BUILDING RESILIENT, INCLUSIVE, FORESTED JURISDICTIONS IN INDONESIA

Sigi District

Earth Innovation Institute

LTKL
LINGKAR TEMU KABUPATEN LESTARI

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1 General overview

1.1 Profile

Sigi is a district located in Central Sulawesi Province, on the island of Sulawesi. The district was established in 2008, based on Law No. 27/2008. Previously, it was part of the Donggala District since 1953, when that district was first established.

1.1.1 Population

The population of Sigi District in 2019 was 239,421 people, with about 20% residing in Sigi Biromaru Sub-District. Dolo Sub-District has the highest population density at 854 people per km^2. Both sub-districts are located in the north of Sigi and located close to Palu City, the capital of Central Sulawesi Province, where 12.47% of the province total population reside, although it holds only 0.64% of the total area.

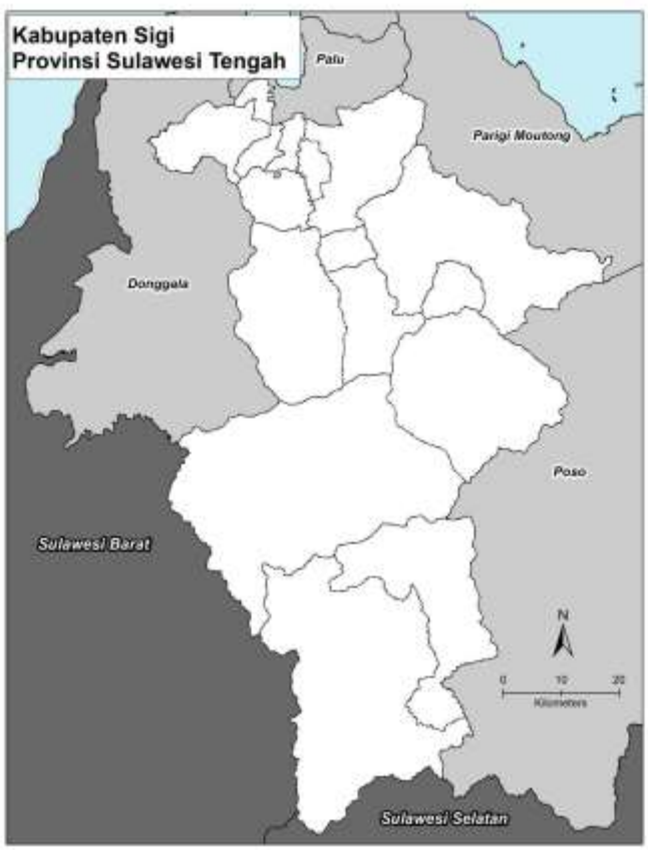


Figure 1. *The administrative map of Sigi*

1.1.2 Main sectors

According to the District Statistics Bureau, agriculture, forestry and fishing are the top sectors contributing to the District's Gross Domestic Product (GDP), with a total of IDR 3,743.55 billion (USD 254.56 million), or 54% of the overall GDP, contributed in 2020. The agricultural products include rice, corn, fruits, vegetables and plantation crops. Sigi District has a large area of agricultural land, 14% across the district and 54% of all areas designated for non-forest use. The commodities that occupy the most land area include cacao, corn and rice. These lands are managed independently by local communities, with support from the district, provincial and central governments.

1.1.3 Livelihoods

In Sigi District, about 55% of the workforce is employed in the manufacturing and service industries, with the remaining 45% in agriculture. The agriculture sector made up 42% of Sigi District's overall GRDP in 2020, making this sector crucial for the district's development. This sector increased from 4 to 6 percent between 2016 to 2019 but grew only 0.5 percent in 2020. According to the 2021–2026 Regional Medium-term Development Plan (RPJMD), some of the main agricultural products include rice, corn, soybeans, coconut, coffee, and cacao.

1.1.4 Geographic profile

Sigi District spans 521,819 hectares (Geospatial Information Agency/*Badan Informasi Geospasial*, or BIG, 2016)[1], with elevation levels varying from 0 masl to about 2,000 masl dominated with areas (35% of total area) with an altitude between 1,000-1,500 masl. Thirty-one percent of the district's area is at an elevation between 500-1,000 masl with the remaining 20% and 14% at an altitude above 2000 masl and 0-500 masl, respectively.

[1] The Regional Regulation No. 1/2021 on Sigi District states that the total area of Sigi District is 521,703 hectares. Due to the relatively modest difference and the use of this spatial data from the topographic map by the Geospatial Information Agency (Badan Informasi Geospasial - BIG) for further spatial analyses, the BIG spatial data will be used in this study.

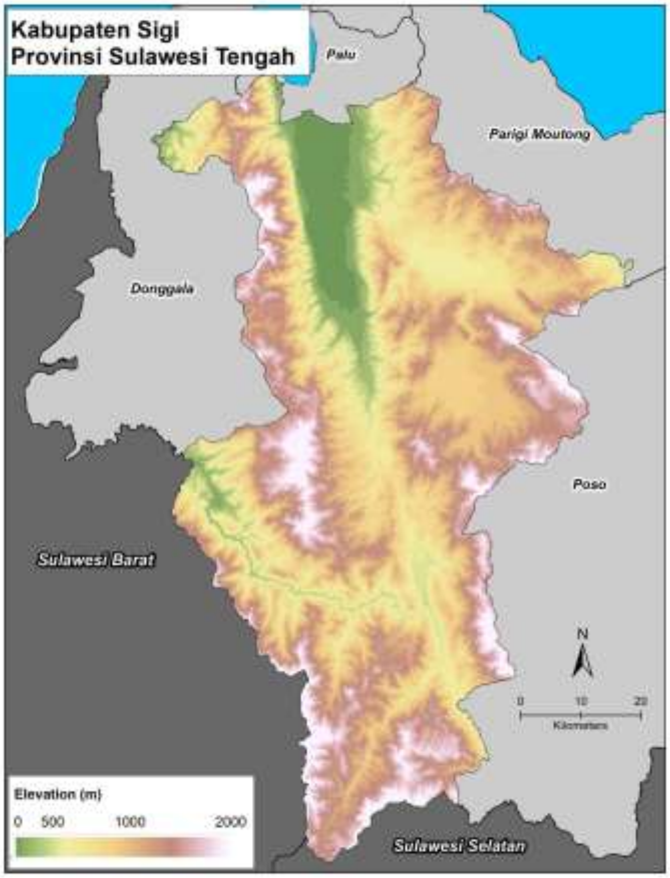


Figure 2. *Elevation map of Sigi*

1.1.5 Policies, commitments, sustainability strategies

1.1.5.1 Sigi Hijau

In 2019, Sigi District government issued Regional Regulation No. 4/2019 on *Sigi Hijau* (Green Sigi), which aims to harmonize the land use and spatial plan to support the district's vision of sustainable natural resource management and environment. Implementation and governance of the regulation will be monitored for environmental and socio-economic sustainability.

The *Sigi Hijau* strategy aims to:

- maintain ecosystem sustainability and restore ecosystem functions that have been degraded;

- increase community and stakeholder participation in the organization and implementation of the *Sigi Hijau* strategy and;

- develop environmental management innovations.

The Green Sigi Program will focus on ecosystem restoration, the creation of green public spaces, the mitigation of weather-related events and climate change, and the creation of networks for environmental management, notably garbage disposal. Additionally, the strategy will actively influence local environmental development and promote the establishment of botanical gardens.

Sigi District has established a multi-stakeholder institution as a key component for accelerating the achievement of joint targets. The members of this multi-stakeholder institution include the Regional Government Agency and development partners, which will function as a strategic forum for accelerating the achievement of Sigi Hijau development targets at the District level.

1.1.5.2 Forest protection

During LTKL's General Assembly in July 2021, LTKL member districts including Sigi, agreed to commit to protecting their forest and peatland areas by 2030, as outlined in the Declaration of the Vision of Sustainable Districts. More specifically, the districts made the commitment to work together with stakeholders across sectors to protect at least 50% of the total forest, peat and other critical ecosystems within the jurisdictions through an approach that ensures that the welfare of at least 1 million families living in and/or around important ecosystems within the districts will be increased. Several means to achieve this target include attracting sustainable investments into the districts, providing new job opportunities and avoiding disasters and climate crisis.

1.2 Forest and land use

According to the Environment and Forestry Ministerial Regulation No. 734/2014, which defines the forest and non-forest zone, the area available for non-forest use, including agricultural activities and urban development, is only 25% of the total area of Sigi District. The rest of the area is designated for forest-related land use, including production forest (25%), protection forest (27%) and national park (23%). These figures are also consistent with the district's latest spatial planning for the 2021-2041 period (Regional Regulation No. 1/2021 on Sigi District spatial plan).

The 2019 land cover data shows that 71% (377,000 hectares) of the district is still covered by forests (60% primary, 11% secondary). In 1990, more than 81% of the land cover was still forested. Between 2009 and 2019, major deforestation and forest degradation were observed. About 9% or 37,421 hectares of the forest were converted to other land uses. During this period, agricultural lands, including rice fields and all other crops, increased by 22%.

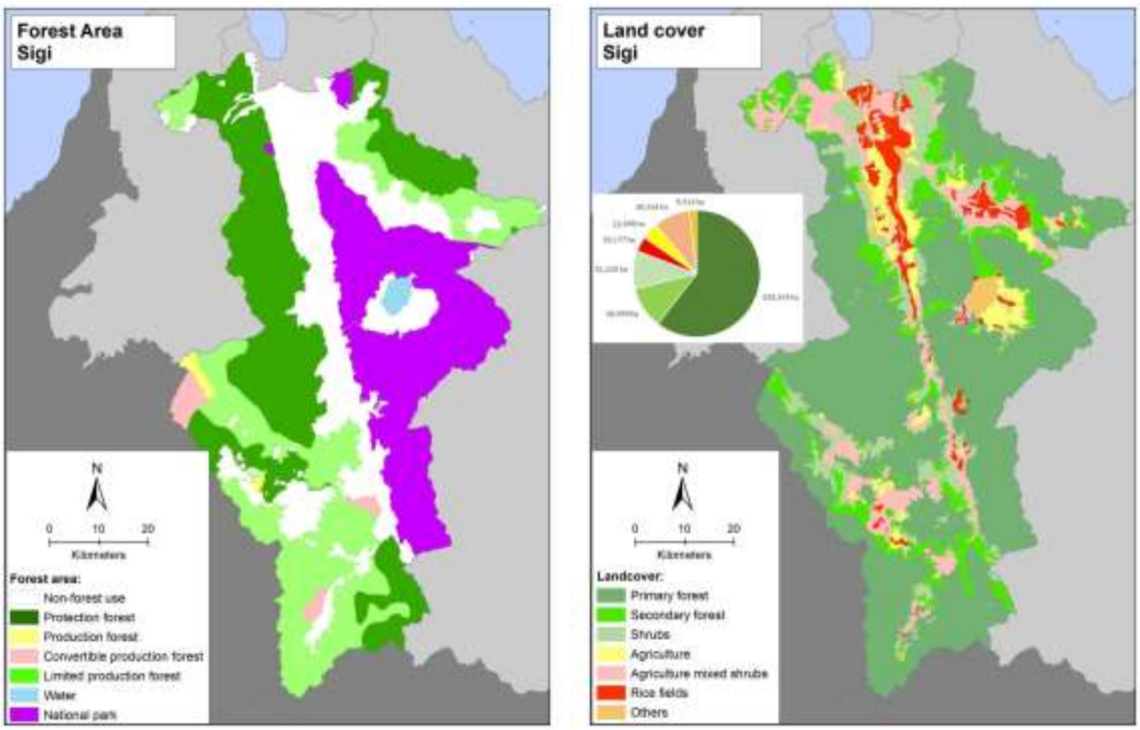


Figure 3. *Maps showing forest and land cover in Sigi in 2019. Source: Ministry of Environment and Forestry*

1.3 Agriculture

1.3.1 Overview

Based on the District Statistics Bureau, agricultural commodities produced in Sigi are divided into four types: fruit, vegetable, plantation and food crops. In 2020, pineapple was the top fruit produced in the district (40,023 tons), followed by avocado (1,249 tons), banana (1,124 tons) and durian (957 tons). For seasonal vegetable crops, chili was in first place with 730 tons, ahead of shallots (627 tons) and tomatoes (287 tons). The three top plantation crops produced were cacao, coconut and coffee, with total district-wide production of 19,224 tons, 2,516 tons and 419 tons, respectively. Rice and corn are also produced in high volumes, occupying a large proportion of the district's agricultural lands. According to the Indonesia Central Bureau of Statistics, 64,949 tons of rice paddy and 56,173 tons of corn were produced in 2020.

Table 1. *Annual production of some top agricultural commodities*

Rank	Commodity | Type		Annual Production (tons)
1	Pineapple	Fruit	40,023
2	Avocado		1,249
3	Banana		1,124
4	Durian		957
1	Chili	Vegetable	730
2	Shallot		627
3	Tomato		287
1	Cacao	Plantation	19,224
2	Coconut		2,516
3	Coffee		419
1	Rice	Food crop	64,949
2	Corn		56,173

The District Government of Sigi has selected a number of agricultural commodities to promote. For staple food crops, the District Government of Sigi has selected corn and rice as its main commodities, whereas for plantation crops, the District has selected coffee, cacao and coconut as their top three crops to promote, according to the district strategic planning document (*Rencana Pembangunan Jangka Menengah Kabupaten Sigi* or *RPJMD 2021-2026*). These crops were selected based on a number of criteria, including land and climate suitability, a designation from the Ministry of Agriculture for Sigi to become a center for agricultural production (as for coffee and cacao), and economical value and demands for these commodities. Considering that Sigi is located close to the new capital city of Indonesia in Kalimantan, the District predicts an increase in demand for the agricultural commodities it plans to promote. According to the 2021-2026 RPJMD, the government aims to enhance the network of collaboration in the commerce and distribution of competitive goods and services with the new national capital.

Strategies to increase the production of Sigi District's main commodities are focused on intensification and diversification of commodities. This means that the production increase is achieved through an increase in productivity within the already cultivated land, as opposed to extensification where productivity increase is achieved through an expansion of cultivated land. To do so, the Government of Sigi District aims to provide and subsidize inputs such as seedlings and fertilizers, technical assistance on Good Agricultural Practices (GAP), and cultivation tools. The Agriculture Agency of Sigi District also aims to strengthen its personnel dedicated to providing technical assistance to farmers to increase the production quality and quantity. In order to give financial support to farmers, the district government provides a 0% interest loan using the district's Regional Revenue and Expenditure Budget (APBD). Moreover, Sigi District aims to strengthen cooperatives and micro-, small and medium enterprises (MSMEs), as well as integrating agriculture, along with culture, nature and the environment, in its tourism sector

Sigi District is committed to pursuing sustainable agriculture, based in the protection of natural resources and traditional culture, formalizing this vision of the agricultural sector in the long-term development plan for 2005-2025. Sigi District aspires to develop into a region that emphasizes agricultural growth while balancing production factors with ecological balance and making use of local knowledge and wisdom. The 2021–2026 RPJMD, the fourth step within the 2005–2025 RPJPD, has 12 key objectives, and two of them—increasing agriculture through intensification, diversification, and extension, and enhancing forest and environmental sustainability—are directly tied to the RPJDP's vision. Sustainable agricultural development, in addition to being contained in the RPJPD, is also regulated in the *Sigi Hijau* regional regulations and implemented by several means, including increasing the capacity of farmers to implement sustainable agriculture with low inputs, introducing the application of organic farming technology, and opening market access for organic agricultural products.

1.3.2 Focus commodities

In this study, we focus on four agricultural products—coffee, cacao, corn and rice—that are produced in large quantities and contribute significantly to the economy of the district. These four commodities also have a link to the district's forest cover changes. The expansion of agricultural land, particularly for the production of these crops, resulted in significant deforestation in the late 1990s to early 2000s. The mid-term development plan document (Rencana Pembangunan Jangka Menengah Daerah or RPJMD 2021-2026) identifies corn and rice as priority staple crop commodities, and coffee and cacao as the top two plantation crops to promote. Therefore, support to increase production of and demand for these commodities may encourage further forest clearing if mitigation measures are not properly designed and implemented. This study examines these four commodities to understand the profitability of their production, the impact they have on the extent of forest cover, and the challenges faced by farmers who want to increase their profits without additional forest clearing.

1.3.2.1 Coffee

Sigi District is the district with the largest coffee plantation area and produces the most coffee in Central Sulawesi Province. This is driven by the strong domestic and international demand for coffee produced in the District and motivates farmers to keep cultivating coffee. Around 30% of the province's coffee plantations are located in Sigi, whose total land area for coffee is 2,641 hectares with an annual production of around 419.2 tons[2]. The average yield of coffee plantations in Sigi between 2015 to 2019 is 0.15 ton/hectares. Kulawi sub-district, with a total land area of 1,143 ha, has the largest coffee plantations among all sub-districts in Sigi. Pipikoro and Lindu Sub-Districts have coffee plantations totaling about 600 ha. With a combined total of 408 tons in 2019, accounting for 97% of the district's overall production, these three sub-districts are the leading coffee producers.

[2] Central Bureau of Statistics. 2017. *Central Sulawesi Province in Figures 2017*.

Table 2. *2018 coffee (robusta & arabica) planted area, production, yield and number of farmers in 2018*

District	Planted area (ha)				Production (ton)	Yield (kg/ha)	Farmers
	Immature	Mature	Damaged	Total			
Banggai Kepulauan	12	15	20	47	1	68	139
Banggai	373	659	149	1,181	298	451	1,632
Morowali	81	125	49	255	50	399	208
Poso	664	1,002	1571	1,823	1,049	1,528	1,865
Donggala	114	536	28	678	356	665	595
Toli-Toli	274	332	18	624	103	310	1,042
Buol	107	279	173	559	154	550	369
Parigi Moutong	204	238	58	500	100	421	638
Tojo Unauna	164	274	5	443	257	939	472
Sigi	1,253	518	931	2,702	431	833	1,255
Banggai Laut	1	1	1	3	0	100	5
Morowali Utara	46	22	1	69	18	811	32
Palu	0	0	0	0	0	0	0
Total	**3,242**	**3,846**	**1,554**	**8,642**	**2,762**	**718**	**8,074**

Figure 4. *Total harvested area and production of coffee in Sigi District. Source: Central Statistics Bureau - Sigi District / BPS Kab. Sigi and Central Statistics Bureau - Central Sulawesi Province / BPS Prov. Sulawesi Tengah*

1.3.2.2 Cacao

Sigi is the largest cacao producer in Central Sulawesi; for the past few years, cacao has been the province's leading export product. Most farmers in Central Sulawesi produce cacao and other cacao-derived commodities. Sigi Regional Regulation No. 7/2019 includes the development of the cacao in the District Industry Development Plan for 2019-2039 as one of the leading industrial commodities.

