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Environmental Sustainability Analysis of Charcoal Production in Mulanay, Quezon, Philippines

ABSTRACT

Global and historical trends show the re-emergence of woodfuels as alternative sources of energy amid concerns over their environmental impacts. Charcoal production, in particular, remains a significant source of indigenous energy for developing countries like the Philippines, where it is perceived as a cause of deforestation and environmental degradation. This study presents a case where charcoal production can be practiced on a sustainable basis by focusing on aspects that affect the environment, namely, wood source, harvesting strategy and production techniques. Key informant interviews, focus group discussions and a survey among charcoal producers in Mulanay, Quezon revealed a preference on hardwoods that produce slow-burning charcoals and other readily-available, usually invasive, tree species. Harvesting strategies include tree felling and pruning and rotational harvesting to allow stock replenishment. Charcoal producers employ an old but simple production technique called 'binulkan', which has an efficiency rate of 7.7% by weight. The study concludes that an environmentally-sustainable charcoal industry in Mulanay can be achieved by planting and utilizing suitable tree species and improving harvesting systems and production techniques. Further study is recommended to assess the feasibility of establishing wood plantations for charcoal production with regard to its poverty reduction potential and continued benefits to the community.

Key words: *charcoal production, environmental sustainability*

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INTRODUCTION

The potential of biomass energy, particularly woodfuels, as an alternative to fossil fuel-based energy sources is currently gaining worldwide attention. The *Food and Agriculture Organization* (*2004*) defines woodfuels as "any type of biofuel derived directly or indirectly from trees and shrubs grown on forest and non-forest land." Woodfuels – fuelwood and charcoal – provide for more than 14% of the world's total primary energy (*FAO 1996*). In its 2005 Update of the Philippine Energy Plan, the Department of Energy (DOE) noted that the country's energy mix was and will continue to be dependent on indigenous energy, including woodfuels. Charcoal, in particular, was used by an average of 35% of all households in the Philippines based on the Household Energy Consumption Survey (HCES) for 1989, 1995 and 2004 (**Table 1**).

Charcoal contributes only 2.2% or roughly 5.5 Million Barrels of Fuel Oil Equivalent (MMBFOE) of the Philippine energy demand on a national scale (**Table 2**) (*DOE 2004*), but it translates to 1.148 MT or more than a billion kg of charcoal consumed every year.

In a developing country like the Philippines, biomass energy in the form of woodfuels and agricultural residues are the sources of fuel and income for the poor. As a source of livelihood, charcoal production and trade become part of a long term agricultural cycle (*Arnold et al. 2006*). During land preparation, instead of just clearing the land and burning biomass, farmers gather small diameter trees, bushes and shrubs to make charcoal as a means to augment their income during the off-harvest season (*Cruz et al. 1991*). For some, however, making charcoal becomes a primary source of livelihood particularly when there is lack of any other economic opportunity.

Since charcoal is produced locally, the employment generated by its production is often cited as a major benefit. Yet this economic contribution is marginally written about at greater lengths (*Trossero 2002a*). Charcoal trade provides income to rural folks whose labor is hugely required in harvesting, processing, transporting and trading of the fuel. Studies reveal that the woodfuel trade, including charcoal, generates 20 times more local employment than other forms of energy within the national economy and on a per unit basis. But because the trade occurs as a small-scale informal sector, no comprehensive statistics on the magnitude of its employment and income generation exists (*FAO 2001a as cited by Trossero 2002b*).

While the charcoal industry provides a viable alternative to fossil fuels and serves as an income source for rural folks, disagreements exist on its environmental impacts and sustainability as a livelihood. It is often perceived as a cause of deforestation and environmental degradation. In this study, charcoal production in Mulanay, Quezon was presented as a case where environmental sustainability couldbe ensured by focusing on the following aspects that affect the environment: wood source, harvesting strategy and production techniques.

Sustainable charcoal production can be promoted as a tool in poverty reduction. As such, this study aimed to analyze and assess the environmental sustainability of charcoal production in Mulanay. Specifically, it was designed to profile the charcoal producers and charcoal production area; develop and test suitable criteria and indicators for environmental sustainability analysis of charcoal production; and used the criteria and indicators in examining the environmental sustainability of charcoal production.

