# Biochar Adoption in Timor-Leste Report


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*Report Cover Photo: MAF Researcher Julieta on her research plot in Baucau, on July 19, 2018.*

## Executive summary

Since 2017, AI-Com and partners have promoted biochar through their research programs. Knowledge transfer on biochar production and application continues to expand from researchers to extension workers and onto farmers. All surveyed farmers (N=28) could articulate the benefits of using biochar, which included improving soil fertility (100%), keeping the soil loose (46%), reducing input use (22%), modifying soil pH (15%), remedy for soil (11%) and increasing crop production (7%). The main factors respondents listed for applying biochar were that biochar was easy to prepare (29%); they had free access to biochar (24%), and biochar lasts for a long period of time (14%).

Most respondents were unable to identify challenges or risks in using and producing biochar. Among biochar users, a challenge they perceived was the potential costs of collecting and transporting rice-hull since they could not easily source rice-hull near their locations. Identifying and connecting with reliable rice-hull sources and rice-milling services at short distances can reduce barriers for biochar adoption beyond the lifespan of these programs.

Considering the low use of inorganic fertilizers and prevalence of land degradation, biochar offers a “greener” alternative that can be incorporated into soil management systems with the added benefits for smallholder to improve crop production and incomes.

# I. Introduction

Biochar refers to carbon-rich material used as a soil amendment to improve soil fertility. Interest in biochar application in agriculture stems from the potential increase in crop productivity, soil health and climate change mitigation (Cox *et al.,* 2020, p.50). Biochar is produced by pyrolysis (i.e., heating in the absence of oxygen) of biomass (i.e., feedstock). Sources of feedstock for biochar products are mainly from agricultural and forest biomass residue. The feedstock undergoes thermal decomposition during pyrolysis and is reduced to a carbon-rich residue, a process known as carbonization (Cox *et al.,* 2020, p.12). Pyrolysis is optimal for biochar production since the main aim is to produce an agronomically useful char product with no adverse environmental outcomes (Cox *et al.,* 2020, p.12). Another advantage of biochar production is that it can be operated at various scales, making it suitable for smallholder farmers to adopt (Verheijen *et al.,* 2010, p.113).

There is clear evidence that incorporating biochar into soil improves its properties, increases crop yield and growth, and increases the efficiency of fertilizer use (Wijitkosum and Jiwnok, 2020). For example, research experiments in Thailand using locally available materials on infertile sandy clay soil and clay loam improved soil properties and increased crop yield and growth (Sriburi and Wijitkosum, 2016). Soils treated with the combination of biochar and organic fertilizer further improved soil and crop yields (Sriburi and Wijitkosum, 2016). In Thailand, feedstock used to produce biochar varies, such as crop residues, hardwoods, softwoods, dung (manures), and agro-industrial wastes (Wijitkosum and Jiwnok, 2020, p.478). Likewise in Kenya, biochar is produced from agricultural waste, such as maize husk and dry corn stalks, wheat husk and rice-hull (Mitchell, 2021).

Biochar materials in Timor-Leste are sourced from several types of organic waste, such as rice-hull, wood shaving and coffee husk. Rice-hull biochar is the main type of biochar used in AI-Com and partners' research conducted in Timor-Leste. Since 2017, AI-Com and its partners such as MAF (through the Directorate of Research and Statistics/DNPE), UNTL (through the Department of Agronomy, Faculty of Agriculture), World Vision Timor-Leste through a project called *"Better Food Better Health (BFBH)"* and the Natarbora Agricultural Technical School/NATS) have been conducting research on rice-hull biochar application across 6 municipalities, including Baucau, Viqueque, Manatuto, Aileu, Bobonaro and Covalima. Different biochar treatments have been used on rice, horticultural crops, legumes and tubers during the dry and rainy seasons. Treatments comprised of rice-hull biochar, combining rice-hull biochar with animal manure as well as combining rice-hull biochar with inorganic fertilizers (N, P and K). There are also a few field experiments currently comparing rice-hull biochar with coffee husk (AI-Com 2020a, p.13) and wood shaving biochar (MAF Directorate of Research, *pers comm*,. 21 June 2020) to identify possible alternative sources of biomass and assess their influence on crop productivity, but both are still under observation.

Out of the aforementioned treatments, the mixing of rice-hull biochar with inorganic fertilizers N and P on rice and horticultural crops have shown large positive responses with a greater economic return from the horticultural crops in Vemasse (AI-Com 2020a, p.15).

Therefore, to increase crop production and improve soil fertility in an environmentally friendly way through reduced reliance of agrochemicals, AI-Com together with MAF and UNTL have developed Biochar Plus, which is a combination of rice-hull biochar with low levels of N and P (AI-Com 2020a, p.15). The on-going studies reported that the effective application rate of Biochar Plus is 1-3ton of biochar with 2% of N and 1% of P for one hectare of land. A ton of Biochar Plus/ha is made from combining 1000kg of rice-hull biochar (1ton) with 43.47Kg Urea (2%N or 20Kg N) and 27Kg SP36 (1%P or 10Kg P). Three tons of rice-hull can produce 1ton of rice-hull biochar. Therefore, it requires 9tons of rice-hull to produce 3tons of rice-hull biochar.

In addition to farmers participating in the above trials, there are farmers who have independently started to adopt biochar, some rice millers who have started to earn income from selling rice-hull and biochar, as well as rice-hull buyers for the purpose of biochar sale in contexts where there is a guaranteed market for them to sell. There are also farmers who source rice-hull to produce biochar for use on their farm.

Considering the multiple potential of biochar to increase production, improve soil health and mitigate climate variability impacts as well as adding to farmers' incomes, AI-Com SOSEK team undertook a survey between August and September 2021 to document the adoption of this new innovation in Timor-Leste.

## II. Aims and Objectives

1) To understand farmers' attitudes (benefits, concerns and risks) towards producing and using biochar in Timor-Leste.
2) To understand the social, economic and environmental impacts of using biochar by:
- Describing the perceived benefits of turning a waste like rice-hull into a source of livelihood income,
- Comparing crop yields and income before and after applying biochar, and
- Documenting impacts on soil quality after biochar application based on researchers' and farmers' observations of changes in soil color, texture and density.

## III. Methodology

This survey used a mixed method approach by drawing on a questionnaire and semi-structured interviews. The questionnaire was designed in Microsoft Excel and uploaded into an online platform called ONA which enables the questionnaire to be implemented through mobile phones using an application called ODK (Open Data Kit). The semi-structure interview was held by using paper, and then the data was transcribed, translated and coded before analyzing it.