Palolo sub-district is the center of organic cacao production. Farmer groups that have obtained organic cacao certificates are: Tunas Muda farmer group, Petimbe Village, Palolo Sub-district, Sabarae Farmer Group, Karunia Village, Palolo District, Cahaya farmer group, Bahagia Village, Palolo District. In addition to developing organic cacao, the Government of Sigi District, Central Sulawesi, continues to strive for the management and utilization of cacao in the area based on technology, one of which aims to improve the quality of cacao.

According to Sigi District's Statistics Agency, there were 27,705 tons of cacao produced in 2019, with the Palolo Sub-District producing the most at 10,855 tons. Other sub-districts that also have the potential for cacao development are Gumbasa, Kulawi, South Kulawi, Pipikoro, and Lindu.

Despite being the top cacao producer in Central Sulawesi, the cacao productivity of Sigi District–around 0.7 tons of cacao beans per hectare–is lower than the national average cacao productivity, which is 0.9 tons/ha. Based on data from BPS, cacao yields in Sigi have consistently decreased from 0.72 tons/ha in 2015 to 0.69 tons/ha in 2019.

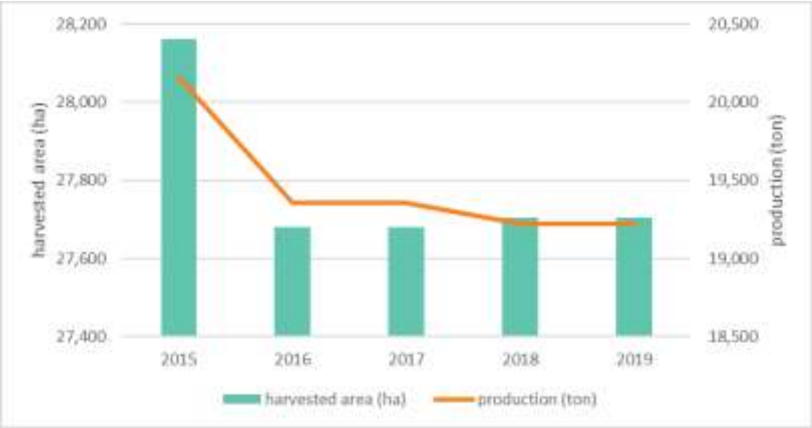


Figure 5. *Total harvested area and production of cacao in Sigi District. Source: Central Statistics Bureau - Sigi District/BPS Kab. Sigi and Central Statistics Bureau - Central Sulawesi Province / BPS Prov. Sulawesi Tengah*

1.3.2.3 Corn

Sigi District is the second largest producer of corn in Central Sulawesi province, with Tojo Una-Una District being the leading producer. While corn is considered a staple food crop, most of the corn produced in Sigi District is intended for animal feed. Despite the higher price tag for corn produced for human consumption (around IDR 5,000 for 3 corn cobs) compared to that for animal feed (around IDR 4,600 for 3 corn cobs), the reduced time required for the animal feed corn variety to become productive (2 months) compared to that for human consumption (4 months) and the larger market demand for corn for animal feed, prompt farmers to choose to produce more corn for animal feed.

From 2015 to 2020, the amount of corn production and planting area in the district increased from around 27,500 tons and 8,500 hectares in 2015 to 56,000 tons and 14,400 hectares in 2020. During the same period, productivity also increased from 3.23 tons/ha to 3.88 tons/ha.

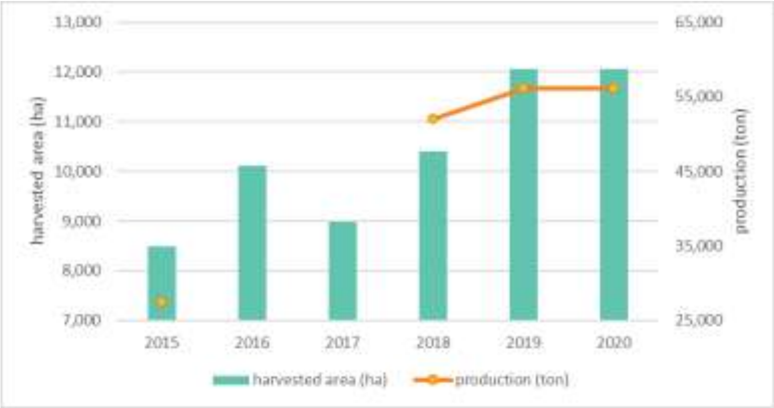


Figure 6. *Total harvested area and production of corn in Sigi District. Source: Central Statistics Bureau - Sigi District/BPS Kab. Sigi and Central Statistics Bureau - Central Sulawesi Province/BPS Prov. Sulawesi Tengah*

In general, every sub-district in Sigi has corn fields; more than 50% of district corn fields are found in Dolo Barat (1,529 ha), Kulawi (1,471 ha), Gumbasa (1,270 ha) and Marawola Barat (1,109 ha) sub-districts. The main varieties of corn produced in the District are hybrid, including Pioneer and BISI-2. The use of hybrid corn seeds is widely used because it has a higher potential yield compared to non-hybrid[3]. Corn fields intended for human consumption can be found in Sigi Biromaru Sub-District, which is located close to Palu.

There are a number of factors that drive local communities to produce corn. The minimum and maximum retail prices of corn are regulated by the Ministry of Trading to ensure the availability of corn, among many other staple food items, and price stability. These prices are set in consideration of a number of factors, such as profits and costs associated with raw materials, labor, land, logistics and distribution and other specific characteristics. If the price of corn falls below the set minimum price, the Ministry will appoint BULOG, a state-owned company, to purchase corn from farmers at the set minimum price. Based on the Regulation of the Ministry of Trading no. 7/2020, the minimum purchase prices of corn directly from farmers range between IDR 2,500 to 3,150 per kilogram, depending on the water content. Such security in the prices, and therefore the profits made by corn farmers, has potentially encouraged farmers to produce corn. Corn

[3] Antara, M. (2010). Efisiensi penggunaan input produksi usahatani jagung hibrida di Kecamatan Palolo, Kabupaten Sigi. J. Agroland. 17(3): 213 – 218.

cultivation is also deemed relatively simple by local communities and requires minimal tending and maintenance.

1.3.2.4 Rice

Rice is one of the leading commodities in Sigi District. In terms of area, the harvested area in 2019 and 2020 was 14,427 hectares with a production volume of 64,949 tons. Meanwhile, according to KLHK land cover data, the area of rice fields in Sigi District in 2019 was 20,177 hectares. The average rice productivity in Sigi District from 2015 to 2020 was 4.5 tons/ha, still lower than the national average yield of 5.2 tons/ha. According to the data collected by BPS at both district and province level there was a significant drop in 2019 harvested area and production volume. This was largely caused by the large earthquake in September 2018 that triggered a tsunami and liquefaction that destroyed the irrigation system for rice fields.

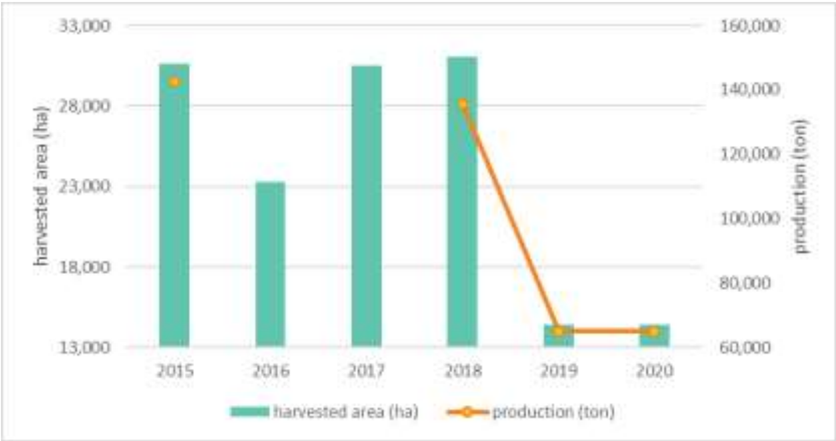


Figure 7. *Total harvested area and production of rice in Sigi District. Source: Central Statistics Bureau - Sigi District / BPS Kab. Sigi and Central Statistics Bureau - Central Sulawesi Province / BPS Prov. Sulawesi Tengah.*

2 Land use change analysis

2.1 Identified drivers of deforestation

The Government of Sigi District has implemented a number of measures to halt deforestation. However, it has still experienced a decline in forest cover over the last three decades. Based on the KLHK land cover data from 1990 to 2019, the annual deforestation rates have consistently declined in that time period. Compared to the decade between 1990-2000, the 2000-2009 annual deforestation rate decreased by 58%. More recently, the 2009-2019 annual deforestation rate also decreased by 65% when compared to the previous decade.

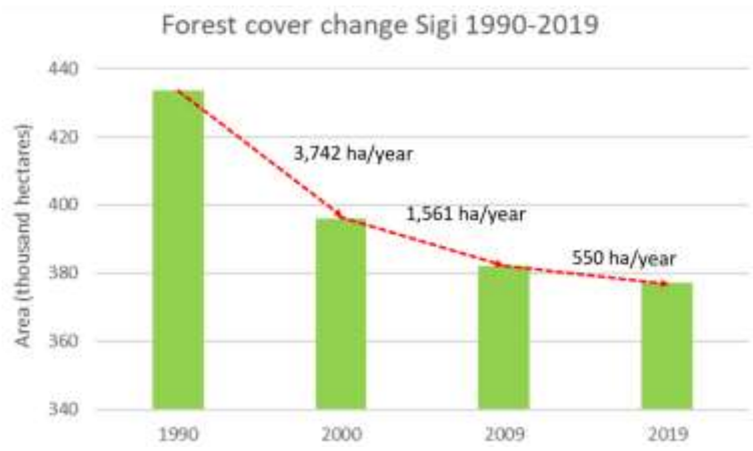


Figure 8. *Forest cover change graphic of Sigi*

Forest clearing occurred in many parts of the district (Fig. 9). Deforestation mainly occurred on the edge of the secondary forests, which are closer to settlement areas. In the southern part of the district, deforestation mostly occurred before 2000. In the northern part of the district, where most settlements are located, some clearing also occurred after 2000.

The Development and Planning Agency has identified a number of drivers of deforestation, including illegal gold mining occurring within the boundaries of the national park. Generally, however, land conversion occurs at the individual level. The District Environment Agency has identified forest conversion to croplands, such as rice and corn fields, as the top strategic environmental issue in the District. Forest conversion has also reached conservation areas, partly attributed to land conflicts between local communities claiming ownership over their lands located in such areas. Based on the stakeholder interviews, many members of the local communities residing in conservation areas stated that they had resided in the areas long before they were designated as conservation areas, and the designation of the areas as conservation areas have restricted their land use activities. The communities also clear forests to grow cacao, even though cacao production has declined for the past five years.

Natural causes also drive deforestation in Sigi District. Unlike many areas in Sumatra and Kalimantan, where a high rate of deforestation occurred due to drought-induced forest and land fires, some of the deforestation that occurred in Sigi was caused by landslides due to the big earthquake in 2018. To an extent, deforestation in steeper areas has an impact on the occurrence of floods when rainfall is high.

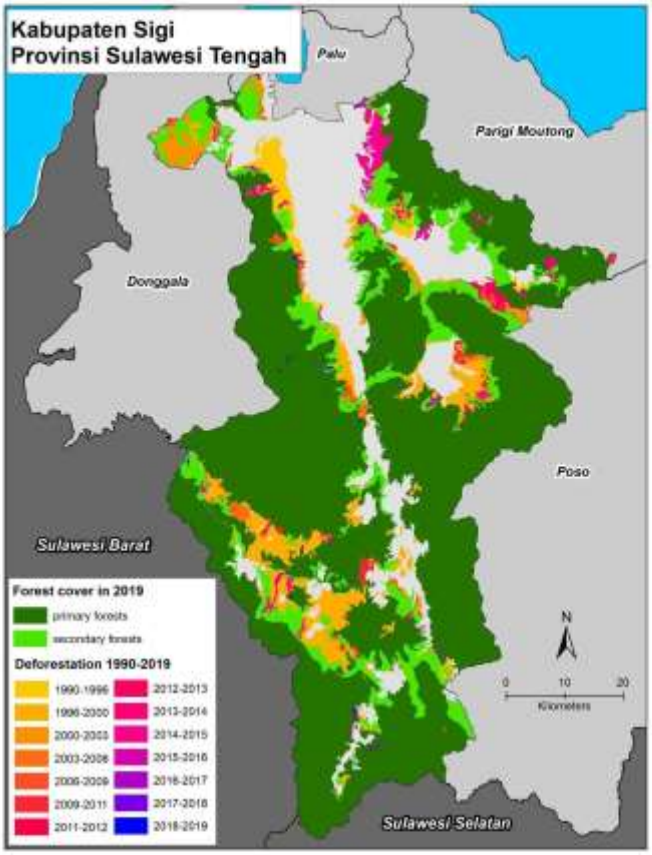


Figure 9. *Forest cover and deforestation map of Sigi*

2.1.1 Agriculture

2.1.1.1 Shifting cultivation

In Sigi District between 1990 and 2000, shifting cultivation was most common in Pipikoro Sub-District, the southernmost sub-district that is hilly and has limited accessibility. Although it is difficult to estimate the total forest lost due to shifting cultivation, according to local residents, this activity was common during the period. Because shifting cultivation has completed a full cycle, new forest clearing is not taking place; rather lands cleared once before are cleared again.

2.1.1.2 Corn

Corn has been a major driver of deforestation in the District, as it provides quick cash. Suitable soil for growing corn in most areas in the district is one of the reasons for the expansion of corn, which can even be planted on steep slopes, which can lead to soil erosion.

2.1.1.3 Cacao

The expansion of cacao plantations reached its peak in the late 1990s to early 2000s, not only in Sigi District, but across all of Central Sulawesi Province. This era also experienced one of the highest deforestation rates that occurred in Sigi District. At that time, it was fairly easy for the community to clear new lands due to lack of proper land ownership certification. Forest was cleared by cutting down trees and leveling the surface to be planted with cacao tree seedlings.

2.2 Potential future deforestation

2.2.1 Increased demand for priority commodities

The Government of Sigi District has selected a number of priority agricultural commodities to support the development of Sigi District and improve the local economy of communities. Apart from the plantation and staple crops described above, other priority commodities include durian, vanilla and candlenut. Durian has become a popular commodity promoted by the district government due to high demand and sale prices and minimal processing required. The Government of Sigi District promotes durian as a replacement commodity for corn around the forest areas and on steep slopes since perennial trees protect soils better. However, adequate planning and safeguards are required to prevent forest conversion to durian plantations; this is particularly important where settlements abut forest areas.

2.2.2 Increased demand for other commodities

Currently there are no commercial-scale oil palm plantations in Sigi District. However, satellite imagery demonstrates that oil palm is being cultivated at small scales by one community in response to demand from companies in the neighboring district. This could threaten forest cover, since the oil palm plantations are located in a village bordering a national park.

2.2.3 Extractive activities

The mining potential in Central Sulawesi is high. Companies and individuals in the districts neighboring Sigi, such as Donggala and Poso, already conduct mining activities. A regulation from the Sigi Head of District, accompanied by strong personal commitment on the part of the current District Head, has so far prevented mining activities in the Sigi District. But given its lucrative potential, mining operations might begin in Sigi District following the District Head's transition after the next election in 2024, if the newly elected leader has different priorities.

2.3 Impacts of deforestation

Floods and landslides are the most common natural disasters provoked by deforestation in Sigi District. Several sub-districts, including Gumbasa and Dolo Selatan sub-districts, have experienced flash floods in the past two years, forcing hundreds of households to evacuate. Some recent landslides have also resulted in the clearing of forest cover in sloping areas, ultimately leading to severe flooding occurring in settlement areas in the lowlands.

2.4 Report focus commodities and forests/land use

In this report, we investigate four focus commodities (coffee, cacao, corn and rice), as explained in Section 1.3.2. The district government of Sigi intends to boost coffee and cacao production. Coffee and cacao cultivation can be sustainable as both are considered to be forest tree species. However, if the government succeeds in attracting investors or buyers, there is potential for deforestation due to expansion of new plantations into forested areas.

The report also focuses on corn and rice. Although not promoted by the district government, corn is still a favorite for local communities. Relatively easy cultivation, a regulated pricing system, and increasing demand for corn as animal feed ingredients are the three main factors underlying potential expansion of corn fields. Although there is not too much land available for corn expansion because of the limitation of land allocated for agriculture purposes, it is still necessary to pay attention to potential corn expansion on land with steep slopes, which has the potential to cause landslides in the future. Like corn, rice field expansion may occur in the district due to increasing demand, especially in conjunction with a national government initiative to meet national rice needs.

3 Value chains of focus commodities

3.1 Coffee

The primary actors of the coffee supply chain in Sigi District are farmers, traders, distributors, service industries, and consumers. The majority of coffee trees in Sigi District are robusta and arabica varieties that have been planted for many years. The cultivation practices implemented by coffee farmers generally include weed removal, application of fertilizers, herbicides and pesticides, and pruning. Three years after being planted, coffee trees start producing coffee cherries, which are harvested throughout the year, with three main harvest seasons every year. Farmers must determine which coffee cherries are ready for harvest and must prepare containers for sorting coffee cherries before they can begin harvesting. Once harvested, coffee cherries are sorted, graded and dried and hulled. Some farmers then sell the hulled coffee as green beans or roast them using a clay-based wok to retain the distinguished coffee aroma. Depending on the intended end products, the roasted coffee beans are sold as beans or ground to be sold as ground coffee. The processed coffee is then packaged for distribution. Sigi coffee reaches many major cities in the country, such as Palu, Jakarta, Surabaya, Yogyakarta and Denpasar, as well as international buyers although to a lesser extent compared to domestic buyers.