METHODOLOGY

The Study Area

Mulanay is part of the twelve municipalities of Bondoc Peninsula, Quezon, at the southern tip of Southern Tagalog. Bounded on the north by Catanauan, on the east by San Narciso, on the south by San Francisco, on the west by Tayabas Sea, Mulanay is accessible via land and water. Located between 13º31.5′ North and 122º24.5′ East, this first class municipality is 279 kilometers away from Manila and 142 kilometers from Lucena City, its provincial capital (**Figure 2**). Mulanay is divided into 28 barangays – four Poblacions and 24 rural barangays. Most of the barangays are along the road while some are remote. 10 of the barangays are found along the coast. As of 2010, total population is 50,826 majority of which rely on subsistence farming and fishing.

The study used household survey, focus group discussion and key informant interviews for data collection. Descriptive statistics, using measures of central tendency, were used to analyze and interpret data. Some relations were estimated using derived measurements. These were analyzed vis-à-vis an adapted set of criteria and indicators based on FAO's Forestry Paper: Criteria and Indicators for Sustainable Woodfuels released in 2010.

Criteria and Indicators (C and I) are neutral assessment tools which measure, assess, monitor and demonstrate progress towards attaining the sustainable management of resources (*Mwampamba et al. 2013*). This set of C and I was guided by overarching principle/s which providing the primary framework for managing forests sustainably (*CIFOR 1999*).

Typically done by international forest management entities to establish proof of sustainable forest management, the concept of C and I are usually presented in a hierarchical structure (**Figure 1**).

A criterion serves to define goals which add meaning to a principle without itself being a direct measure of performance (*Stupak et al. 2011*). Indicators, on the other

Table 1. Trends in household energy consumption.

	% of Households Using Fuel		
Fuel Type	1989	1995	2004
Electricity	64.7	83.9	87.6
Kerosene	74.75	79.9	56.3
LPG	21.9	33.0	51.8
Charcoal	32.1	38.5	34.2
Biomass Residue	46.4	29.2	18.9

Source: DOE's 1989, 1995 and 2004 Household Energy Consumption Surveys

Table 2. Primary energy consumption in the Philippines, 2002 vs. 2001 (in Million Barrels of Fuel Oil Equivalent).

	2002	2001	Percent Change	Share Relative to Total Energy	
				2002	2001
Renewable	108.8	107.4	1.3	43.4	43.2
Geothermal	17.7	18.0	-1.9	7.0	7.2
Hydro	12.1	12.2	-1.0	4.8	4.9
Biomass	78.8	77.0	2.4	31.4	31.0
Wood/Woodwaste	44.7	43.7	2.3	17.8	17.6
Bagasse	11.2	11.0	2.2	4.5	4.4
Charcoal	5.5	5.4	1.3	2.2	2.2
Agriwaste	17.5	16.9	3.1	7.0	6.8
Others	0.	0.2	28.3	0.1	0.1

Source: *DOE 2004*

hand, are quantitative or qualitative variables that are measurable or described and which can show trends over time (*FAO 2010*). Designed to test for socio-cultural, economicand environmental sustainability of forest management, it is also meant to be flexible and adaptable for application globally, regionally and locally at different scales.

For this particular research, analysis for environmental sustainability of the charcoal industry in Mulanay was done using an adapted set of C and I from FAO. In it was a set of principles, criteria and indicators specifically for sustainable charcoal production. The selection of Principle, Criteria and Indicators presented herein demonstrates a more suitable and more appropriate set for Mulanay that was employed in this study (**Table 3**).

In this study, the maintenance of ecosystem function and services was the overarching principle of environmental sustainability for charcoal production and served as the "fundamental law or truth" on which the criteria and indicators were based. Charcoal production is extractive in nature; thus it is important that its non-forest sources were not undermined, since they derive from ecosystems that are part of a bigger landscape providing various goods and services for human consumption (*Thompson 2011*).

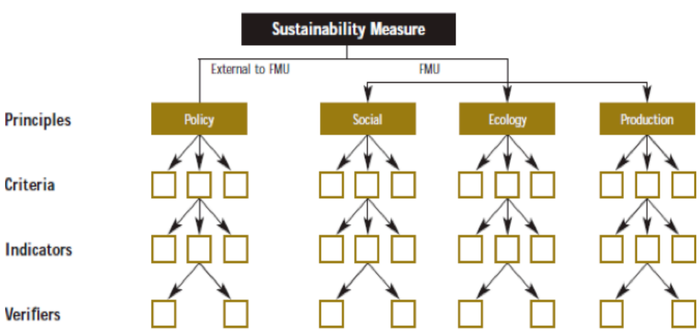

Figure 1. Hierarchical structure of C and I (source: *CIFOR 1999*).