***Biochar Adoption Questionnaire***

This report focuses on biochar adoption in Timor-Leste by focusing on 1) Biochar Users (i.e., farmers who applied biochar) and 2) Biochar Producers (i.e., farmers who produced biochar to apply on their farm and for sale purposes). Survey respondents were recruited from farmers who were directly involved in biochar research with AI-Com and its partners, farmers who have adopted biochar use independently and farmers who have started to

earn an income from producing and selling rice-hull biochar. Purposive sampling was therefore used to identify participants in the MAF, UNTL, WVTL and NATS programs and snowball technique was employed to recruit biochar adopters outside of these programs.

As described in the introduction, research on biochar conducted by AI-Com and partners covers 6 municipalities of Timor-Leste. However, SOSEK team decided to conduct this survey only in two target locations namely Baucau and Bobonaro municipality. Based on the list obtained from AI-Com and partners, farmers who participated in the biochar study numbered between five and 15 in each municipality, and therefore the sample size targeted in the surveys was between 10-20 respondents in each municipality.

A total of 28 respondents were interviewed; all of whom were Biochar Users and 12 were also Biochar Producers. As shown in Table 1, nine respondents were surveyed in Baucau Municipality. They comprised of nine biochar users, six of whom are biochar producers. In Bobonaro Municipality, 19 biochar users were surveyed, among which six produced biochar. Out of these six producers, two participated in MAF's program, two participated in World Vision's program and another two producers were recruited by snowball sampling based on the information given by participants in WVTL and MAF programs.

**Table 1 Total participants recruited for biochar adoption questionnaire.**

| Municipality/Group Category | Respondents surveyed from MAF Researchers | Respondents surveyed from WVTL | Respondents (snowball sampling) | Total Respondents |
|---|---|---|---|---|
| **Baucau** | **3** | **4** | **2** | **9** |
| Biochar Producers | 2 | 2 | 2 | 6 |
| Biochar Users | 1 | 2 | | 3 |
| **Bobonaro (Balibo)** | **3** | **5** | **10** | **18** |
| Biochar Producers | 2 | 2 | 1 | 5 |
| Biochar Users | 1 | 3 | 9 | 13 |
| **Bobonaro (Maliana)** | | | **1** | **1** |
| Biochar Producers | | | 1 | 1 |
| **Overall** | **6** | **9** | **13** | **28** |

***Semi-Structured Interviews***

To document if there is a current supply chain for rice-hull and biochar, a total of 12 rice millers were recruited for semi-structured interviews in this study. This included two rice millers in Atabae who were interviewed in the preliminary survey and three rice millers in Dili to find out if they sold either rice-hull or biochar.

Furthermore, three MAF researchers based in Baucau, Maliana and Viqueque were interviewed in the MAF Headquarters in Dili to understand biochar production and application from scientific/researchers' perspectives as well as to triangulate with biochar users and producers' perspectives.

Lastly, two biochar sellers were also interviewed to learn more about the current status of biochar market in Timor-Leste. This included a former UNTL agronomy student in Hera, Dili Municipality who produced and sold biochar through social media since 2019. Total participants for semi-structured interviews are listed in Table 2.

Table 2 Total participants recruited for semi-structured interviews.

| Participants in the semi-structure interview | Baucau | Bobonaro | Dili | Total |
|---|---|---|---|---|
| Rice-Millers | 2 | 7 | 3 | 12 |
| MAF Researchers | 0 | 0 | 3 | 3 |
| Biochar Seller | 0 | 0 | 2 | 2 |
| **Overall** | **2** | **7** | **8** | **17** |

# IV. Demographic Data

## 4.1 Total Participants and Respondents Categories

A total of 28 respondents were surveyed, nine were sampled in Baucau and 19 in Bobonaro Municipality (Table 3). All respondents used biochar (termed here on as Biochar Users) and 12 of them also produced biochar (termed here on as Biochar Producers).

Table 3 Total respondents for biochar adoption questionnaire (by location and respondent category).

| Municipality | Administrative Post | Village Name | Biochar Users | Biochar Producers* |
|---|---|---|---|---|
| Baucau | Baucau | Buibau | 3 | 1 |
| | | Buruma | 2 | 1 |
| | | Gariwai | 1 | 1 |
| | | Seixal | 1 | 1 |
| | | Triloka | 2 | 2 |
| **Total participants from Baucau** | | | **9** | **6** |
| Bobonaro | Balibo | Balibo Vila | 4 | 1 |
| | | Batugade | 1 | 2 |
| | | Cowa | 5 | |
| | | Leohitu | 3 | 1 |
| | | Leolima | | 1 |
| | Maliana | Raifun | | 1 |
| **Total Participants from Bobonaro** | | | **19** | **6** |
| **Overall Respondents** | | | **28** | **12** |

*Note: All biochar producers are a sub-set of users.

## 4.2 Respondents' Age Range, Education Level and Occupation

Respondents were aged between 24 and 69. Most of them are married (N=23) and five respondents are single/not married. Of the 21 respondents who attended school, nine of them completed secondary school, four completed pre-secondary school and eight attained primary school education. Among those who have attended school, almost all are farmers and only one respondent is a public servant (extension worker). For respondents who have not attended school (N=7), their main occupation was also farming.

# V. Results

The results of this survey are divided into two sections. The first section discusses Biochar Users' attitudes and impacts of application, and the second section focuses on Biochar Producers' experiences in making and selling rice-hull biochar.

## 5.1 Biochar Users

### 5.1.1 Sources of Learning

As Table 4 shows, three respondents started to learn about biochar and applied it from MAF researchers as early as 2017. The main source of knowledge transfer reported is from AI-Com to extension workers and then to farmers; this was similarly reported by MAF researchers and World Vision farmers who stated that training was given to extension workers who taught the leaders of the farming groups, and the leaders in turn shared their knowledge with group members.

Table 4 Year started using biochar and sources of learning.

| Municipality | Source of Learning | Year Started Applying Biochar | | | | | Total Respondents |
|---|---|---|---|---|---|---|---|
| | | 2017 | 2018 | 2019 | 2020 | 2021 | |
| Baucau | MAF Researchers | 3 | 1 | | | 1 | 5 |
| | WVTL | | | 1 | 2 | 1 | 4 |
| **Total Participants in Baucau** | | **3** | **1** | **1** | **2** | **2** | **9** |
| Bobonaro | AI-Com | | 2 | | | | 2 |
| | MAF Researchers | | 2 | | | | 2 |
| | PPL | | | 1 | | | 1 |
| | WVTL | | | 6 | 6 | 2 | 14 |
| **Total Participants in Bobonaro** | | | **4** | **7** | **6** | **2** | **19** |
| **Overall** | | **3** | **5** | **8** | **8** | **4** | **28** |

### 5.1.2 Biochar Application Rates and Treatments

Total frequency sorted indicated that crops planted with biochar are mostly horticulture crops (33%), followed by sweet potato (31%), tomato (24%), legumes (7%) and rice (4%) (Table 5). There are respondents who planted more than one type of crop using biochar (one respondent planted four types of crops, nine respondents planted up to three types of crops, 11 respondents planted two types of crops and only seven respondents planted one type of crop, as shown in Appendix 1, Table 14, based on the season planted).