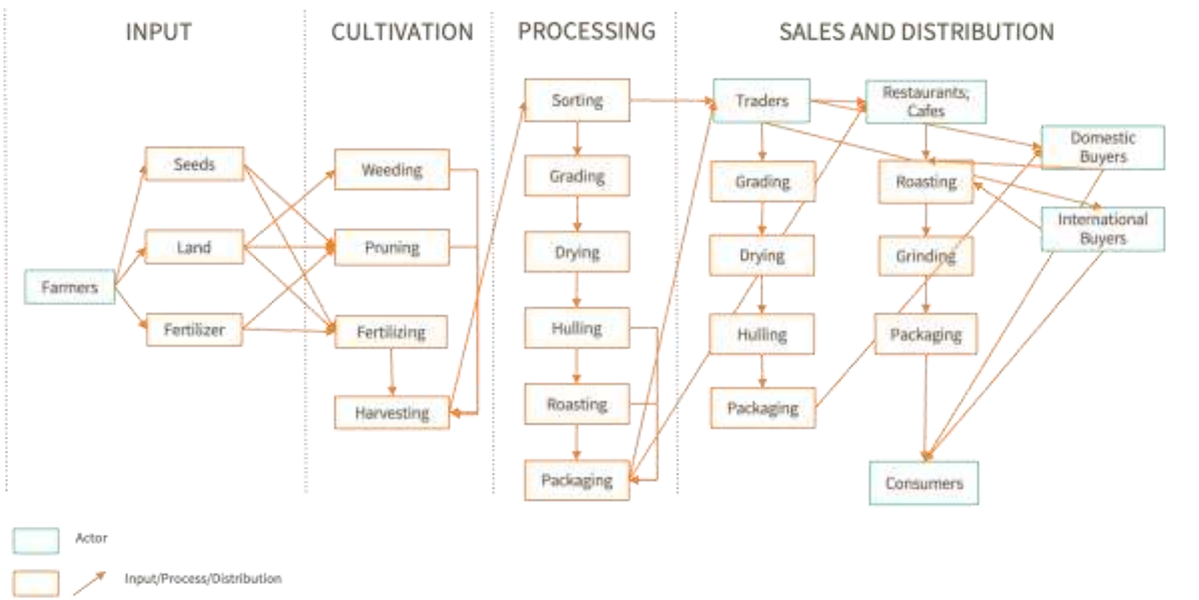


Figure 10. *Flow chart of actors, inputs and processes of coffee production in Sigi District*

Government support for coffee farmers in Sigi District has been directed at increasing the quantity and quality of production. The District Government provides seedlings and agricultural inputs, such as fertilizers and organic pesticides, tools, machines, and facilitates financing through the 0% People's Business Credit (Kredit Usaha Rakyat or KUR). The financing support is intended to subsidize the interest on business loans for farmers in Sigi who access such credit through the District's development budget, as well as to increase farmers' financial capacity to procure agricultural inputs necessary to employ good agricultural practices.

Apart from government assistance, other actors along the coffee supply chain in Sigi also contribute to the value chain processes. In several cases, buyers provide support to farmers to increase the quality and quantity of their products, which in turn are purchased by the buyers. One farmer in Dombu Village receives assistance from a local coffee shop in the form of cultivation and processing tools and training for producing green beans and the coffee shop then buys the farmer's coffee.

3.2 Cacao

In the production phase of the value chain, farmers plant, cultivate, and harvest the cacao, which occurs throughout the year with two main harvest seasons annually. Following harvest, farmers sort and collect the pulp-coated seeds (commonly referred to as "beans"), which are left to ferment in temperature-controlled fermentation boxes for 3 to 4 days. During this process, the pulp naturally separates from the beans. To produce fermented cacao beans, beans are dried together with the pulp in the sun for 3 to 4 days. To produce unfermented cacao beans, the farmers separate the pulp from the beans prior to drying.

In general, the primary actors in Sigi's cacao supply chain are farmers, traders at the village, sub-district and district levels, provincial-level offtakers, exporters and buyers. Two of the largest cacao offtakers in the District, JB Cacao and OLAM, have established their own supply chains. OLAM, for example, employs micro collectors who collect cacao from farmers located in their sourcing areas; these micro collectors transport the produce from farmers directly to the offtakers.

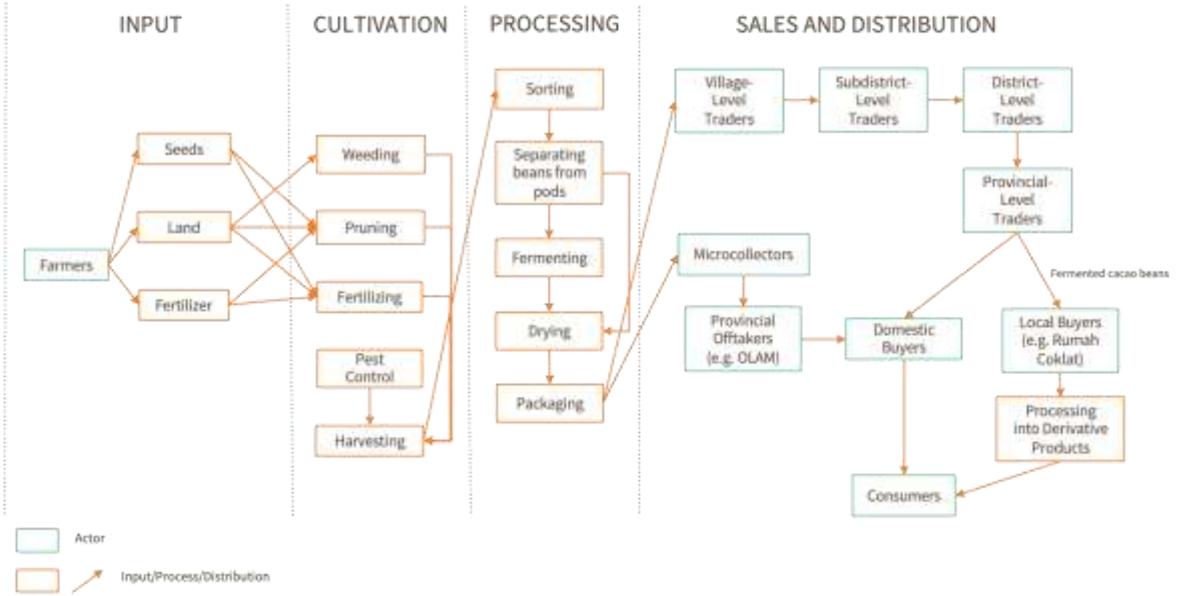


Figure 11. *Flow chart of actors, inputs and processes of cacao production in Sigi District*

While the most commonly produced end product is unfermented cacao beans, some farmers also conduct further processing by fermenting the beans. The difference in the processing of the two products lies in the fermentation process that occurs after separating the beans from the pods, where the pulp-coated beans are fermented in boxes for 3 to 4 days prior to drying. Fermented cacao beans are purchased at a higher price by several buyers, such as Rumah Coklat, which source directly from farmers. The price difference between unfermented and fermented cacao beans can reach 25% or IDR 8,000 per kilogram due to further flavor development achieved through the fermentation process.

Government support for Sigi District cacao farmers is similar to that for the District's coffee farmers, which includes provision of seedlings and agricultural inputs, tools, machines, irrigation infrastructure as well as facilitation of financing through the 0% People's Business Credit (Kredit Usaha Rakyat or KUR). Also, the District government, together with non-governmental actors such as GIZ SASCI+, has pursued the labeling of cacao produced in the Lore Lindu Biosphere Reserve. The aim of this labeling is to indicate that these products are produced using sustainable and fair practices that contribute to the conservation of the Lore Lindu Biosphere Reserve, with the ultimate objective of increasing the reach of Sigi's cacao industry to the global market. A range of stakeholders in the district support such labeling to build a sustainable, transparent and deforestation-free cacao supply chain to ensure that the agroforestry system in the biosphere reserve, where cacao trees are cultivated alongside native and local trees, contribute to the protection of the landscape and ecosystem and the cacao farmers receive decent income.

Many non-governmental actors in the supply chain of cacao in Sigi District also implement initiatives to support cacao production. The two big cacao offtakers in Sigi District, JB Cacao and OLAM, work alongside cacao farmers to increase the productivity of cacao, providing technical assistance, building seedling nurseries accessible to farmers, certifying farmers and buying cacao products from farmers with a price premium of IDR 1,200/kg. The two companies also purchase cacao from other actors along the supply chain, such as from traders, and provide a price premium of IDR 600/kg.

3.3 Corn

Many farmers choose to plant corn due to its short life cycle. Depending on the varieties planted, the life cycle could range from 90 to 120 days between planting and harvesting, providing more frequent income for farmers in comparison to coffee and cacao.

The value chain of corn in Sigi District includes a larger number of actors, compared to those of coffee and cacao. In the production phase, farmers commonly cultivate, harvest, and conduct the initial process of drying (in the sun or with mechanical UV dryers) and shelling the corn using shellers. Upon processing, farmers sell their produce to various actors, including local traders in the village, sub-district and district. The differences between such groups lie in the amount of produce purchased: village-level traders buy the least amount of produce compared to sub-district-level and district-level traders. While there are many routes in the Sigi corn supply chain, the most common path starts with farmers selling their produce directly to traders in the district, who then sell the product to other cities in Indonesia. Depending on the quality of corn purchased, these traders will conduct further drying to increase quality and price. These traders then sell the produce to other cities in Indonesia, including Palu, Surabaya and Makassar, usually to animal feed factories that use corn as an ingredient. Although there is demand from the international markets for corn produced in the District, local production volumes have been insufficient.

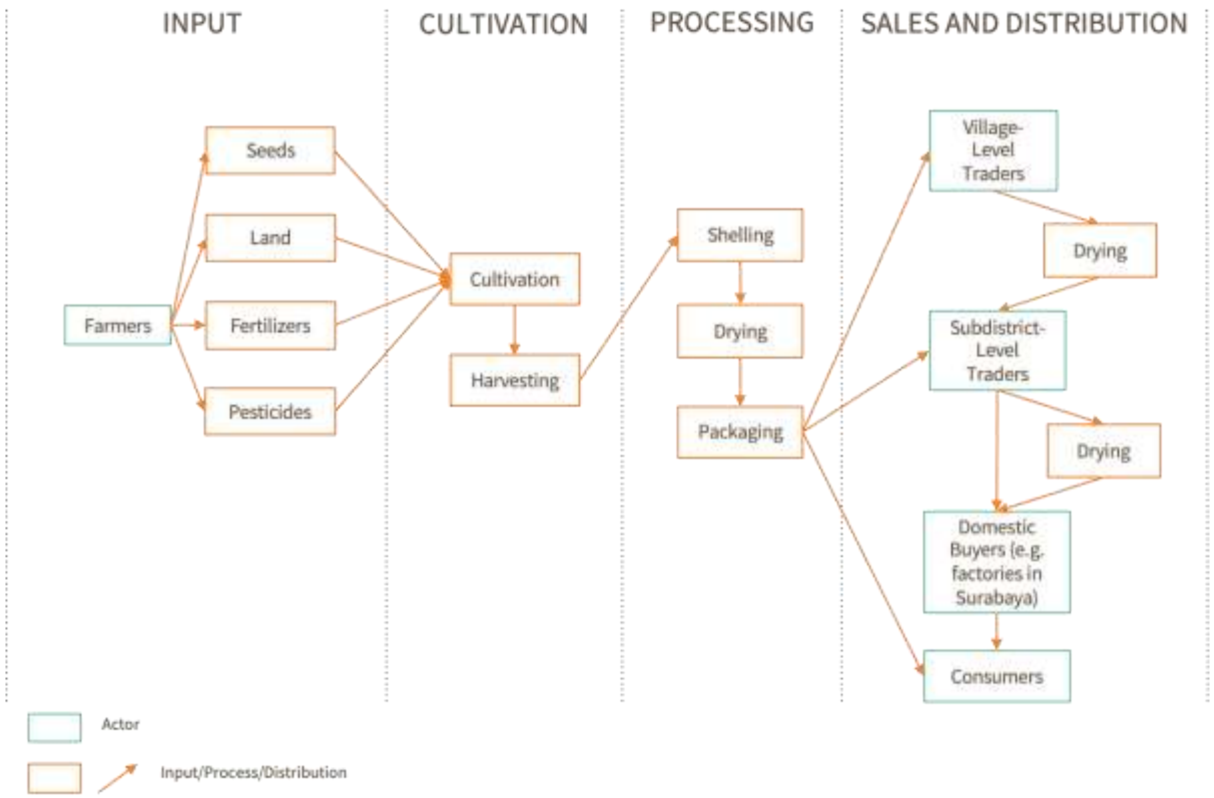


Figure 12. *Flow chart of actors, inputs and processes of corn production in Sigi District*

To support corn farmers, the District Government provides seedlings and agricultural inputs (such as fertilizers and organic pesticides), processing tools and facilities (such as hand tractors and driers). The District Government Agriculture Agency also provides technical assistance via its village-level extension worker stations to assist farmers in implementing good agricultural practices.

3.4 Rice

Many farmers choose to plant rice to fulfill their daily food needs. The demand for rice, a staple food in the country, remains consistently high, which creates a steady income for farmers. The short life cycle of rice, around 90 days between planting and harvesting, also drives farmers to plant rice as it generates income quickly.

The supply chain of rice in the district is generally shorter than that of other focus commodities in this study (Fig. 13). The primary actors in the rice supply chain in the District include farmers, rice millers and buyers. Farmers plant, cultivate, harvest and transport their harvest to local rice millers in the same village. The millers own drying and milling machines that farmers use to process the rice and subsequently purchase the processed rice from the farmers. The rice millers then sell the produce to local markets in Sigi District and Palu. Unlike the previously described commodities, rice produced in Sigi District is distributed mainly within the District and to neighboring districts within Central Sulawesi Province, with a very limited amount of produce sold beyond the province, such as to Gorontalo Province.

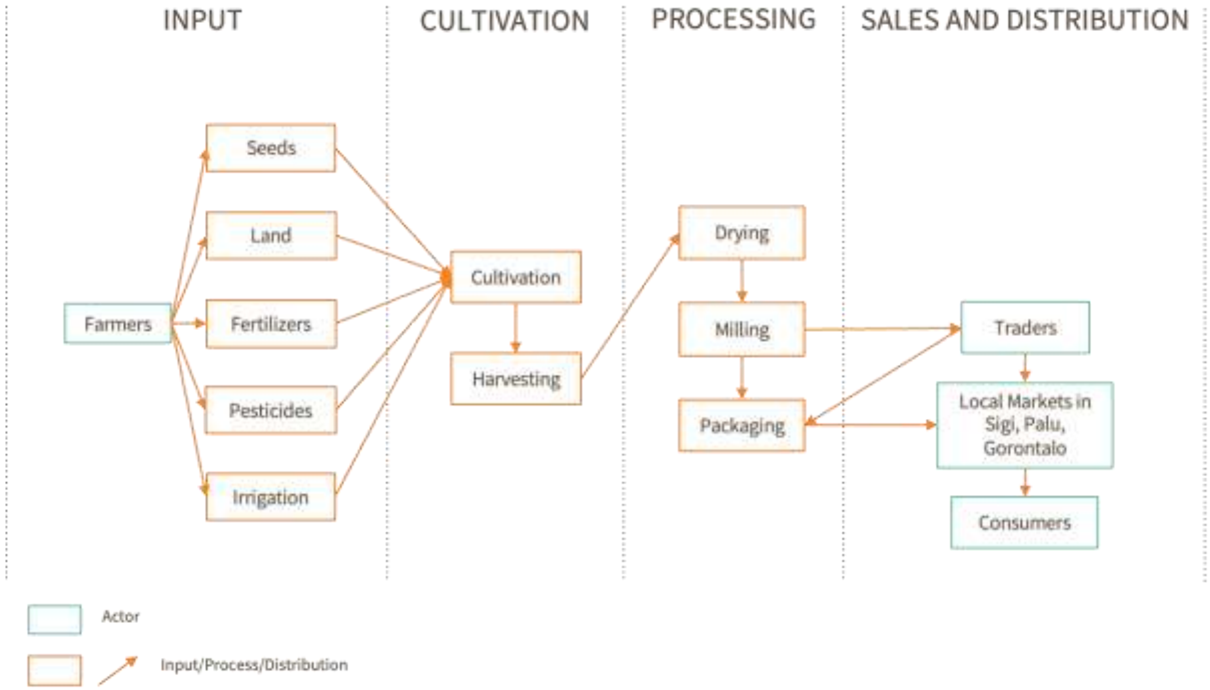


Figure 13. *Flow chart of actors, inputs and processes of rice production in Sigi District*

According to the District Agriculture Agency, the demand for rice in Sigi has been stable in the last 5 years. Agency data show that the local demand for rice in Sigi was 28,252 tons in 2020, which could be met with local rice production that reached 79,538 tons in the same year. This indicates strong resilience and food security in the District. However, more information is needed about how this demand was met, how much of the rice produced in the district was distributed within the District and how much was exported outside of the district.

To support rice farmers, the District Government has provided seedlings and agricultural inputs (such as fertilizers and pesticides) and processing tools and facilities (such as hand tractors and mill machines). The District Agriculture Agency also provides technical assistance through its village extension stations to assist farmers in implementing good agricultural practices.

4 Existing interventions

4.1 Forest conservation

In the land use sector, the District Government of Sigi favors small- to medium-scale businesses over large-scale extractive investments. This commitment is realized in the District's long-term and medium-term development plans, as the District Government has not issued any licenses for large-scale land uses, including for agriculture and mining. Such commitment has reduced the pressure on forests.

In addition to these regulations, Sigi District maintains strong traditional laws, including specific rules against clearing forests. Sanctions for clearing forests vary depending on the indigenous groups and methods for clearing forests. Interviewees indicated that clearing forests by burning is markedly sanctioned relative to other methods.

4.1.1 Develop community-based ecotourism

Lore Lindu National Park, located in Sigi District, is a UNESCO biosphere reserve. Some of the fauna and plants endemic to Sulawesi can be found in Lore Lindu National Park, since the Wallace Line–a zone that connects the Australian and Asian zones–runs through the national park.

4.1.2 Incentives and disincentives

Apart from restrictions to clear forests, various incentive mechanisms are in place to support alternative, more forest-friendly livelihoods. As an illustration, The Lore Lindu National Park Agency has provided livestock and seedlings of forest tree species with economic value to local communities in Simoro Village, which is located in Gumbasa Sub-district, to transition from shifting cultivation practices.

To prevent the expansion of cacao plantations into forest areas, reliable mapping is required to enable the traceability of cacao goods in Sigi District. Cacao products from cacao grown in forest areas may not be accepted in the market, or may be sold for less value than those derived from plantation-grown cacao. Many companies, such as PT. Olam Indonesia (OFI/Olam Food Ingredients), have pledged not to purchase cacao products from properties in forested zones. This system will naturally prevent farmers from expanding their land into the forest areas.