Table 3. Criteria and Indicators for environmental sustainability of charcoal production in Mulanay.

Principle: Ecosystem Function and Services are Maintained	
Criteria	**Indicators**
1. Conservation of species diversity	1.1 Number of preferred species
2. Maintenance of site productive capacity	2.1 Area of land available for charcoal 2.2 Stock density of wood resources
3. Conservation and maintenance of soil and water resources	3.1 Soil and water quality

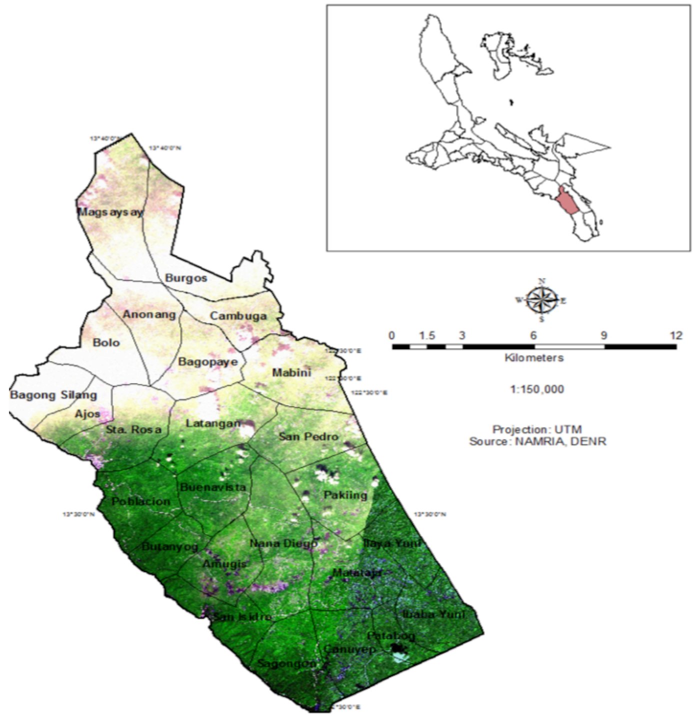

Figure 2. Administrative Map of Mulanay, overlayed with SPOT 5 Image taken October 2004.

RESULTS AND DISCUSSION

Mulanay Charcoal Producers' Profile

A total of 63 charcoal producers were surveyed in Mulanay between February and November 2012. Owing to the labor-intensive nature of charcoal-making, most respondents belong to the 20-59 age range and are predominantly male (73%). Most respondents (76%) were married and many (57%) belong to a small household of at most four people, while the rest have a household size of 5 to 12 people. Very few (3%) had college education, some (33%) reached high school, while the rest (64%) had elementary education. Thirty-five charcoal producer-respondents are natives of Mulanay, while the rest migrated from Marinduque, Bicol and other towns of Quezon because of the farming opportunities and have resided in the municipality for the past 22 years on the average.

Twenty-three of the respondents were producer-landowners, compared with 40 who were producer-farmworkers. Producer-landowners own an average of 4 ha of land, which is planted mostly with banana and coconut, complemented with some fruit trees and annual crops.

To augment income and maximize land value, these small landowners ventured into charcoal-making while waiting for their crops to bear fruit. Trees and shrubs competing with the main crops were made into charcoal for household consumption and sale to charcoal traders. The more enterprising landowners engaged in buying and selling of charcoal in between marketing of their main crops.

Based on interviews with the respondents, two types of producer-farmworkers emerged. The first type was the regular farmworkers, who were given permission to reside in the land while helping in the cultivation and maintenance of the coconut or banana plantation. Aside from their farm income, they engaged in charcoal-making and shared the proceeds with the landowner. The second type was the seasonal farmworkers, who are only called in to help in the clearing of the land for planting and made charcoal out of the wood that has been cleared. Their income from labor came solely from the sale of charcoal after the landowner's share has been deducted. For both regular and seasonal producer-farmers, the same sharing scheme applies, i.e., 10% or one sack for every ten sacks of charcoal produced goes to the landlord.

It has been observed that unemployed producer-farmworkers in Mulanay, presumably realizing the surge in charcoal demand in the market, form groups and look for landowners who will commission them to clear land for charcoal production. Such setup deserves further investigation as to its impact on the sustainability of wood supply. Of the 40 producer-farm workers interviewed, more than half joined such groups, together with their families.

