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ESTIMATING CARBON EMISSIONS FROM HOUSEHOLD CONSUMPTION AND PRACTICES IN EASTERN VISAYAS

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This study estimates carbon emissions from households in the Eastern Visayas region of the Philippines, examining various sources, consumption, behaviors, and socio-economic factors that influence emissions. The study is guided by the Environmental Kuznets Curve (EKC) framework. Carbon emissions were estimated across three scopes: Scope 1 (stationary combustion and purchased gases), Scope 2 (electricity consumption), and Scope 3 (waste generation and commuting). Scope 1 emissions were identified as the largest contributor. Emissions were analyzed by household characteristics revealing statistically significant differences between provinces, community types, family types, education levels, employment statuses, and income groups. The regression results indicated that income and its squared term, community type, electricity consumption, fuel consumption, and commuting activities using public transportation modes are significant predictors of carbon emissions. The regression analysis confirms the presence of EKC at the household level. This is reflected by the positive sign of income and negative sign of the coefficient for income squared suggesting an inverse U-shaped relationship between income and emissions. Additionally, an assessment of potential net-zero emissions highlighted that current tree-planting efforts are insufficient to offset household emissions significantly. To effectively offset carbon emissions, each household would need to plant at least four trees every month. Lastly, respondents' awareness, practices, motivations, and perceived barriers were explored and documented. The study cites several recommendations for policy-makers to focus on to effectively reduce household-level carbon emissions.

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1. INTRODUCTION

In recent years, the growing recognition of climate change as an existential threat has prompted extensive research into the realm of greenhouse gases and their adverse consequences. As the Earth's climate undergoes significant alterations, understanding the detrimental impacts of greenhouse gas emissions has become paramount. Based on the findings of the 2022 Philippines Country Climate and Development Report, if no action is taken to address climate change, it is projected to have significant economic and human costs. By the year 2040, it is estimated that GDP could potentially decrease by as much as 13.6 percent. This adverse impact is expected to be particularly pronounced among the most disadvantaged households (World Bank 2022). In 2021, it was recorded that 18.1 percent of impoverished Filipinos had per capita incomes insufficient to cover their basic food and non-food needs. This equates to approximately 19.99 million Filipinos living below the poverty threshold (PSA 2022). It is within this context of climate change concern and the need to comprehend the adverse effects of greenhouse gases that this study is undertaken.

Carbon emissions, primarily in the form of carbon dioxide (CO2) which makes up 64% of emissions (Buenavista & Tan 2021), have emerged as the foremost driver of climate change (Abeydeera et al 2019). The ever-increasing levels of these emissions in the Earth's atmosphere have led to a rise in global temperatures, triggering a cascade of environmental challenges. The threat of climate change and global warming has brought extreme crises to the planet in many different unprecedented ways possible. As time goes by, these phenomena would eventually worsen and would create greater disaster than what is happening today, that is, if not addressed immediately. Currently, the occurrence of natural disasters has been recorded three times more frequently compared to the last 50 years (UN News 2021).

In response to the escalating climate crisis, international efforts have intensified to combat climate change, aligning with the commitments outlined in the PH NDCs for 2021. It outlines specific targets for reducing greenhouse gas emissions. Recognizing the urgency of climate action, addressing climate change is not solely an environmental concern but also integral to achieving five specific Sustainable Development Goals related to environmental sustainability, economic growth, and urban development. These include SDG 7, 11, 12, 13, and 15 (United Nations 2022).

The Intergovernmental Panel for Climate Change attested that global warming caused by human activities has increased by about 1.0°C (0.8~1.2°C) as compared to the pre-industrial level and if current trends continue, this level will possibly reach 1.5 °C between 2030 and 2052 (IPCC 2021). Households play a significant role in global greenhouse gas emissions, accounting for approximately 72% of the total (Dubois et al 2019). According to Seriño (2016), failing to address household emissions could imperil global attempts to stabilize the climate system, owing to the accrued carbon emissions stemming from domestic consumption.

Within this context, it is crucial to recognize that households, often overlooked in the discourse on climate change, are significant contributors to carbon emissions. These emissions stem from various facets of household consumption and practices, encompassing energy consumption, transportation choices, waste generation, and more. However, despite their noteworthy contribution, studies focusing on quantifying carbon emissions at the household level remain notably scarce.