4.1.3 Customary sanctions

The protection of forests, particularly customary forests, is also enhanced by the existence of strong customary laws that have been in place in Sigi District. Although many indigenous groups inhabit the district, these groups have regarded forests as their source of life, and enforced customary laws against people who disturb forests and nature[4]. The customary laws implemented by these different groups vary depending on the groups. Cases in which forests are disturbed are usually resolved in forums led by the customary groups, and the sanctions that must be provided by perpetrators may include animals such as pigs and buffalos.

In 2020, the Lore Lindu National Park Agency established partnerships with 15 customary groups that inhabit villages around the national park, including villages in Sigi District[5]. The partnerships aim to strengthen and secure the commitments from the parties to protect forests and to acknowledge customary practices as the means for indigenous groups to do so.

4.2 Sustainable agriculture

Promoting alternative livelihoods can also help communities living around forest areas to protect forests. Some non-timber forest products (NTFPs), such as rattan, can be harvested and utilized by the communities. Traditionally, the communities of Sigi District are quite familiar with using rattan, either for constructing furniture or for use in traditional ceremonies.

[4] http://pskl.menlhk.go.id/berita/281-masyarakat-adat-kearifan-lokal-yang-menjaga-hutan.html
[5] https://www.antaranews.com/berita/1972248/upaya-komunitas-adat-lindu-menjaga-kualitas-lingkungan

5 Bottleneck analysis

We conducted an analysis of the steps in each focal commodity's production chain, documenting and describing the steps within each major phase (e.g., cultivation, processing, distribution) and identifying inefficiencies and hindrances ("bottlenecks") within each value chain. Data for the analysis were obtained via interviews with farmers, traders, district agents, among others, as well as from a review of government databases and available literature.

5.1 Non-timber forest products

5.1.1 Non-Timber Forest Product – Rattan

The bottlenecks identified for the rattan value chain are summarized in the table (Table 3) below.

Table 3. *Bottlenecks in the value chain of rattan in Sigi District*

Stage of Value Chain				
Input	**Cultivation/ Production**	**Processing**	**Distribution**	**Sales**
	• Disasters (i.e. mudslides) limiting access of local communities to harvest rattan from forests	• Limited knowledge and information of market demand for rattan products causing a lack of value-adding processes conducted by local communities	• High distribution costs	• Low local market demand • Limited access to wider market

5.1.1.1 Inputs and cultivation

The distance between the villages and the location where rattan is collected is so great that rattan collectors frequently spend the night in the forest. Landslides frequently make it impossible for locals to collect rattan from the forest. These access restrictions are the main reasons why rattan is not a main source of income for communities living near forests.

5.1.1.2 Processing

The communities who collect rattan usually produce products that meet the demand from local communities only. This is caused by lack of information about rattan products that are needed by wider communities in other provinces. Limited local market demand results in minimal income from rattan.

5.1.1.3 Sales and distribution

Villages with many communities who collect rattan are usually more remote and near forests. As a result, the costs of distribution and sales to other villages are high, making the price of rattan more expensive.

5.2 Focus commodities

One of the main issues with the value chains of many commodities in Sigi District is the definition of retail prices across different actors along the chain. The common purchasing system between farmers and traders, called *ijon*, involves upfront agreements and payments from traders to farmers, which the farmers use to fulfill their daily and sometimes urgent needs. Farmers will then give their produce to traders once they have produced enough. This has created heavy financial reliance on traders, and, depending on the urgency for the money, forces farmers to agree with the price set by the traders without much regard to the production cost and profit.

Another issue found in the value chains of various commodities in the district is the limited capacity of the government to provide technical assistance and knowledge to farmers. The Sigi District Agriculture Agency provides technical assistance through its village-based extension workers to ensure that farmers understand and implement good agricultural practices. However, the distribution of knowledge may not be even across all farmers in Sigi District due to the limited government budget that is unable to employ extension workers in all villages and build the capacity of these workers. This, therefore, limits access to information and knowledge on good agricultural practices that should be implemented by farmers. Support for providing or subsidizing agricultural inputs and cultivation and processing tools for farmers has also been limited due to budget constraints and therefore not available to all farmers. As a result, farmers who do not have access to such support may be forced to use more of their own financial resources to procure inputs, conduct less efficient practices or to abandon good agricultural and processing practices.

5.2.1 Coffee

The bottlenecks identified for the Sigi District coffee value chain are summarized in the flowchart (Fig. 14) and table (Table 4) below.

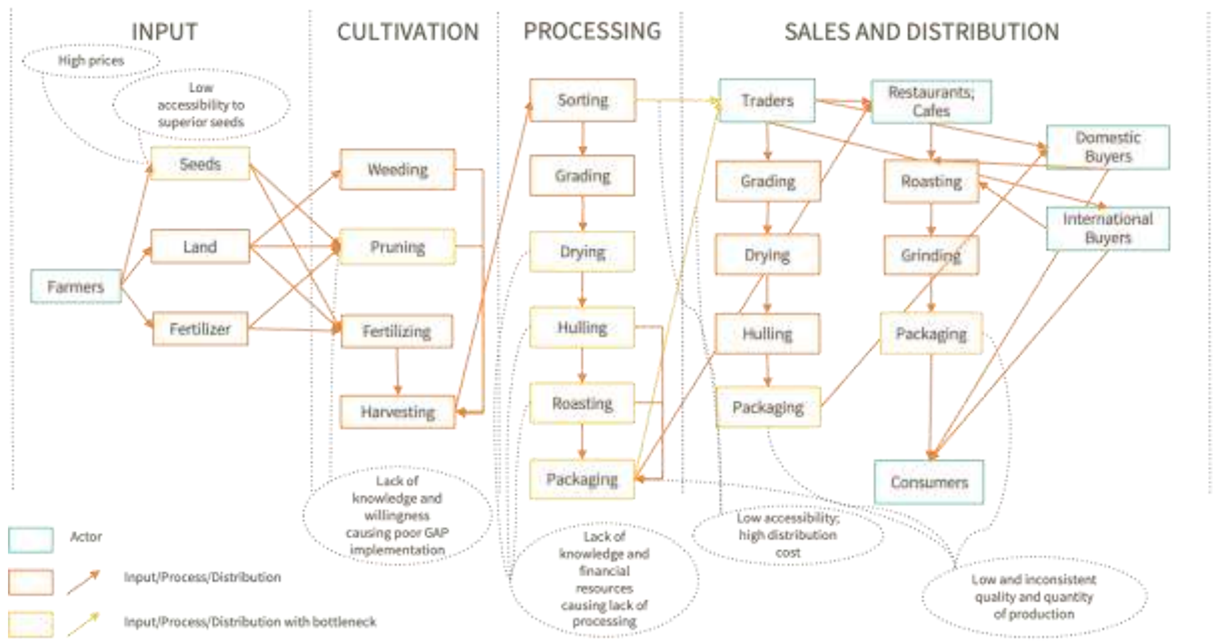


Figure 14. *Flowchart of bottlenecks along the value chain of coffee production in Sigi District*

Table 4. *Bottlenecks in the value chain of coffee in Sigi District*

Stage of Value Chain				
Input	**Cultivation/ Production**	**Processing**	**Distribution**	**Sales**
• High prices and lack of farmers' access to superior coffee seeds	• Low implementation of good farming practices (e.g. pruning, harvesting, replanting) due to lack of knowledge and willingness from farmers • Implementation of unsuitable farming practices for the varieties of coffee planted by farmers due to lack of knowledge	• Low implementation of efficient value-adding processes by farmers due to urgent financial needs, lack of financial resources to procure processing equipment, lack of knowledge for producing good quality products and additional processing time	• Low accessibility to and from production sites causing high distribution costs	• Low and inconsistent production volumes • Inconsistency in quality standards among supply chain actors

5.2.1.1 Inputs and cultivation

The many varieties and breeds of coffee trees require different treatments during the cultivation process due to various unique traits such as disease and pest resistance and fruit yield. The majority of farmers are knowledgeable about the differences between the main coffee varieties (i.e., arabica, robusta, liberica), but there are different subvarieties within them that possess different characteristics about which information is less widely known or available. Farmers need to understand the subvarieties of the coffee trees planted, their suitability of the environments for such subvarieties as well as the specific treatments required to ensure that the coffee trees that they plant produce the maximum yield of the highest quality. However, farmers may not possess knowledge of the specific treatments required. In addition, farmers may not have direct access to superior seeds that are suitable for planting in their lands, and these seeds may be priced higher than the seeds of lesser quality. This, in turn, will hinder the maximization of yield and quality of their produce.

Interviews and discussions with stakeholders revealed that one main factor hindering coffee production in Sigi District is the limited implementation of good farming practices by farmers. For example, not all farmers perform selective harvesting, where only ripe coffee cherries, usually red in color, are harvested. Also, not all farmers conduct pruning and replanting of old, unproductive trees, which limits the yield of the coffee trees. The low adoption of good farming practices can be attributed to a number of factors. Apart from the limited technical assistance and knowledge, as described above, even with the right technical knowledge, many farmers are unable or reluctant to implement such practices, with factors contributing to low adoption rates including limited physical capacity, high prices and scarcity of inputs (fertilizers, herbicides, pesticides) as well as other economic activities that farmers prioritize over coffee farming.

5.2.1.2 Processing

In general, coffee farmers in Sigi District sell the coffee they produce to traders and local cafes as green beans. Apart from specific market demands for green beans, farmers are reluctant to further process these green beans into roasted beans or coffee grounds. In several cases, as indicated by one of the interviewed farmers, farmers also sell their coffee in coffee cherry form, which are priced at around IDR 8,000 per kilogram. The reluctance to process coffee into derivative products that can earn higher prices can be attributed to several factors, including lack of access and capital to procure processing equipment. Although traditional processing methods remain an option for farmers, such methods would require more time commitment from farmers and are less efficient compared to mechanized methods. For this reason, the amount of income that farmers can generate from coffee is limited.

5.2.1.3 Sales and distribution

Coffee plantations in Sigi District are located in areas that are not easily accessible. Factors contributing to the lack of accessibility include the remoteness of these areas, far from city centers, as well as poor roads, which are prone to road closures due to natural disasters, such as landslides. Thus, the distribution of coffee products is often challenging and costly, necessitating a longer supply chain from farmers to consumers.

Coffee produced in Sigi District is not currently produced in a quantity and quality to meet international demands and is therefore sold mainly within Central Sulawesi Province. While some interviewees indicated that coffee beans produced in Sigi have been sold internationally, with Dubai identified as one of the international buyer countries, the official data providing evidence for such trade is not available. In the domestic market, the Sigi District Agriculture Agency foresees an increase in local demand for both robusta and arabica coffee. Based on its observation, there has been an increase in cafe establishments in the District that may drive the increased demand for coffee. However, this may not necessarily mean that these cafes will source their coffee from the District. Adequate promotion and support from relevant stakeholders are needed to help connect these two points in the value chain to help support local coffee production at the farm level.

5.2.2 Cacao

The bottlenecks identified for the cacao value chain in Sigi District are summarized in the flowchart (Fig. 15) and table (Table 5) below.

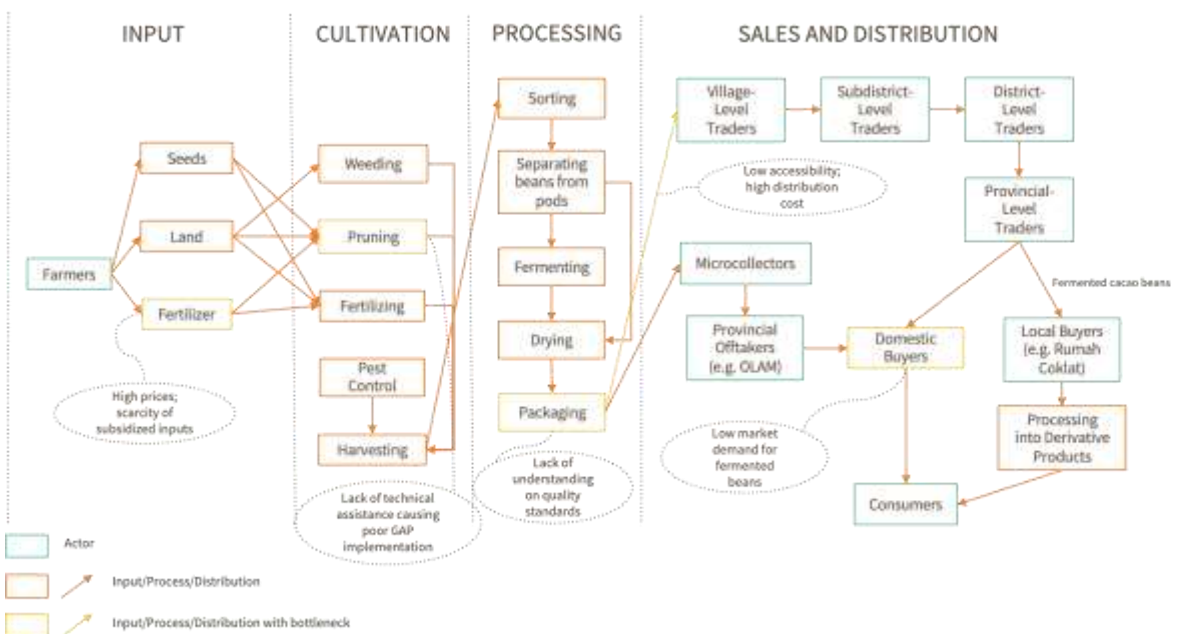


Figure 15. *Flowchart of bottlenecks along the value chain of cacao production in Sigi District*

Table 5. *Bottlenecks in the value chain of cacao in Sigi District*

Stage of Value Chain				
Input	**Cultivation/ Production**	**Processing**	**Distribution**	**Sales**
• Limited financial resources to procure fertilizers and pesticides, coupled with high prices of inputs • Scarcity of inputs • Seed varieties commonly chosen by farmers being less resistant to pests and diseases, leading to needs for more application of inputs • Locations of several cacao plantations in conservation areas, presenting threats from the expansion of existing plantations into conservation areas	• Inadequate and discontinuous technical assistance, leading to a decrease of interest by farmers in farming and implementing good farming practices (i.e. low level of replanting) • Many cacao farmers converting their cacao plantations into cash crop plantations (mainly corn) due to faster income generation • Inadequate access to information on good farming practices	• Lack of knowledge on quality standards for processed cacao products (e.g. fermented cacao beans) across different actors along the supply chain, resulting in inconsistent quality across fermented cacao beans in the market	• Low accessibility to and from production sites causing high distribution costs	• Low market demand for fermented cacao beans due to inconsistent quality of fermented cacao beans produced by farmers • Market competition with lower-priced, mass-produced cacao products from outside of district

5.2.2.1 Inputs and cultivation

Despite being a top priority crop promoted by the District, cacao production has experienced a decline in the last 10 years[6]. Based on previous studies conducted by GIZ SASCI+, this is due to the overmature trees that are not replanted, as well as pest issues. Farmers are reluctant to replace mature trees due to the high costs of replanting, as well as the fear that the new trees will take years before becoming productive, diminishing their source of income. The lack of action to replace overmature cacao trees has decreased overall cacao yield, as cacao tree productivity decreases with age. Cacao trees also suffer from pest infestations, which are costly to address due to the scarcity and high prices of pesticides. This results in

[6] Interview with GIZ SASCI+ (The *Deutsche Gesellschaft für Internationale Zusammenarbeit* - Sustainable Agricultural Supply Chains in Indonesia)

insufficient pesticide application necessary to eliminate pests. With such challenges, many farmers in the district have replaced their cacao trees with other crops, with corn being the most commonly selected replacement crop due to the perceived higher and faster income generation. This has resulted in a decline in the total planted area in the District observed over the last decade.

5.2.2.2 Processing

In general, cacao processing is done in the conventional way, starting with sorting the harvested beans, separating beans from pods, fermenting (which takes about 4 days), traditional drying under direct sunlight, and packaging. The weakness of this conventional process is that it takes a long time and the quality does not always meet the highest standards. Due to the lack of knowledge of quality standards for processed cacao products (e.g., fermented cacao beans) across different actors along the supply chain, the quality of these products in the market is inconsistent.

5.2.2.3 Sales and distribution

The decrease in quantity and quality of cacao production has translated into a decrease in market demand since 2017. As already mentioned, the value of fermented cacao beans is higher than that of unfermented cacao beans. However, the number of dedicated buyers who are willing to purchase fermented cacao beans at a higher price are limited, thus the incentives for farmers to ferment the beans are limited. Due to the limited buyers of fermented cacao beans, farmers either have to sell their fermented cacao beans at the price of unfermented beans or are reluctant to further ferment their produce. According to local stakeholders, the inconsistent quality of fermented beans produced by farmers is the main factor behind the lack of market demand.

Land conflicts also occur within the boundaries of the national park. Many community lands, claimed to be owned by local communities before the designation of the national park area, are planted with cacao trees. This has hindered the marketing of cacao and cacao products. There is a high market demand for sustainably grown and certified cacao. However, considering the land designation in which the cacao is produced, these products cannot be certified.

5.2.3 Corn

The bottlenecks identified for the corn value chain are summarized in the flowchart (Fig. 16) and table (Table 6) below.