There was a marked increase in the number of charcoal producers in recent years. By plotting the year producers started engaging in charcoal production, a surge in the cumulative number of producers was observed starting 2009 (**Figure 3**). One respondent said that he has been engaged in charcoal production since 1968, two since 1992 and one since 1998. By 2000, five respondents were already into charcoal production and the number slowly increased to 15 until 2008. By the end of 2009, twenty-nine of the respondents were into charcoal-making. The number climbed to 41 the next year and to 57 a year after. At the time of the interview, six of the respondents were new charcoal producers. One possible explanation for this phenomenon is the rise in charcoal demand during the past few years. While this study failed to obtain comprehensive data on charcoal demand, the establishment of the charcoal traders' cooperative in 2007 was a response to increasing demand for charcoal in nearby cities (Lucena, San Pablo City and Quezon City). The traders' Cooperative noted an increase in commercial establishments serving grilled food in the said period.

Charcoal Production in Mulanay

Site Selection and Wood Harvesting

According to its 2009 Socio-Economic Profile, land use in Mulanay, Quezon was used predominantly for agriculture (85.19%). Primary crops are banana planted to 20,064.51 ha and coconut growin in 14,015 ha. Naturally-growing trees and shrubs, which serve as wood sources for charcoal production, are found in between these crops.

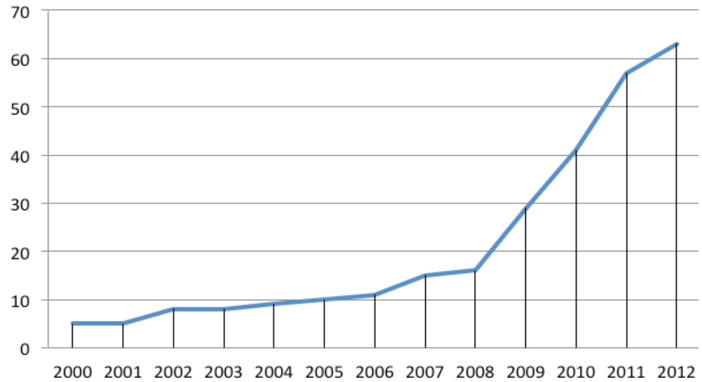

Figure 3. Cumulative increase in charcoal producers from 2000 to 2012 in Mulanay, Quezon, Philippines.

The average charcoal producer works on a four-hectare land. It was a common practice to gather wood for charcoal production strictly within one's own property. Within the property, charcoal producers normally picked a site for kiln construction near areas where they would harvest the wood or where re-growth of naturally-growing trees and shrubs competes with the primary crop for resources. The average distance from the harvesting area to the kiln is 140.28 m. The charcoal producer would set up all the supplies and materials needed not only for charcoal-making but also for temporary dwelling in the area. A temporary shelter made from bamboo and covered with tarp shall be built near the harvesting site to save time and effort in going to and from the house during charcoal-making, as well as to serve as a windbreaker for the kiln. In some cases, an existing kiln and a shelter was already in place from the last production cycle.

Harvesting wood means any of the following: cutting or lopping off branches from individual trees; tree felling or cutting off whole trees leaving only the stump; and the collection of dead and fallen branches for charcoal-making (*Hyman 1983*).

Depending on the size of the tree, most producers made use of *itak* and *kabig* (locally made knives) for harvesting. powersaws, although limited in number in Mulanay, were sometimes rented when harvesting much bigger trees. Cut wood were then transported to the kiln either by hauling it on foot (pasan) or on a carriage pulled by a carabao (paragos). Time spent in harvesting wood depends primarily on the availability of trees to be harvested. Average time spent in harvesting wood was 33.5 hours or at least four days at eight working hours a day.

Wood was then cut into uniform sizes near the kiln for easy stacking. No standard size was observed. Average time spent in cutting wood into uniform sizes was 17.64 h or at least two eight-hour days.

Construction of Kiln

All charcoal producer-respondents used the earth-covered mound kiln. Known in Mulanay as *binulkan*, the earth-covered mound kiln is one of the oldest, cheapest and simplest methods in charcoal-making. Wood was stacked in a pile on the ground and covered with vegetation or pantabon na dayami and then a layer of soil. The size of the kiln varied depending on the availability of wood to process or the amount of wood collected.