In light of this research gap, this study is particularly motivated by the need to understand and estimate carbon emissions at the household level in Eastern Visayas – an ideal area for this study due to its unique characteristics. This region, comprising several islands in the Philippines, offers a compelling context for understanding household-level carbon emissions. Eastern Visayas boasts diverse environments, from coastal regions to upland communities, with a mix of urban centers and rural areas, allowing us to comprehensively examine carbon emissions in various settings. Furthermore, the region is vulnerable to climate change, facing risks like sea-level rise and extreme weather events, making it a critical area for studying emissions and devising climate-resilient strategies.

This study is pivotal in climate change mitigation efforts by estimating household carbon emissions from consumption patterns, guiding targeted interventions. By pinpointing high-emission areas, it addresses climate change's urgency globally. The research emphasizes individual and collective household responsibility - that change starts at home, and demonstrates how household involvement can have a meaningful impact on combating climate change by making informed choices, promoting sustainable behaviors to reduce carbon footprints and raising awareness of environmental consequences of carbon emission. Such efforts not only cut costs but also enhance community well-being. Aligning with national priorities like the Philippines' NDCs and SDGs, it contributes to the body of knowledge, methodologies, and insights into household carbon emissions, fostering further research and interdisciplinary collaboration against climate change. Practical implications extend to policymakers shaping sustainable policies, environmental groups leveraging insights for public awareness and advocacy. Researchers can build upon the study's findings to advance knowledge in this field.

The study aims to understand how household activities and consumption patterns contribute to carbon emissions in the Eastern Visayas region of the Philippines. It seeks to estimate household carbon emissions and identify the main sources, such as energy use, transportation, and waste. Additionally, the study explores differences in emissions across various households and assesses the potential for achieving net-zero emissions. It also seeks to understand household views on nature-based solutions. Ultimately, the study provides recommendations for policymakers to encourage sustainable practices and reduce emissions.

2. THEORETICAL AND CONCEPTUAL FRAMEWORK

This study is guided by the Environmental Kuznets Curve (EKC) hypothesis, which extends Simon Kuznets' 1955 theory. Kuznets proposed that as per capita income increases, income inequality initially rises and then decreases, forming an inverted U-shaped curve. In 1991, this concept was applied to environmental quality, suggesting that as countries develop economically, environmental degradation may initially worsen but then improve. This led to the development of the EKC, illustrating the relationship between environmental degradation and per capita income (Yandle et al., 2004).

The EKC hypothesis emerged through the research of Grossman and Krueger (1991), who argued that economic activity does not inevitably harm the environment; instead, as incomes rise, the demand for environmental improvements and the resources for investment increase. Beckerman (1992) supported this, stating that while economic growth may initially lead to environmental degradation, ultimately, wealth is necessary for environmental improvement. Grossman and Krueger (1991, 1994) provided empirical evidence that the relationship between per capita income and environmental degradation follows an inverted U-shape (as cited in Beyene & Kotosz, 2019).

Figure 1 illustrates the graphical representation of the hypothesis in the form of an inverted U-shaped curve. In this representation, environmental degradation serves as the dependent variable and can be measured through various indicators such as pollutants (including air, water, and soil pollution, or deforestation), in this study's case, we focus on carbon emissions. On the other hand, per capita income is the independent variable.

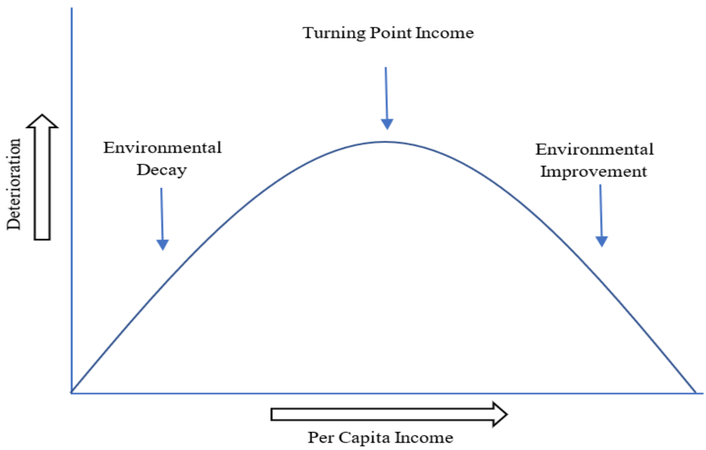

Figure 1. A typical EKC diagram (source: Yandle et al, 2004)

