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Sectoral Assessment of Greenhouse Gas (GHG) Emission in Barangay Bineng, La Trinidad, Benguet

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Abstract

The Climate Change Act or the Republic Act of 9729 mandates the Local Government Unit (LGU) to prepare a Local Climate Change Action Plan. Aside from preparing the adaptation and mitigation plan, one crucial activity that LGUs need to undertake to reduce emission effectively is to undertake GHG inventory. If community GHG is not measured, it will be difficult to measure and monitor the effectiveness of any action plan. This study identifies and quantifies the emission sources of GHGs (carbon dioxide, methane and nitrous oxide) in the major sectors (stationary energy, electricity consumption, transportation, waste, agriculture, and forestry and land use/land cover (LULC)) that occurred in 2018 at Barangay Bineng, La Trinidad, Benguet. Emission and sequestration were established using an excel-based tool developed by the Intergovernmental Panel on Climate Change [IPCC] (2006), the Government of the Philippines, and the United Nations Development Project [GOP and UNDP] (2011). Results showed that the major LULC change in Bineng was the increase in open forest and brushland area. Barangay Bineng emits 2,964.53 tCO_2e generated from stationary energy, electricity consumption, agriculture, waste, transportation, and forest conversion to other land use. Despite the GHG released in the area, the remaining open forest and shrubland that increased in the area played a dominant role in absorbing emitted GHG with an absorption potential of 6,104.54 tCO_2e per year. Thus, barangay Bineng is still a carbon sink. Nevertheless, the LGU must regulate the various GHG emitting activities.

Introduction

The Philippine government supports the world's effort in combatting climate change. Given the global effects of climate change, the government mandates all LGUs to prepare mitigation and adaptation plans to reduce GHG emissions through the Climate Change Act. The LGU and national government have significant roles in promoting mitigation and adaptation measures on climate change, as proven in Albay (Climate Change Commission [CCC], 2017), and in curving human behavior that supports these actions (Almonte, 2011).

The Local Climate Change Action Plan required from LGU (CCC, 2017) to be holistic must include GHG inventory. Its inclusion will allow assessment of the sources of GHG emission, the main driver of climate change, and the carbon pool that mitigates the GHG emission. As said, we can only manage what we measure and monitor. As generally defined by the Drexel University (2008), a GHG inventory is an institution's impact on the environment as measured in greenhouse gases emitted in units of equivalent tons of carbon dioxide, and it is often referred to as an institution's "carbon footprint."

The GHG inventory, an activity to support GHG accounting, is difficult for most LGUs to undertake due to unclear roles and responsibilities, limited technical expertise, and inadequate resources (Almonte, 2011). Since the mid-1990s, when national GHG inventory was made (Francisco, 1996), only a handful of LGUs (6 out 1634 municipalities and cities) were able to submit (CCC, 2017). Most of LGU's commendable actions are directed towards adaptation and increasing the carbon sinks, which primarily consist of our forest.

LGUs are also the protectors of the remaining community forest, which is important in GHG removal. Forest can both be a source and sink of carbon. Even the conversion of land to other LULC, such as forests to agriculture, releases carbon dioxide. Thus, monitoring LULC change is needed for us to reduce GHG emissions. GOP and UNDP (2011), IPCC (2013), World Resources Institute (WRI, 2014), and CCC (2017) provide guidelines on accounting for carbon sinks or carbon emissions.

Some country carbon emission estimations were made (Seriño, 2014, 2017; Mejia, 2016; Sundo et al., 2016), but most of these researches are sector-based and encompass particular small areas, which results in fragmented data. If GHG accounting is to be mainstreamed in the Local Climate Change Action Plan for GHG and resource management options, the baseline must first be established, especially at the community levels. This study seeks to address this concern by looking at a community-level GHG.

The study assessed the total amount of GHG emissions and the net carbon sequestration in Barangay Bineng, La Trinidad, Benguet. It determined the LULC change in Barangay Bineng to establish the baseline GHG emission and the area's sink. It also identified and quantified the GHG emissions of the major sectors of stationary energy, electricity consumption, transportation, waste, agriculture, and forestry, and LULC change.

With this study, baseline information on the status and sources of GHG emission can be established, and actions toward reducing GHG emission to counter the effect of climate change can be planned and monitored. Assessment of sectoral emissions can also provide a basis for reduction strategies and the effectiveness of measures taken.

Materials and Methods

The study was conducted at Barangay Bineng, La Trinidad, Benguet (Figure 1) in 2019. It is one of the rural barangay in the Municipality of La Trinidad in the Province of Benguet with a total population of 1,976 and about 333 households whose majority (243 households) are farmers (Municipal Planning and Development Office, 2018). Barangay Bineng was identified as the study site based on the following criteria: (1) it covers the required anthropogenic emissions by sources of community GHG under the IPCC (2006), and CCC (2017) categories, (2) it encompasses more manageable area for effective surveys and analysis, and (3) it has an existing forest cover.