Stacking wood in a pile requires much skill to ensure optimum distribution of air and heat during carbonization. First, a bottom layer of small-diameter wood was arranged on the ground in a radial pattern identical to a spider's web. Wood was not required to be placed from end to end on the bottom layer. The second layer, also constructed from small-diameter wood, was arranged perpendicular to the bottom layer and was more closely-packed. This will be the platform or the base of the kiln. It was important for this layer to be strong and sturdy.

Construction of the next layer involved actual stacking of wood. Producers begin with the biggest ones and made their way up by filling in all spaces. The key was to pack each wood tightly to prevent collapse of the structure, ensure even carbonization throughout the kiln and produce better yield. Vertical slabs were sometimes placed around the kiln to hold the wood in position. The wood was then covered with a layer of *dayami* (hay), followed by a layer of soil, which usually has already been used from previous cycles (*luto na ang lupa*). Lighting of the kiln depended on its size. For small- to medium-sized kilns, fire was lit in a small hole in the ground at one or two ends of the kiln. For large-sized kilns, a lighting post with *pangos* (half-cooked charcoal) and kerosene was built in the middle of the kiln after the second layer of wood. This would be ignited after the kiln has been completed. Small ventilation holes were left along the surface of the kiln.

Carbonization

Once carbonization starts, the kiln must undergo day and night supervision. The producer controls the rate of carbonization by opening and closing ventilation holes on the covering. Water should always be at hand in case of combustion. As heat was being continually applied, the color of smoke and the smell and temperature around the kiln helped producers identify how far the wood has already been transformed into charcoal. At first, thick, white smoke was visible after ignition. This was the drying phase wherein water was being released from the pores of the wood into the air as vapour (*Foley 1986*).

Actual pyrolysis was taking place when the smoke coming from the kiln darkens in color and leaves a pungent smell. Pyrolysis is a "term loosely applied to describe the set of processes which take place when the chemical structure of wood breaks down under high temperature and in the absence of air" (*Foley 1986*). This process releases chemical substances called volatiles, which cause the smoke to darken and emit a pungent smell. As this continues, loss of volume along the kiln would be very visible as some areas would collapse, indicating that pyrolysis is near completion.

As the temperature around the kiln begun to fall and the smoke changed color to pale blue, pyrolysis was completed and the cooling phase begun. At this phase, the kiln has now shrunk considerably.

Proper care is still important during the cooling phase. This was the part where producers were literally "*nakikipag-agawan sa apoy*" (in competition with fire). The danger of combustion was still present if air enters the kiln before the charcoal's temperature falls below the ignition temperature. Producers also watched out for half-cooked charcoal, because this can ignite spontaneously as it comes into contact with air. Sometimes, charcoal is left to cool by itself but usually the cooling process is accelerated by pouring water around the kiln. When the charcoal cools down to air temperature, it became ready for packing.

The whole carbonization process was the slowest stage in charcoal production. Depending on the size of the kiln, carbonization could take at least one whole day to 14 days to complete.

Packaging and Transport

Charcoal was normally packed inside National Food Authority (NFA)-issued rice sacks, which can be bought for PhP 10.00 to PhP 14.00 each. Since there was now no danger of spontaneous combustion, the entire family usually joins the producer in packing charcoal into sacks. Weight per sack ranges from 10 to 30 kg depending on the tree species used.

Charcoal traders usually picked up the sacks of charcoal from the producer's house if the condition of the interior roads allows the entry of "top-downs", which was a modified tricycle. Meanwhile, others used the *paragos* (carabao-pulled carriage) for charcoal transport. Selling price per sack varies from PhP 80.00 to PhP 120.00.

Aspects of Charcoal Production Affecting the Environment

Wood Source

Charcoal producers in Mulanay used a variety of tree species to make charcoal, including forest trees such as mahogany and acacia, fruit trees such as mango and santol, and naturally-growing trees and shrubs such as *ipil-ipil* (*Leucaena leucocephala*) and *kakawate* (*Gliricidia sepium*). Charcoal producers prefer hardwood that produce slow-burning charcoals and readily-available trees over other species. Using weight-adjusted ranking, the five most preferred species are the following:

Ipil-ipil (*Leucaena leucocephala*). Locally known as *sipres*, this is a small to medium-sized, highly-branched tree that can grow to a maximum height of 20 m. The World Agroforestry Center (ICRAF) database described *ipil-ipil* as "aggressive colonizer which has been attributed to its year-round flowering and fruiting and ability to resprout after fire or cutting." With a heating value of 29 mJ kg^{-1} and recovery value of 25-30%, *ipil-ipil* is a good raw material for charcoal production. In addition, it can sprout 5-15 branches after pruning with 1-4 stems dominating after a year. Wood yield range from 3-4 m yr^{-1} and 10-60 m^3 ha^{-1} a year after rotation of 3-5 years. Mulanay charcoal producers consider this tree as "laging nandyan" or readily-available.