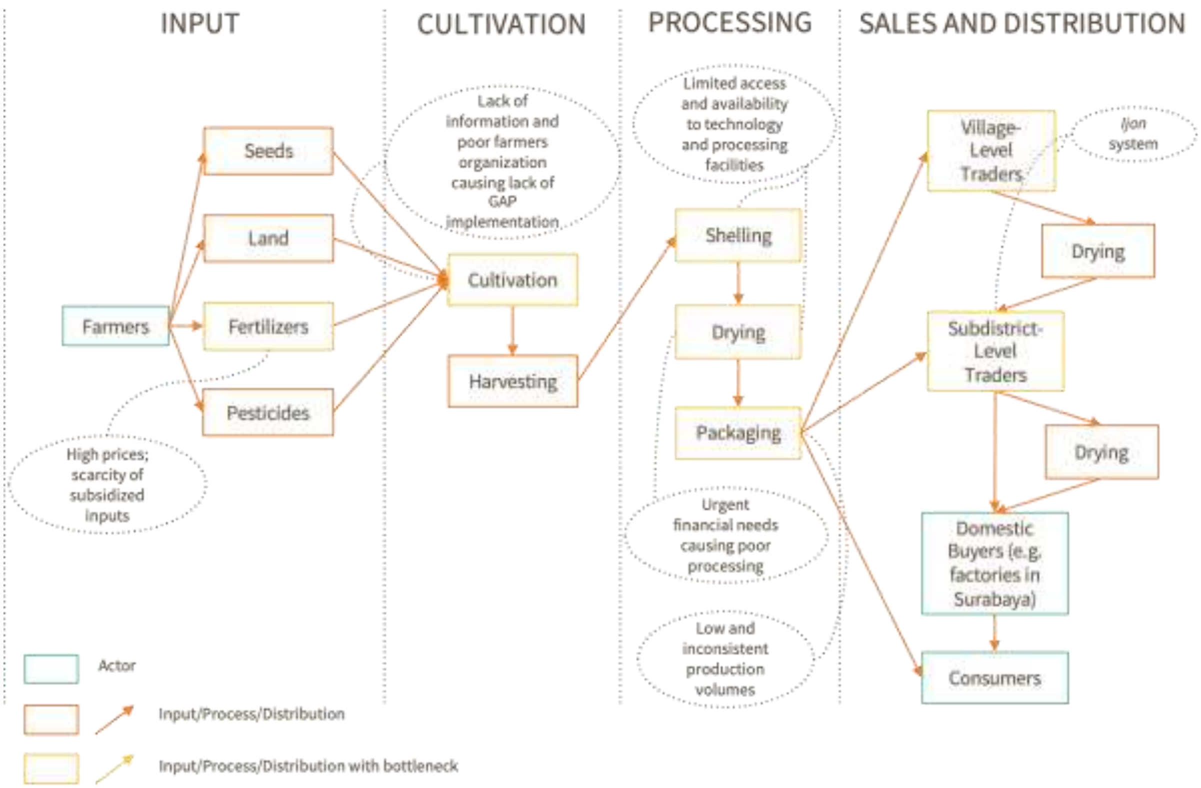


Figure 16. *Flow chart of actors, inputs and processes of corn production in Sigi District*

Table 6. *Bottlenecks in the value chain of corn in Sigi District*

Stage of Value Chain				
Input	Cultivation/ Production	Processing	Distribution	Sales
• Limited financial resources to procure inputs • High prices of inputs, particularly fertilizer • Scarcity of subsidized inputs, particularly fertilizer • Limited areas suitable for corn farming	• Inadequate information possessed by farmers on good farming practices • Poor organization and governance of farmers	• Limited access and availability to technology and facilities for processing • Low implementation of good post-harvest processing due to urgent financial needs		• Low and inconsistent production volumes to meet international demand

5.2.3.1 Inputs and cultivation

Due to the scarcity and high prices of agricultural inputs, coupled with farmers' limited financial resources, many corn farmers are unable to implement agricultural practices that could increase the productivity of the crops and minimize pest attacks such as frequent fertilization and application of pesticides.

5.2.3.2 Processing

The drying process is a crucial value-adding process in corn production, as the price of corn in the market depends on the water content in the produce. While there are tools and facilities provided for farmers to dry their produce properly, such support is limited and does not provide enough capacity to process all produce in the district. As a result, many farmers still rely on sun-drying their corn; this suboptimal post-harvest processing often prevents corn kernels from reaching the desired water content. As drying using conventional methods requires longer processing times (usually between 3 and 4 days depending on the weather) as well, many farmers also are forced to sell their produce before it reaches the desired water content due to urgent financial needs, which limits the amount of profits they can generate.

5.2.3.3 Sales and distribution

Sales of corn are still limited to meeting local needs, as well as the demand from several companies that are willing to accommodate farmers' production, such as PT Havana Agrobisnis Utama. Although the production potential for corn from Sigi is high, to date it has not met international demand because of low and inconsistent production volumes.

5.2.4 Rice

The bottlenecks identified for the rice value chain in Sigi District are summarized in the flowchart (Fig. 17) and table (Table 7) below.

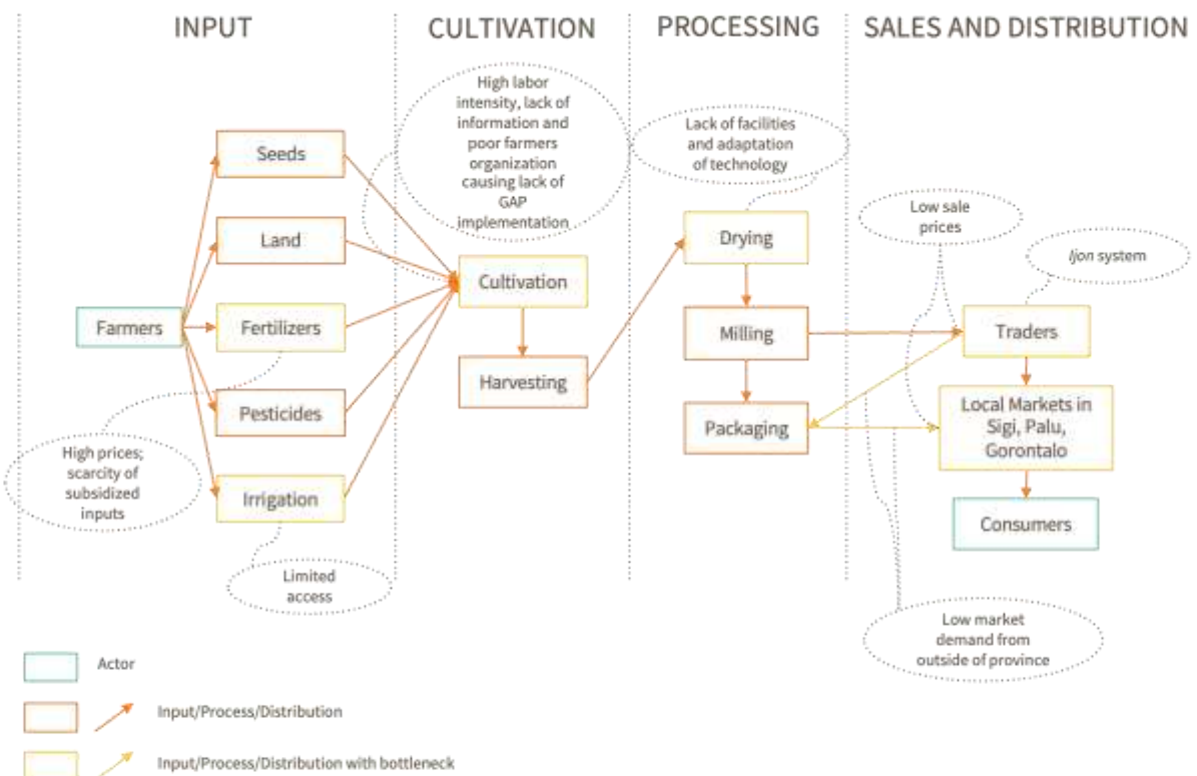


Figure 17. *Flow chart of actors, inputs and processes of rice production in Sigi District*

Table 7. *Bottlenecks in the value chain of rice in Sigi District*

Stage of Value Chain				
Input	Cultivation/ Production	Processing	Distribution	Sales
• Limited access to irrigation • High prices of inputs, particularly fertilizer, hindering the application of inputs according to good farming practices which limits the increase in quality and quantity of production • Scarcity of subsidized inputs, particularly fertilizer	• Lack of facilities and adaptation of technology to produce rice • High intensity of labor limiting the number of replanting cycles • Inadequate information possessed by farmers on good farming practices • Poor organization and governance of farmers	• Low implementation of good post-harvest processing		• Low market demand from outside of Central Sulawesi • Low sale prices, especially during peak harvest season

5.2.4.1 Inputs and cultivation

In 2018, many irrigation networks and sluice gates critical for irrigating their agricultural (primarily rice crop) lands were severely damaged by the major earthquake[7] centered in neighboring Donggala District. This caused farmers' lands to become less productive and forced farmers to find alternative means for irrigating their lands that are less effective. According to interviews conducted with farmers in Sigi Biromaru Sub-District, all rice farmers can still grow rice during the wet season, but only a few can do so during the dry season due to the limited water supply.

Similar to corn farmers, many rice farmers are unable to implement agricultural practices that increase crop productivity and minimize pests, such as frequent fertilization and application of pesticides. This is due to the scarcity and high prices of agricultural inputs, along with farmers' limited financial resources to procure such inputs. The absence of these inputs reduces the productivity and quality of the rice.

5.2.4.2 Processing

[7] https://sulteng.antaranews.com/berita/44652/jaringan-irigasi-di-sigi-hancur-diterjang-gempa

Two of the main issues of rice processing in the district are limited access and availability to facilities for processing and low implementation of good post-harvest processing. In order to address these issues, the Agriculture Agency has provided seven rice milling units to villages. This effort is not sufficient to significantly increase the district's production quality, since there are still many other rice-producing villages that need to have the facilities and assistance to implement good post-harvest processing.

5.2.4.3 Sales and distribution

Unlike corn, the minimum and maximum retail prices of rice are not regulated by the Ministry of Trade. Therefore, for farmers, the sale price of rice fluctuates depending on the available supply, which is directly correlated with the harvest seasons. During the harvest seasons, farmers are often forced to sell their produce at a relatively cheaper price, and are therefore not well compensated for the production costs that they incur. In many cases, the amount paid to farmers by traders may be deducted even further by buyers through the *ijon* system. The price difference between rice sold during and outside of the harvest seasons could reach between IDR 3,000 and 6,000 per kilogram, with rice sold during the harvest seasons falling to as little as IDR 7,000 per kilogram, and rice sold outside of the harvest seasons reaching as much as IDR 10,000-13,000 per kilogram[8].

As mentioned above, rice produced in Sigi District is sold mainly to buyers in Central Sulawesi, with only a limited amount sold to other provinces. According to interviews with the Sigi District Agriculture Agency, this is due to higher demand for rice produced in Makassar, South Sulawesi, which is considered to be of higher quality.

6 Trade-offs

Stakeholders in the district face a series of economic, social, and environmental trade-offs on the path to sustainable, forest-friendly development. On the one hand, forest conversion for tree plantations and cropland to make way for agriculture often provides direct economic benefits, including food security and economic revenues. On the other hand, forest conversion also generates costs that are more indirect and poorly understood, including those associated with disasters, soil erosion, fire, air pollution, and biodiversity loss. Forest conversion also generates costs associated with the loss of direct economic benefits derived from keeping forests standing, such as food provision, NTFPs and ecotourism. Thus, there is an opportunity cost to converting forest for cropland: when one alternative is chosen (i.e. income from croplands), other alternatives are lost (i.e. NTFP and ecotourism income, environmental protection, etc.). Understanding these alternatives and their respective costs is necessary to design effective, appropriate incentive mechanisms and interventions to achieve the district's economic and environmental goals.

[8] https://mediaindonesia.com/nusantara/326866/harga-beras-anjlok-petani-sigi-rugi

In this study, we estimated the typical profits that farmers can expect to generate from producing each of the focus commodities as a measure of the potential forgone profits associated with forest conservation. We also estimated the economic benefits derived directly from forests, including from the harvest of non-timber forest products (NTFPs) and ecotourism activities. We combined these costs to estimate the economic value of standing vs cleared forests from the perspective of local farmers. This opportunity cost is calculated as follows:

Opportunity cost of Forest Conservation = Value of Forgone Profits from Forest-replacing Agriculture - Value of Benefits of Forest Conservation

The value of forgone profits, in this study, refers to the typical profits that can be generated by farmers producing coffee and corn as the focus commodities in Sigi District, whereas the value of the benefits of forest conservation was quantified by estimating and summing the economic benefits derived directly from forests (i.e., food provisioning, NTFP production and ecotourism) and the costs (or avoided economic loss) associated with forest loss (disasters, air pollution, fire, biodiversity loss). The details on the methodologies used for calculating these values can be found in Appendix 1.

6.1 Value of agricultural production

The annual value of agricultural production was estimated from a survey of production costs (inputs, labor, equipment, etc.) and revenues for each of the focus commodities (coffee, cacao, corn and rice), collected via interviews with farmers and relevant district-level agencies in Sigi District. To reflect the actual costs incurred, labor costs were assumed to be negligible for all estimates (costs, profits, net present value) presented below, under the assumption that the work done by farmers and family members is not remunerated. However, calculations reflecting alternative scenarios in which the same work is remunerated are provided in Appendix 1.

6.1.1 Coffee

Based on interviews conducted with farmers and relevant district-level agencies in Sigi District, the average yearly production costs incurred along the value chains of coffee produced in the district, as well as the average yearly revenues, were acquired and presented in Table 8 and Table 9 below.

Table 8. *Costs associated with coffee production in Sigi District*

Activity	Average Yearly Production Costs (IDR)		
	Input	Machines and Equipment	Labor
Land preparation	1,328,000	2,915,000	1,080,000
Pre-planting	17,750,000	-	-
Planting	-	150,000	1,400,000
Post-planting	-	-	-
Cultivation	472,000	4,355,000	150,000
Pre-harvesting	-	-	-
Harvesting	-	33,000	1,470,000
Post-harvesting	-	-	-
Processing	212,500	14,245,000	-
Packaging	12,500	35,000	-
Transportation/ distribution	-	-	-
Sales/marketing	-	-	-
TOTAL	**19,775,000**	**21,733,000**	**4,100,000**

Despite the remote locations of many coffee plantations being identified as a bottleneck, which causes higher distribution cost, this is often not reflected in the production costs as such cost may not be incurred by farmers, but rather by the buyers (e.g. traders) who collect the produce.

Table 9. *Average yearly revenue for coffee farmer in Sigi District*

Product	Price per kg	Revenue (IDR/person/year)
Coffee cherries	8,000	7,200,000
Green beans	80,000	12,500,000

Arabica coffee is valued at a much higher price compared to robusta coffee. Arabica coffee, according to interviews with local actors in the District, is priced at IDR 80,000 per kilogram of green beans. Robusta coffee, on the other hand, is valued at a much lower price of IDR 35,000 per kilogram of green beans. However, farmers who were interviewed for this study produce arabica coffee, and therefore the calculations of revenue, profit, and NPV are based on the price of arabica coffee.

The profits (Table 10) generated by coffee farmers in Sigi District are calculated from the costs (Table 8) and revenues (Table 9) presented above.

Table 10. *Profits generated by interviewed coffee farmers in Sigi District*

Product	Profit (IDR/year)	Profit (IDR/person/year)
Coffee cherries	25,837,067	6,459,267
Green beans	44.367.000	11.091.750

The profits presented in Table 10 were projected over the next 30 years to obtain the net present value (NPV) per capita (Table 11).

Table 11. *Net Present Value (NPV) of coffee production in Sigi District*

Product	Value (IDR/person/year)
Coffee cherries	105,754,027
Green beans	181.599.134

6.1.2 Cacao

Based on the interviews conducted with farmers and relevant district-level agencies in Sigi District, the average yearly production costs incurred along the value chains of cacao produced in the district, as well as the average yearly revenues, were acquired and presented in Table 12 and Table 13 below.

Table 12. *Costs associated with cacao production in Sigi District*

Activity	Average Yearly Production Costs (IDR)		
	Input	Machines and Equipment	Labor
Land preparation	161,700	310,700	-
Pre-planting	1,700	-	8,000
Planting	-	-	40,000
Post-planting	1,000,000	-	-
Cultivation	3,690,000	14,700	-
Pre-harvesting	-	-	-
Harvesting	2,600,000	30,000	-
Post-harvesting	-	-	-
Processing	-	310,000	-
Packaging	3,000	270,000	-
Transportation/ distribution	95,000	1,500,000	-
Sales/marketing	-	-	-
Total	**7,551,400**	**2,435,400**	**48,000**

Despite the remote locations of many cacao plantations being identified as a bottleneck, which causes higher distribution cost, this is often not reflected in the production costs as such cost may not be incurred by farmers, but rather by the buyers (e.g. traders) who collect the produce.

Table 13. *Average yearly revenue for cacao farmer in Sigi District*

Product	Price per kg	Revenue (IDR/person/year)
Unfermented cacao beans	32,000	6,400,000
Fermented cacao beans	40,000	8,000,000

The profits (Table 14) generated by cacao farmers in Sigi District are calculated from the costs and revenues presented above (Tables 12, 13).

Table 14. *Profits generated by interviewed cacao farmers in Sigi District*

Product	Profit (IDR/year)	Profit (IDR/person/year)
Unfermented cacao beans	18,165,333	4,541,333
Fermented cacao beans	24,565,333	6,141,333

These profits were projected into the next 30 years to obtain the Net Present Value per capita (Table 15).

Table 15. *Net Present Value (NPV) of cacao production in Sigi District*

Product	Value (IDR/person/year)
Unfermented cacao beans	74,352,757
Fermented cacao beans	100,548,679

6.1.3 Corn

Based on the interviews conducted with farmers and relevant district-level agencies in Sigi District, the average yearly production costs incurred along the value chains of corn produced in the district, as well as the average yearly revenues, were acquired and presented in Table 16 and Table 17 below.

Table 16. *Costs associated with corn production in Sigi District*

Activity	Average Yearly Production Costs (IDR)		
	Input	Machines and Equipment	Labor
Land preparation	4,700,000	1,525,000	520,000
Pre-planting	7,970,000	-	-
Planting	-	-	7,200,000
Post-planting	12,870,000	-	7,560,000
Cultivation	10,440,000	160,000	9,905,000
Pre-harvesting	-	-	-
Harvesting	1,800,000	-	7,500,000
Post-harvesting	-	100,000	
Processing	-	7,850,000	2,880,000
Packaging	-	-	-
Transportation/ distribution	-	600,000	-
Sales/marketing	-	-	-
TOTAL	**37,780,000**	**10,235,000**	**35,565,000**

Table 17. *Average yearly revenue for corn farmer in Sigi District*

Product	Price per kg	Revenue (IDR/person/year)
Dried corn kernels	4,000	25,500,000

There are many factors contributing to the differences in the costs and revenues across different farmers. These factors include the size of land, cultivation practices and hired labor. The profits (Table 18) generated by corn farmers in Sigi District are calculated from the costs (Table 16) and revenues (Table 17).

Table 18. *Profits generated by interviewed corn farmers in Sigi District*

Product	Profit (IDR/year)	Profit (IDR/person/year)
Dried corn kernels	32,879,933	8,219,983

These profits were projected into the next 30 years to obtain the Net Present Value per capita (Table 19).

Table 19. *Net Present Value (NPV) of corn production in Sigi District*

Product	Value (IDR/person/year)
Dried corn kernels	134,581,274.57

6.1.4 Rice

Based on the interviews conducted with farmers and relevant district-level agencies in Sigi District, the average yearly production costs incurred along the value chains of rice produced in the district, as well as the average yearly revenues, were acquired and presented in Table 20 and Table 21 below.