Table 5 Crops planted by respondents during the dry and wet season (by response frequency (%)).

| Crops planted | Season Planted (%) | | | Total frequency (%) |
|---|---|---|---|---|
| | Dry season | Wet and dry season | Wet season | |
| Horticulture crops | 40 | 28 | 30 | 33 |
| Sweet potato | 20 | 33 | 40 | 31 |
| Tomato | 30 | 17 | 25 | 24 |
| Legumes | 10 | 6 | 5 | 7 |
| Rice | 0 | 17 | 0 | 5 |

When World Vision introduced biochar to farmers during the 2019 and 2020 wet seasons, the treatment, land size and crop were identical, comprising of 25kg of biochar and applied on the 100m$^2$ of land prepared to plant orange sweet potato. There are plots applied in combination with cow manure, only biochar and control. However, when scaled up for tomato during the 2021 dry season, there are farmers who applied the remaining biochar on other crops planted in their home garden; these latter farmers measured biochar amount for use by hand or milk cans.

Respondents who work with MAF researchers stated that the application of biochar depends on the treatments, and therefore, the land size, crops and application rate varied across treatments used. Similar to World Vision farmers, MAF farmers who have started to apply biochar independently use their hands or milk cans as measuring tools. Research by MAF has demonstrated that applying 20kg/ha biochar can improve soil texture and pH. Three ton/ha (3000kg/ha) biochar combined with N2% (80kg/ha) and P1% (40kg/ha) can improve soil fertility and increase production compared to other treatments (MAF Directorate of Research, *pers comm.,* 7 October 2021).

Most respondents applied biochar on the same parcel of land (N=22). Those who used different parcels of land (N=6) or more than one plot explained that they used different plots of land to grow rice or sweet potato during the rainy season and various horticulture crops during the dry. The minimum plot used by these respondents is two and the maximum plot used is three.

Excluding those who produced their own biochar (N=12), most biochar users obtained biochar freely (N=15). Twelve respondents received free biochar from World Vision, two respondents obtained freely from MAF Researchers and one respondent obtained it from a friend. Only one respondent buys biochar for $1.00/25Kg sack.

### 5.1.3 Methods and Application Frequency to Apply Biochar

Broadcasting and incorporation were used to apply biochar. All respondents in Baucau (N=9) applied biochar before planting, with most incorporating biochar into the hole prepared to plant crops (N=7). Only two respondents spread biochar on the bed prepared to plant crops. Similarly, most respondents in Bobonaro applied biochar before planting (N=16) and put in the dug hole (N=14). One respondent applied biochar before and after planting and another two respondents applied biochar during planting. Additionally, four respondents spread biochar on the bed prepared to grow crops and another respondent used both broadcasting and incorporating into the crop planting hole (Table 6).

To better discern the optimal method to apply biochar, a MAF researcher who conducted biochar research was interviewed. The researcher stated that the best method for biochar application depends on the farmer's goal. If the aim of application was to increase production, the best method demonstrated is to incorporate biochar into the crop planting hole, as it can help plants to get nutrition easily and the residue could be used in the next planting season. Broadcasting could be used when the intention is to improve soil structure or soil pH (MAF Directorate of Research, *pers. comm.,* 10 October 2021). An interview with another MAF researcher elaborated that placing biochar in the hole before planting is better to minimise loss by wind and water erosion (see also Major 2010, pp.7-8). After biochar is

placed in the hole, it is recommended to spray with water and leave it for 1 or 2 days before planting, which has proven to be beneficial for plant growth since the biochar is guaranteed to have cooled down after pyrolysis and well absorbed in the soil. This method can help accelerate plant growth by enabling plants to easily get nutrients (MAF Directorate of Research, *pers comm.,* 20 October 2021).

**Table 6 Total respondents' answers on the methods and application frequency to apply biochar.**

| Methods Used | Time Applied (Before, after or during planting) | | | |
|---|---|---|---|---|
| | Before | During | Before and after | Total |
| Put in a hole prepared to plant crops | 7 | | | 7 |
| Spread on the bed prepared to plant crops | 2 | | | 2 |
| **Baucau** | **9** | | | **9** |
| Put in a hole prepared to plant crops | 13 | 1 | | 14 |
| Spread and put in the hole prepare to grow crops | | | 1 | 1 |
| Spread on the bed prepared to plant crops | 3 | 1 | | 4 |
| **Bobonaro** | **16** | **2** | **1** | **19** |
| **Overall** | **25** | **2** | **1** | **28** |

### 5.1.4 Reasons for Applying Biochar

The top three reasons respondents stated for applying biochar are because it is easy to prepare (29%), they have free access to biochar (24%) and biochar lasts for a long period of time (14%), and other reasons as shown in Table 7.

**Table 7 Reasons why respondents wanted to apply biochar (by frequency response (%)).**

| Reasons for applying biochar | Total frequency of responses (%) |
|---|---|
| Biochar is easy to prepare | 29 |
| Have free access to biochar | 24 |
| Lasts a long period of time | 14 |
| Improves soil fertility | 7 |
| Increase the quality of crops produced | 7 |
| Because we have seen that the result is good | 2 |
| Because we joined World Vision's program | 2 |
| Biochar is better than liquid fertilizer | 2 |
| Increase income | 2 |
| Just wanted to try | 2 |
| Makes the plants fertile, save/hold water in the soil | 2 |
| Want to learn new skills and technology from World Vision | 2 |
| We want to participate in this program | 2 |

### 5.1.5 Farmers' Attitudes to Using Biochar

**Benefits of Using Biochar**

The main benefit of using biochar as cited by all respondents is to improve soil fertility (100%). The second most reported benefit is keeping the soil loose (46%), followed by reduced input use (22%), increase soil pH (15%), remedy for soil (11%) and increase production (7%) (Table 8).