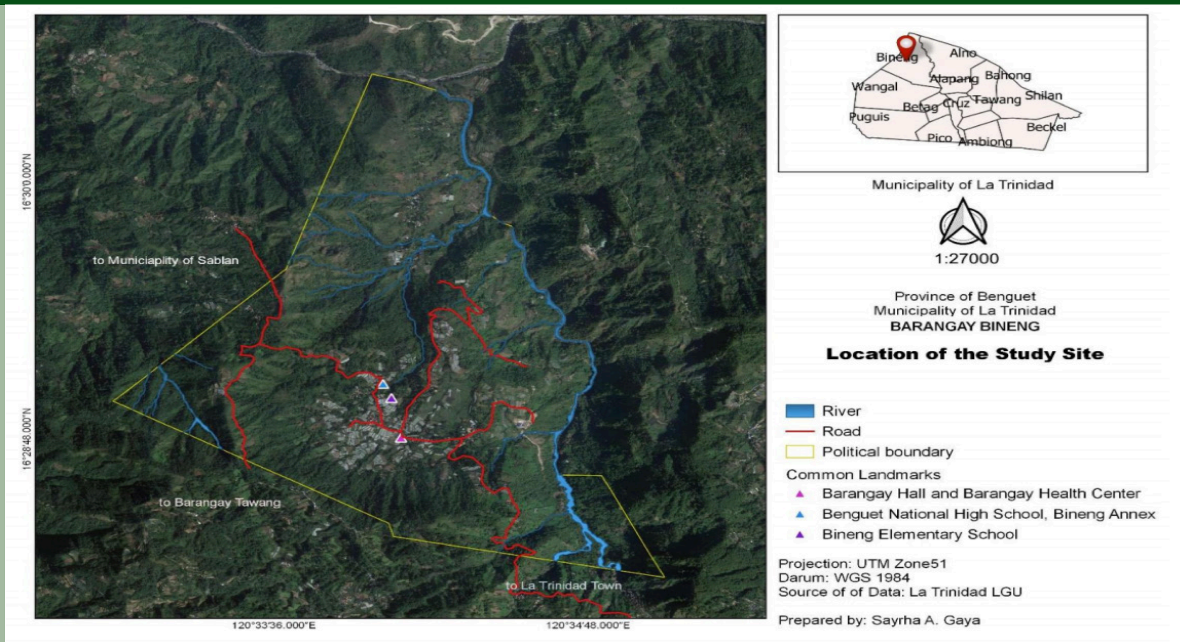
Materials

The study used the political boundary of Barangay Bineng (Figure 1). The baseline year in the assessment was 2018, the most recent year where most of the information needed was available. Other lacking information were obtained from a household survey, key informant interview, and acceptable assumptions based on what has been done by some LGUs, who submitted GHG inventory, especially the study of de Luna et al., (2013). Geographical Information System (GIS) software was also used in the study to determine and analyze the changes in terms of LULC that occurred in the area.

Calculating the GHG emissions used the Excel-based tools (spreadsheet) accompanied by a

Figure 1

Map Showing the Location of the Study Site



user's manual (Community-level GHG inventory for local government units in the Philippines) that can be accessed at https://www.niccdies.ph/ghginventory/local and https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html. This program is a simplified version to undertake the computation process augmented by procedures from the study of de Luna et al. (2013).

For LULC assessment, the 2003 and 2015 LULC digital maps, the latest official maps released by NAMRIA and the Quantum Geographical Information System (QGIS) software version 3.10.1 were used. QGIS is an open-source and freely available program that can be downloaded at https://www.qgis.org/en/site/. Spatial data on LULC and barangay boundary for the study area were taken from the Provincial Environment and Natural Resources Office (PENRO)-Benguet, Benguet State University-College of Forestry, and LGU of La Trinidad, Benguet. The map of Barangay Bineng was produced using these datasets, including the important landmarks (e.g., barangay hall and school), geotagged photos, and downloaded satellite images.

Methods

The base-year used (2018), Tier and Scope were based on prior discussions made with LGU La Trinidad in 2019, participated by Dr. Marissa Parao of Benguet State University and the researcher. All activities being conducted related to GHG emission within the jurisdiction of Bineng were considered in the community inventory. It covers residential, institutional (stationary and electricity consumption), transportation, waste, agriculture, forestry, and other LULC changes as emissions sources. A questionnaire was prepared based on the IPCC (2006) and CCC (2017) guidelines, previous studies conducted in the country, and the consultation made with LGU La Trinidad to address the unavailable data.

The household sample size was computed using Cochran's (1977) formula as used by Poolsawat et al. (2017, 2019). Using a 90% confidence level and 10% precision, about 11% (36) of the total households were surveyed. To account for the differences in the household profile, and considering that socio-economic status is a key driving force of anthropogenic GHG emission (IPCC, 2013; Seriño, 2014, 2017), samples selected were stratified according to their socio-economic status. Respondents were categorized based on income range (minimum, average, and maximum income), and 12 households per category were sampled. Relevant data, proxy measures of activity at the emission source were gathered through actual observation and interviews. Additional data were gathered through purposive sampling and interviews of the different offices of the La Trinidad LGU, PENRO-Benguet, and BENECO.

The study adopted Scope 2 (for electricity) and Scope 1 and 3 (for waste) (World Resources Institute, 2014), or it only considered the direct sources of emissions taking place within the barangay boundary. The IPCC (2006) GHG emission categories or sectors were adopted, and Tier 1 and Tier 2 were used to complete the profile. Excluded in this study were the industrial sector emissions and air and water travel emissions due to their absence. The common commercial business establishments like small retail outlets or sari-sari stores were subsumed in residence under the stationary source and electricity consumption of GHG emissions. When only the municipal data are available, proportions based on area or population sizes were used to estimate the study site's activity emissions. Table 1 shows the general data that were collected for the computation of GHG.

For the determination of LULC change, it was assumed that no significant physical change occurred from the year 2015 to the year 2018; thus, calculations of sequestrations were based on map data of 2015. The QGIS geoprocessing tools such as clip and union under vector menu were used to manipulate and analyze the data. Reclassification of LULC was based on the IPCC class except for brushland/shrubland and open forest within the forestland in the category of the IPCC (2006). The two LULCs, open forest and brushland/shrubland, were separated since the Department of Environment and Natural Resources (DENR) defines brushland/shrubland as an area with discontinuous shrubby plants, which is technically different from an open forest dominated by tree crown cover of 10 to 30% (GOP & UNDP, 2011). The pivot table in Excel was used to track the LULC changes that resulted in either positive or negative changes in terms of the area of each LULC.

