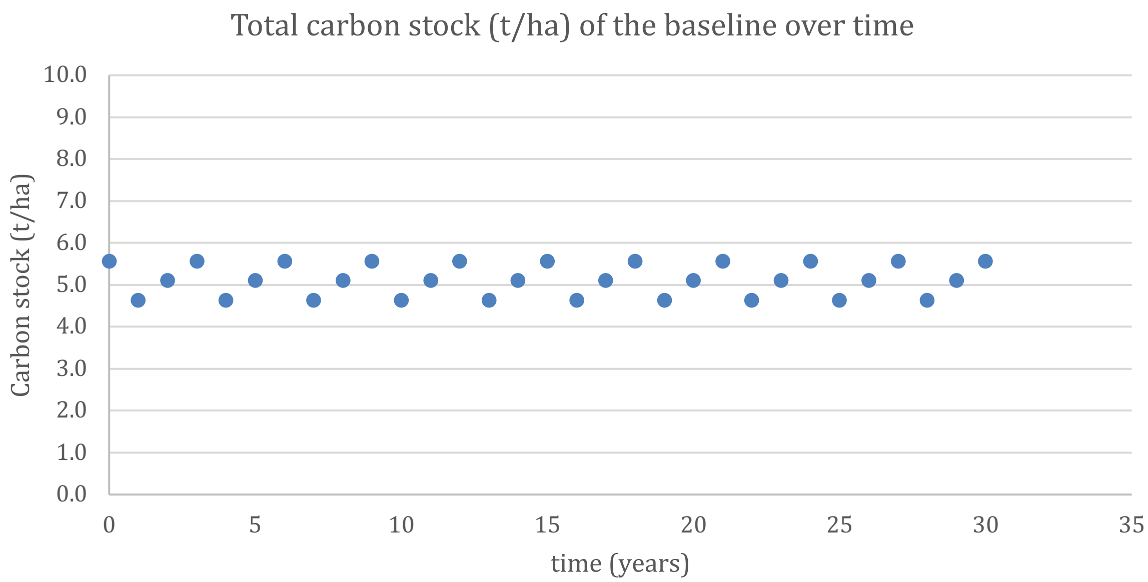

Figure 18: Total baseline carbon stock (t/ha) under the Business as Usual scenario over time (30 years), assuming regularly burning of *Imperata* grasses as the baseline land cover.
Source data: See accompanied Excel file, sheet 'Carbon - baseline'.

G5: Ecosystem service benefits

Climate benefits methodology

Because of the varying interventions and planting times of the trees and plants in the plots, now and in the future, we have chosen to classify the agroforestry plots based on the type of intervention (i.e. ecosystem rehabilitation (EH), improved land management (ILM) and ecosystem restoration (ER)), the location of the plot, and the year of planting of the trees/plants. The trees/plants in the agroforestry systems were planted in 2012, 2013, 2019 and 2020 (Table 11).

Table 11: Agroforestry systems based on the type of intervention and the year of planting of the trees/plants.

Intervention	Location	Planting year
Ecosystem rehabilitation	Paninggahan	2012
Ecosystem rehabilitation	Agam	2013
Ecosystem rehabilitation	Paninggahan	2019
Improved land management	Paninggahan (Subaka)	2019
Improved land management	Air Dingin	2020
Improved land management	Paninggahan	2021
Improved land management	Paninggahan	2022
Improved land management	Selayo	2021
Improved land management	Sirukam	2021
Improved land management	Air dingin (koto baru)	2021
Improved land management	Paninjawan	2022

For each dominant tree species, we defined:

- the annual tree growth in terms of diameter at breast height (DBH) over the project period (t = 30 years) based on information from the literature (if available: see Excel file);
- the annual aboveground biomass accumulation over the project period (t = 30 years), based on the DBH and allometric equations from the literature (if available: see Excel file);
- the aboveground biomass "losses" for each plant or plot due to harvesting and/pruning.

The aboveground carbon accumulation over time for each of the dominant tree/plant species (kg/tree) is shown in the graphs on the next pages. The graphs show that particularly mahogany, jengkol , surian, petai and lamtoro add large amounts of carbon to the agroforestry plots. The calculations and the allometric equations and harvesting/pruning regimes applied to each of the dominant species are shown in the attached Excel file.

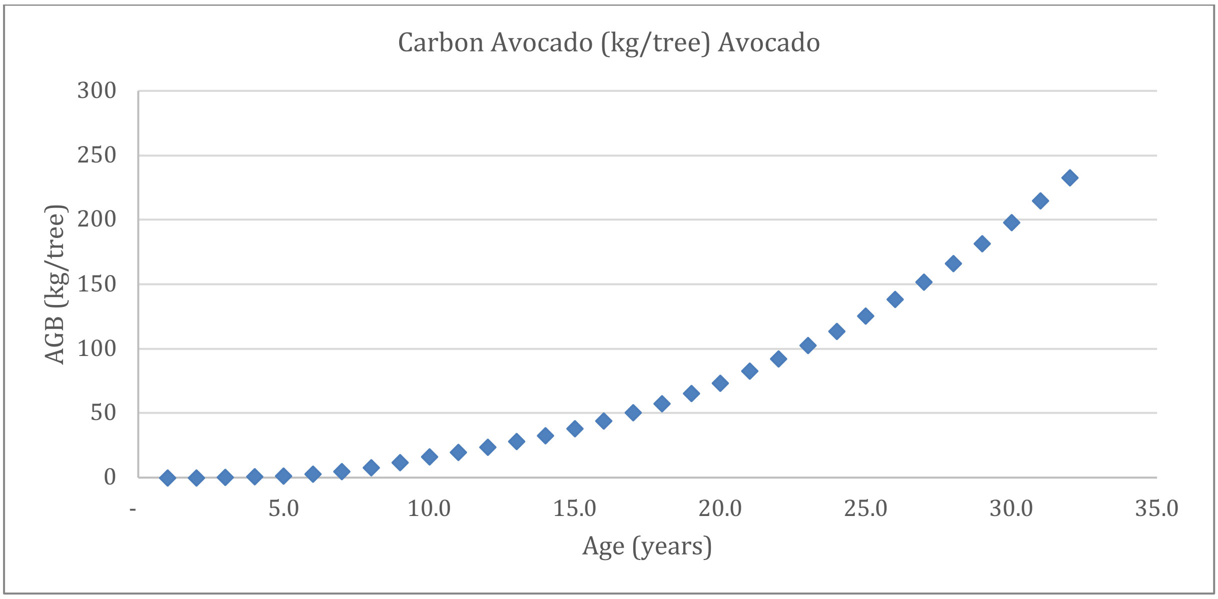

Figure 19: Estimated carbon stock (kg/tree) accumulation over time for Avocado (*Persea americana Mill.*) (Alpukat Mega Paninggahan = local variety) based on field-measured DBH values and assumed DBH growth rate of 1-2 cm/year and height growth rate of 0.3 m/year. Allometric equation based on Chave et al. (2005). Source data: See accompanied Excel file, sheet 'Avocado DBH + B'

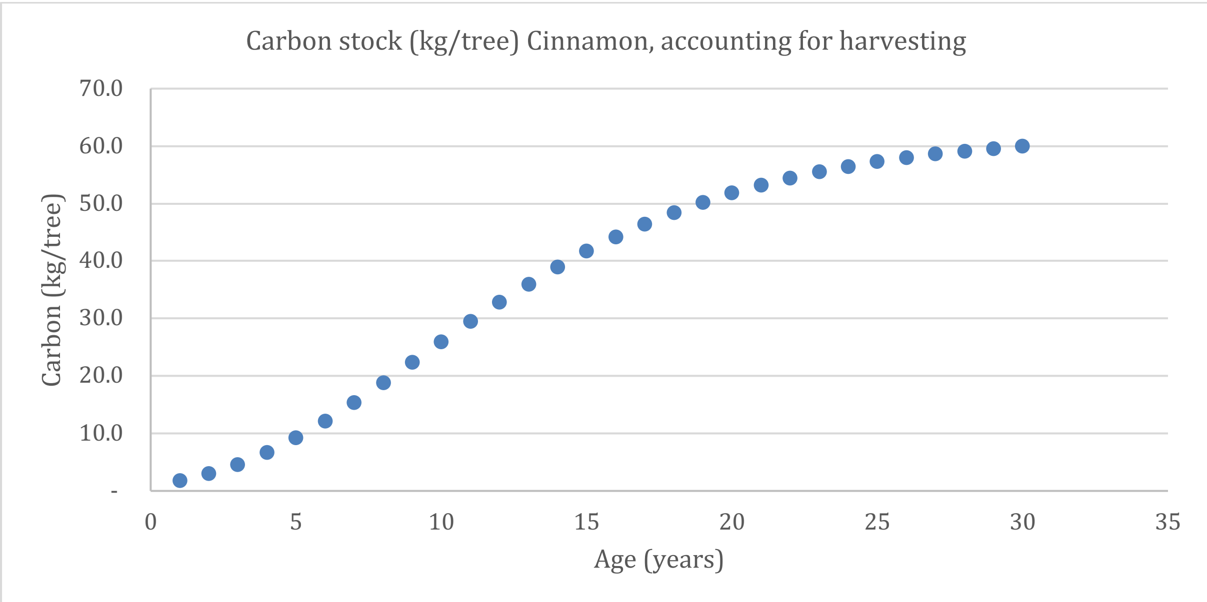

Figure 20: Estimated carbon stock (kg/tree) accumulation over time for Cinnamon (*Cinnamomum zeylanicum* Blume), assuming the DBH and carbon accumulation curve of Ginoga et al. (1999). Source data: See accompanied Excel file, sheet 'Cinnamon DBH + B'

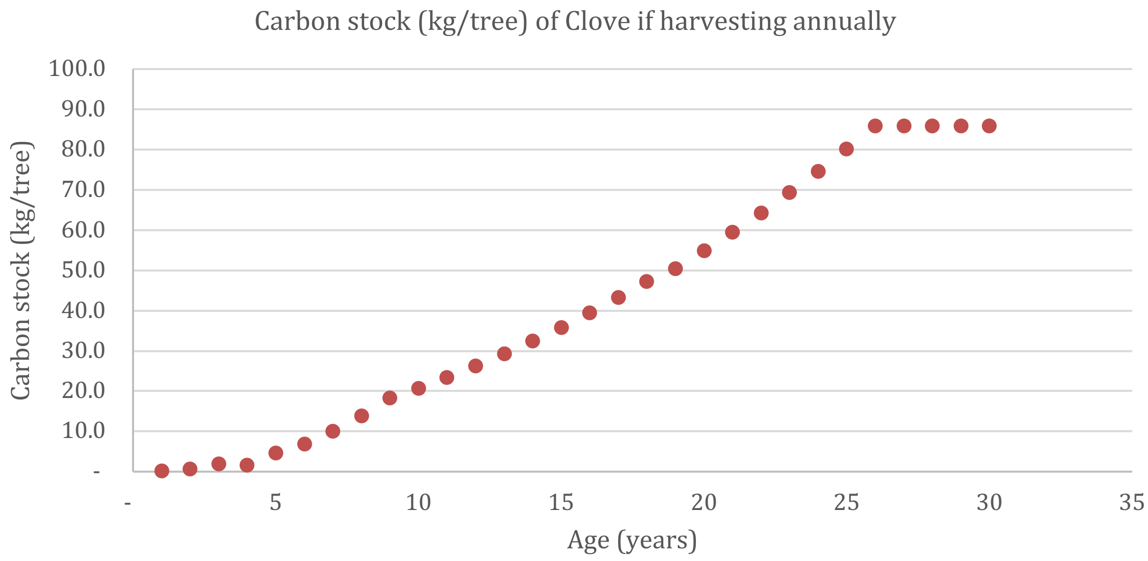

Figure 21: Estimated carbon stock (kg/tree) accumulation over time for Clove (*Syzygium aromaticum* (L.) Merr. & L.M.Perry), applying DBH (growth rate) and aboveground biomass stock based on Hariyadi et al. (2019) and allometric equation from Ketterings et al. (2001). Source data: See accompanied Excel file, sheet 'Clove DBH + B'

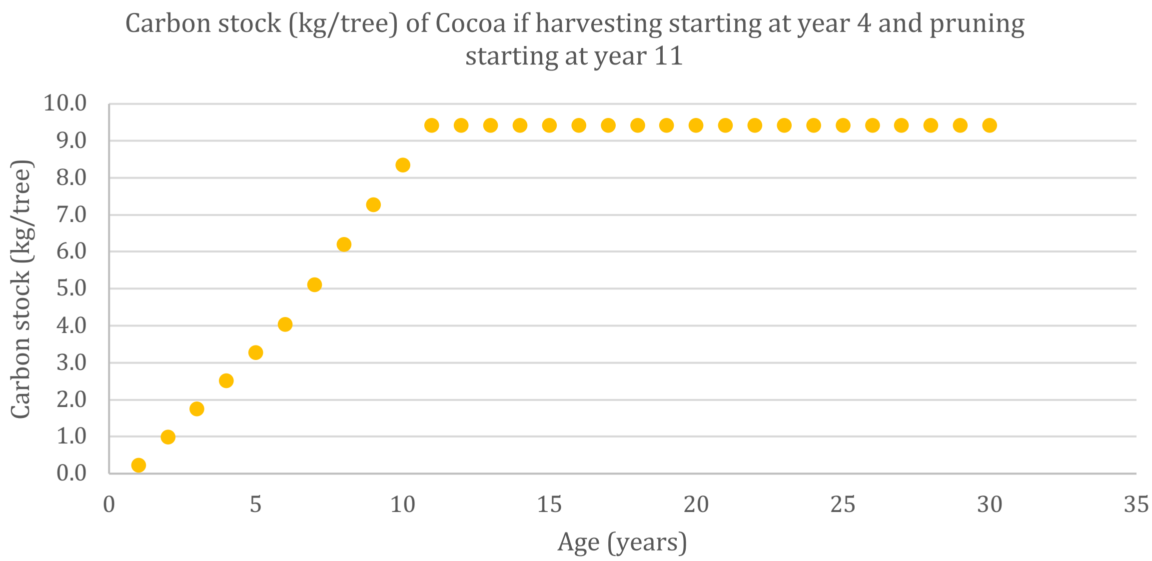

Figure 22: Estimated carbon stock (kg/tree) accumulation over time for Cocoa (*Theobroma cacao* L.), assuming the AGB accumulation rate of Fischer (2018). DBH data are not relevant, since branching at the base of the trunk. Source data: See accompanied Excel file, sheet 'Cocoa DBH + B'