Table 8 Respondents' perceptions of the benefits of using biochar.

| The benefits of using biochar | Biochar Users (%) | Biochar Producers (%) | Frequency of responses (%) |
|---|---|---|---|
| Improve soil fertility | 47 | 53 | 100 |
| Keeping the soil loose | 46 | 45 | 46 |
| Reduce input | 29 | 14 | 22 |
| Increase soil pH | 13 | 18 | 15 |
| Remedy to soil | 13 | 9 | 11 |
| Increase production | 0 | 14 | 7 |

**Challenges and Risks of Using Biochar**

Most respondents were unable to identify challenges or risks in using biochar. Among those who did, relayed that a big challenge was the limited availability of rice-hull since they could not easily source rice-hull near their locations, which becomes a time-consuming activity. There were also respondents who raised technical issues of applying biochar. Some quotes are cited below:

*Quote #1 (Biochar Producer):"The problem is we do not have rice-hull. We must go and ask for it from other people".*
*Quote #2 (Biochar Producer):"We have less rice-hull because we took it from other place".*
*Quote #3: (Biochar User):" There is no rice-hull production around our village".*
*Quote #4: (Biochar Producer):"It takes time when applying biochar".*
*Quote #5 (Biochar User): "My problem is I do not know properly on how to burn rice-hull".*
Quote #6 *(Biochar Producer) "We put into the soil and therefore we do not know if it has a risk or not. Maybe the technical people know about this issue".*

### 5.1.6 Farmers' Perceptions of Soil Quality after Applying Biochar

Farmers were asked to describe their visual observations of changes to the soil after biochar application as part of this survey. Respondents reported that applying biochar changed soil colour from red to brown or softened the soil and enabled moisture to be better retained in the soil. Although respondents were unable to explain the science, MAF soil researchers have undertaken soil pH analyses before and after biochar application. The results of pH (potential Hydrogen) tests in the laboratory showed that biochar has a neutralizing effect on both acidic (increasing from pH 4 to 6-7) and alkaline soils (reducing from pH 8-9 to 7) (MAF Directorate of Research, *pers comm.,* 7 October 2021).

### 5.1.7 Farmers' Perceptions on Crop Quality after Applying Biochar

Additionally, farmers' visual observations of crop quality after biochar application were recorded. Respondents observed noticeable changes from applying biochar, such as larger-sized fruits or tubers, fresh-looking leaves and better taste. Farmers who planted orange sweet potato through World Vision's program explained that plots applied with biochar in combination with cow manure gave better results (2Kg/tubers) compared to plots applied with biochar only as well as control plots (below 1kg/tuber).

### 5.1.8 Biochar Applied Crops for Sale

Of the 28 respondents, 21 respondents sold their crops which they planted with biochar (Table 9). One respondent who did not sell elaborated that their decision not to sell was unrelated to biochar but rather one of supply and demand of crops, *"I did not sell sweet potato because in this village, most of us planted and sell sweet potato and sometimes it is not sold out in the market. Therefore, I decided to consume only and sell other crop products"*.

**Table 9 Sale of crops planted with biochar application (by no. of respondent).**

| Municipality | Do you sell crops produced using biochar? | | Total |
|---|---|---|---|
| | Sell crops | Do not sell crops | |
| Baucau | 7 | 2 | 9 |
| Bobonaro | 14 | 5 | 19 |
| **Overall** | **21** | **7** | **28** |

The survey team found in the survey that there are still no fixed price and stable market for the sale of crops applied with biochar (see Table 15 in the Appendix 2), but a few respondents made profits by increasing their prices because crop production increased. The responses are cited below:

Quote #1, *Biochar User*: *"Before using biochar, bitter gourd was sold for $1.00/8 pieces but after applying biochar, it was sold for $1.00/4 pieces."*
Quote #2, *Biochar Producer*: *"Before applying biochar, we sell sweet potato by sack and the price was $5.00/25Kg of sack. After applying biochar, the sweet potato was sold by weight; it was $1.00/Kg".*

### 5.1.9 Future Plan for Biochar Application

All but one respondent (N=27) stated that they would like to apply biochar in the future because it improves soil fertility and increases their income. One respondent said "yes" on the condition that they will only continue applying if biochar is provided freely to them. The respondent who stated "no" to using biochar in the future explained that rice-hull is not available around their place (Balibo Administrative Post).

Additional reasons cited are as follows:

> *Quote#1 (Biochar Producer): "Have better benefit compared to inorganic fertilizer".*
> *Quote #2 (Biochar Producer): "If there is ready stock, we will use because it makes the vegetables fertile and bear big fruits".*
> *Quote #3 (Biochar User): "Because it makes the soil loose and has moisture".*
> *Quote #4 (Biochar Producer): "Because the result is good. Gain more profit from plots applied with biochar than those that did not apply biochar".*

### 5.1.10 Covid-19 Impacts on Crop Sale

Almost all respondents who sold their crops from using biochar (N=19) were affected by Covid-19 restrictions (Table 16 in Appendix 3). Only two respondents stated that their sales were not affected. These two respondents did not wait at home for buyers or sold at the designated market places. Instead, they sold their produce around their neighbourhood or

they carried the produce on their head to sell in specific rural areas with low vegetable supplies.

The following section focuses on 12 respondents who produce biochar.

## 5.2 Biochar Producers

Out of the 12 respondents who produced biochar, half of them sourced their rice-hull freely and five bought rice-hull from rice-millers. One respondent sometimes obtained free rice-hull and at other times, paid for rice-hull. The price and unit of sale of rice-hull varied as listed in Table 10 below.

**Table 10 The price of rice-hull as reported by Biochar Producers.**

| Price of rice-hull | Baucau | Bobonaro | Total |
|---|---|---|---|
| $1.00/25kg sack | | 1 | 1 |
| $10.00/truck | | 1 | 1 |
| $50/truck | 1 | | 1 |
| $20/truck | 1 | | 1 |
| *It depends on how much the buyer wants to give | 1 | 1 | |
| $1.00/50Kg sack | | 1 | 1 |
| **Overall** | **2** | **4** | **6** |

*Note: The seller does not ask for money but if the buyer intends to obtain rice-hull in the future, the buyer should ideally give some money as a gesture of gratitude and to form a longer-term relationship. The small amount of money is considered "money for cigarettes", rather than a price set for rice-hull. This kind of exchange takes place usually between close social connections, such as family relatives or friends, since the buyer can take as much rice-hull as possible depending on the generosity of the seller, and the money is given in return in gratitude.

Surveyed biochar producers who received free rice-hull (N=7) stated that they are able to get rice-hull at no costs because they have connections with rice-millers (i.e. family or friends). Regardless of whether rice-hull is given freely or purchased, respondents with no source of transport (N=8) paid additional fees to transport rice-hull. Only one respondent used manual labour to carry the rice-hull. For the three respondents who had transportation, one respondent paid $1.00, another paid $2.00 and the third paid $4.00 for fuel per trip, depending on the distance.

### 5.2.1 Biochar Production: Methods

Two pyrolysis methods were used by respondents to produce rice-hull biochar, with each method yielding different amounts of biochar. The older method uses roasting to produce 1:1 ratio of rice-hull to biochar. The new pyrolysis method of burning, known as "chimney method", developed by AI-Com and its partners produces 2:1 ratio of rice-hull to biochar. The chimney method uses a wire mesh placed in the center of rice-hull pile to direct smoke upwards from the wire mesh to produce biochar instead of ash. Despite producing less biochar, the advantages of using the newer method are reduced labour/time requirements and minimises fire hazard. Pyrolysis methods used to produce biochar are presented in Table 11.