The study adhered to the standard process of quantifying GHG emissions based on the methods prescribed in the IPCC (2006) and GOP and UNDP (2011) guidelines. It followed a general formula where:

Activity data x emission factor = tons of CO_2 emissions

Table 1

Required GHG Activity for Data Collection

IPCC Categories	Data Type	Methods of Data Gathering/ Source
a. Stationary energy	Residential fuel and institutional fuel (LPG, charcoal, kerosene, fuelwood)	Survey
b. Electricity consumption	Residential, institution, street lights	BENECO
c. Transportation	Road transportation	Survey
d. Waste	Solid waste and wastewater	LGU, Survey
e. Agriculture	Vegetable, cut flower and rice cultivation, livestock production, agricultural soils	LGU, Survey
f. Forestry & Other LULC	Commercial harvest, fuelwood consumption, LULC change	PENRO-Benguet, NAMRIA maps and its processing tool using QGIS

Activity data were converted into a common unit of measurement, tCO_2e (IPCC, 2006). Other specific formula includes the computation of annual fuel consumption, GHG emission for electricity and fuel and the formula for estimating household waste for Barangay Bineng are as follows.

Annual fuel consumption = Average fuel weight used per household per year x percentage of household using certain fuel type x total number of households.

$\text{GHG emission}_{(\text{electricity})}$ = (Electricity consumed + Systems losses) + Average electricity - Grid emission factor

GHG emission(fuel) = Fuel consumption x Emission factor

Household waste data (2018) = (Population 2019 / Population 2018) x Waste data 2019

The types of data required for emission factors for stationary energy, electricity consumption, waste, transportation, and agriculture and their calculations were based on the IPCC guidelines for the different parameters except for the forestry and LULC change.

For forestry and LULC change, the study adopted the method from "Tracking greenhouse gases: an inventory manual" by GOP and UNDP (2011) to compute forestry and other LULC emissions. The quantification of the GHG emission was based on annual timber removal and area of forest converted to agriculture, settlement and other uses. Reports through cutting permits issued by DENR-PENRO Benguet and apprehended logs were secured for the year 2018. Biomass carbon densities by LULC were derived from the Philippine tracking greenhouse gas guidelines.

The average GHG emission of some sectors was calculated for minimum, average, and maximum income households and compared. Differences in emitted GHG in stationary energy among income ranges were evaluated using the chi-square test.

Results and Discussion

The study determined the changes in LULC of two time periods using NAMRIA maps and the community GHG emission of Barangay Bineng for the year 2018.

Determination of Land Use/Land Cover (LULC) Change

Six LULC classifications were identified after undertaking a matching to the nearest feature activity that was undertaken to compare the two maps derived from NAMRIA (Table 2). The most obvious change from 2003 to 2015 occurred in agriculture, which is surprising since it is the main source of income in the community. The result of the LULC distribution for 2003 to 2015 shows a substantial change in the landscape of the study site (Figure 2). Cropland and grassland declined by 24.07% and 21.51%, respectively (Table 2), and it accrued to forest expansion.

Interviews with LGUs, DENR, and analysis of maps showed that the majority of the LULC changes could be due to (1) natural and human-induced reforestation programs implemented by both government and private sector, (2) farmland abandonment that allows natural regeneration to take place and (3) the low-spatial resolution of the 2003 map which detect plastic greenhouses as part of the settlement areas and which was improved in 2015. Interviews, however, attest this was mainly due to the accelerated rehabilitation of the grassland areas as part of the NGP and HedCor planting activities. Forest recovery has an important implication to community GHG being a sink for atmospheric carbon. As forest cover increased through LULC change, the amount of carbon absorbed by the area also increased.

Greenhouse Gas Emissions of the Different Sectors

Stationary Energy

The study showed that LPG and fuelwood are the preferred energy sources by both residence and institutions in Barangay Bineng (Table 3). The average monthly household consumption of LPG, which is 4.84kg, is much lower than the