To test the hypothesis of EKC, the study will have to calculate income per capita and carbon emissions per capita. To do this, begin by computing the gross income of households, then, divide the total household income by the number of members in each household to obtain the per capita income. The formula for income per capita is:

$$Income\ per\ Capita = Total\ Household\ Income/Household\ Size \qquad (1)$$

Next, to estimate carbon emissions per capita within a household, divide the total carbon emissions per household by the household size. This approach allows us to estimate the average carbon emissions per person within a household. The formula for carbon emission per capita is:

$$Carbon\ Emissions\ per\ Capita = Total\ Household\ Carbon\ Emission\ /Household\ Size \quad (2)$$

Once income per capita and carbon emissions per capita within households are computed, the relationship between these two can be visualized on a graph. On the graph, income per capita is plotted on the x-axis, and carbon emissions per capita are plotted on the y-axis. Each data point on the graph represents a household. This visualization helps reveal the potential presence of the EKC hypothesis within the study's data.

3. METHODOLOGY

This study uses data from the ENHANCE Project conducted in the six provinces of Region VIII – Eastern Visayas: Biliran, Samar, Eastern Samar, Northern Samar, Leyte, and Southern Leyte.

Primary data were collected using a semi-structured survey questionnaire, which included both close-ended and open-ended questions to thoroughly capture information on carbon-emitting domestic consumption and practices. A pre-test of the survey instrument was conducted prior to data collection to ensure its validity and suitability for the study's objectives. Data were collected from March to August 2022, with successful interviews conducted with 360 households. Using proportional sampling, 302 of these responses were utilized. The remaining surveys were conducted from March to April 2024 in Leyte, Western Samar, and Northern Samar to complete the sample size of 385, as determined using Cochran's formula.

Table 1. Proportional sampling of respondents by province in Eastern Visayas.

Location	**2020 Total population by province**	**Proportional percentage**	**Calculated no of respondent**	**No of interview already conducted**	**No of interview conducted**
Biliran	179,312	4%	15	5 (excess 35)	0
Eastern Samar	477,168	11%	41	50 (excess 9)	0
Leyte	2,028,728	45%	172	110	62
Northern Samar	639,186	14%	54	50	4
Samar (Western Samar)	793,183	17%	67	50	17
Southern Leyte	429,573	9%	36	50 (excess 14)	0
Total	4,547,150	100%	385	302	83

Data analysis

The data analysis for this study will adopt a mixed-methods approach, incorporating both qualitative and quantitative methods to provide a comprehensive understanding of household-level carbon emissions using Microsoft Excel and STATA. Employing descriptive statistics, carbon emission factors and regression analysis are instrumental in serving the study's objectives to estimate carbon emissions and determine significant variables influencing carbon emission.
Carbon Emission Factors are sourced from the 2024 GHG Emission Factors Hub by the United States Environmental Protection Agency. The carbon emission factor which is always expressed as a ratio is the average emission rate of carbon dioxide associated with that particular activity or consumption (Climate Change Commission 2015). Carbon emissions from different categories of household consumption and practices can be computed using the general quantification equation, suggested by the Climate Change Commission, expressed as follows:

$$CO_2 = Activity\ or\ Consumption \times Carbon\ Emission\ Factor \quad (3)$$

In estimating carbon emissions from household practices, three distinct scopes are considered. Scope 1 includes emissions resulting from stationary combustion and purchased gases. Scope 2 covers emissions from electricity consumed. Lastly, Scope 3 accounts for emissions generated from waste and commuting activities using public transportation. Carbon emission factors (Table 2) used in the calculation of these emissions are from the 2024 GHG Emission Factors Hub by the United States Environmental Protection Agency.

Table 2. Carbon emission factors.