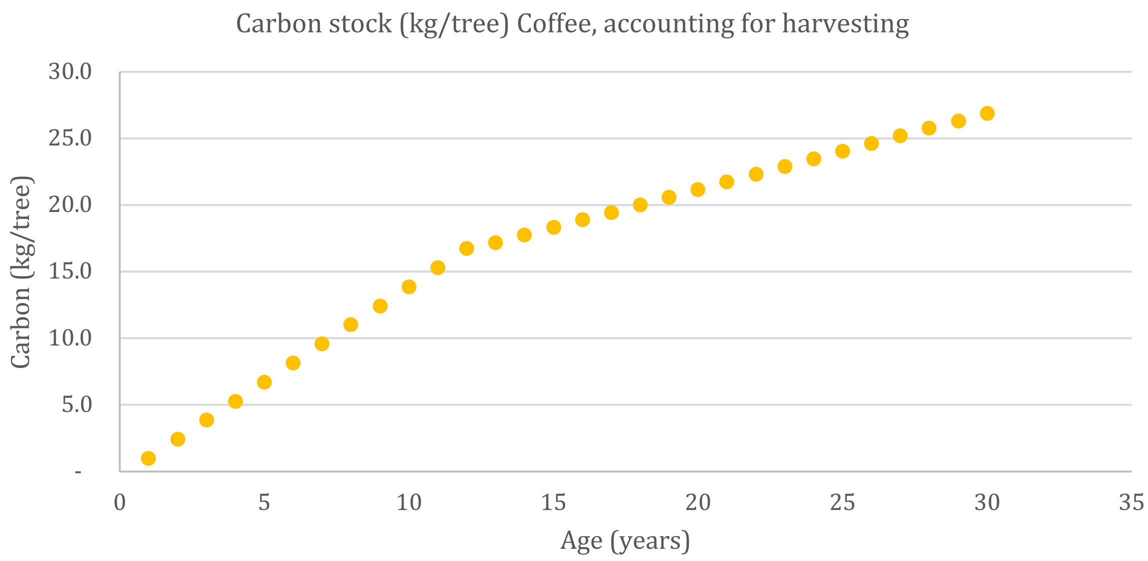

Figure 23: Estimated carbon stock (kg/tree) accumulation over time for Coffee (*Coffea arabica L.*) based on carbon stock data shown in Dossa et al. (2008). The carbon stock accumulation data for Coffee robusta is based on the data for Coffee arabica. Source data: See accompanied Excel file, sheet 'Coffee DBH + B'

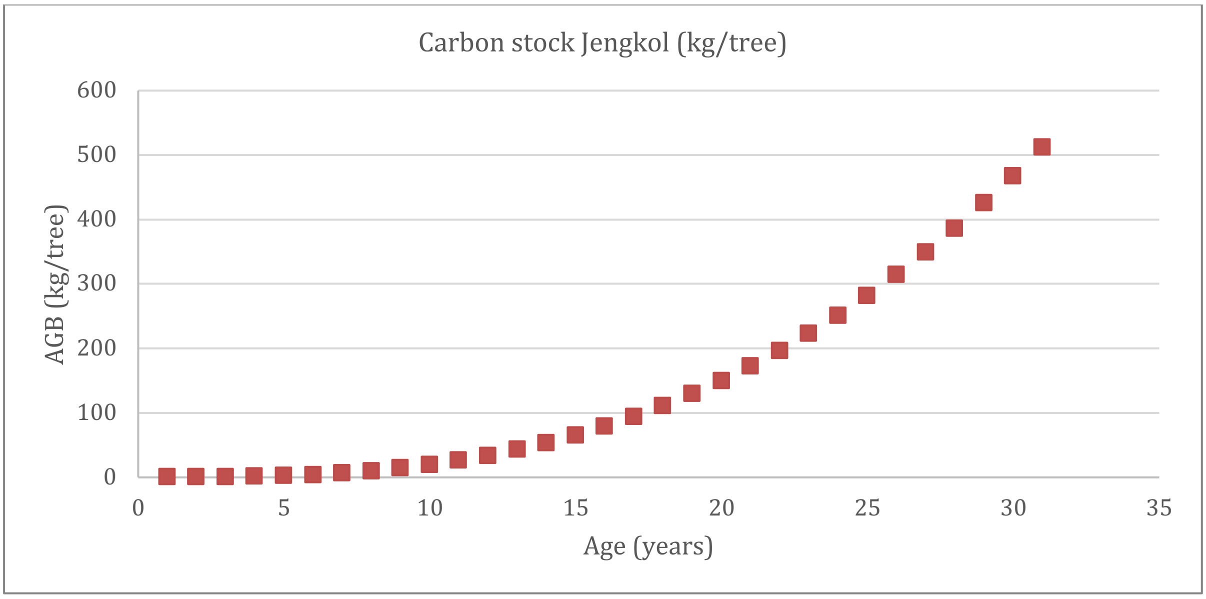

Figure 24: Estimated carbon stock (kg/tree) accumulation over time for Jengkol (*Archidendron jiringa* (Jack) I.C. Nielsen) based on field-measured DBH values and assumed DBH growth rate of 1.5 cm/year and height growth rate based on the allometry of Jirak (assuming a similar growth rate and size as Jirak, and because of missing data specific for Jengkol). Allometric equation based on Ketterings et al. (2001). Source data: See accompanied Excel file, sheet 'Jengkol DBH + B'

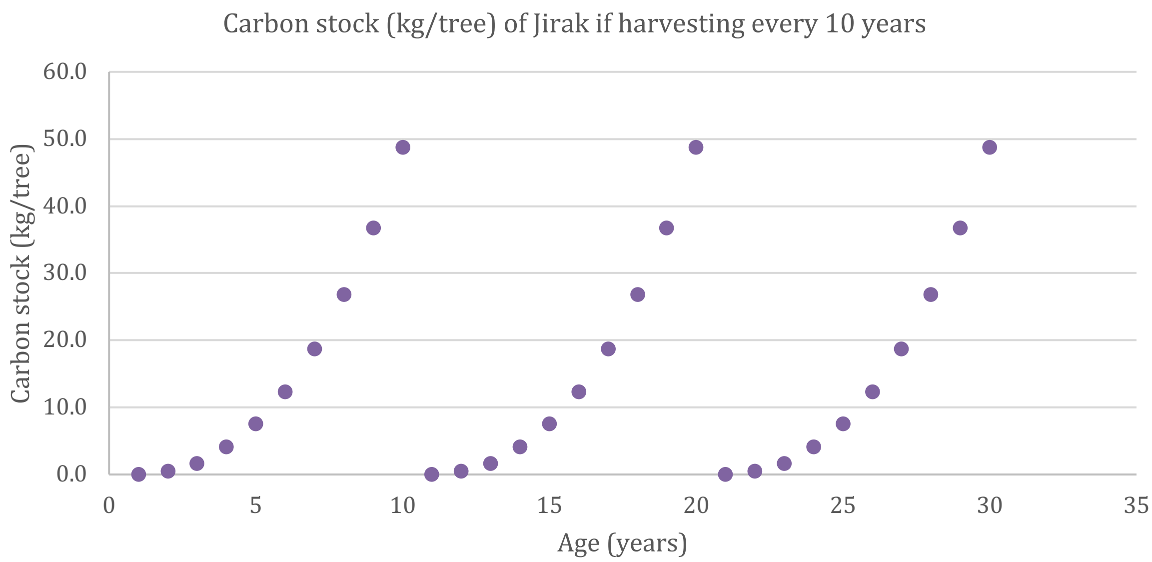

Figure 25: Estimated carbon stock (kg/tree) accumulation over time for Jirak (*Eurya acuminata*), applying DBH and biomass data based on https://eol.org/pages/2889655/data & https://eol.org/data/R805-PK74274381, and allometric equation from Chave et al. (2005; moist forest type). Source data: See accompanied Excel file, sheet 'Jirak DBH + B'

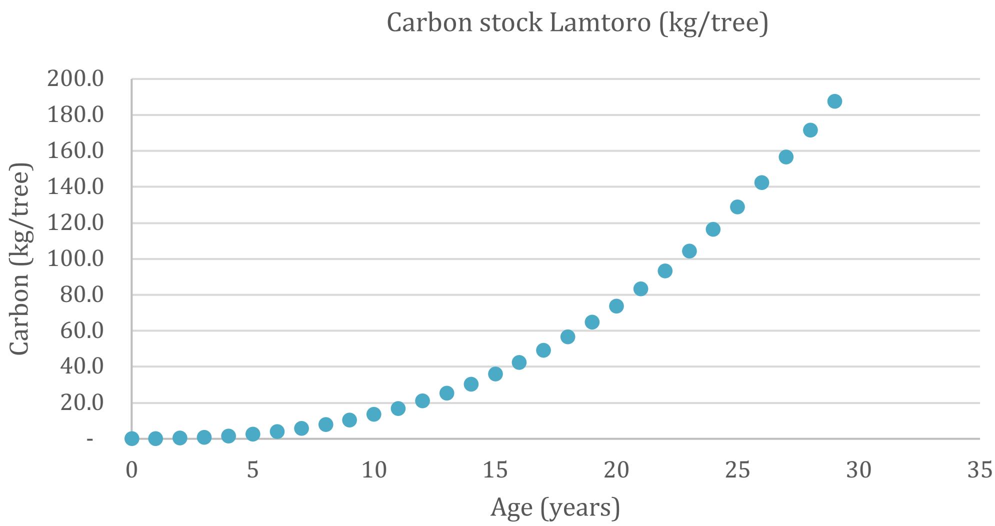

Figure 26: Estimated carbon stock (kg/tree) accumulation over time for Lamtoro (*Leucaena leucocephala* (Lam.) de Wit), assuming a similar growth rate and size as Jirak (without harvesting). Applying DBH and biomass data based on https://eol.org/pages/2889655/data & https://eol.org/data/R805-PK74274381, and allometric equation from Ketterings et al. (2001). Source data: See accompanied Excel file, sheet 'Lamtoro DBH + B'

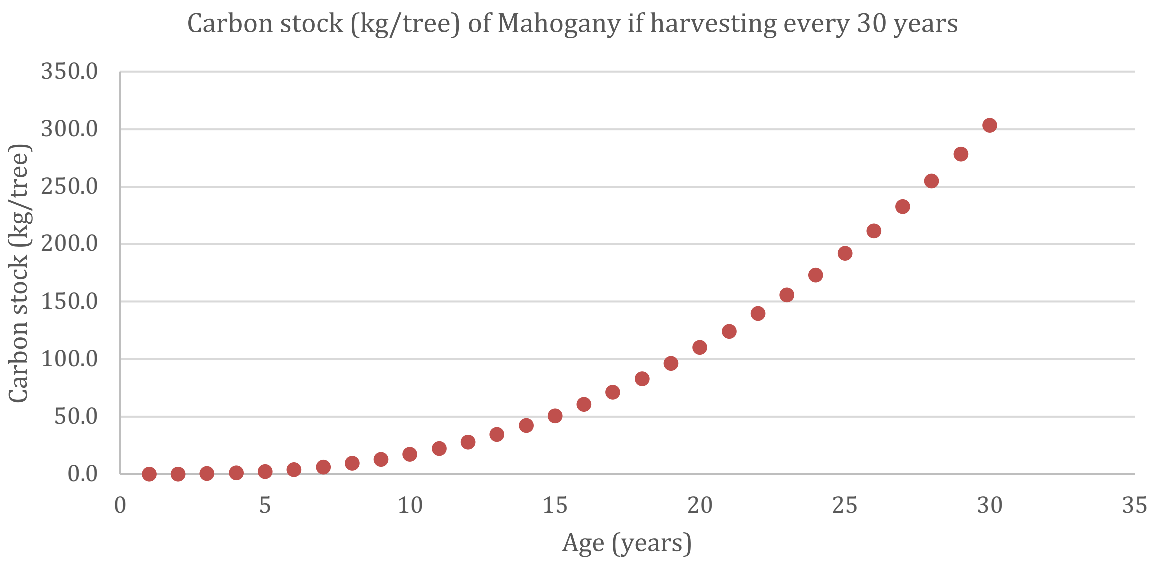

Figure 27: Estimated carbon stock (kg/tree) accumulation over time for Mahogany (*Swietenia macrophylla* King), assuming the DBH growth (site quality class II) in Krisnawati et al. (2011) and the allometric equation from Adinugroho and Sidiyasa (2006) (in Krisnawati et al., 2011). Source data: See accompanied Excel file, sheet 'Mahogany DBH + B'

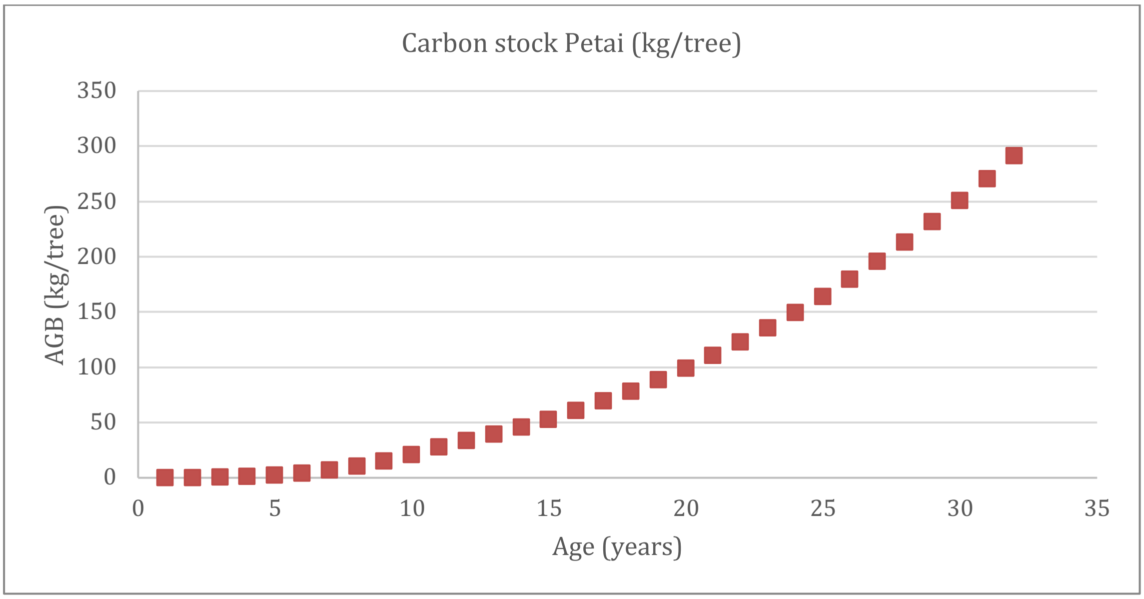

Figure 28: Estimated carbon stock (kg/tree) accumulation over time for Petai (*Parkia speciosa* Hassk.), assuming a similar growth rate and size as Jirak (without harvesting). Applying DBH and biomass data based on https://eol.org/pages/2889655/data & https://eol.org/data/R805-PK74274381, and allometric equation from Ketterings et al. (2001). Source data: See accompanied Excel file, sheet 'Petai DBH + B'

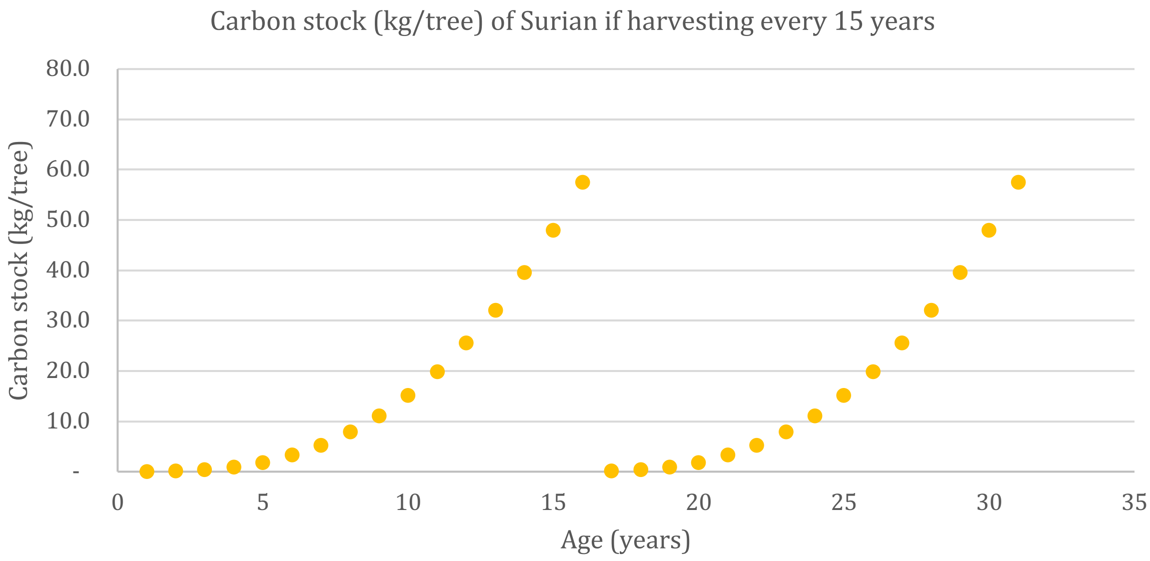

Figure 29: Estimated carbon stock (kg/tree) accumulation over time for Surian (*Toona sureni* (Blume) Merr.), assuming the DBH growth rate in Orwa et al. (2009) and based on the allometric equation from Ketterings et al. (2001). Source data: See accompanied Excel file, sheet 'Surian DBH + B'