Figure 2

Changes in LULC from the Years 2003 and 2015

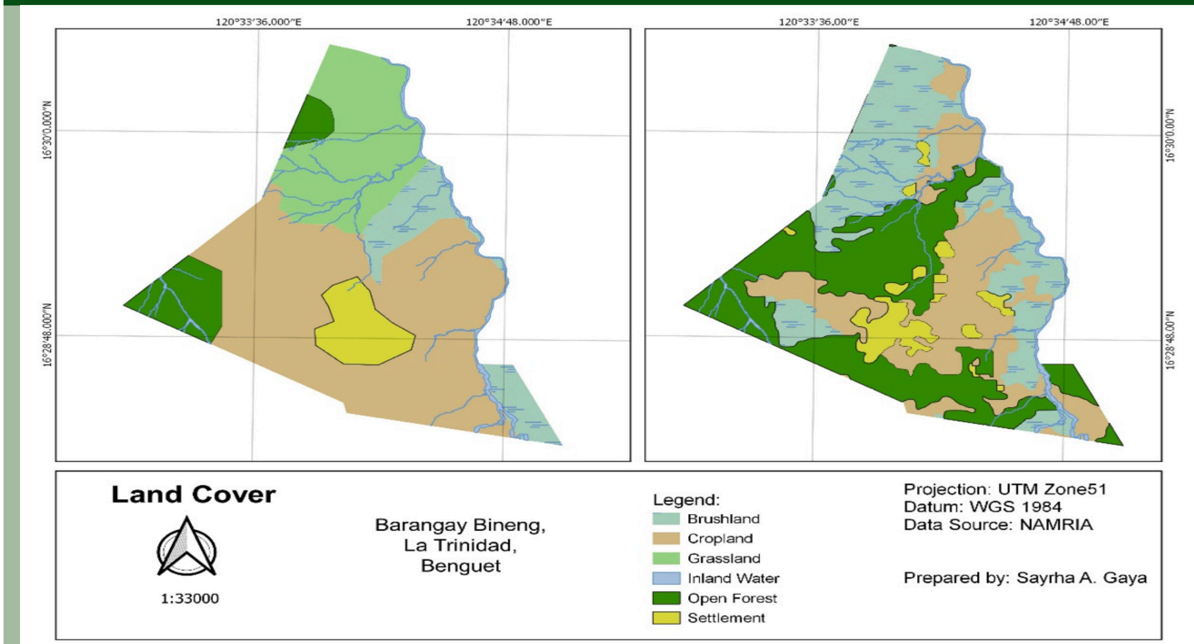


Table 2

Summary of LULC Changes in Barangay Bineng from 2003 and 2015

LULC	2003		2015		Change in % from 2003 to 2015	Net annual change in land area (ha.)
	Area (Ha)	Percent	Area (Ha)	Percent		
Brushland/Shrubland	71.02	9.53	221.15	29.68	20.15	12.52
Cropland	387.41	51.99	208.05	27.92	-24.07	-14.95
Grassland	160.25	21.51	0.00	0.00	-21.51	-13.35
Inland Water	18.22	2.44	18.22	2.44	0.00	0.00
Open Forest	59.48	7.98	252.86	33.93	25.95	16.12
Settlement	48.76	6.54	44.85	6.02	- 0.52	0.33
Total	745.13	100.00	745.13	100.00	0.00	

Note: A negative sign indicates a decrease, and a positive indicates an increase in area coverage of the LULC.

national average at 8.25 kg in 2004 (Philippine Statistics Authority [PSA], 2020). LPG was mainly preferred because it is readily available, accessible, and more efficient than fuelwood and charcoal.

The annual consumption of LPG for Bineng households is at 19,613.63kg, and the various institutions like LGU and schools are at 168.31kg. LPG comprises 98% of the fuel consumption of the community. Despite LPG emitting far higher tCO_2e than charcoal and fuelwood, it is still considered a cleaner alternative than the two, according to Department of Energy [DOE] (2016). Thus, the community is relatively efficient in terms of its fuel use.

The computation of GHG released per income group showed that the same use pattern for fuel types was observed across income classes of sample residents. LPG predominates the source of cooking energy, with fuelwood slightly increasing as household income decreases (Figure 3). Low-income families still prefer LPG, but they also depend on cheaper and readily available fuel (e.g., fuelwood) in case of financial constraints in buying LPG.

The rural setting, household size, income, and preference can be factors in the increase in GHG emission due to energy consumption based on the study of Seriño (2017); however, the chi-square test result between socio-economic variables and fuelwood consumption in this study is not significant (P2=0.884). This means that income is not linked to GHG emissions as sourced from energy consumption by households, nor does it depend on income alone.

Electricity Consumption

The demand for electricity in the area is 496.20MWh in 2018. The energy consumption by residence (477.23MWh) is 60 times more than the combined streetlights (11.40MWh) and public buildings (7.57MWh) (Table 4). The majority have access to electricity. The average household power consumption is 1.43 MWh for 2018, much higher than the national average of 248.1KWh as of 2014 (Statista, 2021), partly due to their

Table 3

Commonly Used Household Fuel in Barangay Bineng

Fuel Type	Annual Volumes (kg)	Percentage Share (%)	Gases (tCO2e) Per Fuel Type
A. Residential			
LPG	19,613.63	69.44	61.10
Fuelwood	7,700.53	27.26	0.12
Charcoal	930.28	3.29	0.91
Total			62.13
B. Institutional			
LPG	168.31	77.10	0.52
Fuelwood	50.00	22.90	0.01
Total			0.53

Figure 3

GHG Emission Among Household Income Classes of Barangay Bineng

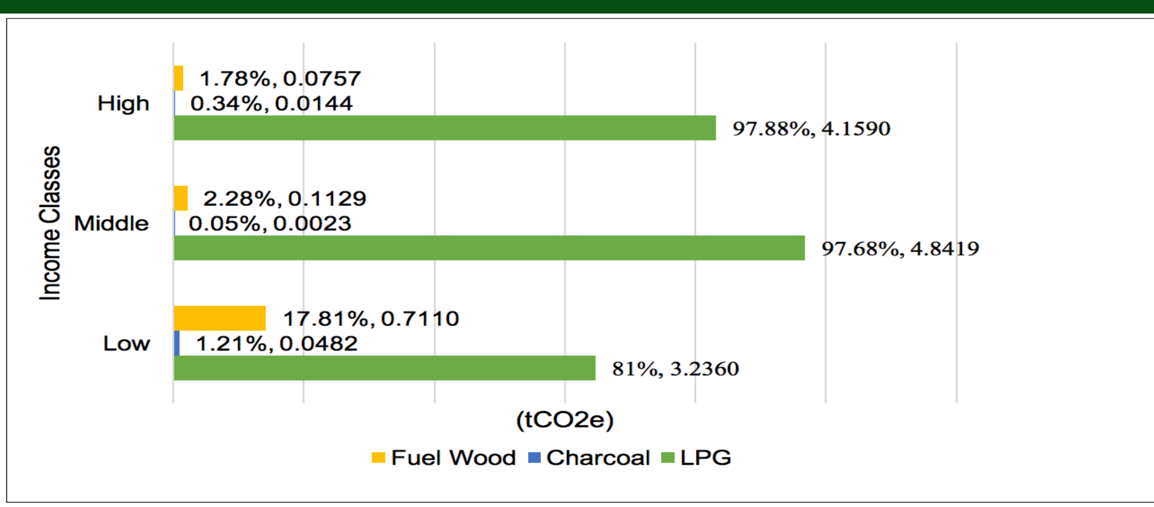


Table 4

GHG Emission from the Use of Electricity in Barangay Bineng, La Trinidad, Benguet

Type of Consumer	Consumption (MWh)*	Percentage Share (%)	Total tCO_2e from Consumption and System Losses
Residential	477.23	96.17	528.90
Public buildings	7.57	1.53	8.39
Street lights	11.40	2.30	12.63
Total	496.20	100.00	549.92

*Source: BENECO

use in gardens and greenhouses. Electricity consumption contributed 549.92 tCO_2e to the total GHG of the barangay.

