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Life Cycle Assessment of Manila Hemp in Catanduanes, Philippines

ABSTRACT

Environmental burdens of one ton baled abaca fiber, which is exported as Manila hemp, were determined using life cycle assessment with three phases: plantation establishment and fiber harvesting, fiber trading, and grading and baling of fiber.

Abaca fiber was organically produced in Catanduanes. One hectare abaca plantation produced an average of 830 kg fiber with a total mean discarded biomass of 5.7 t. A barangay trader can purchased 712 kg of dry fiber per week while Grading and Baling Establishment (GBE) procured and processed 250 t mo^{-1}.

One ton of baled fiber required 1.6 ha plantation with 2,132 undamaged abaca hills that produced 1,052.6 kg dry abaca fiber. Harvesting produced about 80.2 t of discarded materials and weeds which used as mulch, however, estimated soil nutrient loss was 0.5 kg N and 0.1 kg P and 5.4 kg K. Trading and baling produced 52.6 kg fiber by-product used for furniture making; more than 5 kg of fiber dust and a total global warming potential of 47.7 kg CO_2 equivalent.

The following are recommended to improve farm productivity: a) use of organic fertilizer to replace the nutrient loss; b) improve stripping device to enhance fiber quality; and c) utilize farm waste for soil conservation. Local policy on abaca trading was recommended to increase farmer's share. GBE must provide mechanism to improve environmental work condition and strictly enforce the use of ear plug to avoid hearing loss of workers.

Key words: *abaca fiber production, local fiber trading, baled abaca fibers, environmental and social life cycle assessment*

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INTRODUCTION

The Philippines is the principal producer of abaca fiber, known in the world market as Manila hemp. Abaca is traded as pulp, cordage, specialty paper, fiber crafts and hand-woven fabrics. Abaca plays a significant role in Philippine economy and about two million farmers and workers depend on it, either directly or indirectly, for their livelihood (F*iber Industry Development Authority [FIDA] 2007*).

Being an export commodity, Philippines' abaca industry has to "shape up and stand up" against the challenges and emerging developments in the global market brought about by continuing environmental awareness and societal concern on natural resource depletion and environmental degradations. The abaca industry should produce "greener" products. Foreign trade of Manila Hemp expanded to 2,886 MT with shipments to the United Kingdom, Japan and China in 2010. Aggregate revenues generated from the exports of abaca fib*er reached US$3.4 million in the first three months of 2010 (FIDA 2010*).

The abaca fiber has enormous potentials for different industrial uses due to its extremely high mechanical strength and long fiber. Abaca fiber is used in the production of paper money. Abaca fiber based products specifically baled fiber needs proper certification that it is produced in an environmentally sound manner. This will provide the industry a more competitive advantage over synthetic fibers. The conduct of LCA for baled abaca fiber will provide the industry an avenue to meet global standard on green products and eco-labeling for more competitive market.

Life Cycle Assessment (LCA) as a valuable decision-support tool emerged as basis of policy makers and industry in assessing the cradle-to-grave impacts of a product or process. This is due to the following development initiatives: government policies and regulations are moving in the direction of "life-cycle accountability" the notion that a manufacturer is responsible not only for direct production impacts, but also for impacts associated with product inputs, use, transport, and disposal; private entities are actively participating in product stewardship, which seeks to foster continuous improvement through better environmental management systems; and consumer's "preference" for environmentally and organically produced products.

This study determined the environmental burdens of baled abaca production in the Province of Catanduanes to improve fiber productivity and quality and propose policy recommendations on trading of abaca fiber.

MATERIALS AND METHOD

The study had a combination of descriptive and quasi-experimental research design adopting the phases of LCA as interrelated system (**Figure 1**). This was used to analyze the environmental aspects of the process and product in a systematic way.

Goal and Scope Definition

The study aimed to determine the environmental burdens and "hotspots" of the production of baled abaca fiber ready for export as Manila hemp or shipping to other processors or buyers in other provinces in the country.

The functional unit was one ton of baled fiber. The system boundaries started from plantation establishment, fiber harvesting, trading at the barangay and Grading and Baling Establishment (GBE), grading and baling of fiber and storage of baled fiber (**Figure 2**).

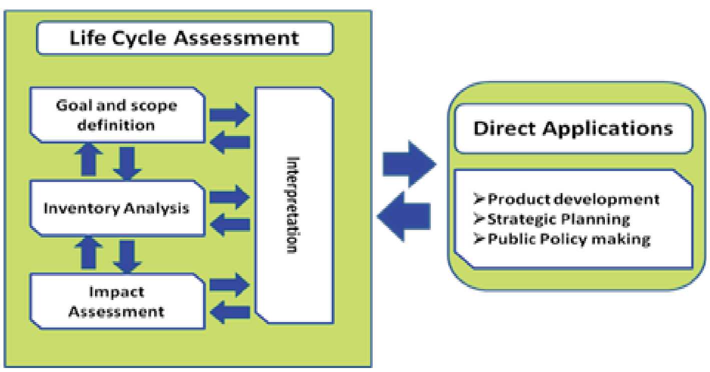


Figure 1. Phases of an LCA (ISO 14040, 1997).

The assumptions and limitations of the study were as follows:

a. The unit of analysis for harvesting was per kg of fiber per unit area/time;
b. The unit of analysis for trading was kg of fiber;
c. The unit of analysis for grading and baling was ton of baled fiber;
d. Cost of transportation was per kg of fiber; and
e. Labor and materials for baling were computed per baled fiber (125 kg).