After estimating the carbon accumulation models, we applied the following step-wise approach to each of the aforementioned systems. We:

1. estimated the biomass stock over 30 years for each of the dominant tree species, accounting for harvesting and/or pruning, which we multiplied with the total number of species in that agroforestry system;
2. added an estimate of the biomass of the non-dominant tree/plant species (as a percentage of the dominant tree species biomass, see Excel file);
3. we accounted for the root biomass by adding 25% of the total tree biomass (based on Mokany et al., 2006);
4. accounted for the understorey/undergrowth biomass by adding 25% of the total tree biomass (based on van Noordwijk et al., 2002);
5. accounted for the soil biomass/necromass by adding the biomass of the baseline land cover (*Imperata* grassland) at the start of the intervention), assuming this biomass is decaying and fully taken up by the soil;
6. estimated the total biomass of the system by summing all biomass stocks of the tree species, roots biomass, soil biomass/necromass and understorey/undergrowth biomass;
7. defined the time-averaged total biomass and carbon stock of the agroforestry system (intervention) by subdividing the total biomass and carbon by 30 years (the duration of the project);
8. defined the time-averaged total biomass and carbon stock of the baseline land cover under the Business as Usual scenario;
9. estimated the time-averaged carbon stock of the 16% biomass/carbon buffer;

10. subtracted the 16% biomass/carbon buffer and the time-averaged biomass/carbon stock of the baseline from the time-averaged biomass/biomass stock of the agroforestry system/intervention, resulting in the time-average biomass/carbon stock additionality;
11. estimated for each of the agroforestry systems the time-averaged carbon stock (by multiplying the biomass stocks with 0.46 – van Noordwijk et al., 2002)) and CO_2 additionality (by multiplying the biomass stocks with 0.46 and 3.67, respectively)

Expected climate benefits

Table 12 shows the carbon and carbon dioxide additionality of all agroforestry systems in the project thus far. The full calculations are shown in the attached Excel file. We found an average carbon additionality of about 37 tonnes of carbon/ha of the systems in Paninggahan (and equals the calculations made for similar systems in Agam), which is equal to about 137 tonnes of CO_2/ha. For the plots in Air Dingin, we found a carbon additionality of about 91 tonnes of carbon/ha, which is equal to about 335 tonnes of CO_2/ha.

Table 12: Carbon and carbon dioxide additionality of the agroforestry systems based on the type of intervention and the year of planting of the trees/plants.

Intervention	Location	Planting year	Area (ha)	Time-averaged net* biomass (t/ha)	Time-averaged net carbon (t/ha)	Time-averaged net CO_2 (t/ha)
Ecosystem rehabilitation	Paninggahan	2012	29.0	77.7	35.3	129.4
Ecosystem rehabilitation	Agam	2013	33.3	86.6	39.4	144.4
Ecosystem rehabilitation	Paninggahan	2019	19.9	112.4	51.7	189.7
Improved land management	Paninggahan (Subaka)	2019	14.4	94.2	43.4	159.1
Improved land management	Air Dingin	2020	65.5	178.1	81.9	300.6
Improved land management	Paninggahan	2021	2.2	142.4	65.5	240.4
Improved land management	Paninggahan	2022	27.1	148.5	68.3	250.8
Improved land management	Selayo	2021	11.0	113.9	52.4	192.3
Improved land management	Selayo	2021	2.5	122.0	56.1	205.9
Improved land management	Sirukam	2021	45.7	130.1	59.9	219.7
Improved land management	Air dingin (koto baru)	2021	14.5	173.1	79.6	292.2
Improved land management	Paninjawan	2022	34.6	132.2	60.8	223.1
Improved land management	Paninjawan	2022	4.5	135.4	62.3	228.7

*net means minus the baseline and 16% buffer

Source data: See accompanied Excel file, spreadsheet 'Carbon additionality results'

G 6 Leakage & Uncertainty

Leakage is defined as the unintended loss of carbon stocks outside the boundaries of the project resulting directly from project activities. The project works solely with small scale farmers. The land within the project area has not been utilised for any (productive) activities since the 1970s. The dominant vegetation here is *Imperata* and “*semak*”, the latter containing less than 5% shrubs and/or trees. This land cover has very low carbon storage levels. Ecosystem restoration on these lands scores high on additionality aspects, and does not compete with other land uses. Leakage is considered very low to zero. For one, the degraded land area is very large, enough for everyone willing to participate. Cutting down forests therefore would mean very hard work, and people usually have to wait a few years before they can start planting, because the biomass/logs need to decay first. This would not fit the tie when we look for additional restoration areas, which must be planted as soon as possible. Secondly, strict indigenous regulations for land use also mean that leakage is minimized, as adat regulations forbid the opening of new forests, in order to protect water sources. Due to the program’s efforts, potential leakage caused by regular fires has also stopped (see annex 9, supporting letter village head on fires). This has significantly reduced the loss of carbon from burning *Imperata*

grasslands into forest areas. The natural regeneration of secondary forests because of this, is therefore even included in this PDD, a result of over 10 years of zero burning. Since the regenerated secondary forest will provide additional income from carbon payments, people will not cut down these secondary forests, although some enrichment planting of economic valuable species might occur. The most important reason to minimize leakage is the fact that the fieldstaff of RPL will always do ground checks of all fields using the GPS coordinates to develop polygons of each participant's field. These polygons are imported into Google Earth satellite images (https://explorer.land/x/project/vcm/). If the selected land would mean cutting down trees/forest, it would not be allowed to be included. Annex 11 shows the satellite maps the field staff uses. The provincial forestry land use map is overlaid, so that they can directly check whether or not a new site is within the forest area. If that is the case, the area will not be included.
During the FPIC process, the forest police (*polisi hutan or polhut*) is invited to explain about the boundaries and dangers when opening forest areas (see picture below). We will also explain to them based on the maps in Annex 11 that we will check the position of selected fields. Annex 11 only shows the sites in Air Dingin and Paninggahan, as these are the only sites eligible for carbon certification. Presenting these maps and discussion with *polhut* staff has also raised awareness among non-participants, not to encroach forest areas, as it may conflicts with the forest police (*polisi hutan)*.

The Forest police (POLHUT) joins village meetings to explain the dangers of forest encroachment

In the case of vegetable cultivation, a change from vegetable cultivation to tree cropping is a desired change initiated by participants themselves. Participants have voluntarily offered these lands to be converted into economically valuable tree cropping systems; an alternative development option that was previously not open to the farmers. They judge this to be a superior land use system compared to high-cost, high-risk vegetable cultivation. Participating farmers explained that they would simply stop vegetable cultivation. There is no leakage for replacing vegetable cultivation for the following reasons:

- Vegetable cultivation was seen as the only option available to improve livelihoods.
- Vegetable cultivation only takes place at the foots of the uplands, because of good access and the availability of water. However, all potential areas have been used already. New areas are not available. Therefore, vegetable cultivation higher up on the hills is absent because of difficult access and complicated irrigation requirements.
- Changing high input vegetable cultivation into low input tree cropping favours biodiversity in surrounding patches of forest.

Therefore, leakage of improved land use substituting vegetable cultivation is considered negligible.

Former land, where vegetables were cultivated are increasingly included in the carbon schemes, by planting trees. It connects surrounding patches of forest, and as pesticides and insecticides are no longer used, it helps the return of biodiversity.

H Risk Management

H1 Identification of risk areas

The ultimate goal of the carbon project is to enable sustainable rural development in the *Singkarak* river basin. Carbon investments are a crucial component to achieve this. Sustainable rural development consists of three pillars, namely economic (financial), social and environmental pillars. Risks in each pillar may affect the other pillar(s). The various pillars and their associated perceived risks have been summarised in Table 13. Each risk item has an associated *Likelihood* and *Severity*, which correspond to a risk score, whereby:

- Very low = 0.05
- Low = 0.2
- Medium = 0.35
- High = 0.5
- Very high = 0.65

The corresponding score for each risk item is calculated as the product of the *Likelihood* multiplied by the *Severity*. The overall risk score is then estimated as:

$$Risk\ \% = 10\ \times \sum(Likelihood\ x\ Severity)$$

According to this risk assessment, the project has a risk for this intervention equivalent to a score of 16%, and a risk buffer of 16% of unsold carbon is proposed.

Table 13: Potential risks and how to manage it.

Risk item	Effect	Internal/ external	Likelihoo d	Severity	Risk management and mitigation	Owner / responsible partners	Score
	FINANCIAL						
Official carbon certification cannot be achieved	Upscaling of carbon credit sales is difficult.	Internal	Low	medium	CO_2Operate BV activities gain momentum and more partners are interested in joining, especially once certification has been achieved (demand for certified credits is increasing). In doing so, we can strengthen ecosystem restoration.	CO_2Operate BV, Plan Vivo, RPL, local *Singkarak* communities	0.07
Carbon sales do not occur	Business case does not develop for upscaling	Internal	Low	medium	Over the past 8 years, carbon credits have been sold at high prices without certification. Organisations from abroad have already requested the purchase of certified credits. Certification combined	CO_2Operate BV, RPL	0.07

Risk item	Effect	Internal/ external	Likelihood	Severity	Risk management and mitigation	Owner / responsible partners	Score
					with good marketing will manage and reduce this potential risk. In doing so, we can strengthen ecosystem restoration.		
Funds invested are too small for forest rehabilitation due to increased costs.	Ecosystem restoration program cannot achieve off-setting targets from clients.	Internal	Low	medium	Over the past 8 years we have developed a transparent and well-functioning system to establish tree-based systems, and involved the community in payment schemes. We do no longer expect major financial constraints as we have made conservative calculations.	CO_2Operate BV, RPL, participating cooperative farmer groups.	0.07
	SOCIAL						
Ecosystem restoration through ANR is not taken up by local community.	No income increases for the local villagers after 5 years from tree crops and improved water retention capacity of area remains low.	Internal	Low	medium	By now, CO_2Operate BV has developed a proof of concept on successful ecosystem restoration in the area. All lessons learned are transformed into a successful approach that minimises risk of failure.	RPL, CO_2Operate BV, Forestry, STKIP	0.07
Corruption and conflicts	Losses of funds, disputes over program aims and targets.	Internal	Low	medium	Corruption at the start has been solved completely by re-organising the institutional set up. Cooperative farmer groups have horizontal social relationships, each with their own bank account so that funds directly enter cooperative bank accounts. Community members have a strong negotiation power through *Adat*, hence corruption is tackled right away if	CO_2Operate BV, RPL, local community, village head, *Adat* council.	0.07

Risk item	Effect	Internal/ external	Likelihood	Severity	Risk management and mitigation	Owner / responsible partners	Score
					needed. The village head acts as the supervising entity.		
Land claim disputes	Destruction of trees, conflicts leading to bad program progress	Internal	Low	medium	Land access is secured through *Adat* regulations, following the matrilineal system. Participants who start rehabilitating a piece of land only do so after approval of the village *Adat* council. The council will discuss who owns and has cultivation rights on the land with participants and family to ensure no conflicts occur.	CO_2Operate BV, RPL, local community, *Adat* council, village head.	0.07
Community does not want to participate in the program.	Carbon program cannot continue	Internal	Low	medium	By starting all new activities with FPIC, everything is well aligned with the participants and community. This has increased sense of ownership among participants, and those not yet participating. Worst case scenario, would be to find new participants.	CO2 Operate BV, RPL, local community, *Adat* council, village head.	0.07
Government of Indonesia (GoI) policies change and (partly) claim carbon from project	Financial loss as the project is forced to sell carbon credits to GoI at a low price to reach NDC commitment	External	Medium	high	We are connected to highest level of forest policy making and get updated when regulations change, so we can anticipate to potential changes.	CO_2 Operate, RPL	0.175
	ENVIRONMENTAL						
Droughts (caused by El Niño	Drought will kill trees	Internal	Medium	High	Occurred in early stages of the Gula Gula Food Forest Program before the use of ANR. The pressed *Imperata* grasses provide an isolation blanket for water in the soil, so that tree growth is hardly	CO2 Operate BV, RPL, local community	0.175

Risk item	Effect	Internal/ external	Likelihoo d	Severity	Risk management and mitigation	Owner / responsible partners	Score
					affected during droughts in establishment phase. Once tree system is established, it can survive periods of drought.		
biodiversity is not improved.	Biodiversity enhancemen t may not develop	External	Low	Medium	Biodiversity is an additional benefit but seen as important to us, as it increase habitat for animals and plants. However, it may not affect carbon sequestration and water retention capacity of the growing productive forest severely. Combining ANR with tree planting has proven to be a good combination to provide a habitat for wild animals and a certain degree of rainforest vegetation.	RPL, Forestry, CO2 Operate BV, STKIP	0.07
Pests & Diseases	Trees killed	External	Medium	High	Pests developed in the past (1970s) because of monoculture stands. Now, mixed agroforestry has reduced this risk significantly. Farmers see that there are none or minor issues related to pests & diseases over the past 10 years. Pests are directly reported similar to the grievance mechanisms., RPL, cO2 Operate seek advice from scientific experts at Andalas University and/or Gadjah Mada University, Yogyakarta. Usually, pests occur in year 0-2 of planting. If solving is difficult, farmers prefer to replace the trees by species which were not affected in their field.	RPL, Farmers, Andalas University, UGM Yogyakarta	0.175

Risk item	Effect	Internal/ external	Likelihood	Severity	Risk management and mitigation	Owner / responsible partners	Score
Earthquake, landslides	Restoration sites destroyed, casualties	External	Medium	high	No management possible. If trees are 3-4 years old, they may prevent landslides and be strong enough to withstand earthquakes.	RPL, Forestry, CO2 Operate BV, STKIP, local communities	0.175
Fires	Fires may destroy ecosystem restoration efforts.	Internal/ External	Medium	High	Fires regularly occurred in *Imperata* grasslands. However, the carbon program has reduced fires to zero. People stopped setting fires to *Imperata* grasslands. Pressing grasses also reduces the fire-proneness, while making of fire-breaks is part of the ANR training.	RPL, CO2 Operate BV, Forestry, STKIP.	0.175
Growth of trees is below expectations	Monitoring is not done	Internal/ external	Low	medium	Our field staff is highly committed already for 10 years. Working with students on this gives them high motivation. Co2 Operate and field staff hold 2 weekly skype meetings to discuss progress and issues, making them feel confident with what they do.	CO2 Operate, RPL, STKIP staff and students,	0.07
Carbon fixation target not met	Time average carbon stocks too high,	Internal	Low	medium	Field carbon measurements are done every 3 years. If real situation is off from initial calculations, new areas can quickly be added, as many farmers like to join the program. Buffer planting may be used	CO_2 Operate, RPL, Farmers	0.07
Total score							1.575
Risk buffer							**16 %**

Buffer planting

For all technical specifications, a planted/restored buffer of 16 % is planted and held for emergency purposes. This action occurs based on the eight years' experience of the carbon program in *Singkarak*. Since the use of ANR, there are no major issues related to tree deaths, delays in growth etc. In addition, the FPIC carbon contract made with the participant farmers states that any tree deaths must be replaced immediately. The field staff holds monthly checks with a strong focus in the first 2 years. The team reacts quickly when trees are not doing well to avoid delays in growth and risk the total carbon target may not be achieved. RPL staff together with STKIP students conduct annual checks and counts of trees in the field, where possible combined with the carbon assessment and evaluation for annual payments. For instance, all trees are counted and labelled after the first planting to ensure that each farmer reaches the minimum number of trees set in the contract.
In addition to these actions, the exact size of the natural regeneration sites, which have developed from fire prevention measures (guarding of the area/fire prevention), still need to be done. The carbon sequestration estimates in these areas are included in the certification process, as it is a direct result of the fire prevention measures developed by the farmers.