Given this, the use of environment-friendly and energy-efficient lighting to save energy and resources such as Light Emitting Diode (LED) can save as high as 65.23% (Poolsawat et al., 2017) and may be considered in the area especially for greenhouse use.

Majority of the electricity generated by BENECO (99%) is produced from coal fired power plant. Hence, there is a need to promote renewable sources of energy as also discussed by Sumabat et al. (2006). But with the continuing operation and improvement of Hedcor mini hydro power plant, there is a chance to produce a low-carbon electricity that comes from renewable energy for Barangay Bineng in the future.

Transportation

The barangay road is classified as a rural type (IPCC, 2006). There were only a few vehicles that traversed the area. The daily average number of vehicles that traverse Barangay Bineng during the survey was 336 units, with an average distance traveled per single trip of 2.28km. The survey mostly observed the passage of PUJ and private vehicles, most of which are motorcycles, hence having a lesser amount of fuel energy consumption and less pollution.

Interview with vehicle owners showed that the most demanded petroleum products were those of gasoline and diesel. Respondents used gasoline for motorcycle (39.68%) and diesel for light duty vehicle, like van and Isuzu elf (60.32%). As a result, gas, and diesel use accounts for 13.34 tCO_2e and 46.10 tCO_2e of the transportation sector's GHG emissions, respectively (Table 5).

Since most are engaged in farming, mobility is necessary to access farm destinations, markets, and homes farther apart. Motorcycles are more convenient for them since they are more affordable and can access the narrow path to farm areas.

The measured amount of GHG emitted by transport per person in Bineng is 0.03 tCO_2e. It is lesser as compared to the per capita emission of Aurora province (0.082 tCO_2e) (de Luna et al., 2013) and the Philippines at 0.23 tCO_2e (Mejia, 2016). The transportation sector generates only 59.44 tCO_2e, but this must be monitored given the rapid population and economic growth. Also, even if transportation ranked 6th or the lowest among GHG emission sources in this study, it can still be targeted for reduction.

Table 5

GHG Emission from the Use of Vehicle in Barangay Bineng, La Trinidad, Benguet

Vehicle Type	CO_2	CH_4	N_2O	TOTAL (tCO_2e)
Motorcycle	12.73	0.08	0.53	13.34
Light duty vehicle	44.81	0.06	1.23	46.10

Waste

The residence of Barangay Bineng generated approximately 58.08 tons of solid waste in the year 2018. This amount of waste resulted from an average daily per capita of residents of 0.03kg/capita/day as compared to an urban area such as Baguio City (0.42kg per day) (Lunag et al., 2019) and other cities and provincial capitals in the Philippines (0.50kg/day) (Tinio et al., 2019). It is much lower than the average waste of Filipino living in rural areas that produce 0.30kg of garbage every day (World Bank, 2001).

Waste generation varies with location and population (Lunag et al., 2019), household consumption pattern (Enteria & Orig, 2019), economic status (Tinio et al., 2019; Xin et al., 2020), and other factors. The solid waste composition generated in Barangay Bineng showed plastic as the dominant waste, with 86.44% (Table 6).

Table 6

Solid Waste Composition of Barangay Bineng

Waste Type	Total (tons)	Percentage Share (%)
Food waste	1.90	3.27
Garden, yard and park waste	4.17	7.19
Wood	0.25	0.44
Paper	0.52	0.89
Disposable nappies	1.04	1.78
Plastics, other inerts	50.20	86.44
Total	58.08	100.00

The waste management systems that were identified in the waste analysis and characterization study and the survey conducted showed that Barangay Bineng residents observe a variety of waste management practices that include selling collected waste to junk shops (23.7%), composting (1.7%), and feeding to animals (2%). The majority, however, are transported to the solid waste disposal sites (SWDS) (55.7%). These are collected and disposed of in the landfill area at Urdaneta City, Pangasinan, in which Barangay Bineng indirectly contributes to GHG emissions. Unfortunately, there were still those who practice open burning of uncollected waste (6.1%).

The GHG emission from solid waste of Barangay Bineng contributes 86.38 tCO_2e (Table 7). Generation rates of GHG in the study area per capita is 0.04 tCO_2e, which is almost two times lower than the country's per capita GHG emission of 0.081 tCO_2e and two times lower than the Aurora province, with 0.026 tCO_2e (de Luna et al., 2013).

Waste management in Barangay Bineng can still be improved. Normally, waste released more methane than other gases, and there is the potential use of methane in producing biogas. Likewise, waste could be lessened by reducing the use of single-use plastics (Enteria & Orig, 2019; Tinio et al., 2019) and source segregation. As shown in Xin et al. (2020) study, efficient segregation of kitchen waste and recyclables followed by incineration of residue can significantly reduce up to 70.82% of GHG emissions. Likewise, active participation of communities in composting and recycling can reduce up to 35.89% of CH_4 and 99.57% of CO_2, but it may increase the N20 emission (Tinio et al., 2019).