Inventory Analysis

The following are the environmental parameters determined during the phases of fiber production:

Production Phases	Environmental parameters
Plantation establishment and fiber production	Number of suckers used Changes in vegetation cover Estimated volume and type of waste produce per activities Estimated weight of total plant biomass harvested Estimated weight of fiber harvested
Trading	Type and volume of waste generated per activity (Inventory of inputs, output and waste)
Grading and baling	Identification of technology/ equipment/logistic used per activity Energy and fuel consumption per kg of fiber at different processing activities

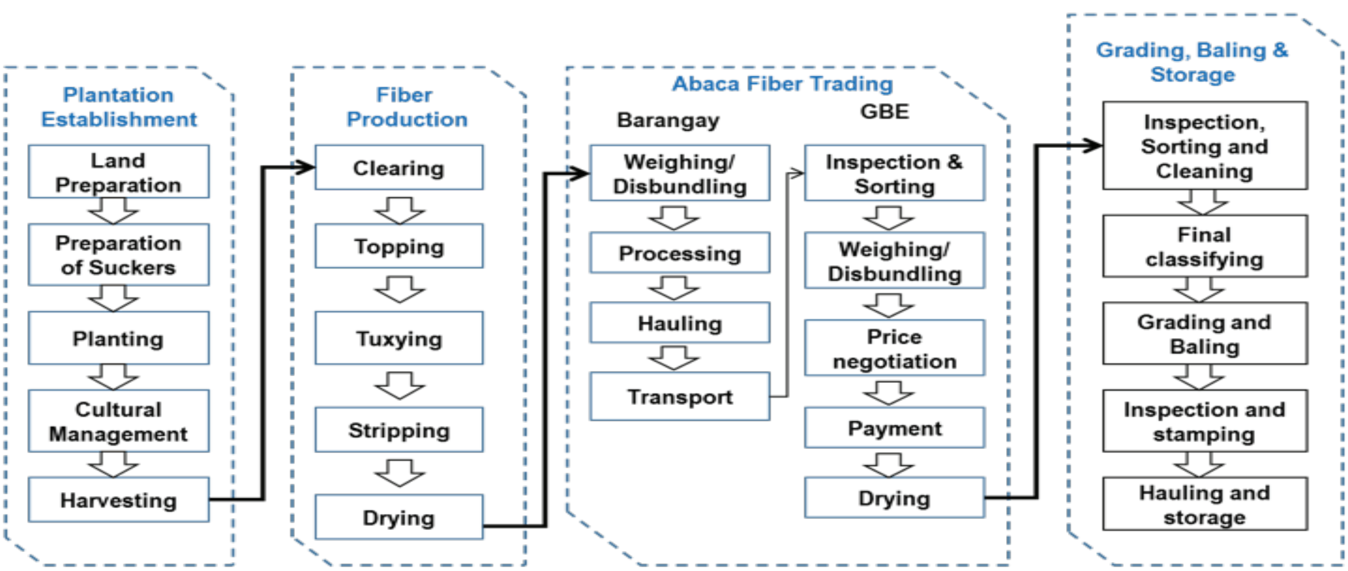


Figure 2. System boundary of the study.

Inventory of the abaca plantation establishment and production systems was conducted in three quadrats measuring 10 x 20 m (200 m^2) perpendicular to the slope of the farms, which serve as the quasi-experimental field. The total biomass and waste generated for every activity/stage of the process and fiber yield were determined. Photographic monitoring using photo points were established to document changes in vegetation cover and structure as a result of abaca harvesting.

The collection of data from arrival of fiber for trading, grading and baling was conducted through a "facility-walk through" following the flow of arriving fiber to storage, grading, baling and storage of baled fiber. The materials, equipment, electricity used, employees involved, product and non-products generated for each process were determined. The unit of analysis for fiber trading was kg of fiber for barangay trader and baled abaca fiber (125 kg $bale^{-1}$) for the GBE. Four traders from the community and one GBE with 30% of its workers were the source of data.

Impact Assessment

The impact categories considered in the study were: a) Resource utilization- micro-climate, land use, production system, vegetation change, discarded/waste biomass; and b) Ecological effects- soil nutrient loss and global warming potential (GWP).

GBE work environment was assessed in terms of air temperature, humidity, light/luminance and noise during the conduct of "facility-walk through". The results were compared with the set standards provided by the government rules and regulation.

Global Warming Potential (GWP) during transport was computed based on the diesel equivalent of transport cost per kg of fiber from traders to the GBE. The volume of diesel used was estimated using fifty percent of the transport cost with jeep for traders and trucks for GBE and the price of diesel (PhP 47.00 l^{-1}). GWP potential was computed using the formula adopted from the 2010 Guidelines to Department for Environment, Food and Rural Affairs (*DEFRA 2010*) for the Department of Energy and Climate Change (DECC). The conversion factors for diesel used to CO_2 equivalent emission using are as follows:

Emission factor per kWh of electricity: Philippines

CO_2	CH_4	N_2O	Total Direct GHG	Total indirect GHG
2.6413	0.0015	0.0292	2.6720	0.5067

Source: http://www.depra.gov.uk/environment/business/reporting/methodology-papers

GWP for electrical consumption during grading and baling of fiber was computed using the 2010 Guidelines of Department for Environment, Food and Rural Affairs (DEFRA) for the Department of Energy and Climate Change (DECC) specifically on the International Electricity Emission Factor. The conversion for direct and indirect GHG emission per kilowatt hour (kWh) was as follows:

Emission factor per kWh of electricity: Philippines

Direct GHG	Indirect GHG
0.53606 kg of CO_2 per KWH	0.07191 kg of CO_2 per KWH

Source: http://www.depra.gov.uk/environment/business/reporting/methodology-papers

Interpretation

The environmental "hot spots" at different phases of fiber production were used as the basis for recommendation to reduce the environmental burdens.