I Project Coordination & Management

I1 Project coordination

CO_2Operate BV builds cooperative partnerships. Before the start of the program in 2009, CO_2Operate BV conducted stakeholder analyses to assess potential impacts caused by stakeholders or stakeholders being possibly affected by the project in West Sumatra (Figure 30). As a result, an equal cross-section of the local society is influenced by and/or influencing the carbon program. People's ideas, desires and knowledge are taken into account and acted upon. So local villagers, local government and knowledge institutions, all fulfil an important role in the success and sustainability of the program. Good relationships have been constructed with the leader of the *nagari* (*wali nagari*), *Adat* Council and the clans and people that form the farmer groups (*kelompok tani*).

The impact level is considered a crucial area for relationship building to maintain the existing status quo and encourage positive sustainable behaviour within the carbon program for ecosystem restoration. However, for the implementation of the program the *nagari* level has been most important. However, stakeholder influence at moderate level has been considered to be important as well. Building good relationships with local government agencies and knowledge institutes are crucial to make the work effective. In 2016, another stakeholder analysis was conducted to see whether the influencers, and those being influenced, have changed. An important change is that the electricity company, the PLN, which runs the hydropower installation in the lake, has expressed more interest in supporting the program as part of their CSR strategies. Some 500 seedlings of durian trees were already given on their behalf to the people in *Paninggahan*.

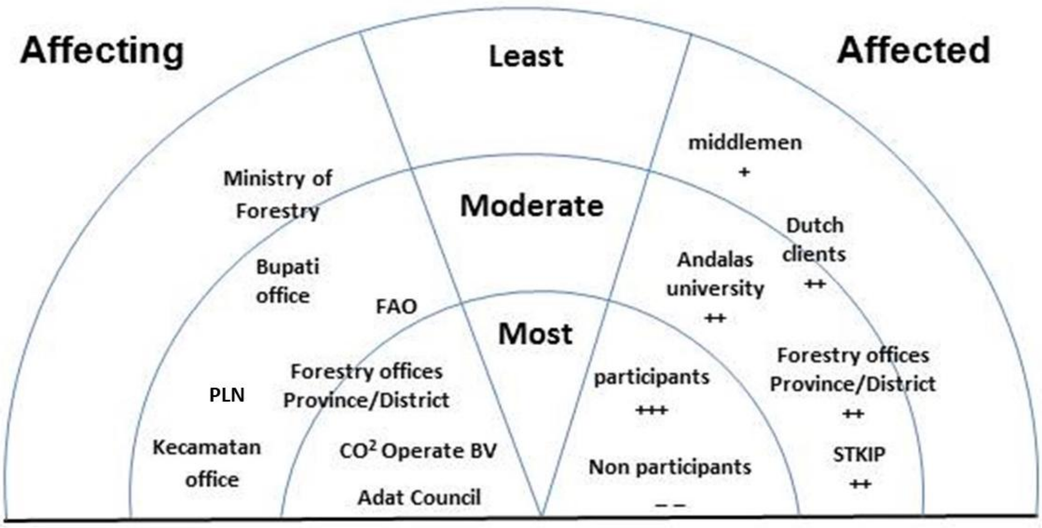

Figure 30: Rainbow diagram showing stakeholders affecting or being affected by ecosystem restoration.

Source: Participatory stakeholder analysis

Coordination and management therefore include some of the most crucial stakeholders/partners. Figure 31 shows the various relationships between CO_2Operate BV and the program in West Sumatra. These actors work together to provide the coordination and implementation of the ecosystem restoration. The influence ranges from funding through to manpower and knowledge. This provides the base understanding to enable the program activities.

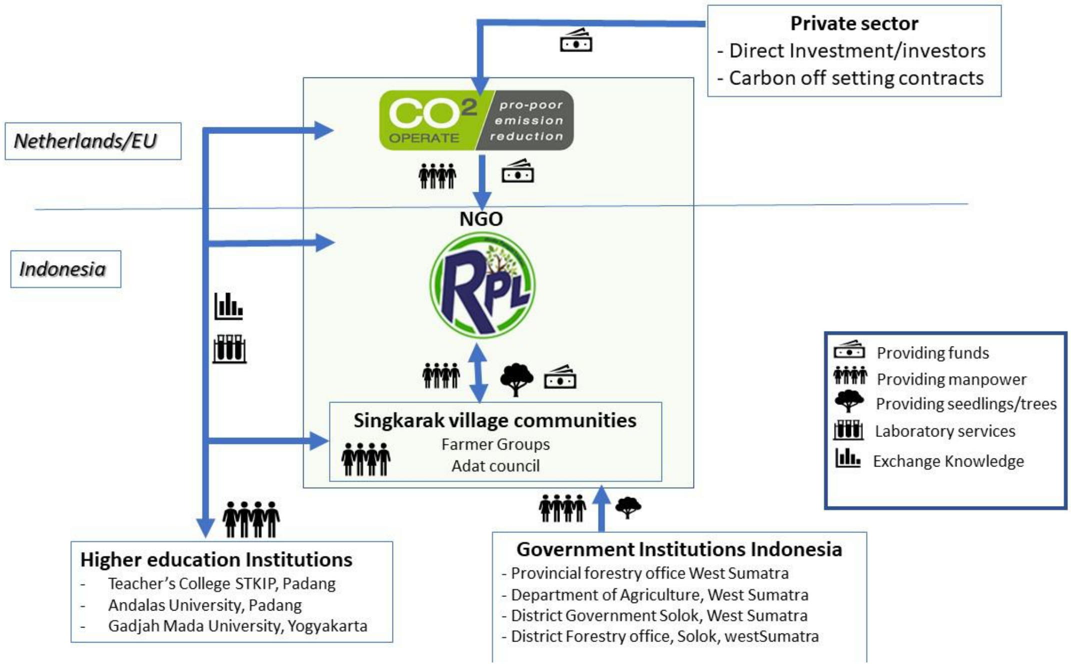

Figure 31: Context of all partnerships built by CO_2Operate BV to successful ecosystem restoration

The various key organizations involved participate in a number of complementary ways. The roles of each organisation are further described in the following sections.

Project coordinators: CO_2Operate BV and RPL

CO_2Operate BV

Main contact: Paul Burgers, Director.

The proof of concept for ecosystem restoration using ANR was developed some years ago by CO_2Operate BV and partners. This shows that ecosystem restoration can combine poverty reduction with mitigating climate change whilst increasing biodiversity. The knowledge and experience of working in the local context, not only at grass-root level, but also scientifically, means CO_2Operate BV and its staff are well positioned as a lead partner. Specific responsibilities are:

- Overall program coordination.
- Financial planning and reporting.
- Reporting (project progress, impact).
- Monitoring and evaluation coordination.
- Quality control.
- Scientific backstopping of ecological restoration technology.
- Monitoring and evaluation.
- Carbon accounting.
- Social media coverage.

- Marketing and sales of carbon credits.

RPL

Main Contact: Mrs. Ai Farida, Director; Mr. Bubung Angkiwijaya, Mrs. M. Gadis

For more than seven years, the Indonesian staff of the NGO RPL have worked together in the field with CO_2Operate BV. The staff is entirely made up from local or regional people, coming from the *nagari* itself or nearby Minangkabau regions of West Sumatra. The NGO has been very active in the socialisation processes, including FPIC exercises, managing and monitoring the tree planting and tree growth. They make essential expertise readily available in relation to community development, negotiations under FPIC exercises, and the implementation of capacity building programs related to ecosystem restoration using ANR. Specific responsibilities:

- Socialisation of new participants together with existing participants.
- Village level training of ANR to new participants, in collaboration with students and staff from STKIP.
- Facilitating/conducting the FPIC processes.
- Setting up cooperative structures and approval processes with the local government.
- Monitoring restoration activities.
- Data gathering related to tree planting, survival rates, and socio-economic data gathering.
- Regular monitoring and verification of program progress.
- Coordinate and participate in carbon assessments.
- Communication channel and data transfer to CO_2Operate BV in the Netherlands.
- Coordinate distribution of carbon payments to cooperative farmer groups.
- Coordinate village nursery activities, including financial planning for nursery establishment.

I 2 Government institutions Indonesia

Provincial Forestry Department, West Sumatra

As the Provincial Forestry Department was involved from the beginning of the project, their support has enabled the *Gula Gula* Food Forest Program to be rooted in the local policy context. They have strengthened the project activities through their guidance on policies, technical knowledge on state forest land boundaries and land use, and by working with communities via their fieldworkers. This is crucial for ecological and social sustainability and secures the future for the project. Most importantly, the project does not interfere with state-owned land.

Extension officers from the Forestry Department regularly join village meetings during the FPIC activities. They provide biophysical and technical knowledge to the participants such as which tree species are suitable for farmers, identifying which trees perform best in given areas, which trees provide good markets, and how to develop a village nursery to manage seeds and seedlings. They support in providing certified seeds and seedlings to the program at subsidised rates. This ensures that the participants receive high quality seeds and seedlings (see Annex 10, supporting letter provincial forestry department, where this is also stated). This mitigates the risk of ecological damage through rogue or invasive species and delivers a genetically robust forest. It also ensures that the trees will provide good a quality and quantity of products which will support livelihood improvements.

Department of Agriculture

Similar to the Forestry Department, the Department of Agriculture provides knowledge on tree growing. In Indonesia, trees are divided into forestry species and agricultural species. So, for the agricultural species, such as clove trees and many fruit trees, the Department of Agriculture he primary source of institutional knowledge. This means that they support the participants with ecologically approved seeds and seedlings at subsidised rates.

Local District Government

The CO_2Operate BV program is known among local government institutions in *Solok* district where the program is implemented up to the provincial level. On an informal basis, good relationships have been built with the head of the district (*Bupati*), and the *Solok* district forestry office. They support the program wherever possible. For instance, recently the BKSDA office (the nature conservation office of the local government) supported the farmers by providing, free of charge, seedlings so that farmers could add more trees on their land under the guidance of the CO_2Operate BV program. Knowing that the trees and farmer groups are monitored, they can see the benefits of linking with the program and see value in these relatively small donations.

Village level institutions

The final, probably most important level of commitment comes from village (nigari) level institutions. In West Sumatra, the *nagari* has quite large autonomous power, where the *Adat* council is important for the overall prosperity of the *nagari* and the villagers. The head of the village (*wali nagari*), elected for 5 years by the villagers, is also an important player within the *Adat* Council. We have built good relationship with both the *wali nagari* and the *Adat* Council in the areas we work. See as an example the supporting letter of the *wali nagari* of Paninggahan (Annex 9).

I3 (National) Knowledge institutions

STKIP, Padang

STKIP is a private college. The mandate of STKIP is to improve knowledge of staff and students through high quality education and research. From the start of the project, STKIP partnered with CO_2Operate BV. With a strong focus on capacity building, targeting especially students coming from low up to middle-income families, staff and students have participated in joint research, training and other activities with CO_2Operate BV in the *Singkarak* river basin. CO_2Operate BV has a MoU with the entire STKIP, meaning that CO_2Operate BV can easily collaborate with all departments, which includes the geography, biology, economics, sociology and mathematics departments (See Annex 2). STKIP brings research opportunities and involvement of staff and students, office space, meeting facilities and equipment, including drones and GPS equipment. CO_2Operate BV director Paul Burgers provides guest lectures whenever a field visit is undertaken, and acts as examiner during the final presentations of graduates.

Andalas University, Padang

Working together with the CO_2Operate BV project since 2008 on an informal basis, Andalas University, a public university, is the oldest university outside of Java. The senior staff from the Biology

Department made several biodiversity assessments to assess the baseline biodiversity. We are currently developing a long term collaboration with the Biology Department for a systematic biodiversity impact studies. Soil samples were (and still are) tested for carbon content to assess carbon uptake in the soil. Litter is also analysed for its carbon content. These processes are regularly carried out using the laboratory services of Andalas University. Carbon content measurements in soil, trees and biolitter (leaves) are part of the ongoing process. A few years ago, the university established the Center for Environmental Sciences. This is a multidisciplinary institute, where various professors from different disciplines work together. This has become the main contact point which enables easy access to the right expertise needed for specific questions or research pertaining to the project agenda.

Gadjah Mada University

Paul Burgers has worked with the Forestry faculty of Gadjah Mada for a long time. One of their staff members, Dr. Ari Susanti, works part-time for CO_2Operate BV offering practical expertise on a number of topics. For example, recently she joined during field activities where she helped farmers with how to avoid stemborers (insects that bore into stems) damaging their clove trees. Very simple measures like fermented cassava in bottles in the tree, or putting lime along the tree trunk, reduces invasive damage from the stemborer. Farmers were shown how to identify the signs of invasion and actions to take to prevent the loss of the tree. Removing the affected branch and keeping the area under the trees branches clear of biolitter offer less hospitality to the stemborer. The clearance of the biolitter also enables easier leaf harvest for essential clove oil, which is a new activity by Co2 Operate and RPL.

I4 Legal compliance

CO_2Operate BV is recognised as a social enterprise, and thus included as a member in the social enterprise network, the Netherlands. CO_2Operate BV adheres to the European definition of a social enterprise (see https://ec.europa.eu/growth/sectors/social-economy/enterprises_en).

In addition, CO2Operate BV has been evaluated by Dutch Development Bank FMO for funding opportunities. This has also been based on approval of adhering to the IFC performance standards e.g. environmental and social governance (ESG), health and safety at work and employment law. A due diligence has been conducted about us and our activities, and FMO staff has visited and evaluated the program in West Sumatra. Approval was given after all these checks, , and a contract for obtaining development capital was signed late April 2020.

Child labour is absent, as working in upland fields is the task of the husband/men. Indonesia has strict labour laws, and child labour is not practiced in our areas. Click the link for going directly to the Indonesian labour (Indonesian Labour Law - Act 13 of 2003 (ilo.org).

In the contracts we make with RPL, we have included the IFC performance criteria as well as the basis for ethical work.

The above-mentioned structure under I means that the program is well embedded in local governance structures, and local partners play key roles in the success of the program. The long term collaboration with STKIP has resulted in signing a Memorandum of Understanding some years ago, and is updated every 5 years. Setting up the Indonesian, local NGO, *Rimbo Pangan Lestari* (RPL) also offers considerable advantages (Annex 8 shows the memorandum of association). They are the legal representative of CO_2Operate BV activities in the field. Through RPL the participating farmer groups get official recognition from district authorities. This allows them to open a bank account, which allows the carbon payments to pass through the local NGO and go directly into the participants' bank accounts. The farmers groups are formed following FPIC processes. New participants are invited by a farmer group and are usually part of the same tribe or clan. The food forests are constructed in mountainous areas where wild animals are present, this makes the work only suitable for adults. Child labour is abhorrent to the CO_2Operate BV philosophy.