Table 7

GHG Emission from Solid Waste of Barangay Bineng

Waste Management	CO_2	CH_4	N_2O	TOTAL (tCO_2e)
Landfill - IPCC FOD method	-	82.83	-	82.83
Biological treatment of waste	-	1.69	1.87	3.55
Incineration	-	-	-	-
Total emissions	-	84.51	1.87	86.38
Percentage (%)	0	97.84	2.16	100.00

As of 2018, there is no treatment plant within or outside the municipality that collects wastewater for treatment. The barangay's yearly averaged Biochemical Oxygen Demand (BOD) per person is 13.51kg, or 0.037kg BOD/person/day. An increase in BOD indicates an increase in the amount of CH_4 that will be produced.

Barangay Bineng generated an annual GHG emission from wastewater per capita of 0.10 tCO_2e, which is twice higher than the national capita of 0.085 tCO2e and is similar to 0.104 tCO_2e of the Aurora province (de Luna et al., 2013). The GHG emanating from domestic water waste accounted for 195.89 tCO_2e (Table 8). These mainly were generated from the kitchen, toilet, laundry, and bathroom. Generally, used water from households goes either into a septic tank, seeps back into the ground, or runs through the common canal that drains to the river system.

Overall, the largest source of GHG emissions from waste in this study is wastewater (69.40%), followed by solid waste (30.60%). The high GHG emission of wastewater is attributed to the lack of wastewater treatment plants. Currently, households rely on septic tanks that provide only on-site system pre-treatment (without desludging) for wastewater.

Agriculture

The barangay is said to be the only rice-producing barangay among the 16 barangays of La Trinidad, with an area of 23.36ha; thus, it emits methane from rice fields. Fields are cultivated once a year at the start of June and end in November or December. Irrigated rice field during wet season has the highest emitted CH_4 per cropping season compared to the other rice-based system (GOP & UNDP, 2011).

The commercial crop cultivation in the area has also been increasing, which resulted in high crop residue. Commercial farming includes the planting of cut flowers such as chrysanthemums, which farmers mostly prefer. Commercial farming is usually associated with applying synthetic fertilizers and chemicals, resulting in additional gas emitted to the atmosphere or leached into the water system. However, this is part of the limitations of this GHG inventory.

Also, livestock production in the area is increasing and is expected to rise due to the increasing demand for meat products. Production in the area is mostly small and backyard scale with a small number of livestock mostly buffalo and cattle. This result means that there is no massive amount of waste produced from animal wastes. Also, chicken and duck commonly raised on a household scale are often the free-range types, and manures are mixed with soil. Likewise, swine manure is mainly managed by digging holes near the pigpen. The waste from grazing animals is also left untreated or uncollected in pasture land.

The total computed emission from agricultural activities is 384.71 tCO_2e from rice cultivation, livestock raising, and agricultural soil (Table 9). The main drivers of the emission seen in this sector were rice cultivation (165.81 tCO_2e) as it contributes to methane flux, followed by livestock (131.69 tCO_2e) which substantiate the country's report of Braatz et al. (1996) that the highest sources of GHG in the agricultural sector are rice and livestock production. The amount of GHG emission emitted per ha of irrigated rice in the study area is 7.10 tCO_2e, twice higher than 3.93 tCO_2e in the Philippines (Bautista & Saito, 2015). This result means that rice production in the area must be given importance to mitigate emissions from the activity. To sustain the increasing

Table 8

GHG Emission from Wastewater of Barangay Bineng

Greenhouse Gas	CO_2	CH_4	N_2O	TOTAL (tCO_2e)
CH_4 from waste water - residential	-	174.17	-	174.17
N_2O from waste water - residential	-	-	21.72	21.72
Total emissions for waste	-	174.17	21.72	195.89
Percentage (%)	-	88.91	11.09	100.00

demands for food without adverse environmental impact, farmers must also learn to reduce waterlogging in the rice fields or set up alternate drying and wetting procedures.

Currently, activities in agriculture are not the major sources of GHG emission compared to other sectors, but it is still important to give attention to this sector since land conversion to farmland is spreading.

Forestry and Other LULC Change

Carbon emission from the management and conversion of land in Barangay Bineng is at 1,625.51 tCO_2e, which amounts to 54.83% of the total GHG emissions in the area. The pivot table analysis of LULC changes showed the annual highest GHG was released by open forest (871.20 tCO_2e) primarily due to the conversion of open forest to brushland/shrubland (17.19ha) and cropland (6.52ha). When converted into other use, the carbon storage capacity of a forest releases huge amounts of GHG into the atmosphere. The carbon stock density of open forest and closed forest varies. Consequently, GHG emission differed and ranged from 8 to 208 tCO_2e per ha (Schultz et al., 2016). Clearing perennial woody plants in the area, especially a permanent ecosystem, releases GHG.

Table 9

GHG Emission from Agricultural Activities for Barangay Bineng

Activity	GHG Emissions (tCO_2e)	Percentage Share (%)
A. Rice Cultivation (23.36 ha)	165.81	43.10
B. Livestock	131.69	34.23
1. Enteric Fermentation	35.59	
2. Manure Management	43.35	
3. Manure Management	52.75	
C. Agricultural Soils	87.21	22.67
1. Animal Manure Fertilizer	36.71	
2. Grazing Animals	9.74	
3. Crop Residues	40.76	
Total	384.71	100.00

The conversion of grassland into an agricultural area (36.75 ha) and a settlement area (3.50ha) emitted 157.73 tCO_2e, considering only the aboveground biomass carbon content of grassland (Figure 4). Usually, the carbon stock in the aboveground herbaceous component is small and relatively insensitive to management (IPCC, 2006).

Similar to what is happening in Barangay Bineng, the conversion of woody vegetated land, including forest and brushland/shrubland, is mainly associated with cropland's expansion. Most of this aboveground biomass is burned and immediately released into the atmosphere as CO_2 (Dale et al., 1993). During the conversion process, the stored carbon in the vegetation from open forest, brushland/shrubland, and grassland were either immediate or slowly released as carbon to the atmosphere.