RESULTS AND DISCUSSION

Plantation Establishment

Abaca farms were established for more than thirty (30) years, considered as marginal land having a slope ranges from slightly rolling to hilly and planted with Lagunoyon and Abuab variety. Abuab was the recommended variety of FIDA while Lagunoyon is a traditional variety in the area. Narra, dapdap, dita and tabgon are the common shade trees found in the area. These shade trees like narra could improve soil fertility of abaca farms being a leguminous tree. Narra and dapdap were considered the best shade trees for abaca as they shed off leaves during rainy months to allow more lights penetration and provide more shading during summer to maintain micro climate suited for abaca. The farmers are starting to adopt coconut as shade trees to replace trees heavily affected by typhoon.

Material inputs included one hectare of land and 1,358 suckers as planting materials (**Figure 3**). Trimmed branches of shade trees were used as fuel wood. Farmers do not use any fertilizer and pesticide. The establishment required 45 man-days for planting then 20 man-days for every weeding and under brushing which were practiced every four months until the first abaca harvesting at 18 months after planting. A hectare of farm had only an average of 1,358 hills due to differences in slope and density of shade trees. Farmers estimated to accumulate about 100 kg of weeds per hectare during every under brushing/weeding.

Impact Assessment. In the establishment of plantation, unnecessary small trees were cut, leaving big trees standing sparsely to serve as shade. However, some unwanted branches of the trees were trimmed to prevent excessive shading. Farmers used the stem of shrubs and trimmed branches of shade trees as fuel wood for their households while the weeds served as mulch for the newly planted abaca suckers. Some abaca suckers were discarded due to damage during transport and replanting was conducted as needed. Soil erosion was

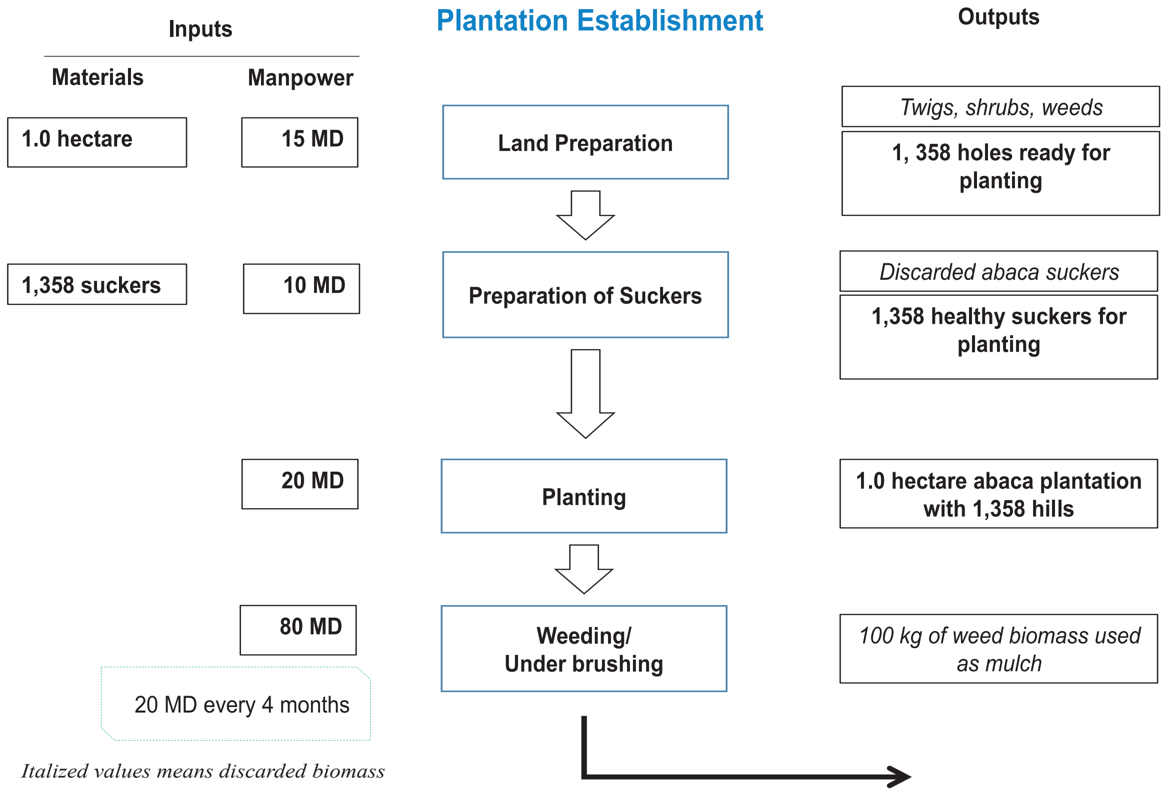


Figure 3. Life cycle inventory in abaca plantation establishment.

considered low due to good ground cover of abaca sites.

Interpretation. Abaca is a shade-loving plant and grows vigorously under canopy of trees. Thus, not much clearing or other disturbance was done to the ecosystem. Minimal soil disturbance with almost zero tillage system and less intensive land preparation reduced soil erosion of the abaca farms.

Fiber Production

The mode of harvesting of abaca varied among farmers. Most of the farmers were harvesting their abaca on daily basis following a six or eight month cycle. The harvesting cycle of six or eight months depends on farmer' preference, however, according to them, price of fiber was a major determinant. Harvesting of one hectare abaca plantation required 69.2 man-days however; farmer' had estimated it about 60 man-days. Stripping and tuxying activities constituted almost 72% of the total labor requirement.

The mean total biomass harvested was 55,997.2 kg during tumbling (**Figure 4**). Topping which include removal of corms, loss mean weight of 12,757.4 kg while the amount of leaves removed was 7,070.4 kg. The mean total harvested pseudostem biomass was 36,169.4 kg. Tuxying loss a mean biomass of 27,582.0 kg. Overall, the mean biomass loss due to topping and tuxying was about 47,409.4 kg. This results almost equal with the report of *Van Dam and Bos* (*2004*) that 48 tons of biomass wastes were produced for every one ton of dry fiber.