The matrilineal society of the Minangkabau provides equal opportunities for both men and women. In fact, men only get access to land when women give permission, as land is exclusively owned by the females. Only land that falls outside the *Adat* boundaries and outside state-owned land could be owned by men. However, there is hardly any such land in the current program area.

I5 Project management

Figure 32 shows the team and organisation to date in more detail. Some boxes have no names, as we aim to fill these positions with new people as we scale up our activities. For the coming period, CO_2Operate BV aims to build a larger organisation. Since the PDD focuses mainly on carbon, the component of product development is secondary but in progress. All partners in the *Gula Gula* Food Forest Program see sustainable product development as a crucial indirect benefit for long term carbon sequestration. Providing market links for all farmers who own trees, both participating as well as non-participating farmers in the food forest carbon project will continue protecting and managing their trees, knowing that they have a long-term, secure (and superior) market for their sustainably produced products.

Paul Burges is mainly involved in business development. The (online) communication for marketing purposes and for client relationships is handled by Niels Lap and Max Graven of Studio Boemel. Our Indonesian, Jakarta-based CO2 Operate member, Rizki Pandu Permana, is the bridge between the EU and Indonesia. He manages and directs operations in Indonesia. He is in constant contact with RPL and the people in the field. This structure will allow growth and manage the scaling up phase, which has In 2020.

Although CO_2Operate BV Staff and RPL will ensure technical support and capacity building, this is further embedded through the involvement of staff members from various knowledge institutions. The staff from the teacher's college STKIP, together with RPL staff, conduct trainings and other capacity-building activities, including carbon assessments. As STKIP staff's daily work is training young people to become a teacher, their didactic qualities, even at grass roots level, offer the farmers solutions to becoming credible forest entrepreneurs.

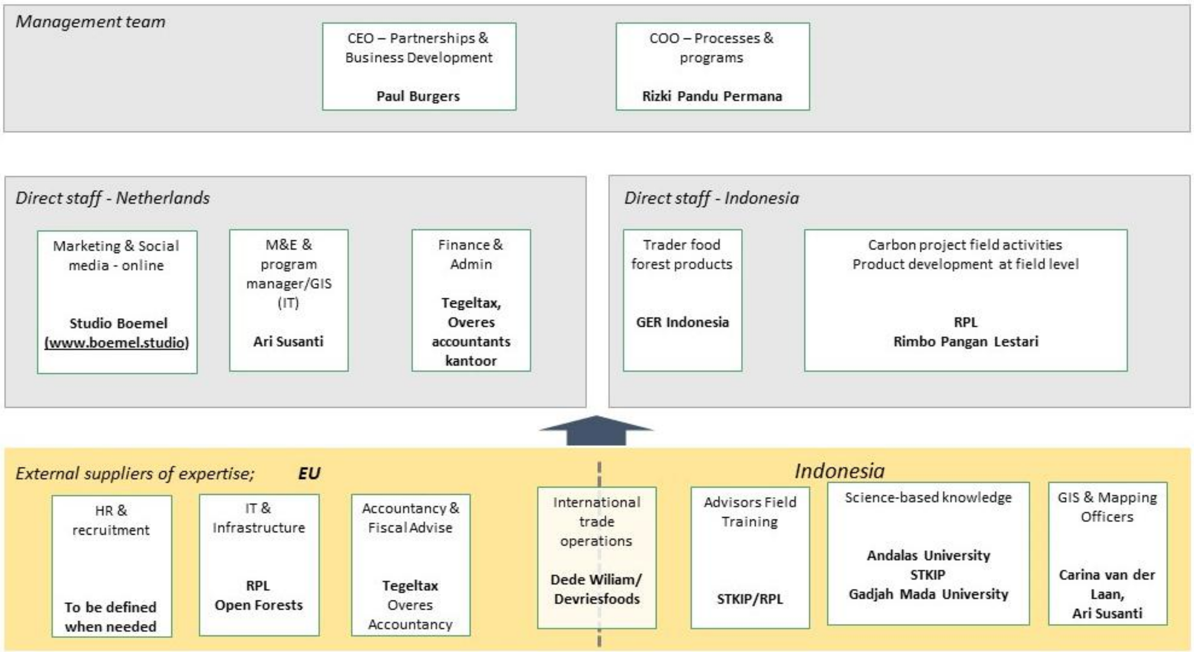

Figure 32: Detailed lay out of the program coordination and field teams in the Netherlands & Indonesia

Building a larger organisation is needed to further strengthen scaling-up activities. These are summarised in Figure 33, which not only graphically illustrates the scaling up phase, but also includes the milestones and achievements to date.

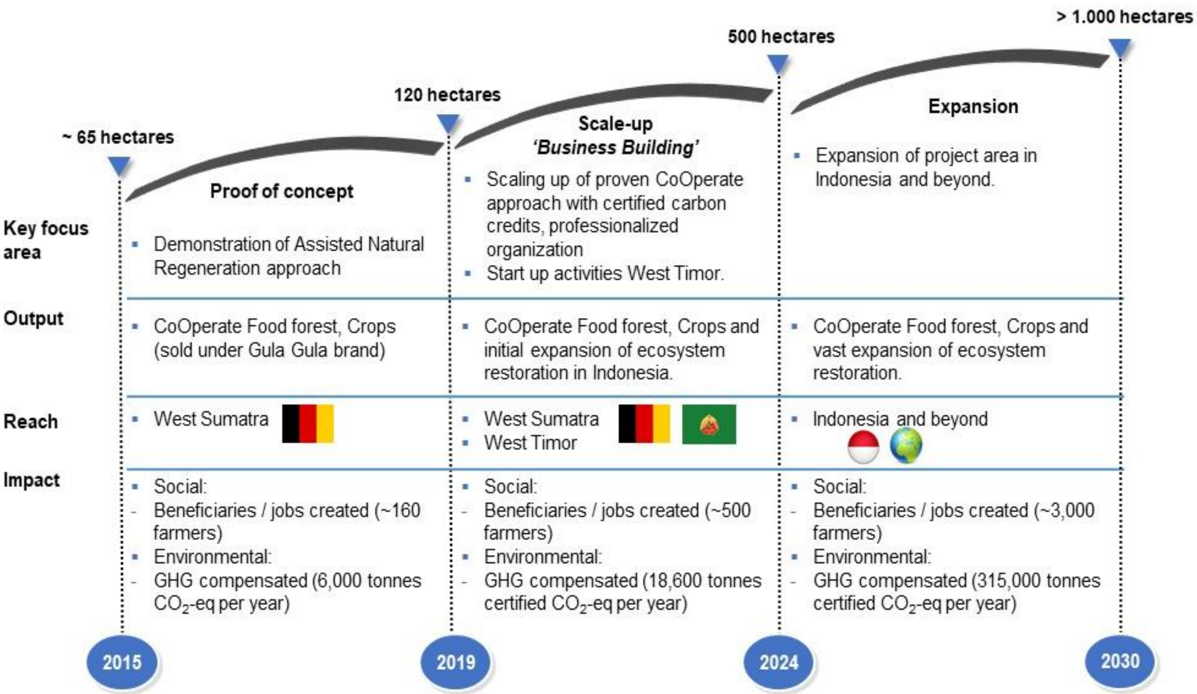

Figure 33: Time-line for scaling up activities.

I6 Project financial management

Figure 33 describes the overall budget for ecosystem restoration over the years. Other income sources, including consultancy assignments (e.g. LCA studies) are not included as they are not directly linked to the *Gula Gula* Food Forest Program.

Most recently, a new carbon contract has been agreed with an off-setting client worth € 260,000 in total (financing that covers a 67 ha reforestation site until 2024). Last April 2020, a substantial amount in development capital, worth € 500,000, has been secured from the Dutch Development bank FMO. Regulations for carbon certification stipulate that tree planting activities before 2014 cannot be included in the certification process. A complete and detailed lay out of the calculations, tree planting dates, clients, claimed and unclaimed carbon since the start can be found in Annex 12. We have not included the 165 ha we have worked on in Central Java in the early years (2008-2009), as these are no longer part of the program. **Error! Reference source not found.** below provides a summary of the total carbon sequestration in the different sites to date.

Table 14: Planting year, ha rehabilitated, and (un)claimed carbon credits (certified/uncertified)

Location	Planting year	Ha rehabilitated	TACO2net* total	Claimed CO2 sequestration***	Unclaimed CO2 Sequestration #	Eligible for PV certification
Paninggahan	2012	29.0	3,751.7	1,638.0	668.8	NO
Agam	2013	33.3	4,810.6	4,760.0	50.6	NO
Eligible for PV certification						
Paninggahan	2019	19.9	3,773.4	2,000.0	1,773.4	Yes
Paninggahan (Subaka)	2019	14.4	2,285.4	2,000.0	285.4	Yes
Air Dingin	2020	65.5	19,694.9	17,225.0	2,469.9	Yes
Paninggahan	2021	2.2	528.9	0	528.9	Yes
Paninggahan	2022	27.1	6,796.0	0	6,796.0	Yes
Selayo	2021	11.0	2,114.8	0	2,114.8	Yes
Selayo	2021	2.5	514.8	0	514.8	Yes
Sirukam	2021	45.7	10,039.2	2,264.3	7,774.9	Yes
Air dingin (koto baru)	2021	14.5	4,237.4	0	4,237.4	Yes
Paninjawan	2022	34.6	7,720.1	0	7,720.1	Yes
Paninjawan	2022	4.5	1,029.0	0	1,029.0	Yes
Total**		**241.9**	**58,733.9**	**23,489.3**	**35,244.6**	

*These are the net CO2 sequestration figures, where buffer planting is already taken out (see excel file Tech Specs).
**Total is for eligible PVs only.
*** Claimed means sold as uncertified, or under reservation for future purchase by clients
# Unclaimed means available stock for sale.

*These are the net CO2 sequestration figures, where buffer planting is already taken out (see excel file Tech Specs).

Figure 34 shows the revenue streams, which includes revenues from carbon sales. In kind contributions come from our local partners. It has been converted in monetary terms, simply because their contributions are and have been crucial to develop the program and also enabled us to reach the stage of up-scaling.

INVESTMENTS AND GRANTS	Informal investor (50% distributed):	**€ 90,000**
	FAO (ANR testing, 2012-2013):	**€ 80,000**
	SBIR faciliteit (2010-2011)	**€ 45,000**
	FMO: Development Capital (2020)	**€ 500,000**
	RVO: TA Funding	**€ 57,000**
IN KIND	Provincial forestry Department (in kind through trees):	**€ 5,000**
	PLN (in kind through seedlings):	**€ 950**
	Indonesian company (in kind through oil distilling machine):	**€ 1,000**
	STKIP/Andalas (staff time & student involvement)	**€ 5,000**
	KU Leuven (Belgium) (staff time & student involvement)	**€ 2,000**
INCOME	Revenue from selling carbon certificates since start in 2009:	**€ 550,000**
	Revenue from product sales	**€ 350**
	Advisory services	**€ 50,000**

Figure 34: Revenue streams to date (updated until September 2020)

With the potential revenues from unclaimed carbon credits, it is important to adhere to Plan Vivo's 40-60 divide for carbon payments. However, it must be well understood that the Gula Gula Food Forest program depends entirely on carbon revenues, or investments which are returned through the sale of carbon credits. In contrast to many NGOs, this program runs without donor funding, hence management costs are also part of the 40-60 divide, as management is directly related to community support to enable the local community members to participate successfully in the program. As an example, mapping is a very crucial component, to ensure that no land will unintentionally be situated within state forest areas (see Annex 12). It is highly appreciated by the participants, who completely lack any knowledge about these boundaries and potential consequences it might have (many of them have no schooling or primary school only). During the FPIC process, when this is being discussed, a forest police officer will discuss what it could mean when land is located within state forest land (see section G6). With the low education of many participants, the support of a local community facilitator is crucial. This person supports the community for a period of at least 5 years to negotiate with the bank about payments coming in, bank account issues, get registration at district level for the farmer group, discuss with the local BPDAS office to obtain the seedlings (a very bureaucratic process requiring polygons and ID cards of each farmer), organise the collection of the seedlings, and whatever is need to directly support the community in the entire reforestation process. The field facilitators have supported each cooperative farmer group to open their own bank account, where annual carbon payments are paid directly from the Netherlands. Each carbon contract shows how much will be paid and when, and into the cooperative account. After the annual evaluation of tree planting and tree counting is finished and agreed upon by everyone, including the farmer group (and if needed replacement of trees), staff of CO_2 operate BV will transfer the amount for that particular year directly and transfer directly into the cooperative account through internet banking. This usually takes 1-2 days, after which the head and treasurer of the cooperative farmer group will take the money and start handing out the carbon payment to its members. RPL staff will usually be present and support in the distribution of the funds, calculating the amount for each member, checking the amount (related to the area they manage) and making sure everyone agrees and signs the receipt of their payment.

Table 15: Average lay-out of the 40-60 divide for carbon payments on a per ha basis (at €13/ton CO_2)

	€ 2275/ha	
CO_2 Operate BV Netherlands (40%)	910	- Staff costs, marketing, overhead, biodiversity and carbon assessments, impact measurements
Indonesia (60%)	**€ 1365/ha**	
a. Direct payment farmers	500	- Direct carbon payments to farmers in 5 year contract.
b. Nursery Development and Training	150	- Polybags, organic fertilizer, seeds, - Net, bamboo poles, rope - Truck hire for several trips to collect seedlings from local government nursery (BPDAS) - Management nursery (1-2 local farmers), raising seedlings. Payment local daylabourers (mostly women)
c. Mapping of farmland participants	55	- Local guides, geography students, GPS use, map making, accommodation and meals.
d. Local community facilitators (for a 5 year period) (a form of local employment)	350	- Supervision, supervise/help with carbon payments, facilitate bank account, organise farmer groups and meetings (incl. FPIC process, participatory monitoring), contract negotiations/signing, facilitate seedling distribution, tree (growth) records for each participant.
e. Project field expenses, including trainings (for a 5-year period).	275	- Facilitate transport for participants to meet, costs for meetings (incl. meals), vehicle/motor rental - Training ANR (booklets, writing materials, planks, ropes, - Training nursery establishment (booklets, writing materials, food).

		- Training on importance of mapping, use of GPS for selected participants.
f. Farmer souvenir (hat, t-shirt)	10	- Important for participants to wear a T shirt of hat from the program.
g. Back up	25	- Needed for potential tree replacement costs. Whatever is not used after 5 years, it is used to include more farmers.

I7 Marketing

Error! Reference source not found.shows what carbon credits are eligible for planvivo certification and which are not (those planted before 2017). However, these credits had already been sold as uncertified ex ante credits. **Error! Reference source not found.** also shows what credits are already claimed by clients since 2017, and which are still available for sale/unclaimed (73,059.7 credits). Claimed, not yet certified credits will be taken out of the market for the clients who made ex ante payments since 2017 for their emission reduction targets. Some unclaimed credits of an existing client may eventually be sold to compensate for new emissions by the organisations when appropriate.

Some unclaimed credits are exempt from these agreements, and can be sold to external organisations who many not require certified credits. CO_2Operate BV has had numerous meetings with buyers reselling organisations to scope potential sales opportunities for these credits, and will continue this so until suitable buyers are found. There is high interest among organisations to buy Gula Gula Food Forest carbon credits.

J Benefit sharing

J1 PES agreements

Entering into PES agreements with the local villagers is an integral part of the CO_2Operate BV FPIC process (see section E1). All components, including performance indicators, penalties and evaluation before payments, are discussed in detail with the new participants. If new groups wish to make amendments or changes to contracts, this will be negotiated to fit stakeholder requirements. What works for one group may not be valid for another group. That is why, with each new group of participants, the FPIC process is carried out to cater to their needs. Participants have their say in the rules, regulations and requirements for all parties in the agreement. Each aspect within the contract is being discussed where the requirements for both the seller (the participants) and the buyer (CO_2Operate BV) are written down in a contract with the new participants. CO_2Operate BV blends the local cultural negotiating techniques (a form of traditional FPIC) with the FPIC standards agreed by the United Nations and the International Labour Organisation (ILO). This gives a stable negotiation platform to protect both parties and build a mutually beneficial future together.