Variable	**Fuel type**	**Co_2 Factor**	**Unit**
	SCOPE 1		
1a. Stationary combustion	Wood and Wood Residuals	1,640	$kgCO_2$/short ton
	Liquefied Petroleum Gas (LPG)	5.68	$kgCO_2$/gallon
	Butane	6.67	$kgCO_2$/gallon
1b. Purchased gases	Kerosene	10.15	kg CO_2/gallon
	Gasoline	8.78	kg CO_2/gallon
	Diesel	10.21	kg CO_2/gallon

	SCOPE		
2. Electricity consumed	Megawatt hour	0.7122	tCO_2/MWH
	SCOPE 3		
3a. Wastes generated (Landfilled materials)	Steel Cans	0.02	tCO2/short ton
	Glass	0.02	tCO2/short ton
	Mixed Paper	0.89	tCO2/short ton
	Mixed Plastics	0.02	tCO2/short ton
	Food Waste	0.68	tCO2/short ton
3b. Commuting via Public Transportation	Passenger Car	0.1752	kgCO2/mile
	Motorcycle	0.3767	kgCO2/mile
	Bus	0.0707	kgCO2/mile

Source: US EPA, 2024 GHG emissions factors hub

Regression model

To identify significant variables, the regression equation is expressed as follows:

$$logCO_2 = \beta_0 + \beta_1 logINC + \beta_2 logINCSO + \beta_3 FT + \beta_4 CT + \beta_5 EDUC + \beta_6 CCA + \beta_7 KWH + \beta_8 FUELS + \beta_9 WG + \beta_{10} PT + \epsilon \quad (4)$$

Where the log of the total household carbon emissions is the dependent variable on the left-hand side and variables on the right-hand side such as log of Income, log of Income2, Family Type, Community Type, Education, Climate Change Awareness, Electricity Consumption, Fuels, Waste Generation, Public Transport, are the independent variables.

4. RESULTS AND DISCUSSION

Demographic profile of respondents

The data covers five provinces of Eastern Visayas, with Leyte having the highest frequency at 172 respondents, making up 44.68% of the sample. The respondents were spread across different ecological settings, with rural areas having the highest representation at 206 respondents.

Table 3. Distribution of households by province in Eastern Visayas.

Province	Frequency	Percent
Biliran	15	3.9
Eastern Samar	41	10.65

Leyte	172	44.68
Northern Samar	54	14.03
Samar	67	17.4
Southern Leyte	36	9.35
Total	385	100

Table 4. Distribution of households by community type.

Community	Location (Ecological setting)			
Type	**Coastal**	**Lowland**	**Upland**	**Total**
Rural	82	42	82	206
Urban	46	97	36	179
Total	128	139	118	385

Most respondents are female, accounting for 80.52% of the sample. The reason is twofold. Firstly, women as housewives most of the time stay at home while husbands are typically at work. This leads to a situation where women are more available to participate in the survey. Secondly and accordingly, women often have firsthand knowledge as they handle a lot of domestic activities within households so they are more likely able to answer the survey than men.

The majority of respondents fall between the ages 30 to 69, which is 74.54% of the respondents. The average age of respondents is approximately 46 years. The largest portion of respondents are married (67.27%) and are Roman Catholics (88.83%).

For educational attainment, 40.52% of respondents have reached college level or above, 37.92% have reached high school and 21.56% reached the elementary level. Meanwhile, most respondents (62.34%) are employed.

Table 5. Summary statistics of respondents' profile.

Demographic characteristics		Frequency	Percent
Sex	Female	310	80.52
	Male	75	19.48
Age Range	10-29	72	18.7
	30-49	151	39.22
	50-69	136	35.32
	70-89	26	6.75
Civil Status	Live-in	3	0.78
	Married	259	67.27
	Separated	7	1.82
	Single	89	23.12
	Widow	27	7.01

Religion	Roman Catholic	342	88.83
	Not Roman Catholic	43	11.17
Educational Attainment	Elementary Level	83	21.56
	High School Level	146	37.92
	College Level and Above	156	40.52
Employment Status	Employed	240	62.34
	Unemployed	145	37.66
Household Family Type	Extended	105	27.27
	Nuclear	280	72.73

With regards to household family type, the majority of households are nuclear (72.73%) with an average household size of around 5 members. Lastly, the average household income is about 10,382.49 pesos per month. This income level is remarkably lower by 3,414.51 pesos compared to the 13,797 pesos poverty threshold in the Philippines for a family of five to meet their monthly basic needs for food and non-food items (PSA 20231).

Table 6. Summary statistics of household size and income.