Table 20. *Costs associated with rice production in Sigi District*

Activity	Average Yearly Production Costs (IDR)		
	Input	Machines and Equipment	Labor
Land preparation	28,000,0000	1,500,000	2,000,000
Pre-planting	790,125	-	900,000
Planting	-	-	2,430,000
Post-planting	-	-	-
Cultivation	20,700,000	40,000	2,520,000
Pre-harvesting	-	-	-
Harvesting	-	10,140,900	7,000,000
Post-harvesting	-	-	-
Processing	-	13,325,000	2,700,000
Packaging	1,050,000	-	-
Transportation/distribution	-	-	-
Sales/marketing	-	-	-
TOTAL	**50,540,125**	**25,005,900**	**17,550,000**

Table 21. *Average yearly revenue for rice farmers in Sigi District*

Product	Price per kg	Revenue (IDR/person/year)
Rice	9,500	18,341,775
Husk	2,143	771,428.57
TOTAL		19,113,204

The profits (Table 22) generated by rice farmers in Sigi District are calculated from costs (Table 20) and revenues (Table 21).

Table 22. *Profits generated by interviewed rice farmers in Sigi District*

	Profit (IDR/year)	Profit (IDR/person/year)
TOTAL	8,850,016	2,212,504

These profits were projected over the next 30 years to obtain the Net Present Value per capita (Table 23).

Table 23. *Net Present Value (NPV) of rice production in Sigi District*

Product	Value (IDR/person/year)
TOTAL	36,224,124.89

6.2 Benefits of forest conservation-based activities

6.2.1 Direct benefits from forest conservation-based activities

6.2.1.1 Non-timber forest products

In order to estimate the benefits from forest conservation, the household living surrounding the forests that are more likely to obtain direct benefits from forest, including non-timber forest products. In this study, the forest-dependent communities in the district are estimated by using settlements within 2 kilometers from the forest edges. The household is estimated using the total household for each sub-district divided by the settlement areas in each sub-district. In total, 19,442 households are identified to get the benefit from forests.

Food is often and easily obtained from the forest. Many people who live around the forest collect vegetables for food, including rattan shoots, palm shoots, bamboo shoots, vanga shoots, suka leaf, taro and palm tree trunk. The frequency of collection is not too frequent, which is about twice a month. Finding the economic value of this food is not easy because people never sell it in the market. However, the price of alternative products that can be found in the market is IDR 20,000/Kg. Thus, the community's economic benefits from harvesting vegetables from the forest is around IDR 9.33 billion per year.

Apart from vegetables, the community also takes protein food sources from the forest which is the habitat of several animals that are usually caught by the community, such as the green pigeon, forest dove and forest chicken. Like vegetables, people usually only get one of these animals twice a month, which have alternative product prices on the market around IDR 40,000 per Kg.

In addition to food, the community also takes bamboo and rattan, which are typically utilized as building materials and as decorations. Both are very infrequently used by the community and are only utilized when absolutely necessary, including during a traditional occasion or house renovation. Only approximately twice a year do these products get taken, and the alternative option costs roughly IDR 5,000 each bunch.

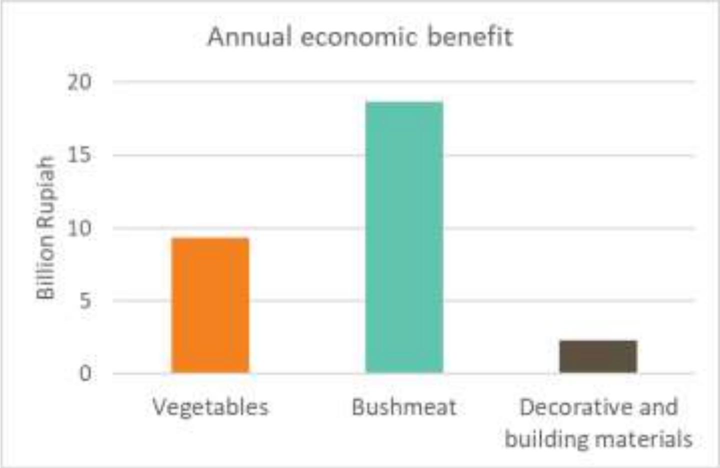


Figure 18. *The comparison of annual economic benefit from three different type of NTFPs*

Table 24. Profits generated from and value of NTFPs in Sigi District

Product	Profit (IDR/person/year)	Value (IDR/person/year)
Vegetables	120,000	1,964,694
Bushmeat	240,000	3,929,388
Decorative and building materials	30,000	491,174

6.2.1.2 Tourism

Sigi District has the potential for ecotourism which is supported by preserved forests in the district. Several tourism objects have been managed by the local government in collaboration with village communities. From the data collected from the district's Tourism Office, there are two tourism spots that generate revenue for the local government, namely the Matantimali paragliding site and the Bora hot spring. In 2020, when the pandemic came, the revenue from these two locations decreased by more than 40%, but could increase again in 2021. On average, local revenue from these two locations per year is IDR 180 million.

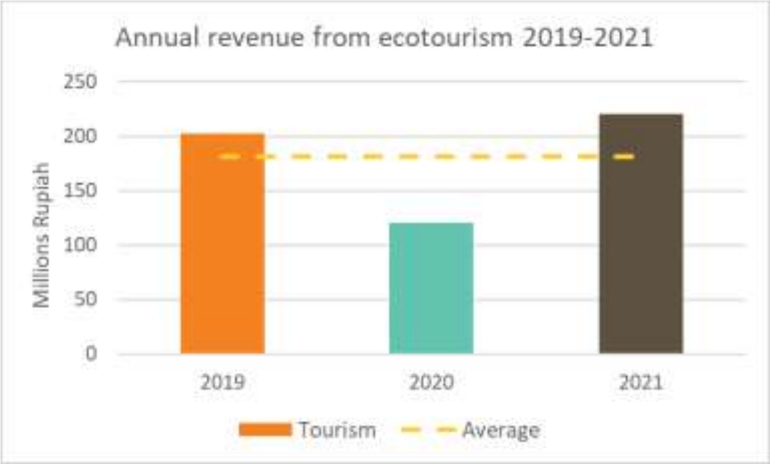


Figure 19. *Annual revenue from ecotourism from 2019 to 2021*

Table 25. *Profits generated from and value of two ecotourism spots in Sigi District*

Tourism spot	Profit (IDR/person/year)	Value (IDR/person/year)
Matantimali paragliding site	229,926	3,764,452
Bora hot spring	37,404	612,395

6.2.2 Indirect benefits from forest

6.2.2.1 Water regulation

Many of the forests in Sigi District are located in the upstream areas which in turn can benefit the people living in the downstream areas. Some of the benefits for communities in the downstream area are adequate supplies of groundwater, protection from flash floods during torrential rains, and water supplies for agricultural irrigation. In order to preserve the forests in the upstream, communities living in the upstream need to limit their land expansion and find other alternatives for their livelihood. Currently there are several types of incentives that can be given to the community or local government to maintain forests in order to support the livelihood of people in other areas, one of which is Payments for Ecosystem Services (PES). In this study, the PES scheme for water regulation in Cidanau watershed[9] is implemented. The total forest cover in Sigi District is 377,018 ha. If the price of IDR 4 million/ha/year applied, the total benefit from forest conservation for water regulation in Sigi is IDR 1,508 billion/year.

[9] Budhi, Gelar Satya, S. A. Kuswanto, and Muhammad Iqbal. "Concept and implementation of PES program in the Cidanau watershed: a lesson learned for future environmental policy." *Analisis Kebijakan Pertanian* 6.1 (2008): 37-55.

6.2.2.2 Air quality

Assessing ecosystem service values of forests in terms of its ability to enhance air quality can promote understanding of forest protection and management. In this study the methodology on quantifying the economic value of forests in improving quality that have been tested in Wuhan, China[10] is implemented. In total, there are four ecological services values that are calculated, including O_2 generation, air temperature amelioration, SO_2 removal and NO_x removal. The economic value of each ecosystem service is shown in Table 26.

Table 26. *The total economic value of forests in enhancing air quality*

Ecosystem services	Total Value (billion IDR/year)
O_2 generation	36,331
Air temperature amelioration	130
SO_2 removal	378
NO_x removal	5,014
Total	**41,853**

6.2.2.3 Disaster mitigation: flood, landslides and fire

The methodology of estimating the economic loss from disaster developed by the National Agency for Disaster Mitigation is employed to estimated how much the forest ecosystem could mitigate the impact of flood[11], landslides[12], and forest and land fire[13]. Based on their spatial data, the risk level of each disaster is shown in Figure 20 and is classified as:

- Low $(H \leq 0.333)$
- Moderate $(0.333 \leq H \leq 0.666)$
- High $(H > 0.666)$

[10] Xie, Q., Yue, Y., Sun, Q., Chen, S., Lee, S. B., & Kim, S. W. (2019). Assessment of ecosystem service values of urban parks in improving air quality: A case study of Wuhan, China. *Sustainability*, *11*(22), 6519.

[11] Badan Nasional Penanggulangan Bencana. (2019). Modul Teknis Penyusunan Kajian Risiko Bencana Banjir. Jakarta, Indonesia: Direktorat Pengurangan Risiko Bencana BNPB

[12] Badan Nasional Penanggulangan Bencana. (2019). Modul Teknis Penyusunan Kajian Risiko Bencana Tanah Longsor. Jakarta, Indonesia: Direktorat Pengurangan Risiko Bencana BNPB

[13] Badan Nasional Penanggulangan Bencana. (2019). Modul Teknis Penyusunan Kajian Risiko Bencana Kebakaran Hutan dan Lahan. Jakarta, Indonesia: Direktorat Pengurangan Risiko Bencana BNPB

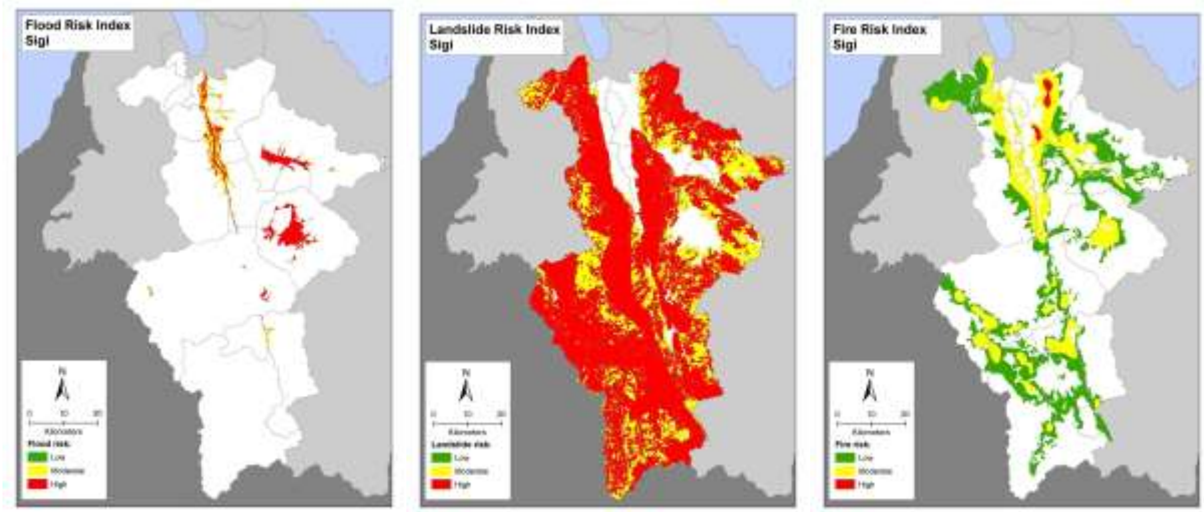


Figure 20. *Map of risk level of (a) flood; (b) landslide; and (c) forest and land fire*

The economic loss is estimated by calculating the number of buildings located within each of the disaster risks identified by BNPB. While a complete building footprint data necessary to do this calculation are not available, these data are estimated by calculating the building density using the available data from OpenStreetMap and settlement area from BIG (Badan Informasi Geospasial/Geospatial Information Agency). These buildings would then divided into three types of damage rate, including Low: no damage; Moderate: 50% of the number of houses affected by light damage multiplied by the regional price unit; and High: 50% of the number of houses affected by moderate damage multiplied by the regional price unit, and 50% of the number of houses affected by heavy damage multiplied by the regional price unit. The light, moderate and heavy damage costs 25%, 50% and 100% of the regional price unit, respectively. Table 27 and 28 shows the total building impacted by each disaster and the economic loss from building damage, respectively.

Table 27. *Number of buildings potentially affected by natural disasters in Sigi District*

Risk level	Number of buildings		
	Flood	Landslide	Forest and land fire
Low	0	238	90
Moderate	4,207	574	396
High	2,535	891	0

Table 28. *Potential economic loss from building damage due to natural disasters in Sigi District*

Risk level	Economic loss from building damage (million IDR)		
	Flood	Landslide	Forest and land fire
Low	0	0	0
Moderate	94,657.50	12,915.00	8,910
High	342,225.00	120,285.00	0
Total	**436,882.50**	**133,200.00**	**8,910**

6.2.2.4 Biodiversity

The approach used to estimate the economic benefit of forest conservation in preserving biodiversity is by estimating the cost of offsite protection of rare and endangered species[14]. The rare and endangered species are identified by referring to the IUCN (International Union for Conservation of Nature) Red List of Threatened Species. In Sigi, the species are Anoa (*Bubalus depressicornis*) and Babirusa Sulawesi (*Babyrousa celebensis*). Then, the distribution patterns of suitable habitats for rare and endangered species are predicted spatially. In total, the area of suitable habitats for these two species in Sigi is 8,649 ha. There are five costs included to estimate the offsite protection cost of rare and endangered species, which are labor cost, land lease cost, forest pest control drug, medicine for disease and pest control in grassland and agricultural irrigation cost. The total annual for offsite protection is IDR 560,293,016,500 per ha and total cost is IDR 484.6 Billion, of which 60%, 18% and 15% of the total costs contributed by labor costs, land lease cost and pest control and irrigation costs.

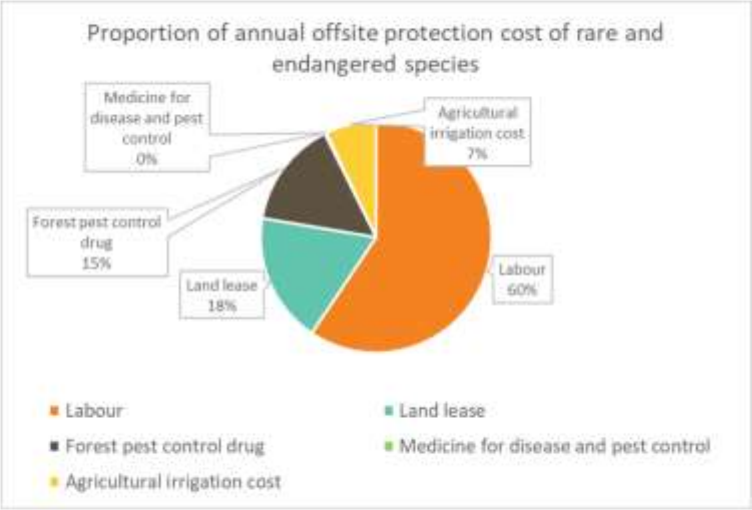
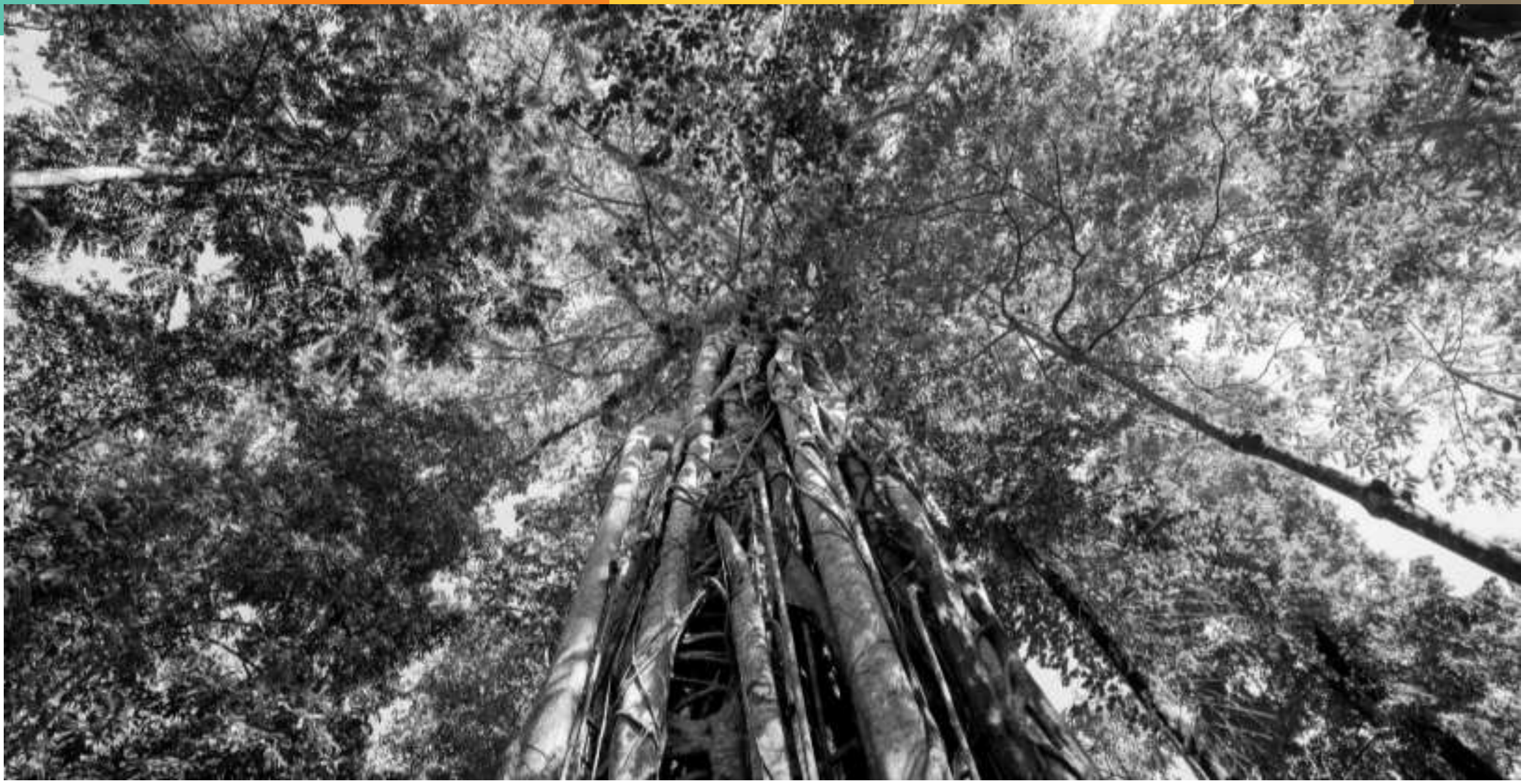


Figure 21. *Proportion of annual offsite protection costs of rare and endangered species*

[14] Zhao, X., Wang, J., Su, J., Sun, W., & Meng, H. (2021). Research on a Biodiversity Conservation Value Assessment Method Based on Habitat Suitability of Species: A Case Study in Gansu Province, China. *Sustainability*, *13*(6), 3007.