The *Minangkabau* have special terms for any intervention that is brought to them. Negotation (*muryawarah*) and reaching consensus (*mafakat*) are two steps that always need to be followed. Once consensus has been reached with the (new) participants, the contract is finalised and will be signed by, and in the presence of, the participants, the heads of the farmer group, and the village head (the *wali nagari*). The *wali nagari* is also the head of the *Adat* council, as such both organisations are represented. A translated PES contract in English about all aspects discussed and covered is provided in Annex 3. Details of annual payments are described in the next session. Every year, before payments are done, farmers and our field staff will do tree counts and monitor tree health. Usually, the first two years are crucial for trees to establish. During the first two years there may be some replacement of trees. Once all are established, root systems have developed, trees will continue to grow, and no deaths are recorded anymore. Trees that may be replaced are being replaced (and changes are recorded). Since our team is always in the field during weekdays, and organise at least once a month a monitoring meeting with the participants, tree replacements are quickly responded to, and are more of an on -going process throughout the year. This means that hardly any significant delays are experienced after one year, when payments are due once annual targets are achieved.

Table 16 Annual tree planting targets for payments to farmer participants

	Monitor annual tree planting targets per farmer	Carbon payments (% of total 5 year payment)	Tree planting target
Year 1	-Field preparation (ANR and/or Slashing) - Digging holes for trees - Plant trees for that particular year	40%	Land preparation done Nursery established and all seeds planted
Year 2	Finish all tree planting if needed	20%	100% of targeted trees are planted.
Year 3	Monitor tree health/growth Replace trees if needed	20%	100% of all trees planted, including replanting
Year 4	Monitor tree health/growth Replace trees if needed	15%	All trees planted and grow, 100% of all trees planted, including replanting
Year 5	Monitor tree growth Replace dead trees if needed	5%	At least 95% of trees continue to grow. Tree product harvesting begins

This payment system (described in Table 16) covers the 5-year PES agreement (see Annex 3). This is because farmer groups are assigned to buyers (who buy the Plan Vivo Certificates (PVCs) on a 5-year agreement with the buyer. If there are any left-over PVCs, i.e. PVCs that have been generated by the participants but are not covered by this 5-year PES agreement, then the project coordinator will form another PES contract with the farmer group for the sale of these PVCs. Such secondary contracts would have a different payment structure and set of targets depending on the PVCs yet to be sold. Considering that trees would be productive by year 5, the PVC sales can be less depended upon for assuring permanence. However, the project coordinator will ensure that all the 60:40 benefit sharing arrangement is met for any PVCs sold, and the project coordinator will endeavour to sell all PVCs.

As a result of meetings with all the relevant parties listed above, the *Gula Gula* Food Forest Program now has two different types of carbon off-setting contracts to cater to different farmer group requirements supported by the carbon sales.

Contract 1: Offsetting contract (ex-ante), based on project costs: rehabilitation of degraded areas.

A price per ton of potential captured CO_2 is paid in advance (ex-ante carbon credit sales), which ensures that the costs of the project development are covered. These carbon off-setting contracts enable the restoration of specifically-identified new degraded areas, converting the land into a productive food forest. Carbon clients agree as they can see that their investments are making a permanent change for the good. The contract is for 5 years, the time is needed firstly for a large enough average carbon capture and secondly for trees to grow and produce harvestable products, including fruits and spices (see previous sections). The 5-year carbon offsetting contract bridges the income gap between planting and harvesting under specific payment requirements, developed by the participants. Under this contract arrangement, CO_2Operate BV sells the carbon ex-ante to a client.

Over the past 7 years, the monitoring and field-data collection of carbon sequestration on restoring 65 ha of land gives a trustworthy indication of the average levels of carbon sequestration that can be achieved. There is a net-result of around 60 tons of (time-averaged) CO_2 per year during the first 5-7 years of food forest establishment. The benefit sharing mechanism is 33% for CO_2Operate BV while 20% goes to the local NGO (RPL) for program management and farmer support in the field. As RPL directly works for the benefit of the participants, CO_2 Operate BV considers this as a direct benefit for the participants (hence 67% of the funds are reserved as benefitting the carbon program/participating farmers). Approximately half of the remaining percentage is directly invested in the cooperative farmer groups. These group payments cover annual farmer carbon payments, costs related to land rehabilitation, the establishment of seedlings and management of the village nurseries (section I5 provides an example).

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Perbaiki Hutan,
Dapat Rp7,5 Juta per Hektare

First payment of a new carbon contract is sometimes done through a ceremony, by inviting our partners from the local government and/or University. This will attract a journalist from a regional newspaper (here Padang express).

The farmer carbon payment is derived from the initial 5-year contract which comes from payments by clients who invest in rehabilitating the degraded land. In the contract with the participating farmers, a detailed lay out of payments is included. In general, the payments scheme for a 5-year contract is as follows:

Year 1: 40%
Year 2: 30%
Year 3: 15%
Year 4: 10%
Year 5: 5%

It shows that 70% of the contract is paid to participants in the first two years. This division was initiated by the farmers, and to date, the distribution of the funds still follows these percentages. The reason for the high percentage pay-out is in order to make the project successful. The majority of the farmers costs are incurred during the first two years and the trees are not yet producing crops, meaning that a bridging income stream is crucial to success. From year 2 onwards, some trees start to produce a harvest but high value crops like cloves start producing after 4-5 years.

Following the participatory evaluation to check whether the goals have been reached, farmer payments are transferred at the end of that year provided the contractual agreements have been met. If the agreed number of trees have not been planted, payments are withheld until the target has been reached. There is a previously agreed length of time to allow a reparation reaction from the farmer group. This mostly concerns individual cases. During the FPIC process, where the carbon contract was discussed in full detail with all participants, participants have stated that whenever a participant does not perform according to the plan, the group should be able to financially punish or even replace the person. The financial punishment and replacement terms depends on the contracted FPIC agreement that the new groups and CO_2Operate BV made at the beginning of the carbon contract.

Payments are transferred into the farmer group account or to individual farmers. The farmer group uses the funds to either distribute among its members, or jointly agree to invest in productive activities, such as a cattle fattening program, extend the area of land to be restored or any other productive activities.

Contract 2: Price-based offsetting contracts: the (international) trade in carbon certificates once trees have been planted already several years ago.

Sale of carbon credits may follow international prices paid for a ton of CO_2. It may also depend on the type of food forest that will be established. The technical specifications show that some systems sequester relatively high amounts of carbon. In those cases, the amount of carbon credits may be high enough to follow international carbon price mechanisms. It is understood that prices in the international market maty range between U$ 6- U$ 12 per ton CO_2. This way of carbon sales is becoming more important, especially since we received investment funds from the Dutch development bank FMO. Returning the investment fund can be done by selling carbon credits, once the proposed restoration areas have been planted and trees are growing for several years, hence carbon sequestration has already occurred for several years. Increasingly, carbon credit brokers are asking us to become reseller of carbon credits. This provides a good opportunity to sell large amounts of credits relatively easy.

K Monitoring

CO_2Operate BV implements business principles to achieve its predetermined social and environmental goals. CO_2Operate BV has identified several KPIs to gauge the effectiveness and progress towards achieving the economic, social and environmental goals simultaneously. Profitability is measured using annual financial statements and measuring the social and environmental returns on investment (KPIs) that have resulted from the Theory of Change (Figure 1).

The ultimate goal is to reverse the negative effects of poverty and climate change. This goal is to be achieved by using climate smart pro-poor ANR methods that restore the original ecosystem functions, so rejuvenating the land into biodiversity-rich food forests. These produce permanent incomes and increases the value of the standing forests to the farmers, which encourages them to secure the forests' future under local protection. The objectives as described in section A have formed various social and environmental KPIs:

- Amount of carbon sequestration (above and belowground), based on Plan Vivo carbon credits (annex 16).
- Number of hectares of rehabilitated forest (annex 13-15, showing progress and final results per farmer).
- Number of project-employed household members, split by gender (annex 13).
- Income gains for participating farming households compared to minimum wage of West Sumatra (annex 4).
- Quantity of (tree) products brought to market. (Annex 4. Will be intensified, starting 2021).

Biodiversity accounting. Food chain and camera traps already in place. Before project assessments on plant biodiversity done. In 2021 we will begin systematic biodiversity monitoring in collaboration with Andalas University. (pics throughout the PDD, report on before project assessment on plant biodiversity).

These KPI's and communal goals form parts of the contracts between all stakeholders, including the participating farmers. Whenever possible, participatory approaches are used, while most use is being made of local partners. Staff and students from STKIP and Andalas University participate in all impact measurements, being the carbon assessments, socio-economic data gathering and the biodiversity assessments. Table 17 below summarizes the various KPIs, their indicators and who will engage in what activity. It must be noted, that the monitoring reports and FPIC processes (see Table 4and Figure 13: The FPIC process for ecosystem restoration in the Gula Gula Food Forest Program) provide valuable input for measuring/analysing the progress towards achieving the KPIs.

Table 17: The KPIs, indicators and metrics, and who is responsible for what KPI

KPI	Sub theme	Indicator	Metrics	who
		Climate		
Biomass and carbon sequestration in forest landscape restoration activities	Mitigation	# aboveground biomass stock per hectare per year # Belowground biomass stock per hectare/year # soil organic carbon/ha/year # Wildfire events reported each year	Total amount of measured above and below ground carbon per ha from permanent sampling plots (in ton CO2e).	CO_2Operate BV, RPL, participating farmers, staff and students from Andalas University Soil carbon analysis done in soil lab, Andalas University
		Livelihoods		
Economic improvement from restoration	Economic benefits from restoration Access to market	# income change from restoration related activities # of tree products entering (inter)national market	Data sheets showing volume of tree products harvested per year (kg) Income from sale of tree products (euro/rupiah) Producer's share of final price of tree product (euro/rupiah Income from carbon credits (euro/rupiah # participants selling tree products to (inter)national markets (counts)	Annual production sheets by participating farmers, with supported from STKIP students. Data analysis done by STKIP students and staff RPL/CO_2 Operate BV.
Increased social impact from restoration	Perception of nature-based restoration Employment Gender balance Social cohesion	# of participants applied ANR # of participants managing restored area after 5 years # collaboration among villagers has increased # of participants in landscape restoration # women involvement in the program	# participants trained in ANR # original versus # participants after 5 years working in land restoration # increase of participants under offsetting agreements (counts) # % of women involved in land restoration.	Farmer group discussion facilitated by RPL/Co2 Operate staff. Data from offsetting contract.
		Biodiversity		
Increase in biodiversity See also table 20)	Community (plant and wildlife) composition and connection between habitats.	# of ha reforested # of indigenous trees # of planted agroforestry trees #Wildlife assessment based on table 20.	# of indigenous trees per ha (protection and planted) # of species of each planted agroforestry trees # Results from rotational camera trapping	(Agro) biodiversity assessment by staff and students from Biology Department, Andalas University, RPL. Wildlife inventories, using camera traps, nets etc.(table 20)

			# increase in tree cover in between natural habitat areas(forest). #bird species, mammals (see table 20 for details).	Use of drones and satellite images

Monitoring climate benefits

Carbon assessments are conducted at regular intervals, namely once every 3 years starting from the baseline assessments, to quantify the increase (and potentially: losses) in carbon stocks within the project area. These actual figures from field measurements are compared to the technical specifications. In this way, it is relatively easy to see if the tech specs outcomes on time averaged carbon stocks are in line with the real carbon measurements. If needed, updated figures based on actual measurements are done. Here we discuss the field measurement methodology.

After pressing Imperata grasses, existing (small) trees can grow quickly, providing favourable micro-climatic conditions for economic valuable trees to be intercropped (bottom right, e.g. clove trees)

Protocols to assess above and belowground biomass

In order to monitor carbon stocks, permanent sampling plots have been established from where we measure and calculate increases in biomass and carbon stocks (Figure 36). Initial selection of fields to set up permanent sampling plots are done using our explorer.land maps where each farmer plot is made visible on top of high resolution satellite images (0.5 - 1.5 meter resolution). This is done together with the mapping staff of RPL, who know every plot as they measured them all in the field. The satellite images have a good enough resolution to make inventories of the baseline vegetation. We will select plots based on these images and with agreement from the mapping staff, based on

variations in vegetation cover (if any), altitude or steepness of the area. If there is hardly any variation, as is the case in Air Dingin (all bare land covered with ferns), fewer plots are set up to measure progress. We will also decide on variations in planting densities and selected tree species by the farmers. Once these are selected, the team will do the ground-check and set up the circular permanent sampling plots if all is ok (as described below). From experience we know that this works well, and no alternative locations needed to be found. Doing this selection using our satellite image from explorer.land works well, efficient, time-saving and saves substantial costs.
The carbon assessment is based on the IPCC guidelines (IPCC, 2006) including the following three steps for assessing the various carbon pools at plot level:

- Assessment of aboveground and belowground biomass (root-shoot ratio)
- Assessment of necromass (completed in laboratory of Andalas University, Padang)
- Assessment of soil organic matter (completed in laboratory of Andalas University, Padang).