Binunga (*Macaranga tanarius*). This is a pioneer, fast-growing tree that can grow up to 20 m in height. It is naturally-growing because it is wind-dispersed. In the Philippines, the bark produces a gum used as glue in making musical instruments. Its bark and leaves are used in making *basi*, a fermented drink from sugar cane. Because of its foliage, *binunga* has been recommended as a shade tree to promote natural regeneration. It is said to be a good source of fuel (*ICRAF n.d.*).

Acacia (*Samanea saman*). Easily recognizable because of its characteristic umbrella-like canopy, the acacia can reach a height of 30 m and 4.5 m dbh (*ICRAF n.d.*). A favourite shade tree forFilipinos, the crown normally reaches 30 m in diameter. Although massive in size, the acacia is considered a moderately fast-growing tree with growth rates of 0.75-1.5 m yr^{-1} and has very good coppice ability (*Staples and Elevitch 2006*). Because of its vast size, acacia wood produces 5200-5600 kcal kg^{-1} when it burns, making it a high-quality source of firewood and charcoal (*ICRAF n.d.*).

Tibig (*Ficus nota*). This is a fast-growing evergreen that can grow to a height of 8-10 m. Also known as the Filipino Fig Tree, it is commonly used medicinally. It can also serve as a pioneer species for reforestation (*Fernando 2004*). Commonly found in areas saturated with water, the tibig trunk has a watery sap that is known to be a cure for common ailments like fever and muscle pains.

***Kakawate* or madre de cacao** (*Gliricidia sepium*). *Kakawate* can grow 2-15 m in height. It may be single or multi-stemmed and has a feathery crown (*Suttie n.d.*). Commonly cultivated as shade for crops because of its fine foliage, it is also used in fuel production because it can be coppiced and can even tolerate repeated cutting. Its growth rate is over 2 m yr^{-1}, relatively fast in its early years or when pruned annually. Wood yield can reach as high as 3.5-4.5 kg $tree^{-1}$ yr^{-1} in Central America and fuelwood volumes in the Philippines produces 23-40 m^3 ha^{-1}. (*Elevitch and Francis 2006*). *Kakawate* wood burns slowly and emits little smoke when burned, making it a preferred species for charcoal production (*ICRAF n.d.*).

Harvesting Strategy

Charcoal producers in Mulanay practice coppicing by tree felling (leaving the stump) and pruning (cutting off branches only). Based on interviews, charcoal traders practiced rotation of harvesting and allowed the stock to recover for 3-5 years before wood was again harvested for charcoal production. This means that traders needed to have a relatively wide network of small landowners to be able to sustain the demand for charcoal. Since charcoal producer-landowners and producer-farmworkers on the average have 4 ha of land from which to obtain wood supply, and the average harvesting radius was 140 m from the kiln, the four-hectare land was just enough to supply wood for one kiln for a limited time. In other words, producer-landowners and producer-farm workers did not rotate harvesting within their respective areas but charcoal traders did rotate their buying pattern over a wide area, since some areas need to "rest" for at least three years to replenish their stock. This explains why majority of producer-respondents were just "occasional" charcoal producers, engaging in charcoal-making only twice or four times a year. For these producers, charcoal-making remained as a a part-time job designed to augment income and to remove trees considered obstructive to crops. Respondents who claim to have engaged in charcoal-making on a regular or full-time basis were seasonal farmworkers who seek other areas to clear in exchange for wood supply. It was from these producers that charcoal traders could rely on a steady supply of charcoal for trade.

All producer-respondents used the *binulkan* type of kiln to carbonize wood. Depending on the skill of the producer or the amount of available wood, the kiln could be constructed in different sizes. The average height of the kiln was 1.53 m and the average diameter was 3.43 m. Using these dimensions and the formula for computing the volume of a half-sphere, the volume of wood needed to fill an average kiln was estimated at 9 m^3.