Net Carbon Sequestration

Quantifying Greenhouse Gas Emissions

The total GHG emissions of Barangay Bineng in its base year 2018 was 2,964.53 tCO_2e (Figure 5). The forestry and LULC sector accounted for 54.83% of the total GHG emission in Barangay Bineng, followed by electricity consumption (18.55%), agriculture (12.98%), and waste (9.52%). The two lowest emissions were observed for stationary energy (2.11%) and transportation (2.01%). The baseline inventory study shows that human activities, especially those related to agriculture, can change the land cover, which can upsurge the release of GHG. The other major sources of GHG came from the reliance on coal and natural gas that produce electricity. Among the diverse range of sources from agriculture, the main drivers of emission were rice cultivation and livestock.

On the other hand, the continuing dependence of household on LPG reduce their carbon footprint. In terms of waste, the majority of generated wastes end up in a landfill. This practice releases more methane, which consists of 97.84% of the total solid waste emission. Likewise, the wastewater treatment system in the area

Figure 4

GHG Emissions from Forest and Other LULC

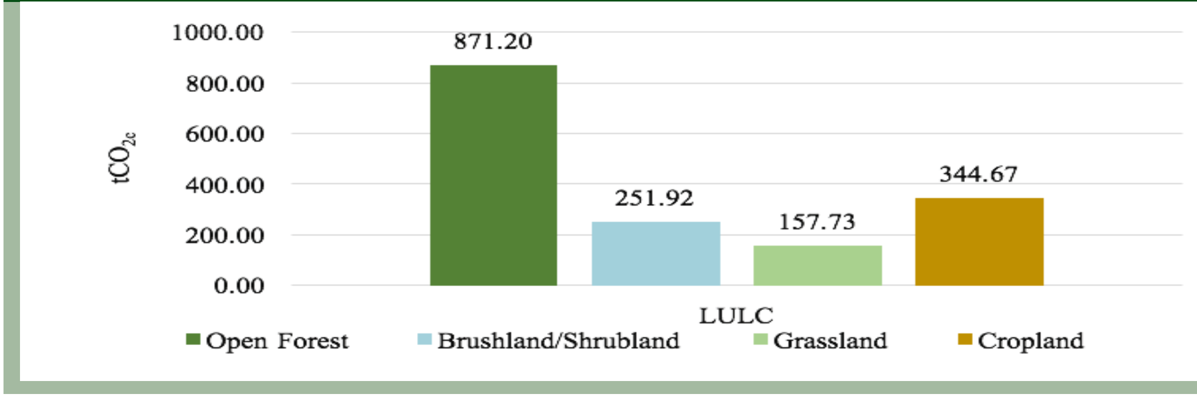
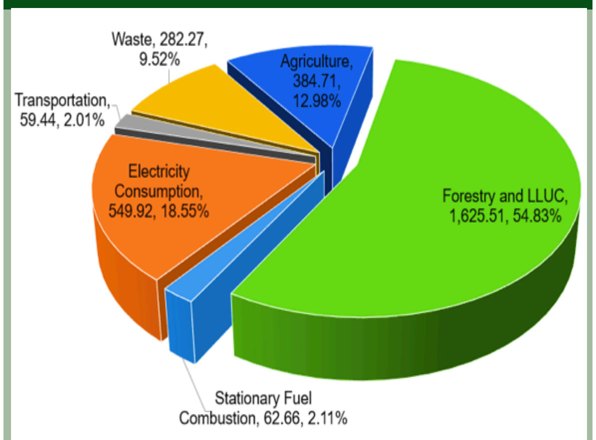


Figure 5

Distribution of GHG Emissions (tCO2e) from Different Sources in Barangay Bineng



represented by a septic system and latrines contributes higher GHG emissions than solid waste. Further, the low traffic congestion in the area caused a low level of GHG emissions from transportation.

With these results, it can be stated that activities such as LULC change are essential for carbon sequestration and mitigating climate change. Mitigation can be achieved by focusing on LULC activities that promote reforestation and LULC management through local LULC planning and forest management activities. There is no doubt that forest and brushland/shrubland have considerable potential in mitigating the changing climate (Lasco & Pulhin, 1998). The ongoing reforestation program of the government and HedCor, which is already proven effective in increasing forest area can reduce carbon emission and must be continued. However, DENR's technical support to LGU and HedCor especially on advice as to what tree species to promote that can sequester more carbon must be given, and financial support from LGU to fund community awareness and promotion of reforestation activities must be continued.

GHG Removal

Barangay Bineng is a net carbon absorber despite the forestry and LULC change as the highest GHG contributor. The carbon absorption from open forestland and brushland/shrubland biomass is 6,104.54 tCO2e (Table 10). Thus, the amount of carbon being absorbed is twice the amount emitted from land conversion activities. The potential carbon sequestration capacity of the LULCs is associated with tree planting and the increased stocking on understocked land, including open forest and brushland/shrubland. These can provide the greatest potential to increase carbon sequestration, while reforestation and agroforestry projects in the area absorbs the carbon released in the community (Perez et al., 2020). Since the area is a carbon sink, the simplest way to maintain and expand carbon stock is to avoid land conversion to an agricultural area and maintain established reforestation area (Dale et al., 1993).

Given the gross GHG emission for Barangay

Table 10

Absorption of GHG Emission by Forest and Brushland/Shrubland at Barangay Bineng

LULC	Area as of 2015(ha)	GHG Emissions Removal (tCO_2e)	Percentage Share (%)
Open Forest	252.86	2,651.64	43.44
Brushland/Shrubland	221.15	3,452.90	56.56
Total	474.01	6,104.54	100.00

Bineng in 2018 at 2,964.53 tCO_2e and the CO_2 sequestration potential of the forest of the barangay at 6,104.54 tCO_2e, the net CO_2 absorption of Barangay Bineng, which is primarily due to forestry and LULC is 3,140.02 tCO_2e. Therefore, Barangay Bineng is a carbon sink for the municipality of La Trinidad.