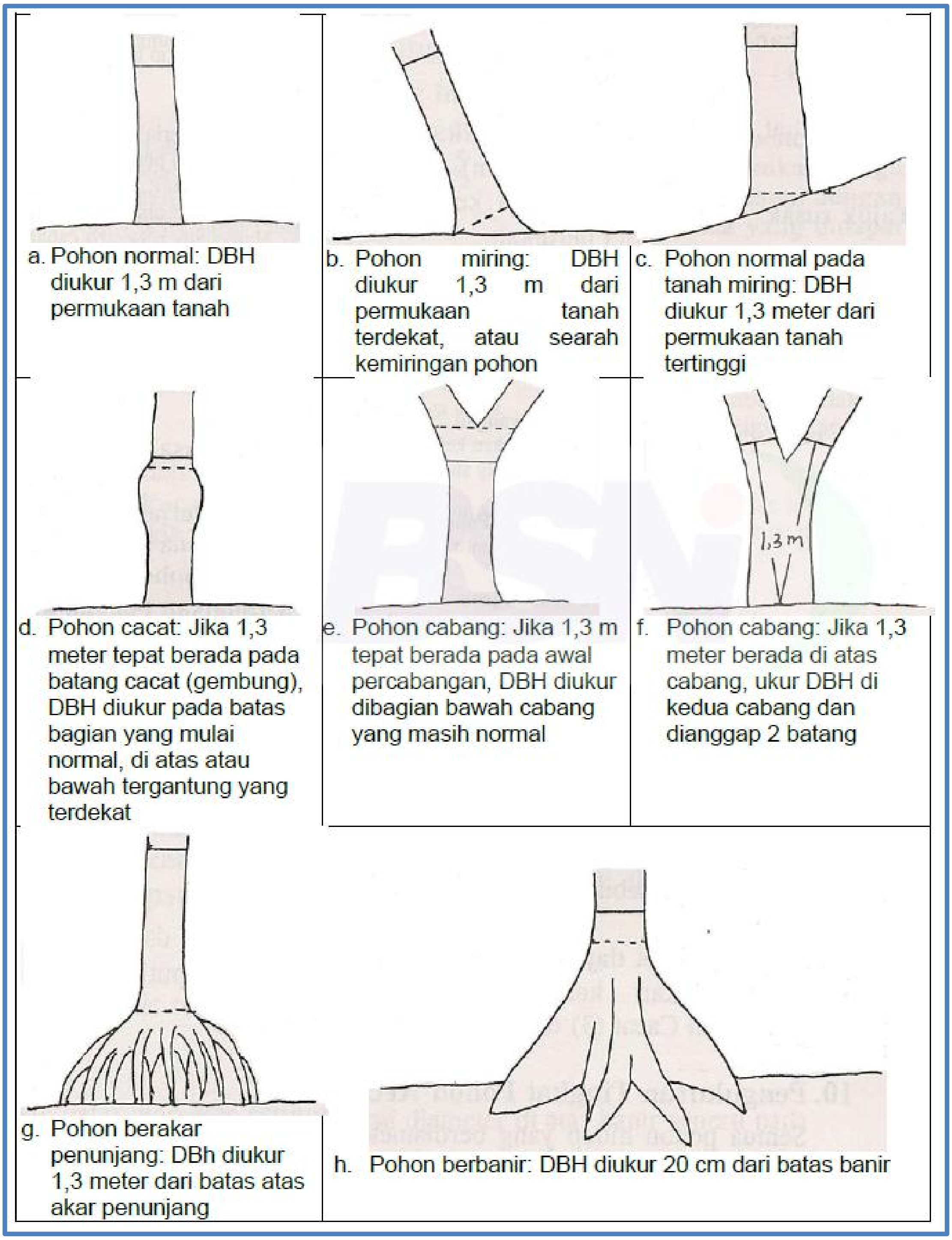


Figure 35: Standardised techniques applied by our technicians when measuring DBH of trees in permanent sampling plots, as described by the National Standard Association Indonesia (BSNI, 2011)

Following Jenkins et al. (2018), the chosen plot size and shape must be used for all plots in the stratum. In addition, it was assumed that soil fertility and steepness of the slope would have an effect on soil properties (solum depth, soil nutrient element content, soil humidity, etc.). This assumes to influence the growth patterns of the trees, and the carbon sequestration associated with the tree growth. We have therefore also made a distinction between upper, middle and lower parts of the hills to set up permanent sampling plots. The lay-out of our circular sampling plots are shown in Figure 36, which follows the method developed by van Laar and Akca (2007). As shown in the figure, three different compartments are distinguished and laid out in the field to measure trees with different DBH ranges.

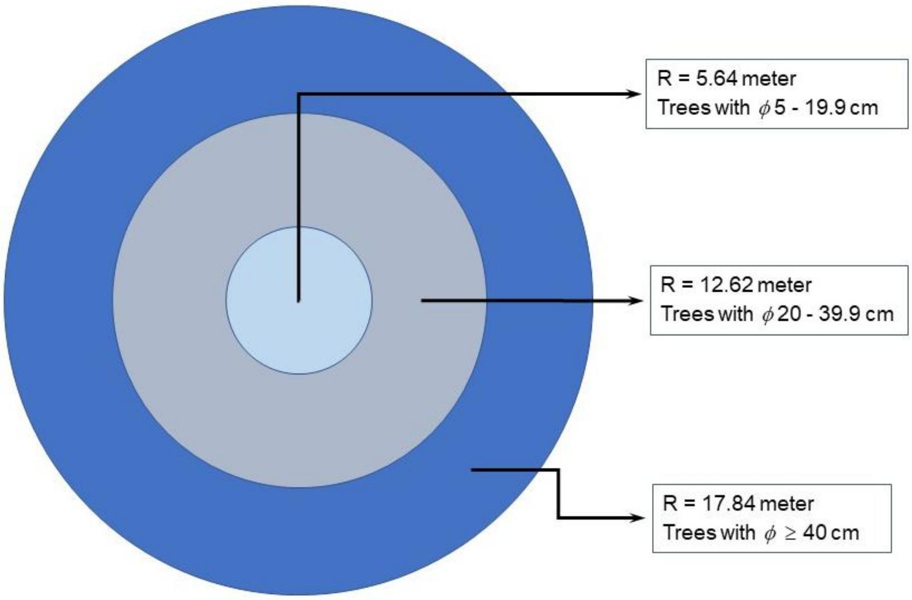


Figure 36: Circular sampling plot with three compartments to measure trees with different DBH ranges.

Source: Based on Van Laar and Akca (2007).

To calculate AGB biomass, an allometric formula developed by Ketterings (2001) is used:

B= biomass

P= wood density

D= diameter at breast hight/dbh

$$B = 0.11\ p\ D^{2.62}$$

This formula was considered as the most appropriate for the prevailing site conditions at the *Gula Gula* food forest project site across the various plots. To calculate the carbon in trees, the carbon percentage suggested by the ISO 7724:2011 (Indonesian national standard) was used:

C= Carbon

B= Biomass

$$C = B * 47\%$$

Field measurements are done by staff from RPL and senior staff from the Geography Department of STKIP. CO_2Operate has provided training in conducting the biomass measurements. The training was done by the carbon assessment expert of the World Bank in Jakarta. Being well-trained, with support from the carbon expert regarding the initial lay out of the permanent sampling plots, students from STKIP conduct the DBH measurements, with help from the participating farmers. Farmers usually help with DBH measurements, since it gives them insight into the growth of the trees. STKIP staff also join the fieldwork to have a thorough understanding of the field conditions when doing the calculations of the carbon assessment data. The carbon expert of the World Bank usually checks the outcomes of the DBH and carbon estimations to ensure external verification of the results.

Root-shoot ratio

The root-shoot ratio was estimated using the approach developed by Hairiah et al. (2011), and is specifically geared at the Indonesian context. For upland areas, a root shoot ratio of 10:4 is considered valid. This means that the roots are about 40% of the AGB.

Litter

Dead wood with a diameter of less than 10 cm and other fallen material such as twigs, leaves and branches, are categorised under litter. Measurements for litter were made in the form of a circle with a radius of 30 cm using the approach in AR-AM0002/version 1 of 2006. For practical purposes in the field, we could use a rattan or steel ring with a radius of 35 cm. Litter measurements were made in the plot centre of the AGB measurements.

For the assessment, we decided to use the stock-change approach, rather than the gain-loss approach, as the community plantations are mostly planted with longer period tree species (hardwood, fruit trees, spices trees). As carbon pools, above-ground biomass will be analysed. Tree biomass can be measured non-destructively, using allometric biomass regression equations. Below-ground biomass may be estimated by using an available root-shoot ratio (RSR), as described above.

Soil

Soil samples are taken using the 35 cm rattan or steel ring used for litter sampling. After taking out the litter from the ring, soil samples are taken from the plot centre. The scoop is put 30 cm deep into the soil and the entire soil sample from the scoop is put in a plastic bag. Then the wet weight is noted down and taken to the soil lab at Andalas University. Subsequently, the soil samples are analysed in the lab on their soil carbon content. The necromas is, together with the soil samples, taken to the lab in Andalas University, where it is analysed for its carbon content. This is made possible because of our collaboration with Andalas University, and we only need to pay for materials used, which means that all analyses can be done at very low costs.

Carbon assessment in practice: aboveground carbon measurements and collecting soil for analysis using a coloured rattan ring. Heavy rains do not stop the team.

Calculated climate benefits

At regular intervals for the last 8 years, carbon assessments have been conducted. This is carried out by a team of CO_2Operate BV staff, students and staff from the teacher's college STKIP and local participating farmers. Lab analysis of the carbon content in litter and soil took place at Andalas University, Padang. Figure 37shows the results. All of the project land is covered with *Imperata* grasslands, either with or without ferns, shrubs or sporadic trees.

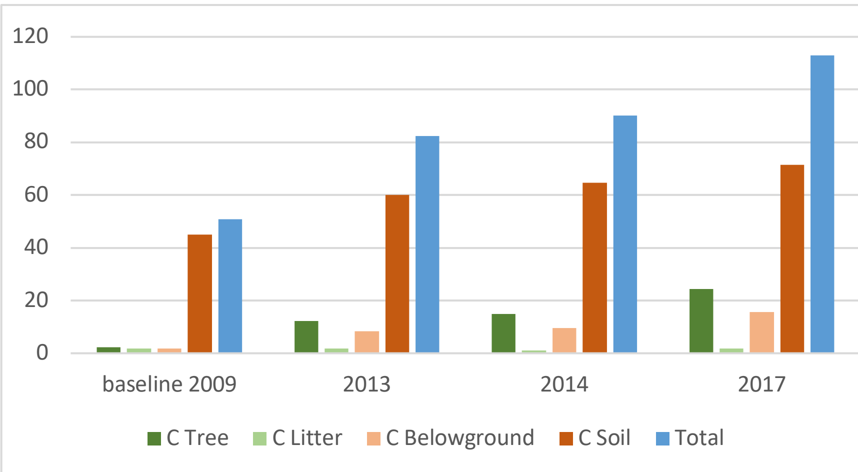


Figure 37: Carbon sequestration (tC/ha) in above and belowground biomass, including soil carbon

Source: Field data carbon assessments

Monitoring performances of the cooperative farmer groups and individual members

CO_2Operate BV creates various performance-based cooperative farmer groups and MOU's, depending on the role of the stakeholders, but it always aims at achieving the communal goals together. Creating as much overlap as possible between the stakeholders to offer transparency through monitoring, verification and reporting is seen as a good way to learn from each other, and move forward together.

Table 18 summarizes the monitoring and evaluation exercises. Participatory monitoring is carried out on a monthly basis between the farmers and RPL. This supports direct project progress in line with the farmer carbon contract. The carbon assessments are carried out by staff and students from STKIP, Andalas University, RPL and local farmers, who enjoy doing measurements with RPL and students.

Monitoring and evaluation with individual farmer groups usually take place in the field, sometimes during/after dinner. The mosque accommodates the sessions with all participating farmers (left).

Data from the harvests of (tree) products are monitored by farmers themselves. However, support is given by RPL field staff and students from STKIP to record annual production data. In the future we aim to export some tree products as well. These records will be kept by CO_2Operate BV staff.
The main monitoring is carried out by the farmer groups themselves, facilitated by RPL. The farmers have identified the benefits of the project and are acting positively to build a better future. CO_2Operate BV puts the farmer in a central position with special attention to farmer requirements. The first two years of a contract were designed jointly with the participating farmers to ensure that the participating farmers have a large sense of ownership of the carbon project they are working on (see Table 4).

The outcomes of monitoring sessions and work are recorded by the relevant field staff and reported back to CO_2Operate BV using a template. This template is filled in every month (See Annex 5 for an example).

At least twice a year, the staff of CO_2Operate BV visit the area and organise progress meetings with the farmers to discuss any issue related to the program. Issues to be raised are already prepared by RPL, so that meetings can be conducted in an open discussion efficiently. In addition to listening to farmer's concerns, issues (if any) raised by RPL staff are also jointly discussed. There is however daily/weekly contact throughout the year with RPL staff, using WhatsApp, WhatsApp call or skype and email. This enables most issues to be resolved prior to visits and meetings.

Table 18 Detailed lay out of the participatory monitoring and evaluation

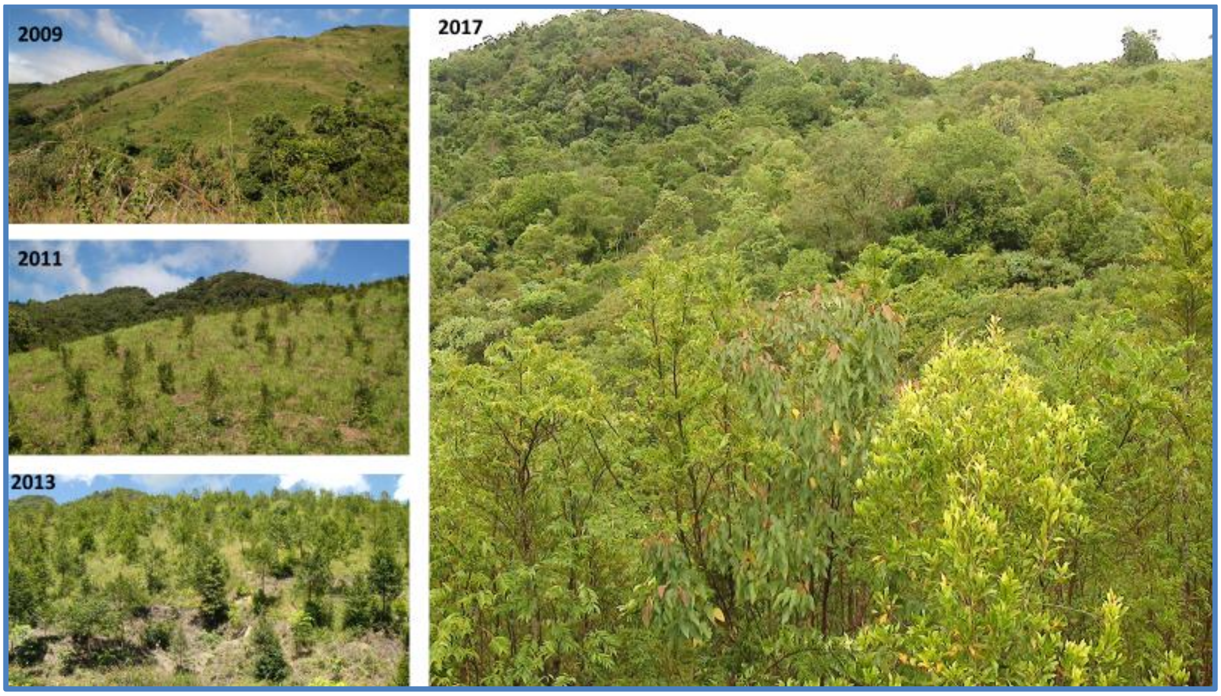
What	How	when	Why	Who	Output
Internal monitoring by farmer groups	Each farmer group meets regularly to discuss progress and issues	Monthly	To identify issues or challenges in time, and monitor progress.	Head of cooperative farmer group, with members.	List of achievements and to do things for next month.
External monitoring by RPL	Checks in the field with participants on tree growth and potential issues for discussion.	Monthly	Identify in time issues related to tree growth/planting, monitor participant performance.	RPL, head of cooperative farmer groups, participants	Monthly monitoring report for Co2 Operate staff to evaluate.
Annual performance evaluation	Evaluate if all annual targets are achieved.	Once a year during a carbon contract.	Annual evaluation is done to make annual carbon payments to each participant.	RPL, CO_2 Operate, the head of each cooperative farmer group , all participants in that particular carbon contract.	Report on tree performance and income from tree products. Sheets with individual payments to participants.
Carbon sequestration monitrring	Carbon assessments following IPCC methodology	Baseline assessment, & than once every 3 years.	To monitor progress in carbon sequestration targets.	RPL, students from STKIP and Andalas University. Soil Lab Andalas University.	Files with field data on above and below ground carbon sequestration.

Annual participatory evaluation, together with RPL staff and the farmer participants, are conducted with CO_2Operate BV staff in the field before carbon payments are made. Together with participating farmers (usually the head of the farmer group with 1-2 participants) field checks are carried out on tree growth and planting. If the targets are achieved, funds are transferred. If agreed farmer targets are not met, the farmer group concerned is given 4 weeks to meet the agreement before their payment is transferred. If there is still not enough progress, cooperative farmer group members discuss how to solve the issues quickly. In many cases, these relate to someone lagging behind the schedule. Participants themselves have in the past regularly decided to replace a person who did not perform well. These "repercussions" are entirely brought forward by and done by the farmer participants.

The *Adat* council is available for adjudication if the problems cannot be resolved within the farmer group. The KPI's are measured annually or whenever it becomes useful to measure (e.g. it takes 2-5 years before trees start producing fruits, so income improvements depend on harvest times).