Variable	Mean	Min	Max
Household Size	5.197403	1	14
Household Income	10382.49	0	100000

Household Carbon Emissions Estimates

Scope 1a Emissions from Stationary Combustion. CO2 emissions associated with various fuel types, including LPG, Butane, Wood and Wood Residuals, and Kerosene were systematically assessed. For each fuel type, we converted the respective units to gallons and short tons and then multiplied them by their corresponding emission factors to estimate CO2 emissions in kilograms. These emissions were then converted to metric tons for clarity and comparability (Table 7). LPG stands as the prevailing energy choice for household cooking purposes. Although LPG is expensive, people purchase it for its convenience, as it saves time and effort, particularly during hours when they need to rush to school or work. LPG usage for the region yielded an estimated emission of 5.50 tCO2 a month. This is based on combusting 967.80 gallons of LPG. Similarly, liquified butane gas in a canister is a crucial backup for cooking within households when conventional utilities are unavailable, especially during emergencies. Its recent popularity stems from its compact size, lightweight nature (typically around 230 grams per canister), and high portability. The quick and easy setup makes it ideal for both indoor and outdoor activities, such as camping and picnics. On average, households in the region emit 0.13 tCO2 monthly from combusting 20.09 gallons of butane gas. Additionally, kerosene combustion emitted approximately 0.83 tCO2 from a consumption of 82.08 gallons. Meanwhile, using wood and wood charcoal for cooking, despite the inconvenience of smell and smoke it produces, remains a popular alternative due to its ready availability and affordability. However, while it serves as the secondary option for cooking when conserving LPG usage, it's noteworthy that among the four stationary combustion sources, it exhibits the highest consumption (15.94 short tons of wood) and emits the highest amount of emission at 26.15 tCO2 monthly.

Scope 1b Emissions from Purchased Gases. Among all households, 59% own a vehicle. Owning a vehicle necessitates purchasing gas for it to run. For Scope 1b emissions, the analysis continued by examining the CO2 emissions associated with the two major fuels used in household vehicles and equipment - gasoline and diesel fuels. Following the same methodology used for Scope 1a, liters of gasoline and diesel were converted to gallons, multiplied by their respective emission factors, and then converted to metric tons (Table 7). For gasoline, which is primarily used for motorcycles, combustion of 2,120.07 gallons (8,024.47 liters) emitted an estimated 18.61 tCO2. Similarly, the combustion of about 229.71 gallons (869.47 liters) of diesel fuel, commonly used for cars has emitted 2.35 tCO2.

Table 7. Scope 1 estimated emission.

	Initial Volume/Weight		**Conversion Factor**	**Final volume/ weight**		**CC_2 factor**	**$kgCO_2$**	**tCO_2**
Scope 1a. Stationary Combustion								
LPG	1,868.34	kg	0.518	967.80	gal	5.68	5,497.12	5.4971
Butane	188,600.00	g	0.0001065	20.08	gal	6.67	133.97	0.1340
Kerosene	310.66	L	0.2642	82.07	gal	10.15	833.09	0.8331
Wood	14,466.60	kg	0.001102	15.94	T	1640	26,145.19	26.1452
Total							32,612.32	32.6123
Scope 1b. Purchased Gases								
Gasoline	8,024.47	L	0.2642	2,120.06	gal	8.78	18,614.18	18.6142
Diesel	869.470	L	0.2642	229.714	gal	10.21	2,345.37	2.3454
Total	8,893.94	L	0.2642	2,349.78	gal		20,959.56	20.9596

Scope 2 Emissions from Electricity Consumption. Nine in every ten households uses electricity for lighting (PSA 20232). The calculation of Scope 2

emissions focused on estimating the CO2 emissions associated with the households' monthly electricity consumption. Using the same approach, kilowatt-hours (KWH) were converted to megawatt-hours (MWH) to ensure consistency in measurement units. Next, the National Grid Emission Factor 2015-2017 (computed by the Department of Energy) equivalent to 0.71 tCO2/MWH was applied to calculate CO2 emissions per MWH of electricity consumed. For instance, the estimated monthly electricity consumption amounted to 2,0821.33 MWH. This is associated with an emission of around 14.83 tCO2.

Table 8. Scope 2 estimated emission.