Table 11 Methods used to produce biochar by respondents.

| **Burning/Chimney Method** |
|---|
| Quote #1: "50 sacks (25kg of sack) of rice-hull can produce 25 sacks (25kg of sack) of biochar".<br>Quote #2: "1 sack of rice-hull can produce a half of sack of biochar".<br>Quote #3: "100Kg of rice-hull can produce 30kg of biochar".<br>Quote #4: "3 wheelbarrows of rice-hulls can produce 2 wheelbarrows of biochar". |
| **Roasting Method** |
| Quote #5: "25Kg of rice-hull can produce 25kg of biochar because we did not burn; we only roast as roasting coffee".<br>Quote #6: "10 sacks of rice-hull can produce 10sacks of rice-hulls because we did not burn. We only roast as roasting coffee". |

Family members were typically involved in making biochar. None of the biochar producers paid for labour. Nine respondents stated that making biochar was easy work and can be undertaken by women. Three respondents explained that women in their family were not involved in making biochar because they had other work, such as house chores, formal employment (teaching) and childcare responsibilities.

### 5.2.2 Biochar Production: Sources of Learning

Biochar producers learned how to make rice-hull biochar from MAF researchers, WVTL, AI-Com, family relatives and MAF extension workers, as shown in Figure 1.

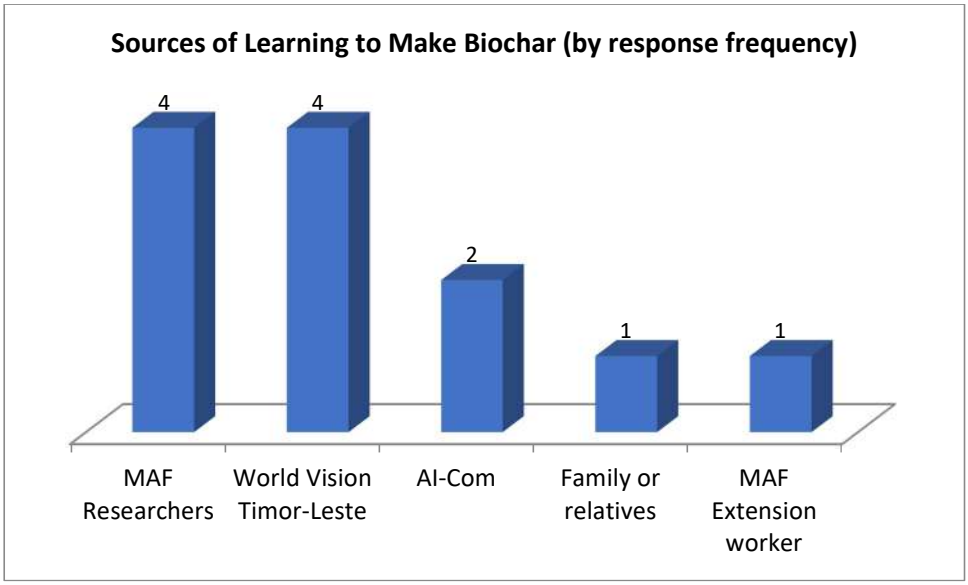


Figure 1 Sources of Learning to Make Biochar (by response frequency).

### 5.2.3 Biochar Production: Benefits, Challenges, Risks and Opportunities

**Benefits of making biochar**

Producers have the basic knowledge that by making biochar, they are able to add value to an agricultural waste product like rice-hull (N=9) which can provide an extra income source (N=8). They also recognised biochar production as an opportunity to learn a new technology (N=7) (Table 12).

Table 12 Benefit of making biochar by total frequency of responses.

| Benefits of making biochar | Total Responses (#) |
|---|---|
| Add value to a waste product | 9 |
| Learning new technology | 8 |
| Have extra income | 7 |

## Challenges and Risks in Making Biochar

In addition to the challenges of time spent and long distances to source rice-hull, most respondents were concerned with the impacts linked to burning and roasting rice-hull to make biochar. In particular, producers reported that smoke not only creates air pollution, but dust particles cause them to cough. Based on SOSEK's observations and respondents' explanations, these issues were faced particularly by respondents using the old method of roasting rice-hull. Roasting requires respondents to stay close in a manner similar to the Timorese way of roasting coffee over firewood. Moreover, this old method requires using a lot of firewood. In response, SOSEK shared with these respondents AI-Com's brochure which explained the newer method (chimney method) of burning which does not require roasting or using firewood, which they were pleased to receive. The roasting method furthermore causes skin burns since respondents must stand very close to the flames. Some respondents wore masks and practised standing at a safe distance from the fire as strategies to tackle these health and safety problems.

## Perceived Opportunities of Producing Biochar

Biochar producers described several opportunities associated with making biochar. Firstly, biochar production is considered as a new way to increase domestic products (11%). This included respondents who stated using biochar can increase production, turn agricultural waste products into biochar and promoting use of organic products instead of agrochemicals. Secondly, biochar can increase income (5%) and thirdly, there is opportunity to expand the rice-milling market to connect with a biochar market (5%). (Figure 2).

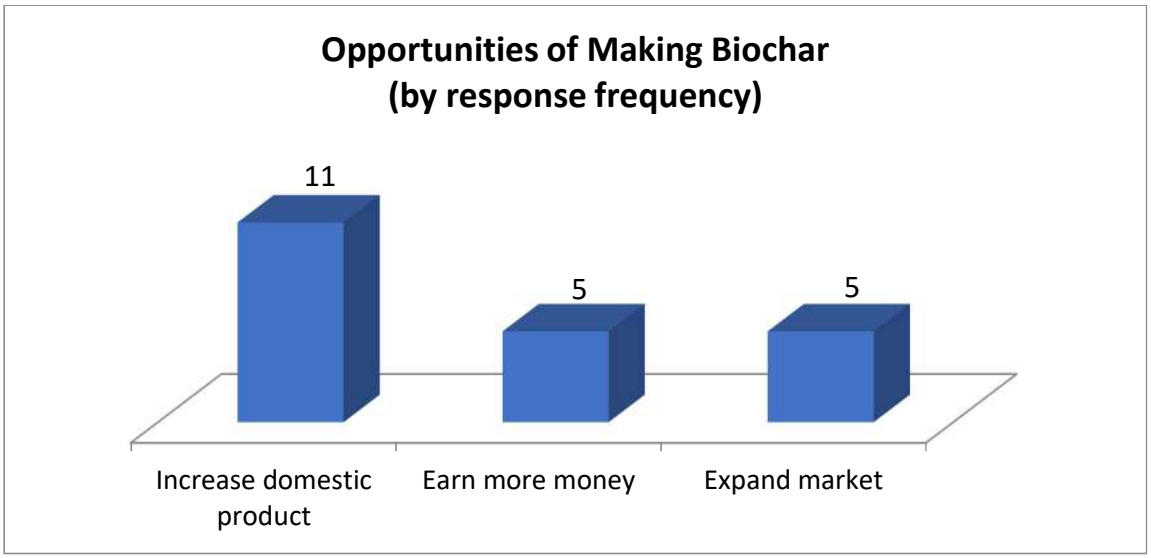


Figure 2 Opportunities of making biochar (by response frequency).