The average diameter of cut wood used by producers and the approximate height of an early maturing tree were used to come up with an estimate of the volume of wood obtained from a tree. From the survey, the average diameter of cut wood is 16.31 cm and the approximate height of an early maturing tree is 8 m. From these dimensions, it was estimated that an early maturing tree will yield 0.167 cu m of wood. Therefore, 54 trees were needed to fill the average kiln having a 9 m^3 capacity.

Production Techniques

This study attempted to estimate the efficiency rate of the binulkan production technique by comparing charcoal yield of the kiln with the amount of raw wood used. Based on the survey, the average yield of each cycle of production was 22 sacks of charcoal, with each sack weighing 17.8 kg on the average. From these figures, it was estimated that the average weight of charcoal produced in an average kiln was 391.6 kg.

Wood density was then approximated using data on the dimension and weight of an average cut of wood used in the kiln. An average cut of wood was 0.1631 m in diameter and 0.6122 m length, while the average weight is 7.27 kg. The volume of the average cut of wood was computed as 0.0128 cu m. Dividing the weight of the wood (7.27 kg) by its volume (0.0128 m^3), the density was estimated to be 567.97 kg m^{-3}. Multiplying the volume of the kiln by the density of the wood (9 m^3 x 567.97 kg m^{-3}), the weight of the raw wood used was estimated to be 5,111.73 kg.

Comparing the weights of the charcoal yield with the weight of raw wood, the efficiency rate of the kiln, by weight, was estimated at 7.7%, which was comparable with the 7.5% computation of *Nahayo et al.* (*2013*) and the expected rate of no more than 10% by *Foley* (*1986*).

Soil and Water Management

In studying the effect of the charcoal industry to soil and water quality, one should look at two aspects of the charcoal production process: the extraction and the carbonization of wood. Of the two, wood extraction was expected to have a greater impact on soil and hydrology.

However, a review of available studies reveal that there is little or no significant reduction in soil organic matter and nutrient availability due to wood extraction for charcoal production (*Chidumayo et al. 2003*). In cases where there were reductions, longer rotation period in between harvest can mitigate the loss through litterfall.

A range of impacts on the hydrological processes and water quality could also happen especially during harvesting and site preparation. Groundwater and aquatic ecosystems could be subject to changes in water yield, stream temperature and increased turbidity and sedimentation (*Lattimore et al. 2009*).

From site visits and interviews with charcoal producers and traders, there appears to be no immediate threat to soil and water quality because of charcoal production. Charcoal kilns occupy only a small portion of land. Harvesting was done near the location of the kiln, hence no significant reduction to soil quantity. Any reduction in soil organic matter and soil nutrients are replenished through the rotation periods in between harvest. No kilns were found to be near any water source. There were also no reported incidents of water contamination.

CONCLUSION

This study aimed to analyze and assess the environmental sustainability of charcoal production in Mulanay, Quezon. Specifically, it attempted to profile the charcoal producers and to describe the charcoal production process in study area, to develop and test suitable criteria and indicators for Environmental Sustainability Analysis and use these in examining the environmental sustainability of charcoal production.

There was a marked increase in the number of farmers involved in charcoal production since 2008. This coincidedwith the formation of a 90-member charcoal traders' cooperative, indicating a growing demand for charcoal from the Bondoc Peninsula, Philippines.

Charcoal producers in Mulanay can be classified as producer-landowner, producer-regular farmworker and producer-seasonal farmworker. The first two types consider edcharcoal-making as a means to augment income while the third type was lured into full-time charcoal-making because of unemployment and the opportunity to have stable income.

The charcoal-making process in Mulanay employs one of the oldest and simplest methods of charcoal production – the binulkan method. One production cycle could last up to 14 days and involves wood harvesting, kiln preparation, carbonization and packaging. The efficiency rate is low at 7.7% recovery rate by weight. An average charcoal producer works on a four-hectare land, has two to four cycles of production in a year, and produces 22 sacks of charcoal per cycle. The estimated charcoal yield ha^{-1} is 88 sacks yr^{-1}. It is also found out that there is no immediate threat to soil and water quality in and around charcoal production areas.

However, this study identifies the aspects of charcoal production process that could put immense pressure on the environment and thus threaten the sustainability of charcoal production as a livelihood. This study asserts that charcoal production in Mulanay can be made environmentally-sustainable given that: suitable tree species (fast growers, good quality) are planted; charcoal harvesting systems are improved; production techniques are improved; and soil and water management programs are integrated.

Finally, an assessment of the feasibility of establishing wood plantations for continued provision of benefits to the community and its potential contribution to poverty reduction is recommended for further studies.