Stripping had a mean biomass loss of 3,248.7 kg thus the mean fresh fiber yield was only 5,302.7 kg per hectare. The mean dry fiber harvested for market was only 830.3 kg as the mean weight of biomass loss with drying was about 4,472.2 kg. A 15% to 30% shrinkage loss depending on the trader' assessment was deducted from the total weight of delivered dry fiber. Farmers on daily basis could harvest 10-12 kg of dry fiber ready for market. Majority of the farmers estimated to harvest a net of 600 kg of dry fiber per ha per cycle.

Impact assessment. Harvesting of abaca did not markedly change soil and air temperature and relative humidity of the microclimate in the plantations (**Table 1**). After harvesting mean soil temperature increased by 0.95^{o}C while the air temperature, 1.18^{o}C. Canopy opening did not significantly alter maximum or minimum soil or air temperature during any season of the year (*Clinton 2003*). The mean change in relative humidity was 1.96% while change in light intensity was about 11,051.75 lux. The highest recorded mean relative humidity was 84.6 % while the lowest was 76.8%.

The change in canopy cover of abaca plantation in the lower slope of the sample farms was still affected by the presence of shade trees in the upper landscape position depending on the angle of the sun. The change in density of abaca plants and the opening of the canopy could allow more light penetration on the ground but shade trees still reduced light transmission. However, the shade trees maintained the microclimate although variation occurred with reduction in canopy cover of abaca.

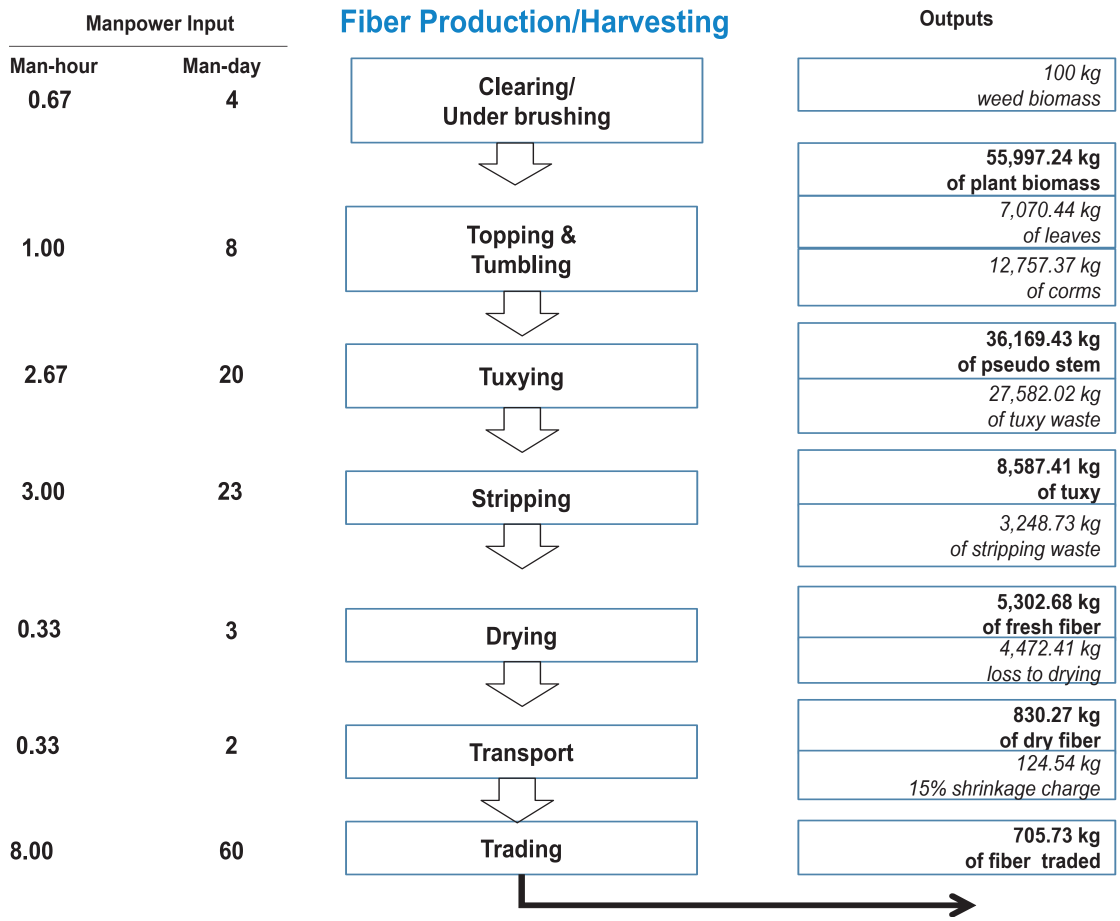


Figure 4. Average Dry fiber yield and waste produced per hectare.

Table 1. Microclimate of cooperators' farms before and after harvest.

Farm Condition	Farmer 1		Farmer 2		Farmer 3		Farmer 4	
	Before	After	Before	After	Before	After	Before	After
Soil temperature (C0)	22.0	22.5	15.4	16.4	19.6	20.8	19.5	20.6
Air temperature (C0)	22.6	23.2	20.7	21.8	24.0	25.2	22.8	24.5
Relative humidity (%)	81.7	84.6	76.8	78.6	77.5	79.0	79.7	81.3
Light intensity (shade condition) (Lux)	1,742	11,436	1,619	14,015	1,609	11,029	1,417	14,023

The farmers usually practiced under brushing, topping of mature leaves of abaca, and thinning before tumbling the selected abaca with either flag leaf or "bungahan". Thinning was conducted to allow more growth for good suckers and remove the stunted ones. The wastes from tuxying were used as mulch in the plantation.