### 5.2.4 Future Plans for Biochar Production

All biochar producers (N=12) stated "yes" to produce biochar in the future. Some respondents wanted to continue since they considered biochar to be the best soil amendment to apply on their farm and some wanted to produce to increase/improve family income. However, a few respondents only wanted to produce biochar if they can get sweet potato vines or rice-hull at no costs. Reasons given are listed in Table 13.

**Table 13 Producers' reasons to produce biochar in the future.**

| Respondents | Reasons to produce biochar in the future |
|---|---|
| Producer 1 | *Will continue to produce biochar but it depends on whether we can get rice-hull from family/relatives or we can afford to buy it* |
| Producer 2 | *Because we can get rice-hull freely, we will continue to produce to use or sell* |
| Producer 3 | *Because biochar helps to improve soil fertility* |
| Producer 4 | *To increase family income* |
| Producer 5 | *Will increase the quantity of rice-hull prepared in order to be able to produce biochar to sell in the market* |
| Producer 6 | *Because of the income. If the price is good in the market, we will make biochar again* |
| Producer 7 | *Because biochar is easy to prepare and is best for soil* |
| Producer 8 | *If there is a demand (If people search for it), I will prepare again* |
| Producer 9 | *Because it helps to make soil and plants fertile. Our neighbours do not want to use because they do not know the benefit yet* |
| Producer 10 | *Because we want to apply on our farm. But the problem that we face now is we are no longer get rice-hull for free. We need to buy* |
| Producer 11 | *Yes. We want to work but World Vision needs to bring the seeds of sweet potato cuttings/vines to us* |
| Producer 12 | *If there is a demand, we will burn to sell otherwise we will burn for use only* |

The following sections (5.2.5 and 5.2.6) are based on four respondents' experiences of selling biochar.

### 5.2.5 Producers' Experiences of Selling Biochar

Of the 12 biochar producers, only four respondents produced for sale. The other eight respondents only produced to use on their farm. The type of biochar produced for sale is rice-hull biochar and none of the four respondents combined it with other organic or inorganic matter. These respondents mostly sold biochar to horticulturists (N=4), floriculturists (N=3), World Vision Timor-Leste (N=2), AI-Com (N=1 respondent) and rice farmers (N=1).

The price of biochar was the same in Baucau and Maliana, $0.75USD/kg, $1.00USD/Kg and $6.25USD/25kg sack. The maximum total income obtained from selling biochar among respondents was $500.00USD and the minimum income reported was $37.00USD. Biochar are packed in plastic bags or sacks and placed along the main road to make it easy to catch buyers' attention or sold directly in the farm area where respondents produced biochar. Biochar was promoted mostly through family and friends but there is also a seller who uses social media as a marketing channel.

Biochar is not yet an established market since some sellers only prepared biochar on demand. These sellers explained, *"we only prepare biochar when people order"* or *"we only prepared once, and it was based on the demand requested"*. One biochar producer in

Bobonaro Municipality who has sold biochar since 2019 prepares two to three times weekly to sell along the main road as well as to World Vision's farming groups in Balibo Administrative Post.

### 5.2.6 Covid-19 Impacts on Biochar Sale

Of the four respondents who produced biochar for sale, only one respondent in Bobonaro reported experiencing reduced demand for biochar during the Covid-19 pandemic, pointing out that *"people did not come to buy because of covid-19 prohibitions"*. This respondent sold biochar to World Vision as well as passers-by along the main road. This respondent added that before Covid-19 restrictions were imposed in March 2021 – due to the detection of Covid-19 Delta variant in Timor-Leste, even farmers from Aileu (central upland, approximately 4-5 hours' drive from Bobonaro) came to buy biochar. By contrast, the remaining three respondents reported their sales were not affected by Covid-19 since they only produced biochar for farmers nearby (mostly World Vision farmers) or MAF researchers.

## VI. Discussion and Conclusion

Since 2017, AI-Com and partners have promoted biochar through their research programs. Knowledge transfer on biochar production and application continues to expand from researchers to extension workers and onto farmers. All surveyed farmers (N=28) could articulate the benefits of using biochar, which included improving soil fertility (100%), keeping the soil loose (46%), reducing input use (22%), modifying soil pH (15%), remedy for soil (11%) and increasing crop production (7%). The main factors respondents listed for applying biochar were that biochar was easy to prepare (29%); they had free access to biochar (24%), and biochar lasts for a long period of time (14%).

Respondents mostly applied biochar on horticulture crops (33%), sweet potato (31%), tomato (24%), legumes (7%) and rice (4%). Most respondents sold their crops planted with biochar (N=21) and some respondents were able to increase their prices because crop production increased (Appendix 2, Table 15). However, almost all of them (N=19) reported reduced income during the period of Covid-19 restrictions. The impacts of Covid-19 restrictions also coincided with heavy rainfalls and major flooding in March and April 2021 which led to crop destruction.

Almost all respondents (N=27) stated "yes" to apply biochar in the future. In particular, they understood that biochar improves soil fertility, which in turn can help to increase their income through improved crop quality and production. Based on their visual observations, farmers reported applying biochar changed soil color from red to brown or softened the soil and enabled moisture to be better retained in the soil. Respondents' descriptions are supported scientifically by MAF lab-based soil physics and chemical analyses before and after biochar application, demonstrating improved soil structure and neutralizing effects on acidic and alkaline soils (MAF Directorate of Research, *pers comm.,* 7 October 2021). Additionally, improved crop quality after biochar application in combination with manure or inorganic fertilizer was reported by farmers who described harvesting larger-sized fruits or tubers (2kg/tubers as compared to less than 1kg/tuber without biochar or only biochar), fresh looking leaves and better taste .

SOSEK recommends providing additional technical training and advice to biochar users and producers throughout the lifespan of these biochar research programs to ensure that knowledge and skill transfers are cemented, and biochar adoption can continue to expand nationwide. Even though socialization and training were implemented prior to the start of these programs and during field trials (MAF Directorate of Research, *pers comm.*, 7, 15 and 20 October 2021), some respondents did not fully understand the proper pyrolysis method to burn rice-hull or the impacts of applying biochar. Some producers used the old method of roasting rather than burning rice-hull using wire mesh which is known as "chimney method" by AI-Com and partners; the former requiring more time and firewood which produces a lot of flame and smoke. SOSEK team provided the brochure of chimney method that explains a more efficient method of burning rice-hull developed by AI-Com and partners. The next iteration of the brochure could include occupational health and fire safety advice concerning the safe handling, transport and storage of biochar that reduces dust exposure and fire hazard (Major 2010, pp.6-7; Verhenijan *et al.,* 2010, pp.111-113).