REFERENCES

Arnold, M., Kohlin, G. & R. Persson. 2006 Woodfuels, livelihoods and policy interventions: changing perspectives. World Development Vol. 34, No. 3, pp. 596-611 Center for International Forestry Research (CIFOR). 1998. Occasional Paper Number 17. November 1998.

Chidumayo, E. N., and L. Kwibisa. 2003. Effects of deforestation on grass biomass and soil nutrient status in miombo woodland, Zambia. Agriculture Ecosystems & Environment, v. 96, no. 1-3, p. 97-105.

Cruz, F.A., M.V.O.Espaldon, J.C. Duma. 1991. Rural-Urban Dependence on Wood Energy in a Selected Area in Laguna Province, Philippines.

Department of Energy. 1989. 1989 Household Energy Consumption Survey. DOE, Philippines.

Department of Energy. 1995. 1995 Household Energy Consumption Survey. DOE, Philippines.

Department of Energy. 2004. 2004 Household Energy Consumption Survey. DOE, Philippines.

Department of Energy. 2005. 2005 Update of the Philippine Energy Plan. DOE, Philippines.

Elevitch, C. R. and J.K. Francis. 2006. Special profiles for Pacific Island forestry. www.traditionaltree.org

Fernando, E. S. 2004. Flowering plants and ferns of Mt. Makiling. Seoul, Korea: ASEAN-Korea Environmental Cooperation Unit.

Foley, G. 1986. Charcoal making in developing countries. Technical Report No. 5, Earthscan Energy Information

Programme. International Institute for Environment and Development, London, U.K.

Food and Agriculture Organization. 1996. Report: Forests, Fuel and the Future: Wood Energy for Sustainbale Development. Forestry Topics Report.

Food and Agriculture Organization. 2004. Unified Bioenergy Terminology.

Food and Agriculture Organization. 2010. Criteria and indicators for sustainable woodfuels. FAO Forestry Paper No. 160. Rome, Italy.

Hyman, Eric L. 1983. Analysis of the Woodfuels Market: A Survey of Fuelwood Sellers and Charcoal Makers in the Province of Ilocos Norte, Philippines. Biomass International Journal, Vol. 3, pp. 167-197. 1983.

Lattimore, B., C.T. Smith, B.D. Titus, I. Stupak and G. Egnell. 2009. Environmental factors in woodfuel production: Opportunities, Risks and Criteria and Indicators for Sustainable Practices. Biomass and Bioenergy.

Mwampamba, T.H., Gilardi, A. Sander, K. & K. Chaix. 2013. Disspelling common misconceptions to improve attitudes and policy outlook on charcoal in developing countries. *Energy for sustainable development*. Volume 17: 75-85.

Municipal Government of Mulanay. 2009. Socio-economic profile of Mulanay, Quezon. Mulanay, Quezon, Philippines.

Nahayo, A., I. Ekise and A. Mukarugwiz. 2013. Comparative study on charcoal yield produced by traditional and improved kilns: A case study of Nyaruguru and Nyamagabe Districts in Southern Province of Rwanda. Energy and Environment Research, 3(1). Canadian Center of Science and Education.

Staples, G.W. and C.R.. Elevitch. 2006. Special profiles for Pacific Island forestry. www.traditionaltree.org

Stupak, I., Lattimore, B., Titus, B. & C.T. Smith. 2011. Criteria and indicators for sustainable forest fuel production and harvesting: a review of current standards for sustainable forest management. Biomass and Bioenergy 35(2011) pp. 3287-3308.

Suttie, J.M. n.d. http://www.fao.org/ag/AGP/AGPC/doc/Gbase/data/pf000156.htm. Accessed 13 August 2014.

Thompson, I. 2011. Biodiversity, ecosystem thresholds, resilience, and forest degradation. FAO-Unasylva Journal. *Unasylva* 234. 62(2).

Trossero, M.A. 2002a. Socio-economic Aspects of Wood Energy Systems in Developing Countries: A Focus on Employment. Paper prepared for the IEA Bioenergy Task 29 Workshop. Cavtat, Croatia. September 19-21, 2002.

Trossero, M.A. 2002b. Wood Energy: The Way Ahead. *FAO-Unasylva Journal*. Vol. 53 2002/4.

World Agroforesrty Centre website. http://www.worldagroforestrycentre.org/. Accessed 8 September 2014.