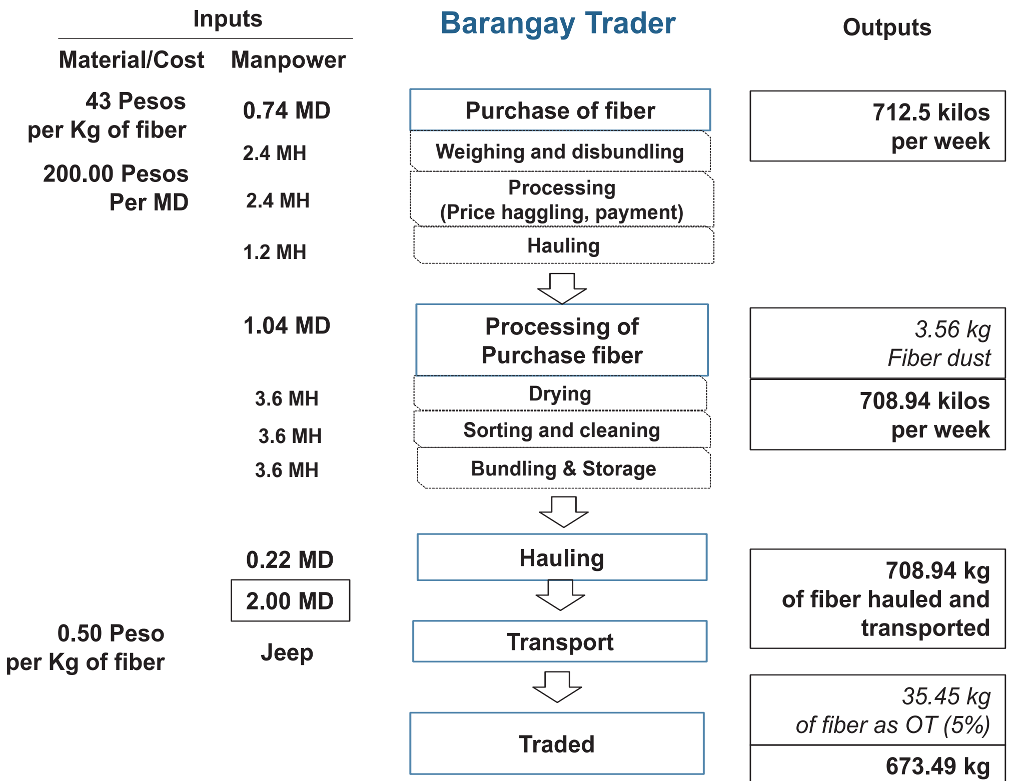
Interpretation. The continuous harvesting of fiber and the non-application of fertilizer would mean depletion of the soil nutrients. Fiber harvesting resulted to nutrient loss of about 0.5 kg N, 0.1 kg P and 5.4 kg of K per cycle based on the 830 kg of dry fiber yield per ha. This value was based on the study of *Armecin* (*2009*) on the nutrient content of abaca fiber at harvest with 0.038 N (%); 0.010 P (%) and 0.416 K (%).

At harvest, the highest amount of biomass discarded during tuxying was about 27,582.0 kg ha^{-1}. The total estimated discarded biomass per ha was 50,694.6 kg. The discarded biomass was not considered to contribute to greenhouse gas emission (GHG) as *Moraes Sá*, cited in his paper and by other authors (*Paustian et al. 1997; Sá et al. 2001; Six et al. 2002 b; Kong et al. 2005; Bayer et al. 2006; Tristram and Six 2007*). They suggested that the amount and quality of crop residues that naturally decomposed in the field is one of the most important factors to increase carbon sequestration and increase soil organic carbon stock even with climate effect on the decomposition rates and whatever the characteristics of clay mineralogy and soil type.

Fiber Trading at the Barangay Level and Grading and Baling Establishment (GBE)

Barangay Level

Traders in the barangay were able to purchase about 712.5 kg of dry fiber per week at PhP 43.00 kg^{-1} (**Figure 5**). The bulk of activity in abaca trading was on purchasing (0.74



Italized values means waste/shrinkage in fiber trading

Figure 5. Life cycle inventory of fiber trading at the barangay.

MD) and processing of fiber (1.04 MD). About 0.50 kg of fiber dust per every 100 kg of fiber was produced during drying and re-bundling. They claimed that Grading and Baling Station (GBE) purchased 5% of the weight of traded fiber at PhP 1.00 per kg. Only about 2 man-days per week were used for fiber trading for it was their secondary occupation. All of the barangays traders had their mini groceries that served as their main occupation and support mechanism for fiber trading.

GBE Level. GBE had a set of personnel for purchasing and processing of fibers. The station manager supervised the day-to-day activities of the four (4) office staff, fifteen (15) direct workers and contract workers. The direct personnel were on casual employees with benefits based on government labor regulations. Estimated monthly expense for the direct hired personnel was PhP 123,560.00 with 22 working days. The workers were paid on a daily basis at PhP 200.00 d^{-1} while the office staff, at PhP 370.00. The corporation adopted the no work no pay policy. The station manager was paid on monthly basis at PhP 25.000.00 mo^{-1}.

After the manager had acknowledged the delivery of abaca fiber, this was weighed according to the agreed classification between GBE and the trader. The deduction in weight due to moisture and downgrading of fiber due to color and length were discussed during price negotiation. Traders were paid in cash with deductions of their cash advances. They were also required to sign in their book of accounts as evidence of transaction. GBE provided transport allowance for traders who delivered fiber, which was equal to 50% of the actual transport cost or PhP 0.50 kg^{-1} of fiber. The estimated cost of traded fiber per month was PhP 11,451,250.00. (**Figure 6**).

Impact Assessment. About 3.6 kg of fiber dusts were produced during drying and re-bundling of fiber for weekly average transaction of 712 kg of a barangay trader. About one half of the transport cost of fiber purchased by barangay trader was assumed to be the cost of fuel. With PhP 47.00 l^{-1} of diesel, the estimated GWP was 24.1 kg of CO_2 equivalent from the transport of weekly average transaction of the barangay traders.