6.2.2.5 Carbon sequestration and storage

6.2.2.5.1 Aboveground biomass (AGB)

The estimation of aboveground biomass (AGB) is carried out by implementing the mean AGB that has been carried out by the Ministry of Environment and Forestry[15] by collecting data from surveys conducted on each forest type in Indonesia. In Sulawesi Island, at least 433 measurement plots have been carried out, which results in the mean AGB for primary dryland forest and secondary dryland forest being 275.2 t/ha and 206.5 t/ha, respectively.

6.2.2.5.2 Biomass conversion to carbon

To estimate the amount of carbon (C) in each forest type, information on carbon fraction is needed. The carbon fraction of biomass (dry weight) was assumed to be 47% (1-ton biomass = 0.47 tons C) following the IPCC 2006 Guideline.

Table 28. *Estimate of the economic value of forest carbon storage*

Forest area 2019 (ha)	Mean AGB (t/ha)	Total AGB (t)	Total C (t)	Carbon storage economic value (million IDR)
Primary: 320,319	275.2	88,151,789	41,431,340	6,214,701
Secondary: 56,698	206.5	11,708,137	5,502,824	825,423
	Total	33,764,748	15,869,432	7,040,124

[15] MoEF, 2015, National Forest Reference Emission Level for Deforestation and Forest Degradation: In the Context of Decision 1/CP.16 para 70 UNFCCC (Encourages developing country Parties to contribute to mitigation actions in the forest sector), Directorate General of Climate Change. The Ministry of Environment and Forestry.Indonesia

6.3 Trade-offs estimation

Table 29. *Potential profits of focus commodities and benefits of forest conservation in Sigi District*

Source of income		Value (IDR/person/year)
Focus commodities	Coffee (cherries)	105,754,027
	Coffee (green beans)	181,599,134
	Cacao (unfermented beans)	74,352,757
	Cacao (fermented beans)	100,548,679
	Corn	134,581,275
	Rice	36,224,125
Forest-based activities	NTFPs (Vegetables)	1,964,694
	NTFPs (Bushmeat)	3,929,388
	NTFPs (Decorative and building materials)	491,174
	Tourism (Matantimali paragliding site)	3,764,452
	Tourism (Bora hot spring)	612,395

Trade-off scenarios:

We developed a series of nine alternative scenarios based on the plausible combinations of commodities that can be cultivated by any given farmer depending on his/her location in Sigi District (e.g., in a given sub-district, a farmer can cultivate coffee and corn but will not also plant cacao). In each scenario, we subtracted the estimated value of the economic benefits of forest-based activities from the estimated value of the agricultural activities to estimate the potential profit or loss to farmers from keeping forests standing. For purposes of the analysis, in order to estimate the cost of forest-boosting interventions from the perspective of local farmers, we assume that the agricultural commodities (coffee, cacao, corn) would replace the forest-based activities, rather than both being carried out simultaneously. The scenarios are described below:

Scenario ID	Description
Scenario 1a	Coffee (cherries) and corn vs the total benefits from forest
Scenario 1b	Coffee (green beans) and corn vs the total benefits from forest
Scenario 2a	Cacao (unfermented beans) and corn vs the total benefits from forest
Scenario 2b	Cacao (fermented beans) and corn vs the total benefits from forest
Scenario 3a	Coffee (cherries) and cacao (unfermented beans) vs the total benefits from forest
Scenario 3b	Coffee (cherries) and cacao (fermented beans) vs the total benefits from forest
Scenario 3c	Coffee (green beans) and cacao (unfermented beans) vs the total benefits from forest
Scenario 3d	Coffee (green beans) and cacao (fermented beans) vs the total benefits from forest
Scenario 4	Rice vs the total benefits from forest

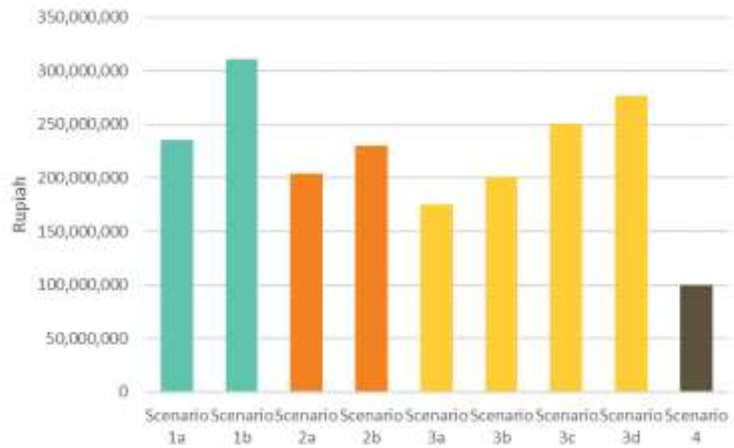


Figure 21. *The opportunity cost of forest conservation under alternative plausible commodity production scenarios in Sigi District*

Table 30. *Economic indirect benefits of forest conservation in Sigi*

Ecosystem services	Value (IDR/person/year)
Water regulation	6,298,529
Air quality regulation	174,809,227
Disaster mitigation: flood	19,394,841
Disaster mitigation: landslide	21,358,526
Disaster mitigation: forest and land fire	3,051,369
Biodiversity	2,021,544
Carbon sequestration and storage	29,404,271

7 Recommendations

Sigi District faces many challenges in the quest to protect its vast areas of forests and simultaneously support its economy. Many opportunities exist, as well, however. While forests in the district provide multiple direct economic benefits mainly to local communities, they also provide a number of ecosystem benefits that go beyond local communities, such as disaster management and biodiversity habitat. Therefore, interventions to increase the economic benefits of standing forests need to be introduced and strengthened and land-based sectors and economic activities need to be supported in a way that ensures that forests are protected. In other words, the economic value of lands with standing forests needs to be creased to offset the value of lands already cleared of forests. Simultaneously, the value of existing agricultural lands needs to be increased to prevent expansion into forests and to increase the welfare of farmers. Adequate support and safeguards are needed to ensure that the production of the two commodities promoted by the district government—coffee and cacao—can be increased to meet the target demand without compromising standing forests.

The analyses of value chain bottlenecks and trade-offs among alternative activities carried out in this study yield a set of recommendations for simultaneously improving the production of the focus commodities and protecting forests in the district.

- **For the District Government (Agriculture Agency)**:

Economic factors are influencing people to encroach on forest areas. Increasing the income of farmers who live near forests is important to prevent farmers from clearing forests to expand agricultural land to increase income. Providing support for livestock, honey and durian are some potential alternatives to increase the income of people living near forests, based on discussions with stakeholders. Furthermore, increasing farmer understanding of the impact of deforestation is also necessary to prevent further deforestation because many farmers still do not acknowledge the benefits of the forest or the consequences if they lose forests.

Making agricultural activities more economically viable for farmers is essential to preventing them from being lured to seek other revenue streams that could harm forest cover. One of the current factors affecting agricultural profitability is farmers' lack of ability to produce high-quality agricultural products. To address this issue, farmers need capacity-building to meet the quality standards required by buyer companies. Another issue is lack of access to superior seeds; this problem could be addressed by establishing nursery facilities that can provide high quality seeds for farmers. Finally, agroforestry concepts could be applied to develop coffee and cocoa farming.

- **For the District Government (Cooperatives and SMEs Agency)**:

In Sigi District, NTFPs have not yet been leveraged to their full potential, including the two most common NTFPs, rattan and honey. Rattan is an important forest product in the district that requires better management. Currently, rattan in the district is only used domestically because it cannot reach markets outside the region due to the low-quality derivative products and low prices that make it unprofitable. Local government intervention is needed to provide technical assistance to rattan craftsmen to produce higher quality products. In addition, market research is needed to identify the types of rattan products that are in demand by the market, so that products produced in the regency have a market with high demand. There is also a need for support to promote and develop NTFPs, through BUMDes (village-owned enterprises) or Koperasi (cooperatives), to increase direct economic benefits from forests. Farmers have a heavy financial reliance on traders (*ijon* system), which make it difficult for them to get fair prices. This can be addressed through facilitating the establishment and/or strengthening of BUMDes (village-owned enterprises).

- **For the District Government (Industry and Trade Agency)**:

Better links between actors along the coffee supply chain of coffee are needed. As a first step, the government should map actors and designate roles for processing and quality control of coffee in the district. This will help to increase the quality of coffee products in the district.

8 Conclusion

The Green Sigi regulation, launched in 2019, about a year after a major earthquake that triggered the tsunami and liquefaction, demonstrated the firm intention of the district government to develop and rebuild the district sustainably. Looking back several decades, the rate of deforestation in Sigi has continued to decline, which may be practical evidence of the local government's efforts to protect the environment. With half of its area is allocated for forest protection and conservation, the government needs to find ways to grow the economy and preserve the natural environment.

Sustainable agriculture is a key priority in Sigi District because the agricultural sector employs a large number of people and contributes to the majority of the district's GDP. Currently, there are some general bottlenecks within the value chains of the focus commodities in the district that restrict their success. In general, the productivity and the quality of the products are low due to several factors, including low-quality seedlings, inefficient processing methods and inadequate implementation of good farming practices.

According to the findings derived from discussions with various parties in Sigi District and other analyses, a number of changes could be introduced to promote sustainable agriculture and enhance livelihoods. Across the multiple focus commodities studied, strengthening the governance of all actors involved in the production, processing and distribution can help address the bottlenecks related to increasing and maintaining product quality and yield and ensuring fair pricing. Also, increased technical assistance at the village level can help address the issues related to good cultivation and processing practices, ensuring that all relevant actors understand and are capable of implementing them, which could lead to an increase in the quantity and quality of the production. Specific interventions, such as the establishment of nurseries, can also be introduced to address the issues related to seedling shortage and replanting coffee and cacao trees.

The opportunity cost to conserve forests in Sigi is very high and varies based on the type of crops and the derivative products. However, there are substantial indirect economic values in the standing forests that exceed the benefits of agricultural activities. This points to a high potential for intervening to enhance forest values to favor forests.

Appendix 1: Methodology for Calculating Opportunity Cost

The trade-off between forest preservation and agricultural production was estimated using opportunity cost calculation of net present value of foregone profits from agricultural production minus the benefits of forest conservation, using the formula below:

$$Opportunity\ cost = Net\ Present\ Value\ of\ forgone\ profits - Benefits\ of\ Forest\ Conservation$$

In the calculation of net present value of forgone benefits, as part of the opportunity cost calculation in this study, the forgone benefits refer to the benefits from alternative use of forests if they are cleared as opposed to protected. In this case, we focused on the use of cleared forest areas for agricultural production, where we calculated the profits from the production of the focus commodities (i.e. coffee, cacao, corn and rice) based on the production costs and revenues for the respective crops.

The production costs were calculated using figures obtained through in-depth interviews with two farmers for each crop, which were selected based on the locations of their land areas to provide a comprehensive overview. These figures are expenses incurred by farmers and categorized into three categories: (1) inputs; (2) machines and equipment; and (3) labor. Inputs refer to tangible materials that need to be purchased regularly, mostly every planting cycle, and include seeds and seedlings, fertilizers, insecticides, pesticides, fuels (gas, electricity, etc.) for machines and equipment and packaging. Machines and equipment refer to tangible items that are purchased or rented and used to conduct production processes until the products are sold to the immediate buyers, including sprayers, land mowers, hoes, garden shears, containers, peelers, roasting machines, packing machines and transportation. Machines and equipment are different from inputs as they may not be purchased every planting cycle and have their own economic lifespans, usually multiple years, in which they have economic values. Labor costs refer to expenses incurred by farmers for employing workers to support the production, processing and sales of their products. As observed through interviews with several partners, many farmers were actively involved in the production and sales of their products and assisted by family members, where the work was not remunerated. However, to provide a more accurate assessment, two scenarios are provided in the calculation, where the labor costs of remunerating farmers and family members are included and excluded. In the first scenario, where the work done by farmers and family members is remunerated, the calculations were done using hours worked for each person and an hourly rate based on the rate that the farmers use for paying workers.

Table A1. *Production activities and items associated with the identified costs*

Production Phase	Activities/Items
Land preparation	Input: herbicide, insecticide, fuel (for operating land clearing machines) Machines/equipment: mower, tractor, sprayer, machete Labor: hiring workers
Planting	Input: seeds or seedlings, fertilizer and/or polybags (for seedling production) Machines/equipment: planter, hoe, sickle Labor: hiring workers
Cultivation	Input: fertilizer, pesticide, herbicide Machines/equipment: sprayer, sickle, shears Labor: hiring workers
Harvesting	Input: fuel (for operating harvester) Machines/equipment: harvester, container Labor: hiring workers
Processing	Input: fuel (for operating processing machines) Machines/equipment: peeler, huller, dryer, sheller, roaster, wok, drying mat, container Labor: hiring workers
Packaging	Input: pouch, label Machines/equipment: packer, weighing scale Labor: hiring workers
Transportation/distribution	Input: fuel (for operating vehicle) Machines/equipment: vehicle, transport fee Labor: hiring workers

Information on the revenues obtained by farmers from these economic activities were also gathered by interviewing farmers. Calculation on the revenue was done using figures on the frequency of harvesting per year, average production yield per harvesting, yield of end products that farmers were able to produce as well as sale prices of the products. The annual profits were then calculated by calculating the difference between the annual revenues and the production costs. These profits were then calculated in terms of Net Present Value (NPV), projecting the annual net income likely to be received by farmers from these forest-replacing economic activities for 30 years into the future with a discount rate of 5 percent.

The calculations of forgone profits, although do not account for short-term fluctuations, were calculated using a number of assumptions to provide conservative profit projections, using references obtained from desktop research and stakeholder interviews. General assumptions used for calculating the annual net profits of all focus commodities are as follows:

1. All trees and plants were planted at the same time .
2. The agricultural practices throughout the production are conducted consistently.
3. The revenues that the farmers are able to generate are the maximum amount of revenues, assuming that all of the products are sold.
4. One working day consists of 8 hours of work.
5. When figures were given in ranges, the upper limit of the range was used in the calculation.
6. When farmers were unable to provide exact figures, figures were obtained from other farmers producing the same crop in the same district or from desktop studies, using official governmental data whenever possible.
7. Unless information on the frequency of machine and equipment replacement was obtained through the interviews, the calculation of the costs associated with the replacement of machines and equipment was done using official governmental document[16] detailing economic lifespans of the respective machines and equipment.

The following assumptions were made for calculating the annual net profits from coffee production:

1. Coffee trees are planted at 3m x 4m spacing.
2. All trees have reached their productive age after 3 years and will remain productive for 30 years.
3. The productivity of each coffee tree is 1 kilogram per year.
4. Eight kilograms of coffee cherries are needed to produce 1 kilogram of green beans, which can be processed into 800 grams of roasted beans or ground coffee.

We made the following assumptions to calculate the annual net profits from corn production:

1. The weight of dried corn kernels (end product) is 39% of the weight of the harvested, unshelled and undried corn cobs[17] .

We applied the following assumptions to calculate the annual net profits from rice production:

1. The weight of dried rice (end product) is 56.22% of the harvested, unhulled and undried rice[18] and the price of unhulled rice is IDR 4,829/kg[19]; these assumptions were used when fees incurred by farmers for processing the rice into the final products were paid with yield (as opposed to money).
2. The yield of rice husks that one of the interviewed farmers sells as animal feed is 20% of the total harvested rice.

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[16] https://peraturan.bpk.go.id/Home/Details/121997/perbup-kab-banjar-no-4-tahun-2019
[17] http://bppgalur.blogspot.com/2017/02/konversi-padi-jagung-kedelai-kacang.html
[18] https://sultra.bps.go.id/statictable/2022/08/14/4023/angka-konversi-gkp-ke-gkg-dan-gkg-ke-beras-2018.html
[19] https://www.bps.go.id/indicator/36/1034/1/rata-rata-harga-gabah-bulanan-menurut-kualitas-komponen-mutu-dan-hpp-di-tingkat-petani.html

To provide a comparable assessment of net present value of profits from agricultural production and benefits of forest conservation, the calculation for both values was done using a per-capita basis as opposed to the per-hectare basis. This is due to the vast forest areas in Sigi District that may not be utilized equally due to the different levels of accessibility. In other words, forest edges may be utilized more and provide more benefits to communities where they can easily access them for harvesting food, non-timber forest products and establishing facilities for ecotourism, compared to forest interiors that are less accessible. However, it is worth noting that many indirect benefits of forest conservation, such as provision of good air quality and habitat for biodiversity, may be derived from the entire forest areas, including forest edges and interiors, and the overall forest conservation can benefit not only communities living in close proximity to the forests but also a much wider range of population.

Coffee

Based on interviews conducted with farmers and relevant district-level agencies in Sigi District, the average yearly production costs incurred along the value chains of coffee, as well as the average yearly revenues, throughout the 30-year projection were acquired and presented in Table A2 and Table A3 below.

Table A2. *Costs associated with coffee production in Sigi District*

Average Yearly Production Costs				
Activity	**Input**	**Machines and Equipment**	**Labor (if work of farmers and their family members is remunerated)**	**Labor (if work of farmers and their family members is not remunerated)**
Land preparation	1,328,000	2,915,000	1,080,000	1,080,000
Pre-planting	17,750,000	-	-	-
Planting	-	150,000	2,100,000	1,400,000
Post-planting	-	-	-	-
Cultivation	472,000	4,355,000	23,675,000	150,000
Pre-harvesting	-	-	-	-
Harvesting	-	33,000	11,180,000	1,470,000
Post-harvesting	-	-	-	-
Processing	212,500	14,245,000	9,000,000	-
Packaging	12,500	35,000	3,125,000	-
Transportation/ distribution	-	-	-	-
Sales/marketing	-	-	-	-
TOTAL	**19,775,000**	**21,733,000**	**50,160,000**	**4,100,000**

Table A3. *Average yearly revenues for coffee farmers in Sigi District*

Average Yearly Revenue			
Product	**Price per kg**	**Overall revenue per hectare**	**Overall revenue per capita**
Coffee cherries	8,000	14,400,000	7,200,000
Green beans	80,000	25,000,000	12,500,000

There are a number of factors contributing to the differences in the prices of coffee. Coffee is sold in many quality grades, which corresponds to the prices of the coffee. Different farmers also process their coffee into different products, depending on a number of factors such as market demands, farmers' capacities and available technology. However, the price rates of the coffee vary depending on the quality of the final product. Actors along the supply chain also play a role in determining the prices of the coffee and neither local nor national governments regulate the prices of Pinogu coffee.