Biochar application rates is influenced by biochar materials, soil types and crops (Major, 2010). AI-Com and partners' research on combining biochar with inorganic or organic matter have demonstrated better results as compared to treatment control or biochar on its own during trials on sweet potato and horticulture crops in various types of soil, particularly red soil which has low nutrient content. The ongoing study with MAF and UNTL researchers have reported the most effective application rate of Biochar Plus is 1-3t/ha on horticulture crops and sweet potato. Combining biochar with cow manure (20t/ha) gives better results than the control treatment and only biochar. Farmers can also apply biochar on its own if the aim is to improve soil texture, structure or soil pH, and the ongoing study reported that the effective rate is between 5t-20t/ha. Since adding biochar helps to improve soil fertility, more options are now available for farmers to choose, rather than relying on large amounts of chemical input; This builds on existing practices found in SOSEK's inorganic fertilizer survey (2020) which documented low use of chemical fertilizers by sampled farmers. One of the advantages of Biochar Plus is that only a small quantity of biochar is needed, which is between 1-3t/ha but there are labour and financial costs to sourcing and purchasing inorganic fertilizers. The advantage of combining biochar with cow manure is the manure is readily available without costs since smallholder farmers commonly rear livestock. However, more biochar is required since the effective rate is between 5t-20t/ha.

Another benefit of using biochar is that it can remain in the soil for an extended period (Major 2010; Wijitkosum and Jiwnok, 2020). Therefore, AI-Com and partners recommends single application or in gradual increments since biochar residue can remain effective for several planting seasons. An ongoing study on biochar residue conducted by MAF and UNTL researchers have to date demonstrated that crop production continues to improve if biochar residue remains in the soil (AI-Com 2021, p.12). One concern raised by respondents was poor access to rice-hull; this challenge, however, could reduce in the longer term since the benefits of applying biochar should improve with time.

Although the knowledge and skills to produce biochar is gradually expanding, the market for biochar in the target municipalities are still in early development. Apart from the 12 producers who made biochar for their own use and among them, four of whom who sold biochar, there were also some extension workers and MAF staff who produced biochar

independently for use and retail in Maliana and Viqueque. Nonetheless, most of them only produced biochar on-demand for sale when they received order requests (MAF Directorate of Research, *pers comm.,* 15 and 20 October 2021).

Moreover, considering 11 out of 16 surveyed biochar users and 7 out of 12 biochar producers obtained rice-hull at no costs, it suggests rice farmers and rice-millers have yet to recognise the opportunities of adding value to an organic by-product like rice-hull at this time. Interviews with rice-millers in both target municipalities highlighted that none of the private rice-millers sold rice-hull or produced biochar for sale. For example, ACELDA, a rice-milling company in Baucau gave a tomato farmer free rice-hull (ACELDA, *pers comm.,* 9 Nov 2021) to use as biochar to tomato seedlings and as compost combining with cow manure for tomato crops (Lutumuto and Darasula, *pers comm.,* 9 Nov 2021). Furthermore, only one out of two rice millers interviewed in Atabae sold rice-hull and produced biochar if there was a demand. Another example is a rice-milling company in Maliana which produced Biochar Plus for sale but the buyers were AI-Com and TOMAK. The interviewed worker stated that they stopped producing Biochar Plus due to Covid-19 restrictions as there was less income and therefore the company owner was forced to lay-off several staff for three months, including those responsible for burning rice-hull into biochar. The workers have since resumed work when SOSEK team undertook this survey, but they had not been asked by the owner to resume making biochar (Maliana, *pers comm.* 18 August 2021). In a follow-up interview, the company owner stated that they have Biochar Plus to apply in a trial to grow rice during this year's wet season which will be used as a way of introducing biochar to farmers. The company plans to produce and sell at a larger scale by next year's dry season (Graca Agro Trading Unipessoal LDA, *pers comm*., 23 November 2021)

Most respondents were unable to identify challenges or risks in using and producing biochar. Among the users, a challenge they perceived was the potential costs of collecting and transporting rice-hull since they could not easily source rice-hull near their locations. For example, in Balibo, where World Vision and MAF researchers implemented their program, the survey team observed that although biochar producers lived very close to rice fields, and some owned rice fields and grew rice yearly, they needed to travel to Maliana or Atabae (approximately 1-2hrs to drive) when they wanted to mill rice. None of the respondents were rice millers and not all the surveyed areas with rice fields had access to rice-milling machines which could produce rice-hull. For instance, the survey team observed one rice-milling machine which churned out rice-hull in fine powder form – less suitable to make biochar and more suitable for use as pig feed. Similarly, the survey team found only three rice-millers in Baucau who operate their businesses in the city center of Baucau (*Kota Baru)*, close to the market. Of these three, only one was open daily while the other two opened during market days on Mondays and Thursdays. Longer traveling distances to source rice-hull can also contribute to increased greenhouse gas emissions by requiring more fuel, which can reduce the carbon offsetting potential of biochar (Verheijen *et al.,* 2010). Identifying and establishing networks with reliable rice-hull sources and rice-milling services at short distances before the end of the research programs can reduce barriers for biochar adoption beyond the lifespan of these programs.

Comparatively, a more established biochar market is thriving in the administrative capital, Dili. Biochar producers there promote biochar through social media like Facebook, pivoting

on special events, such as agriculture or tourism expositions organized by the private sector or TL Government, as well as giving training on how to make biochar and introducing biochar during trainings with farmers (Hera., *pers comm,* 23 June 2021 and Catholic Relief Service Office, *pers comm.*, 19 October 2021). Additionally, two surveyed biochar producers in Dili also sold biochar as compost, by combining it with organic matter, such as rotten wood and manure. There are also local producers who supply biochar to some agricultural shops in Dili (Boaventura and Agi Agriculture shops, *pers comm.,* October 19 2021). Moreover, the rice-hull market is more developed in Dili. Unlike in the two municipalities where rice-hull was generally given away at no charge, all rice-millers in Dili (N=3) were surveyed and they sold rice-hull for $2.00/50Kg sack or $30.00/truck. They also prepared and sold biochar ($2.00/25Kg sack) if there was demand. Otherwise, they sometimes made biochar to apply on their horticultural crops (N=2).