GBE workers were mostly males because handling of abaca fiber required continuous lifting and moving of fiber during inspection into hauling and storage. The noise levels at the inspection and sorting sections of the GBE were slightly higher than the accepted level of noise of 70 db for light industries (*Philippine Clean Air Act 1999*).

Interpretation. Abaca fiber from the barangay traders produces minimal GWP due to transport with only about 3.3% by volume of fiber traded per week. Noise level inspection and sorting sections of the GBE was due to use of equipment on the baling of fiber.

Grading and Baling of Fibers

Grading and baling of fiber started with inspection, sorting and cleaning of fiber where the deducted weight of abaca was separated (**Figure 7**). Inspection, sorting and

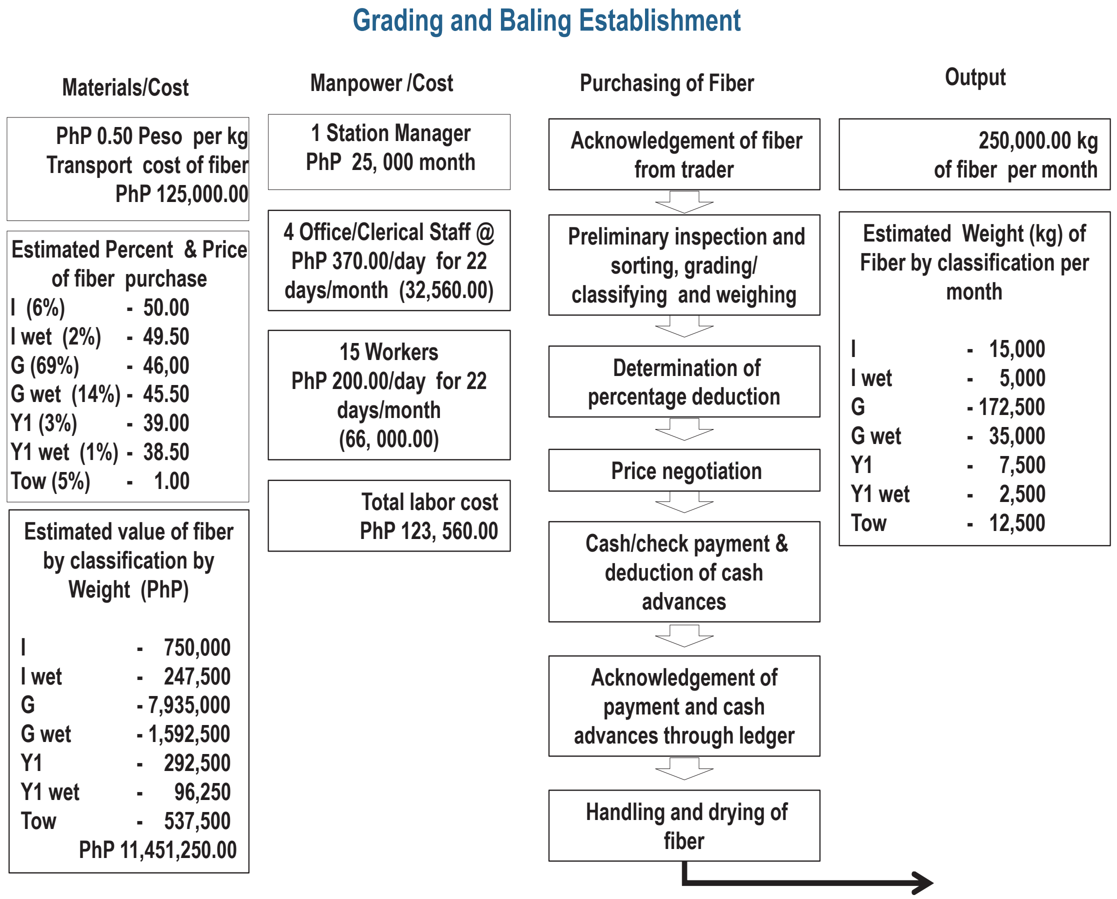


Figure 6. Life cycle inventory of fiber trading at the GBE.