Conclusions

The result of reclassification of land, based on their utilization or characteristics shows an increase of built-up areas and forested land. The government and the private reforestation program had a positive effect on the increase of potential carbon sink. The valuable intervention of national and local governments, the private sector, and the community during this development period must be recognized and continued.

Quantification of the major gases based on IPCC key sectors allows identification of alternative strategies for the LGU. In this study, the conversion of other land covers into forest areas is the largest source of carbon absorber in Barangay Bineng. Sustaining and protecting the existing forest area can significantly increase the capacity to store carbon. Forest protection can be done through the collaborative efforts of the LGU, DENR, the private sector, and the community. Further, a high proportion of electricity use from non-renewable sources increased GHG emissions in the energy sector. It is noted that electricity in the Philippines is produced through the use of coal and natural gas. Considering that there are many renewable energy sources in the country, such as hydro (water), solar, and wind, investments in these types of electricity production systems are more sustainable. This should be supported, considering this is cheaper and more available than coal production. With the continuing effort to develop clean and efficient energy from renewable energy, a significant reduction of GHG emissions is possible.

This baseline study can serve as a starting point of standardization or refinement for the next GHG inventory. Besides being a baseline, it can also be used for monitoring improvement in GHG emissions due to particular interventions the LGU will undertake in the future. It can also be used to develop mitigation policies and practices, especially in the highest GHG contributing and reducing sectors, namely forestry and LULC change. Taking the initial steps to deal with this sector is essential in reducing emissions and increasing carbon sequestration.

Recommendations

Improving the forest cover as a potential carbon absorber requires the support of all concerned stakeholders and agencies, given that each has a vital role in conserving forests. The community must seize the opportunity to participate with the existing government and HedCor programs on reforestation and the improvement of existing open forests. The DENR and LGU can provide farmers with more technical interventions, particularly on tree-based farming systems, agro-industrial cropping, and marketing-related technologies.

In response to the result of the baseline GHG inventory of the barangay, the following reduction activities are recommended for GHG management of each sector:

a. Sustaining fuel for cooking and heating energy can be done by providing alternative and greener materials such as biogas and eco-charcoal that are already available in the rural area and market. The low GHG emitted by these fuels must be taken into consideration by policymakers or government agencies. Formulating policy guidelines that will encourage their use and provision of financing programs to the community to encourage them to adopt the technology can also improve public appreciation. In addition, the LGU must encourage the community to continue the use of locally available materials and waste materials such as agricultural residues and fallen branches and twigs to reduce the threat of harvesting trees for fuelwood;

b. There must be continuous government policy interventions to improve technologies and construct facilities producing electricity with low-carbon emission using renewable energy sources (e.g., solar, water, and wind). The government must prioritize this type of program, considering it is cheaper, available, and more efficient than the traditional coal-power plant. Individuals can also help reduce the emission coming from electric consumption, such as the use of solar LED bulbs;

c. Encouraging the community to choose public transport instead of private vehicles can reduce pollution and traffic congestion from transportation. Private vehicle owners can save energy and money since they will spend less on fuel and vehicle maintenance. It is also recommended that residents plan the route and trips when running errands from the community to town proper, like going to the supermarket. Doing so helps conserve time, energy, and resources and reduce hassle. There are also potential energy-saving schemes along the agri-food chain, like pulling resources in transporting goods to the market. A farmers cooperative can establish a collection center or facility within the most accessible part of the barangay.

d. Since reducing the amount of waste at home is the best place to start lowering the community's carbon footprint from waste, the LGU and DENR-Environmental Management Bureau (EMB) must develop better strategies adaptable and convenient to the population being served. One potential household activity is backyard composting or installing a simple compost pit in readily available spaces. For long-term solutions to address plastic pollution as the main source of GHG emissions from solid waste, the national government must limit the entry of plastic packaging products. Plastic must slowly and completely be replaced with biodegradable alternative materials. A household must take the ultimate responsibility of constructing septic tanks with at least two compartments for wastewater. The LGU must monitor the construction of wastewater facilities like in building permit to ensure that the standard design is implemented;

e. As part of mitigation strategies for GHG emission, farmers must be informed about the problem of emission from agriculture, its relation to climate change that affects their source of livelihood, and convince them to take part in mitigation strategies. Rice cultivation as a major source of methane can be a starting point of reducing methane through cutting or reducing flooding in rice paddies. Also, the LGU, Department of Agriculture, or DENR-EMB must monitor commercial livestock raisers and farmers group permits to ensure that rules and regulations on pollution control are carried out, especially during the operational stage. Livestock farm owners must collect animal waste and give or sell it to crop growers as fertilizers to plants or be processed into biogas.

f. The forestry and LULC as the largest GHG source can be reduced by focusing on sustainable resource management. It is in the best interest of the LGU and DENR to implement effective environmental and natural resource management. Enforcing the existing land use plan (Comprehensive Land Use Plan, Forest Land Use Plan) and natural resource policies with an allotted budget could reduce emission issues from various sources and other land use activities.

There must be information dissemination on GHG emissions to the public to increase awareness on how much emissions are generated by certain activities. Furthermore, creating public awareness may influence one's behavior towards reducing consumption or generation of waste.

Future studies may focus on the sector-specific determination of GHG emission across different municipalities; it can be more helpful in crafting GHG reduction measures and emission factors. In addition, specific and detailed data collection and methodologies can lower the risk of uncertainties.

Also, the GHG inventory process can be improved to make it more beneficial to the local government by formulating specific quantification methods to be used in helping the community establish their baseline of GHG emission at the municipal or barangay level.

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