In addition to sale prices, the revenues obtained by farmers from coffee production also depend on the total area of land owned by farmers that is planted with coffee trees. In this study, each of the interviewed farmers owns and plants coffee trees within 2 hectares of land each. As shown in Table A3, the calculation of farmers' revenues used a per-hectare basis to provide a comparable assessment between farmers, and a per-capita basis was used to provide a comparable assessment between the net present value of profits from coffee production and benefits of forest conservation.

Based on Table A2 and Table A3, the profits generated by coffee farmers in Sigi District are as follows:

Table A4. *Profits generated by interviewed coffee farmers in Sigi District*

Average Yearly Profit				
Product	**Average yearly profit per hectare (if family members work is remunerated)**	**Average yearly profit per hectare (if family members work is not remunerated)**	**Average yearly profit per capita (if family members work is remunerated)**	**Average yearly profit per capita (if family members work is not remunerated)**
Coffee cherries	(-12,230,133)	12,918,533	(-6,115,067)	6,459,267
Green beans	8.278.870	22.183.500	4.139.435	11.091.750

These profits were projected into the next 30 years to obtain the Net Present Value (Table A5).

Table A5. *Net Present Value (NPV) of coffee production in Sigi District*

NPV				
Product	**NPV per hectare (if family members work is remunerated)**	**NPV per hectare (if family members work is not remunerated)**	**NPV per capita (if family members work is remunerated)**	**NPV per capita (if family members work is not remunerated)**
Coffee cherries	-200,237,259.05	211,508,054.34	-100,118,629.53	105,754,027.17
Green beans	135.545.399,70	363.198.267,35	67.772.699,85	181.599.133,68

Cacao

Based on the interviews conducted with farmers and relevant district-level agencies in Sigi District, the average yearly production costs incurred along the value chains of cacao produced in the district, as well as the average yearly revenues, throughout the 30-year projection were acquired and presented in Table A6 and Table A7 below.

Table A6. *Costs associated with cacao production in Sigi District*

Average Yearly Production Costs				
Activity	**Input**	**Machines and Equipment**	**Labor (if work of farmers and their family members is remunerated)**	**Labor (if work of farmers and their family members is not remunerated)**
Land preparation	161,700	310,700	104,000	0
Pre-planting	1,700	-	8,000	8,000
Planting	-	-	40,000	40,000
Post-planting	1,000,000	-	4,080,000	-
Cultivation	3,690,000	14,700	-	-
Pre-harvesting	-	-	-	-
Harvesting	2,600,000	30,000	-	-
Post-harvesting	-	-	-	-
Processing	-	310,000	540,000	-
Packaging	3,000	270,000	-	-
Transportation/ distribution	95,000	1,500,000	-	-
Sales/marketing	-	-	-	-
TOTAL	7,551,400	**2,435,400**	**4,772,000**	**48,000**

Table A7. *Average yearly revenues for cacao farmers in Sigi District*

Average Yearly Revenue (IDR)			
Product	**Price per kg**	**Overall revenue per hectare**	**Overall revenue per capita**
Unfermented cacao beans	32,000	12,800,000	6,400,000
Fermented cacao beans	40,000	16,000,000	8,000,000

Based on Table A6 and Table A7, the profits generated by cacao farmers in Sigi District are as follows:

Table A8. *Profits generated by interviewed cacao farmers in Sigi District*

Average Yearly Profit				
Product	Average yearly profit per hectare (if family members work is remunerated)	Average yearly profit per hectare (if family members work is not remunerated)	Average yearly profit per capita (if family members work is remunerated)	Average yearly profit per capita (if family members work is not remunerated)
Unfermented cacao beans	6,720,667	9,082,667	3,360,333	4,541,333
Fermented cacao beans	9,920,667	12,282,667	4,960,333	6,141,333

These profits were projected into the next 30 years to obtain the Net Present Value (Table A9).

Table A9. *Net Present Value (NPV) of cacao production in Sigi District*

NPV				
Product	NPV per hectare (farmer/ family members remunerated)	NPV per hectare (farmer/ family members not remunerated)	NPV per capita (farmer/ family members remunerated)	NPV per capita (farmer/ family members not remunerated)
Unfermented cacao beans	110,033,785	148,705,515	55,016,892	74,352,757
Fermented cacao beans	162,425,629	201,097,358	81,212,814	100,548,679

Corn

Table A10. *Costs associated with corn production in Sigi District*

Average Yearly Production Costs				
Activity	**Input**	**Machines and Equipment**	**Labor (farmer/ family members remunerated)**	**Labor (farmer/ family members not remunerated)**
Land preparation	4,700,000	1,525,000	570,000	520,000
Pre-planting	7,970,000	-	-	-
Planting	-	-	7,200,000	7,200,000
Post-planting	12,870,000	-	7,560,000	7,560,000
Cultivation	10,440,000	160,000	17,010,000	9,905,000
Pre-harvesting	-	-		-
Harvesting	1,800,000	-	2,400,000	7,500,000
Post-harvesting	-	100,000	300,000	-
Processing	-	7,850,000	-	2,880,000
Packaging	-	-	-	-
Transportation/ distribution	-	600,000	-	-
Sales/marketing	-	-	-	-
TOTAL	**37,780,000**	**10,235,000**	**35,040,000**	**35,565,000**

Table A11. *Average yearly revenue for corn farmers in Sigi District*

Average Yearly Revenue (IDR)			
Product	**Price per kg**	**Overall revenue per hectare**	**Overall revenue per capita**
Dried corn kernels	4,000	46,000,000	25,500,000

Based on Table A10 and Table A11, the profits generated by corn farmers in Sigi District are as follows:

Table A12. *Profits generated by interviewed corn farmers in Sigi District*

Average Yearly Profit				
Product	**Average yearly profit per hectare (family remunerated)**	**Average yearly profit per hectare (family not remunerated)**	**Average yearly profit per capita (family remunerated)**	**Average yearly profit per capita (family not remunerated)**
Dried corn kernels	9,753,311	11,886,644	7,819,983	8,219,983

These profits were projected into the next 30 years to obtain the Net Present Value (Table A13).

Table A13. *Net Present Value (NPV) of corn production in Sigi District*

NPV				
Product	**NPV per hectare (if family members work is remunerated)**	**NPV per hectare ((if family members work is not remunerated)**	**NPV per capita (if family members work is remunerated)**	**NPV per capita (if family members work is not remunerated)**
Dried corn kernels	159,685,608	194,613,504	128,032,294	134,581,274

Rice

Table A14. *Costs associated with rice production in Sigi District*

Average Yearly Production Costs				
Activity	**Input**	**Machines and Equipment**	**Labor (if work of farmers and their family members is remunerated)**	**Labor (if work of farmers and their family members is not remunerated)**
Land preparation	28,034,100	1,512,500	2,137,500	1,987,500
Pre-planting	790,125	-	990,000	900,000
Planting	-	-	2,430,000	2,430,000
Post-planting	-	-	-	-
Cultivation	20,703,000	40,000	4,560,000	2,520,000
Pre-harvesting	-	-	-	-
Harvesting	-	10,140,900	7,000,000	6,953,760
Post-harvesting	-	-	-	-
Processing	-	13,325,580	3,060,000	2,699,000
Packaging	1,050,000	-	-	-
Transportation/ distribution	-	-	-	-
Sales/marketing	-	-	-	-
TOTAL	**50,540,125**	**25,005,900**	**20,177,500**	**17,550,000**

Table A15. *Average yearly revenue for rice farmers in Sigi District*

Average Yearly Revenue (IDR)			
Product	**Price per kg**	**Overall revenue per hectare**	**Overall revenue per capita**
Rice	9,500	46,803,150	18,341,775
Husk	2,143	3,085,714	771,428.57
TOTAL		49,888,864	19,113,204

Based on Table A14 and Table A15, the profits generated by rice farmers in Sigi District are as follows:

Table A16. *Profits generated by interviewed rice farmers in Sigi District*

Average Yearly Profit				
Product	**Average yearly profit per hectare (if family members work is remunerated)**	**Average yearly profit per hectare (if family members work is not remunerated)**	**Average yearly profit per capita (if family members work is remunerated)**	**Average yearly profit per capita (if family members work is not remunerated)**
TOTAL	3,736,385	5,686,385	1,293,754	2,212,504

These profits were projected into the next 30 years to obtain the Net Present Value (Table A17).

Table A17. *Net Present Value (NPV) of rice production in Sigi District*

NPV				
Product	**NPV per hectare (if family members work is remunerated)**	**NPV per hectare (if family members work is not remunerated)**	**NPV per capita (if family members work is remunerated)**	**NPV per capita (if family members work is not remunerated)**
TOTAL	61,173,788	93,100,067	21,181,935	36,224,124

Benefits of Forest Conservation-based Activities

Table A18. *Types of ecosystem services included in calculations of forest conservation benefits*

Ecosystem services	Benefit	Beneficiary	Type of economic benefit
Water regulation	Irrigation water	Farmers	Indirect
Non-timber forest products	Rattan, sago, honey, gaharu, bamboo, etc. Food e.g. crops, fruit, fish	People living near the forest	Direct
Air quality regulating	Good quality air	Everyone	Indirect
Disaster mitigation	Flood control	People living in flood-prone areas	Indirect
	Landslide prevention	People living in landslide-prone areas	Indirect
	Fire prevention	People living in fire-prone areas	Indirect
Biodiversity	Protecting rare and endangered species	Everyone	Indirect
Carbon sequestration and storage	Climate regulation	Everyone	Indirect
Tourism and recreation	Recreational hiking and camping	Hikers, campers	Direct

Estimation of economic value of each forest ecosystem services

1. Water regulation

   The total forest area in Sigi is 377,018 ha. If the price IDR 4 million/ha/year[20] applied, the total benefit from forest conservation for water regulation in Sigi is IDR 1.5 Trillion.

2. Air quality

   a. O_2 generation

      Previous studies show that the mean O2 generation per unit of forest, lawn, and water areas is 109.53 ton/ha, 46.18 ton/ha, and 0.17 ton/ha, respectively. The cost of producing O_2 through industrial processes was used in this study to estimate the benefit of O_2 generation at a value of IDR 879,810/ton.

   b. Air temperature amelioration

[20] Budhi, Gelar Satya, S. A. Kuswanto, and M. Iqbal. "Concept and implementation of PES program in the Cidanau watershed: a lesson learned for future environmental policy." *Analisis Kebijakan Pertanian* 6.1 (2008): 37-55.

Average annual evaporation per unit water is 927.1 mm. Based on the water area in parks, the overall evaporation of water bodies can be obtained. The ecological service value of evaporative cooling was calculated as IDR 283.74 per unit. The transpiration amount for forest and grass areas is 22.61 × 106 KJ/ha and 11.75 × 106KJ/ha, respectively. With the residential electricity price at IDR 1,444.70/kwh, transpiration cooling can be valued.

c. SO_2 removal

The SO_2 removal per unit forest area was based on the average amounts per broad-leaved and coniferous tree, with a value of 152.13kg/ha. For the land cover type of lawn, the value is 279.03 kg/ha. As aquatic plants absorb only a small amount of sulfur oxides from the atmosphere, the ecological service of SO_2 removal by water was neglected in this study. According to the literature, the marginal cost of SO_2 in China is IDR 6,600/kg.

d. NO_x removal

Previous studies have indicated that NO_x removal per unit of forest and unit of grassland is 380 kg/ha and 6 kg/ha, respectively. The benefit of NO_x removal in water bodies can be neglected. The vehicle exhaust denitrification treatment cost was used in calculating the ecological service value of NO_x removal, with a value of IDR 35 million/ton.

3. Disaster mitigation: flood

a. Number of buildings

Initially, the building data that will be used to calculate the number of buildings that are located within the disaster-prone area is sourced from OpenStreetMap (OSM) data. But, due to incomplete data, the settlement area by BRG and existing data by OSM is used to calculate the average number of buildings in a hectare of the settlement area. In Sigi, the building density is 18 buildings per hectare. Below is the result of the analysis of buildings based on the risk level to flood.

Table A19. *Estimate of the number of buildings in flood risk zones*

Risk level	Settlement area	Total buildings
Low	0	0
Moderate	234	4,207
High	141	2,535

b. Building damage rate

- Low: no damage;

- Moderate: 50% of the number of houses affected by light damage multiplied by the regional price unit;
- High: 50% of the number of houses affected by moderate damage multiplied by the regional price unit, and 50% of the number of houses affected by heavy damage multiplied by the regional price unit.

c. Economic benefit
- Moderate= $\frac{1}{2} \times 4{,}207 \times \frac{1}{4} \times IDR\ 180{,}000{,}000 = 94{,}657{,}500{,}000$
- High= $\left(\frac{1}{2} \times 2{,}535 \times \frac{1}{2} \times IDR\ 180{,}000{,}000\right) + \left(\frac{1}{2} \times 2.535 \times IDR\ 180{,}000{,}000\right)$

  $= IDR\ 114{,}075{,}000{,}000 + IDR\ 228{,}150{,}000{,}000 = IDR\ 342{,}225{,}000{,}000$
- Total $= IDR\ 94{,}657{,}500{,}000 + IDR\ 342{,}225{,}000{,}000 = \ IDR\ 436{,}882{,}500{,}000$

4. Disaster mitigation: landslides

a. Number of buildings

Table A20. *Estimate of the number of buildings in landslide risk zones*

Risk level	Settlement area (ha)	Total buildings
Low	12	238
Moderate	29	574
High	45	891

b. Building damage rate
- Low: no damage;
- Moderate: 50% of the number of houses affected by light damage multiplied by the regional price unit;
- High: 50% of the number of houses affected by moderate damage multiplied by the regional price unit, and 50% of the number of houses affected by heavy damage multiplied by the regional price unit.

c. Economic benefit
- Moderate= $\frac{1}{2} \times 574 \times \frac{1}{4} \times IDR\ 180{,}000{,}000 = 12{,}915{,}000{,}000$
- High= $\left(\frac{1}{2} \times 891 \times \frac{1}{2} \times IDR\ 180{,}000{,}000\right) + \left(\frac{1}{2} \times 891 \times IDR\ 180{,}000{,}000\right)$
  $= IDR\ 40{,}095{,}000{,}000 + IDR\ 80{,}190{,}000{,}000 = IDR\ 120{,}285{,}000{,}000$
- Total $= IDR\ 12{,}915{,}000{,}000 + IDR\ 120{,}285{,}000{,}000 = \ IDR\ 133{,}200{,}000{,}000$

5. Disaster mitigation: forest and land fire

a. Number of buildings

Table A21. *Estimate of the number of buildings in forest and land fire risk zones*

Hazard level	Settlement area	Total buildings
Low	5	90
Moderate	20	396
High	0	0

b. Building damage rate
   - Low: no damage;
   - Moderate: 50% of the number of houses affected by light damage multiplied by the regional price unit;
   - High: 50% of the number of houses affected by moderate damage multiplied by the regional price unit, and 50% of the number of houses affected by heavy damage multiplied by the regional price unit.

c. Economic benefit
   - Moderate= $\frac{1}{2} \times 396 \times \frac{1}{4} \times IDR\ 180{,}000{,}000 = IDR\ 8{,}910{,}000{,}000$

6. Biodiversity
   a. Identification of rare and endangered species
      1. Anoa (*Bubalus depressicornis*)

         Lowland Anoa (*Bubalus depressicornis)* has most recently been assessed for The IUCN Red List of Threatened Species in 2014. *Bubalus depressicornis* is listed as Endangered under criteria C1+2a(i).

      2. Babirusa Sulawesi (*Babyrousa celebensis*)
         Babyrousa celebensis has most recently been assessed for The IUCN Red List of Threatened Species in 2016. *Babyrousa celebensis* is listed as Vulnerable under criteria A2cd; C1.

   b. Estimation of offsite protection cost of rare and endangered species
      1. Labor cost

         IDR 2,303,711 per month

         IDR 3,917,942,536 per km2

2. Land lease cost

   IDR 1,200,179,569 per km2

3. Forest pest control drug
   75,000 g/km2
   IDR 13,205 per gram
   IDR 990,375,000 per km2
4. Medicine for disease and pest control in grassland
   180 g/km2
   IDR 86,437 per gram
   IDR 15,558,660 per km2
5. Agricultural irrigation cost
   IDR 36,019,925 per km2
   Trees: IDR 180,099,625 per km2
   Herbs: IDR 288,159,400 per km2

   Total cost = IDR 5,602,930,165 per km2

c. Habitat analysis and cost estimation

Table A22. *Estimate of the offsite protection cost of rare and endangered species*

Land use	Elevation	Slope	Distance to river	Distance to settlement	Area (km2)	Cost (IDR)
Primary forest	0-1000m	9-25%	800-1000 m	6-8 km	86.49	484.6 B

7. Carbon sequestration and storage
   a. Aboveground biomass (AGB)

The estimation of aboveground biomass (AGB) is carried out by implementing the mean AGB that has been carried out by the Ministry of Environment and Forestry by collecting data from surveys conducted on each forest type in Indonesia. In Sulawesi Island, at least 433 measurement plots have been carried out, which results in the mean AGB for primary dryland forest and secondary dryland forest being 275.2 t/ha and 206.5 t/ha, respectively.

b. Biomass conversion to carbon

To estimate the amount of carbon (C) in each forest type, information on carbon fraction is needed. The carbon fraction of biomass (dry weight) was assumed to be 47% (1-ton biomass = 0.47 tons C) following the IPCC 2006 Guideline.

Table A23. *Estimate of the economic value of forest carbon storage*

Forest area 2019 (ha)	Mean AGB (t/ha)	Total AGB (t)	Total C (t)	Carbon storage economic value (million IDR)
Primary: 320,319	275.2	88,151,789	41,431,340	6,214,701
Secondary: 56,698	206.5	11,708,137	5,502,824	825,423
	Total	33,764,748	15,869,432	7,040,124

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