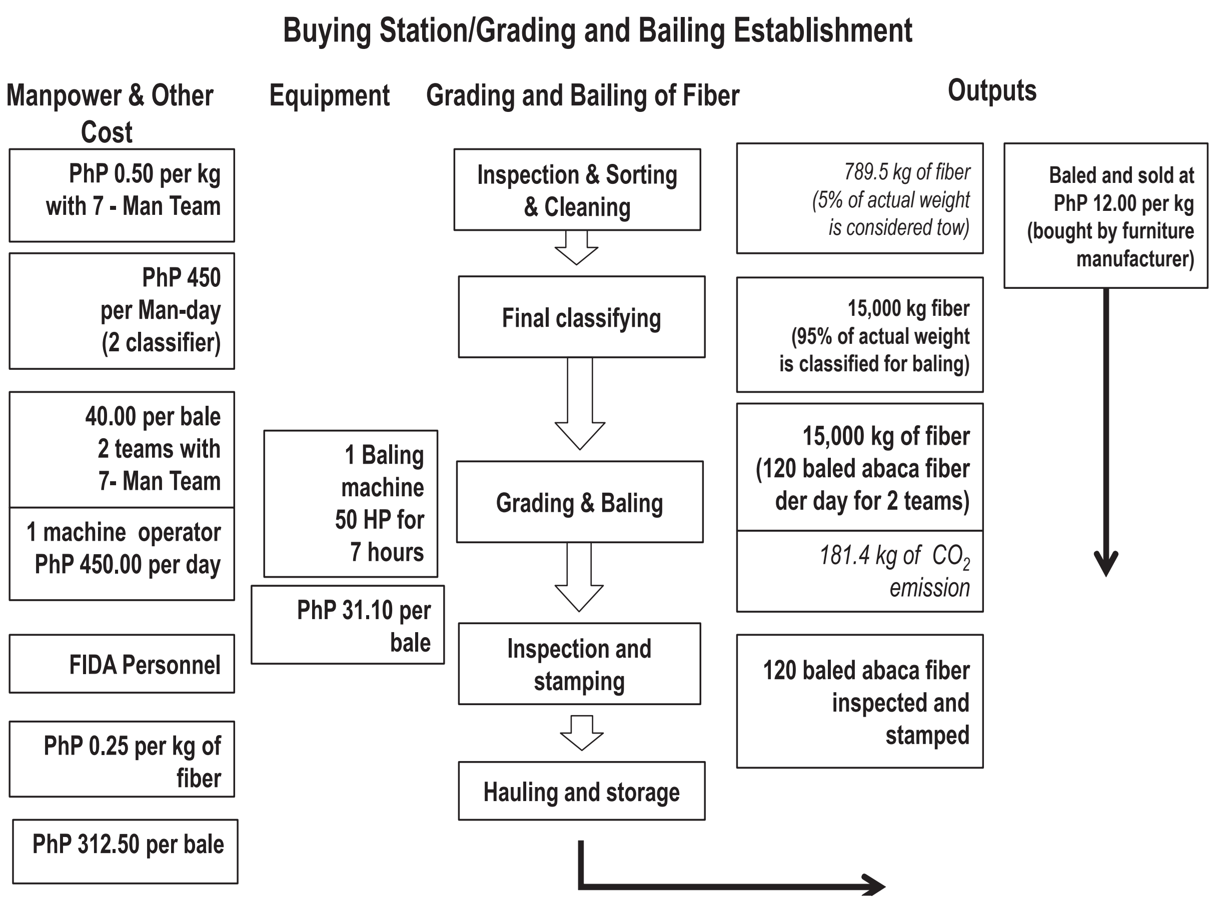


Figure 7. Life cycle inventory during grading and baling of fiber.

cleaning of fiber were performed by seven-man team, who was paid at PhP 0.50 kg^{-1} depending on the number of baled abaca in a day. Final classification was performed by FIDA accredited classifier and paid at PhP 450.00 d^{-1}. An accredited classifier had rigid training and field evaluation with supervision by FIDA personnel. The baling of fiber was done by two (2) seven-man teams that alternately loaded the 125 kg classified fiber in the baling machine. The team was paid at PhP 40.00 per bale. Pressing of fiber into desired size was done by a 50 horsepower machine with a machine operator paid at PhP 450.00 d^{-1}.

Inspection and stamping of baled abaca was also supervised by FIDA personnel assigned to the GBE before storage. The cost of hauling and storage of fiber was estimated at PhP 0.25 kg^{-1}. The estimated cost per baled of abaca was PhP 312.50.

A 7-man team could finish 60 baled abaca fibers in a day or GBE had a daily output of 120 baled or 15,000 kg of abaca fiber. About 789.5 kg of fiber or 5% of the total weight was deducted, baled and sold at PhP 12.00 kg^{-1} for the furniture maker. The computed electrical consumption for 50 horsepower machine for 7 hours of operation was about 298.3 kW at PhP 12.50 kW^{-1} and the cost was PhP 3,728.8 or PhP 31.10 per baled. Electrical consumption was computed only for seven (7) hours due to lag period during loading and unloading of fiber and during break periods. The cost of electricity in Catanduaes was slightly higher compared to Bicol mainland. The estimated mean number of baled abaca per month was about 2,000 pieces or 250,000 kg of fiber.

Environmental condition of the work station showed that the well - lighted area was the inspection and sorting because it required thorough check up of the fiber for classification (**Table 2**). The most humid part was also the inspection and sorting area followed by grading and baling area. The hottest area was the weighing and disbundling site while the coolest area was the grading and baling site. The noisiest area was the grading and baling area due to the presence of the machine. The storage area had the lowest humidity and higher temperature compared with inspection and sorting area and grading and baling area as it is an enclosed area to maintain dryness of fiber. The noise level at the inspection and sorting and grading and baling sections were slightly higher than the required level of noise of 70 decibel for light industries (*Philippine Clean Air Act 1999*).

Impact Assessment. Very minimal amount of fiber dust was produced in the GBE station. Baling of fibers used 50 HP machine and had a daily electrical consumption of 298.3 kw and a GWP of 181.4 kg CO_2 equivalent. Workers were also exposed to noise level slightly higher than 70 decibel for light industries (*Philippine Clean Air Act 1999*).

Interpretation. Air plug must be provided for the workers assigned in the grading and baling sections of the GBE to prevent occurrence of noise- induced hearing loss and other harmful effect such as hypertension, hyperacidity, palpitations and disturb relation and sleep (*Philippine Occupational Health and Safety Standard 2009*).

To produce one ton baled fiber, 1.6 ha of land was needed with 2,132 hills (**Figure 8**). The establishment of plantation required 196 man-days and with an average dry fiber yield of 830 kg ha^{-1}. The harvesting of fiber produced 79,590 kg of discarded biomass, which were used as mulch. Fiber harvesting resulted to nutrient loss of about 0.5 kg N, 0.1 kg P and 5.4 kg of K.

Fiber trading at the barangay level required 3 man-days to produce the fiber needed. About 5 kg of fiber dust per 100 kg of fiber was observed by the traders. Transport of fiber from the barangay to the GBE resulted to GWP of 35.6 kg of CO_2 equivalent.

GBE only required 1.9 man-days to produce one ton of baled fiber and had an electrical consumption of 19.9 kw with a GWP of 12.1 kg of CO_2 equivalent. One ton of baled abaca fiber had a total GWP of 47.7 kg CO_2 equivalent.