K1 Ecosystem services benefits

In relation to ecosystem services benefits, from day one of the project, CO_2Operate BV has monitored tree growth along with carbon sequestration in both the actively restored ecosystems and those where natural regeneration is taking place. CO_2Operate BV has carried out carbon sequestration monitoring for more than 8-years. Picture have been taken to monitor change (see below and page 35). The indicator used is *gains in carbon stock compared to previous land use according to the baseline scenario* (mostly *Imperata* grassland). Carbon assessments are conducted at the start of a 5-year off-setting contract (baseline), after 3 years, and after 5 years (the end of a carbon offsetting contract based on project costs). This allows accurate comparisons between the projected tree growth and increase in carbon stocks with actual figures. Carbon assessments are carried out in a participatory way, where farmers of the cooperative farmer groups, staff and students from STKIP/Andalas University and RPL field staff work together in the field to obtain the relevant data. Involving the farmers means they are able to share first-hand information within the group during their meetings. STKIP staff calculates the above-ground carbon sequestration, while soils and bio litter are being analysed in the laboratory of Andalas University. The total change in carbon compared to the baseline scenario is set out in a table (see Figure 37). These are also given to carbon clients for their own annual CSR reporting.



ANR stimulates the growth of existing indigenous trees. Combined with intercropping of economic valuable trees, a mixed productive food forest establishes within 5-7 years.

Water infiltration

CO_2Operate BV and partners are in the process of collecting hydrological measurement. Farmers increasingly say that there is a positive change in the water availability in the soils as some wells are developing in the food forest.

A well developed in the food forest after 5 years.

We are in the process of developing a plan for monitoring water infiltration. Measurements will be gathered by setting up water infiltration measurement points in the permanent sampling plots used for the carbon measurements. The baseline will be taken from nearby, still existing *Imperata* grasslands locations, which have not yet been converted and match the additionality criteria for an accurate and fair comparison.

K2 Socio-economic impacts

The following indicators were identified in line with the KPIs:

Incomes improve to levels above the official minimum wage of West Sumatra.

Local incomes in general (non-participants) in the river basin have become very irregular, and have seriously declined as fish stocks in the lake are significantly reduced (Figure 5). This irregular work (often day labour to get money for daily needs) has made it hard for CO_2Operate BV to gather reliable measurements as a baseline scenario in the project sites. However, literature sources and local government Statistics (BPS) show that the monthly income is around €70/month, which is almost half the official minimum wage per month for West Sumatra, set at around €154 per month since May 2020 (https://wageindicator.org/salary/minimum-wage/indonesia). CO_2Operate BV uses the holistic project benefits and income streams to increase incomes, targeting above the minimum wage for West Sumatra.

Optimal income improvement projections have been made from the sale of every tree product and for all trees that the participants have planted over the years (Figure 38). Prices are based on actual local market prices (*Solok* district) for all forest products, assuming all the products are made available (not eaten or gifted by farmers) and sold. Although only a selection of the products will be sold in reality, it provides insights into earning potentials. Fruits, especially, are eaten by the *suku* members, and often given away to neighbours for free. CO_2Operate BV monitors income improvements by collecting data on production and sales annually. This starts 2 years after planting, when the first trees begin to produce a harvest. Clove trees, however, start producing products after 4-5 years.

CO_2Operate BV with partners started collecting data by providing the farmers with a sheet, where they can fill in the kgs harvested, prices they received etc. (Annex 4). This gives an annual insight into their income improvements from the carbon project. Adding this to the carbon payments, it represents how much the Food Forest Program enables an income well-above the official West Sumatra minimum wage.

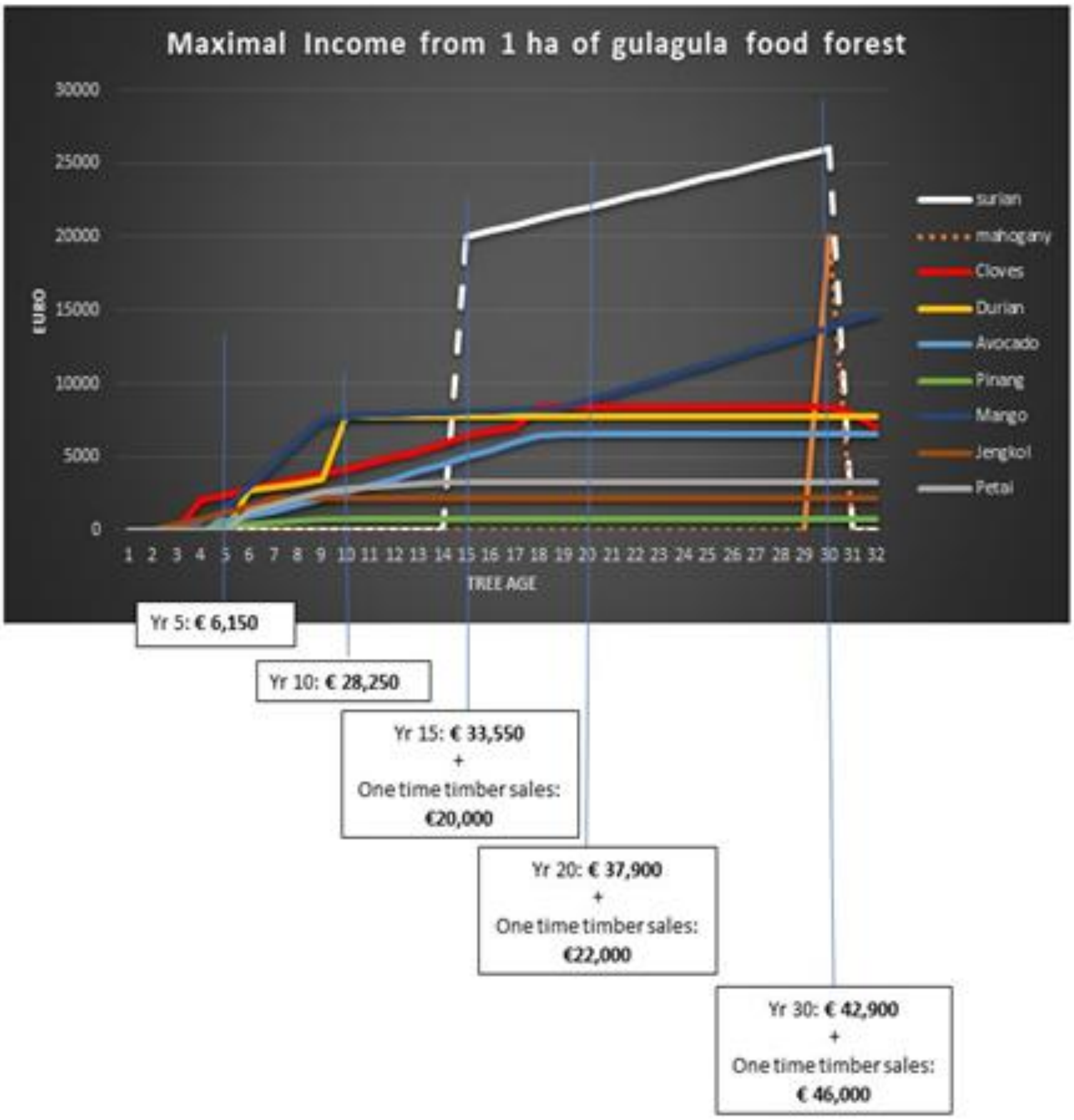


Figure 38: Projection of maximum incomes from tree products per ha, based on local market prices.

Improved market access for biodiversity-rich forest products

Since trees planted at the beginning of the program are beginning to produce substantial quantities of tree products, a recent development to improve and diversify socio-economic conditions from the carbon project is to support the community with improved (global) market access for their tree products. For now, the focus is on cloves and essential clove oils (from clove leaves). Supporting market access for the food forest products will also increase the security of permanence, as incomes are secured when tree products are harvested and sold.

Once a market is secured for these products, CO_2Operate BV will increase the product range, by creating different essential oils (e.g. intercropping of lemongrass for oil production), and sales from the *Gula Gula* food forest. For essential oil production, a collaboration has started with an essential oil company in Padang/Jakarta. Farmers are pleasantly surprised to see that fallen leaves can provide another revenue stream. The process of collecting the leaves also reduces tree disease risk as fallen leaves can harbour the stemborer that can damage clove trees. CO_2Operate BV is monitoring the growing interest among participants and non-participants. The big advantage is that this opportunity benefits a wider cross section of the local village community. Some farmers hire people to collect the leaves for them and the distillation machine is situated closer to the village in a controlled environment, which offers alternative employment opportunities. Besides additional employment, it also means that non-participants can easily benefit from the program by selling leaves for distillation. This activity will have direct positive effects on the entire village community, as the market for clove essential oil is increasing worldwide. Purchasing products from the villagers supports income improvements. As the farmers only started to experiment and produce essential oils 2 months ago, the data is young but very promising.

Gender and employment

The involvement of women in the program is also monitored as a part of membership counts and employees. Records are being kept regarding the amount and gender of participants. This includes the monitoring of jobs created. It must be noted though, that we are working in a matrilineal society, where women own the land. Men, who have no voice in access to clan land, can acquire use-rights from the wife's family after marriage, or from their own female line in the clan if not yet married. Men are traditionally obliged to provide the income of the family, hence they are often given land access by the women for income-earning activities. The *Gula Gula* Food Forest Program fills that important function for families. This may explain why a majority of participants are men, who are told by the women to work on the *harta pusaka* land. However, so far, we still have around 40 % direct engagement of women (often unmarried women) in the field.

Both men and women show interest in using ANR for ecosystem rehabilitation

Capacity building

The theory of change (Figure 1) has also included capacity building (training) as one of the KPIs to achieve successful restoration. Every new participant is required to learn how to conduct assisted natural regeneration (ANR) for land rehabilitation, which will provide socioeconomic benefits by ecologically developing their environment into revenue streams.

A second capacity-building program currently being implemented is to teach farmers how to guarantee the best quality of the fallen clove leaves, so that the best grade and highest oil yield can be achieved from distillation. Monitoring the number of farmers, and to what extent the produced oil matches the potential production (a maximum of 2.5% oil can be obtained from leaves if leaves are being processed within 2 days of falling to the ground), is a good KPI for socio-economic improvement, as this shows both income and capacity building components for lasting impact. The initial production has shown that distillation of oil from the leaves reaches between 1.2-1.6%. Hence, improvements on production can still be made by training farmers and organising the supply. This has recently been taken up with co-funding from the Netherlands Enterprise Agency RVO.

K3 Monitoring Biodiversity impacts

Baseline assessments for plant biodiversity in the two villages in Agam district and Paninggahan village, Solok District have been conducted in 2012-2013 by staff and students from the Faculty of Biology at Andalas University. These were done before the carbon projects were implemented into the areas. The main purpose of these baseline assessments has been to determine the potential of the present vegetation for natural forest regeneration and what factors may limit this process. This information is important not only to have an understanding of the baseline in plant biodiversity, but also to estimate biodiversity gains when using ANR techniques. In short, the following methodologies have been used during the baseline assessment for different vegetation clusters (*Imperata* grasslands and secondary forest) :

Quadrate Method/Secondary Forest Sub-cluster

Data of quantitative plant diversity on secondary forest was obtained by determining sampling plots in 300 – 1000 meter long and 20 meter width a line transect made in specific locations. This method is developed by Muller-Dombois and Ellenberg,H. (1974). Along this transect 3-10 square quadrate plots are created. Quadrate sizes are given inTable 19.

Table 19 Quadrate plot sizes for inventory of different plant types

No.	Plant type	Quadrate size (metres)
1	trees	10 x 10
2	Saplings	5 x 5
3	seedlings	1 x 1

Circle Method/Grassland sub-cluster

This method is used for grassland areas, covered with Imperata with or without shrubby vegetation. The common procedures are:

1. Select a representative area to be studied.
2. Position a bamboo pole as central of the circle
3. Mark out the circular sample plot of radius 10 m.
4. Count and identify all saplings in this plot.

Whenever identification in the field cannot be done, plants are taken to the Herbarium of Andalas University (ANDA), where staff of the Herbarium is able to identify the plants, and provide the botanical names.

This collaboration has worked well, and both staff and students are very interested in supporting the gula gula food forest program.In the 4th quarter of 2020, The Biology Department will conduct similar biodiversity assessments in Air Dingin, where we are starting up new rehabilitation efforts, and where cinnamon trees and coffee arabica will be intercropped with present vegetation. These baselines will continue to be done whenever a new area is being restored, and present vegetation cover needs to be identified.

Use of camera traps

In the current food forest areas, participating farmers already noticed after 2-3 years of restoration activities, that leaves of young trees were regularly eaten, branches were cracked, and evidence of wild boar, droppings of animals and foot prints could be found (see pictures on page 25). Also, they noticed more and more birds. Therefore, we place several camera traps in the area to get an idea of present wildlife. The cameras are placed for one month in one location, after which they are relocated. Over a year of rotating the camera traps in a particular food forest area, a good insight into the terrestrial and arboreal wildlife is achieved. The photographic evidence from the cameras shows that animals from every trophic level of the food web can be found. Farmers help with the location of the cameras, as they know exactly where animals can be found in the food forest, where animals seem to enter the food forest area and how they wonder around in the food forest.

Usually, RPL staff and farmers collect the pictures and videos from the camera traps. The participating farmers are excited to see which animals roam around in their food forest. Increasingly the farmers themselves check what is on the camera, and whenever there are new pictures and/or videos of animals, RPL staff is contacted. The files on the SD card of the camera are downloaded on a computer. Some of the pictures taken by our camera traps in the *Gula Gula* food forest.

Currently we are in the process of developing a multi-year plan of biodiversity monitoring with the Biology Department of Andalas University. This will involve biology students, who can do research in our sites (BSc and MSc level (probably even PhD students). Supervision is done by us in collaboration with senior staff of the Department. Table 20 below provides a first draft of what we have discussed to monitor and measure with initial methodologies. A joint proposal for collaboration on the biodiversity monitoring should be ready in September 2020, so that activities can start by the end of 2020, which coincides with fieldwork for students. The Department has already agreed to use equipment from the Department, which includes at least 15 camera traps, bird trap nets and animal traps.

Table 20 Initial overview of biodiversity monitoring project with *Andalas* university.

	Methodology	Frequency	Who
Vegetation analysis	In addition to carbon assessments, a baseline study in new rehabilitation sites, using Plant-diversity index	Carbon assessments once every three years. Baseline whenever a new site will be rehabilitated.	RPL, Biology Department Andalas University. Herbarium FMIPA, Andalas University. participating farmers
Presence of birds	Point counts, 10-15 minutes/count in 1 plot. No, of plots to be discussed with biology departments Net traps Finding nests might add to presence of birds.	4 times per year	RPL, Biology Department Andalas University, participating farmers
Terrestrial mammals	Direct observation of footprints, excrements, animal-incudes damage, etc. One day traps for small animals Camera traps, rotating eqch month in the sites during a year.	During fieldwork, but in a systematic way. To be discussed with biology department.	RPL, participating farmers, Biology Department Andalas University participating farmers
Arboreal mammals	Direct observation dan auditory census binocular and digital camera (nests, footprints, excrements, animal-induced damage) Camera traps, rotating in the site during one year.	During fieldwork, but in a systematic way. To be discussed with biology department.	RPL, Biology Department Andalas University participating farmers
Macro fauna soil	Tulgren funnel (with hand sorting) Soil samples to be analysed (using extraction). To be discussed in more detail with biology department Andalas University.	To be discussed	RPL, Biology Department Andalas University Laboratorium Taksonomi Hewan Jurusan Biologi Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Andalas (FMIPA UNAND)