Biochar application is growing in the municipalities where biochar research is underway. Below are additional examples to illustrate how Timorese farmers are being introduced to biochar. AI-Com and partners regularly conduct "field days" in all sites where research is undertaken. Through holding field days, farmers and extension workers are invited to see the results and demonstrations, including demonstrations on how to make biochar. A MAF biochar researcher in Viqueque reported that they were invited to train all extension workers in Viqueque on how to produce biochar. As a direct result, the extension workers have transferred their new knowledge to farmers in two new locations in Viqueque (MAF Directorate of Research, *pers comm.*, 20 October 2021). Furthermore, in 2020, a former Agronomy student who participated in AI-Com and UNTL's research on biochar in Vemasse, was invited by a farmer in Natarbora to work on the farmer's farm to plant watermelon using biochar (AI-Com 2020b, p.1). Since then, more farmers and students have participated in this field research and they have obtained significant result out of treatments used to improve soil pH, soil fertility, crop production and income. These examples highlight the potential for biochar adoption in Timor-Leste to expand over time. Considering the low use of inorganic fertilizers and prevalence of land degradation, biochar offers a "greener" alternative that can be incorporated into soil management systems with the added benefits for smallholder to improve crop production and incomes.

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# Appendices

## Appendix 1: Crops planted sorted by respondents based on planting season.

**Table 14 Crops planted by respondents (by season).**

| Crops Planted | Count of Respondents based on the season planted | | | Total Respondents |
|---|---|---|---|---|
| | Dry Season | Wet Season | Dry and Wet Season | |
| Horticulture crops, Legumes, sweet potato and tomato | | 1 | | 1 |
| Horticulture crops, legumes and rice | | | 1 | 1 |
| Horticulture crops, sweet potato and tomato | 3 | 3 | 2 | 8 |
| Horticulture crops and tomato | 2 | 1 | | 3 |
| Horticulture crops and sweet potato | 1 | 1 | 4 | 6 |
| Horticulture crops and legumes | 2 | | | 2 |
| Sweet potato | | 3 | | 3 |
| Tomato | 1 | | 1 | 2 |
| Rice | | | 2 | 2 |
| **Overall** | **9** | **9** | **10** | **28** |

## Appendix 2: Crops sale and profits before and after applying biochar.

**Table 15 Profits before and after using biochar (by crop type).**

| Crops sale | Before/without biochar application | Profit after or with biochar application |
|---|---|---|
| Vegetable (modo) | I sell but only able to earn small amount of money. | The production of vegetables is better so I am able to gain more money. |
| Sweet potato | $5.00/25Kg of sack. | $10/25Kg of sack. |
| Sweet potato | $5.00/25Kg of sack. | We sell sweet potato with the same price $5.00/25Kg of sack. |
| Not mentioned crops | Without biochar the result is not that good. | The production is better with biochar application. |
| Not mentioned crops | Get enough money. | Better. |
| Not mentioned crops | The profit is very small. | Get better production with biochar application. |
| Not mentioned crops | The production is not good. | Get better production with more profits. |
| Not mentioned crops | Get little profit. | Get bigger profit. |
| Not mentioned crops | The profit is not so good and not much. | Get more profit. |
| Sweet potato | It depends on who came to buy. For family and friends, the price is $5.00/25Kg of sack and for NGOs, the price is $10.00/25Kg of sack. | The price is ranged between $5.00 and $10.00, depends on who the buyer is. |
| Sweet potato | $5.00/25Kg of sack. | We sell based on the weight, the price is $1.00/Kg. |
| Sweet potato | $10/25kg of sack. | Same price. |
| Bitter gourd | $1.00/8 pieces. | $1.00/4 pieces. |
| Not mentioned crops | Before applying biochar the production was not so good. | After applying biochar we gain more profit because the production is good. |
| Tomato, chili and mustard | First time planted using biochar independently. | Tomato 2$2.00/bucket[1] chili $5.00/bucket[1], mustard $2.00/5 bundles. |
| Tomato | It depends on the market | It depends on the market, and it changes every week. Normally we sell tomato for $8.00/bucket[2]. It changed to $4.00/bucket[2] and the current price is $1.00-$1.5/bucket[2]. |
| Tomato | Same price. | Same price. |
| Sweet potato and tomato | We did not sell sweet potato and for tomato it was $8.00/bucket[2]. | We did not sell because of covid-19 crises. |
| Tomato | $2.00/bucket[3]. | Same price. |
| Horticulture crops | Between $10.00-$15.00 | With biochar application gain more profit because it looks fresher. We can gain profit up to $100.00 from the same size of land (0.5ha). |
| Cauliflower and sweet potato | Cauliflower: $20.00/plot (120m$^2$) and obtained $30.00/plot from selling sweet potato. | Obtained $50.00/plot (120m2) from selling cauliflower and $40.00/plot from selling sweet potato from the same size of land. |

[1](a bucket with number of size 20); [2](big bucket called kunci mas).

## Appendix 3: Covid-19 impacts on respondents' incomes from selling local crops.

**Table 16 Covid-19 impacts on respondents' crop sale and incomes.**

| Has Covid-19 affected your income from selling local crops? | Reasons why covid-19 affected or not their market/income (N=21) |
|---|---|
| Yes | We could not sell vegetables because of public transportation prohibition and therefore no people are able to come to buy our crops products. |
| Yes | Our products are not sold out in the market because of no buyers. |
| Yes | No transportation and buyers to buy our crops products. |
| Yes | Because sometimes the market is closed and public transportation is prohibited due to covid-19 restriction. |
| Yes | Because sometimes we are not allowed to sell our products in the market. |
| Yes | Because people seldom come to buy our crops products and therefore the income is very low. |
| Yes | People seldom by our sweet potato harvested. |
| Yes | People seldom by our crops products. |
| Yes | Because people are afraid of covid-19 infection and therefore did not go out to buy our crops products. |
| Yes | The price of sweet potato has dropped to $2.50/20Kg of sack because we were only able to sell in our neighbourhoods. Our neighbour could not afford to buy with the normal price and we also need money and therefore we decided to sell with a lower price. |
| Yes | People did come to buy at home and we were not able to go out to sell in the market and therefore we just consume. |
| Yes | Transportation fee is expensive, people did not come to buy and therefore we ate more than sold. |
| Yes | People did not come to buy and no public transportation accessible. |
| Yes | Because of lockdown and we were not able to sell our crops products. |
| No | Because we could still sell our products as usual. During covid-19, we took our crops products to the main road and were sold out. |
| Yes | Because of covid-19 restriction. |
| No | People continue to buy our vegetables. We have no different way in selling our vegetables before and after covid-19. Normally we sell around the village and carry on head on the way to sell in Kaisidu (the place is very dry and no vegetables growing). |
| Yes | Because nobody comes to buy our crops products. |
| Yes | People did not come to buy our crops products and even if we took to the market, it was not sold out. |
| Yes | The crop products became rotten because nobody came to purchase. Moreover, changing of the weather affected all peanuts planted. |
| Yes | Because we only wait to sell from home. We could not bring to sell anywhere. Some of our crops products got rotten, especially in last April due to flood. |

Figure 3 HH interview with biochar farmer Mrs. Ana in Darasula, Baucau Municipality.

Figure 4 Survey team with biochar farmers in Leolima, Balibo, Bobonaro Municipality.