SUMMARY AND CONCLUSION

Baled abaca fiber from Catandunes can be considered organic fiber having free from synthetic inputs such as fertilizer and pesticides and with very low environmental burden of only GWP of 47.7 kg CO_2 equivalent per ton. Farm yield and quality was considered low, however, it could be improved with organic fertilizer application and used of improved stripping device. The recycled nutrient from farm waste is not enough to sustain better fiber yield.

Table 2. Environmental condition in the GBE.

Environmental parameters	Section			
	Weighing and disbundling	Inspection and sorting	Grading and Baling	Storage
Light (Lux)	381.7	637.3	300.3	355.9
Humidity (%)	62.0	77.9	77.0	69.0
Temperature (C0)	24.8	19.3	19.6	19.8
Noise Level (decibel)	55.8	72.2	72.7	50.6

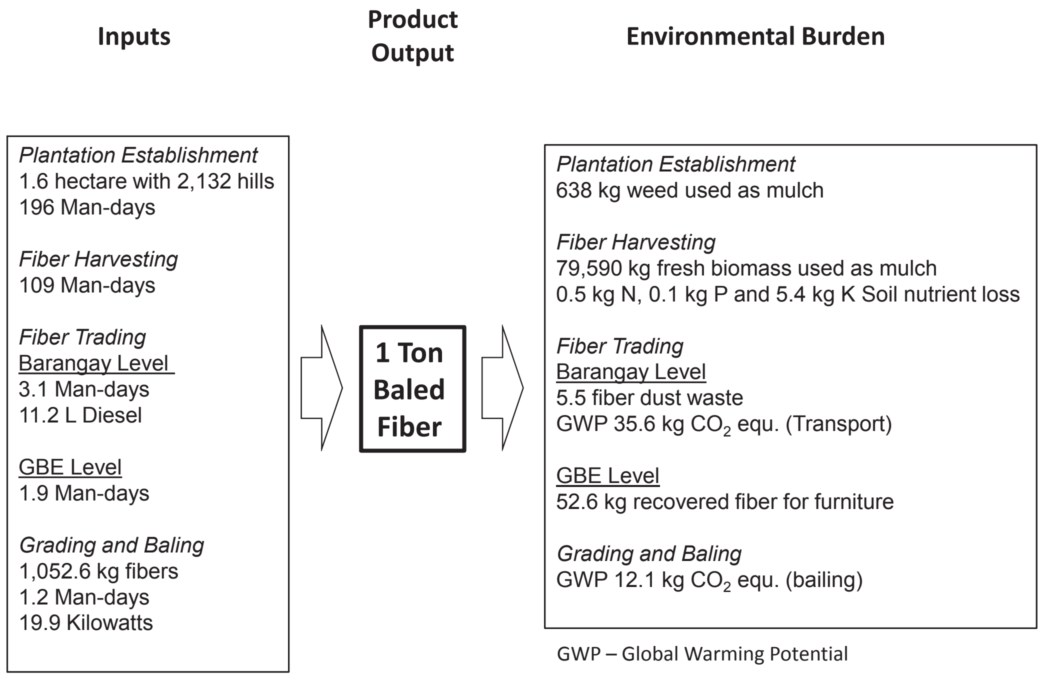


Figure 8. Inputs and environmental burden in production of one ton baled fibers.

Regular under brushing of farm is needed to lessen nutrient competition and improve growth and development of abaca plants. Work environment of the inspection, sorting, grading and baling sections needs improvement and/or use of equipment to improve air rotation.

To improve abaca fiber production it is recommended that replanting of abaca plantation using quincunx method to increase the number of hills per unit area; utilization of discarded plant materials from abaca harvesting and fiber extraction as mulch should be applied across the slope for erosion control; and for environmental sustainability and increase farmer share on the value of his produce, farmers training on fiber grading and moisture determination and institution of local policy to modify the "all-in" system must be formulated to encourage farmers to have better fiber quality.

REFERENCES

Armecin, R. B., 2008, Nutrient Composition of Abaca (Musa textilis Nee) at Seedling, vegetative, and Flagleaf Stages of Growth', *Journal of Natural Fibers*, 5:4,331 – 346

Andrews, E.S. 2009, Guidelines for Social Life cycle Assessment of Products UNEP-SETAC Life Cycle Initiative at UNEP, CIRAIG, FAQDD and the Belgium Federal Public Planning Service Sustainable Development, ISBN: 978-92-807-3021-0

Clinton, D.B. 2003. Light, Temperature, and soil moisture responses to elevation, evergreen understory, canopy gaps in the Southern Appalachians, Elsevier, *Forest Ecology and Management*, 186 (2003) 243 - 255

Department of Labor and Employment (DOLE) 2009. Philippine Occupational Health and Safety Standard

Fiber Industry Development Authority (FIDA), 2007 Annual Report

Fiber Industry Development Authority (FIDA) 2010, Abaca Fiber Market Report, Jan. – March 2010

Garner, A. and G.A. Keoleian, 1995; Industrial Ecology: An Introduction, University of Michigan School of Natural Resources and Environment

Jensen, A., K. Christiensen, and J. Elkington. 1997 Life Cycle Assessment – A Guide to Approaches, Experiences and Information Sources. Environmental Issues Series, EEA, Copenhagan

National Statistic and Coordinating Board (NSCB) 2005, Bicol Regional Report

Philippine Clean Air Act, 1999

UNEP, 2009 Guidelines for Social Life Cycle Assessment of Products

Van Dam Jan E.G. and H. L. Bos, 2004 "The Environmental Impact of Fiber Crops in Industrial Applications, Agro-technology and Food Innovations, (A&F) Wageningen UR, Wageningen, Netherlands. Consultation on Natural Fibers, December 15 – 16, 2004