Electricity consumption	KWH	Conversion factor	MWH	CO_2	TCO_2
Consumed	20,821.3263	1000	20.8213	0.7122	14.8289

Scope 3a Emissions from Waste Generated. In the assessment of Scope 3a emissions originating from wastes, the CO2 emissions associated with various waste types, including glass, mixed paper, food, cans, and mixed plastics were analyzed. The weights of these landfilled waste materials expressed in kilograms were converted to short tons before applying the provided emission factors per short ton to estimate CO2 emissions for each waste category in metric tons (Table 9).

Notably, among the 5 waste categories, mixed plastics are mostly generated at 1.82 short tons (1,650.27 kg), emitting around 0.04 tCO2 (36.37 kgCO2). This is due to plastics providing low-cost consumer goods to poor and middle-income families (World Bank 2021). However, when it comes to CO2 emissions, plastics rank third as food waste ranks as the top category among all waste types in terms of emitting the highest amount. Food wastes, totaling 1.46 short tons (1,321.26 kg), emit 0.99 tCO2 (990 kgCO2). Followed by mixed paper, amounting to 0.96 short tons (872.70 kg), which emits approximately 0.86 tCO2 (855.92 kgCO2). Additionally, the disposal of 0.67 short tons (606.29 kg) of cans generated approximately 0.013 tCO2 (13.36 kgCO2) emissions. Similarly, the disposal of 0.037 short tons (332.41 kg) of glass waste resulted in approximately 0.007 tCO2 (or 7.33 kgCO2) emissions.

Scope 3b. Emissions from Commuting Using Public Transportation. In analyzing Scope 3b emissions stemming from commuting activities, CO2 emissions associated with different types of vehicles, including passenger cars, motorcycles, and buses are assessed. Since the type of fuel used in public vehicles is not determined and only considering the vehicle type ridden and distance traveled that the household can provide information, the distance-based method was used to determine CO2 emissions per unit of distance traveled. By applying the provided emission factors per mile, CO2 emissions for each vehicle category were estimated (Table 9).

Households in the region predominantly use motorcycles for transportation, as motorcycles are the most accessible mode of travel within the locality. Consequently, motorcycles account for the highest distance traveled among the three modes, owing to their frequent use totaling a distance of 21,688.47 miles, resulting in approximately 8.17 tCO2 emissions. Following motorcycles, commuting via bus is common, particularly for longer distances such as returning to hometowns on a weekly or monthly basis. Commuting via bus over a distance of 17,017.30 miles emitted 1.20 tCO2. Lastly, travel via passenger cars, while also used for long distances, is less favored due to its higher cost of fares compared to buses, leading to fewer households opting for this mode of transportation. Commuting via passenger cars totaling a distance of 3,955.92 miles emitted approximately 0.69 tCO2.

The estimation of Scope 3b commuting activities is underestimated because commuting via ferry boats or sea trips was not included. The author was unable to find CO2 emission factors for these modes of transport, even though the distance traveled (308.8 km or 192.1 miles) is available.

Table 9. Scope 3 estimated emission.

	Weight (kg)	**Conversion factor**	**Weight (T)**	**CO_2 factor**	**tCO_2**
3a. Waste Generated					
Glass	332.4050	0.001102	0.3663	0.02	0.0073
Paper	872.6950	0.001102	0.9617	0.89	0.8559
Food	1,321.2550	0.001102	1.4560	0.68	0.9901
Cans	606.2850	0.001102	0.6681	0.02	0.0134
Plastics	1,650.2650	0.001102	1.8186	0.02	0.0364
Total	4,782.9050	0.001102	5.2708		1.9031

	Distance (km)	**Conversion factor**	**Distance (miles)**	**CO_2 factor**	**$kgCO_2$**	**tCO_2**
3b. Commuting via public transportation modes						
Car	6,360.0000	0.622	3,955.9200	0.1752	692.8895	0.6929
Motorcycle	34,868.9200	0.622	21,688.4682	0.3767	8,171.0518	8.1711
Bus	27,359.0000	0.622	17,017.2980	0.0707	1,203.2521	1.2033
Total	68,587.9200	0.622	42,661.6862		10,067.1935	10.0672

Major Contributors of Carbon Emission

In the comparative assessment of emissions across three scopes, the highest emissions were recorded in Scope 1A, emanating from stationary combustion sources, with a total of 32.61 tCO_2, securing its position as the primary contributor. Following closely behind, Scope 1B, encompassing emissions from purchased gases, accounted for 20.96 tCO_2. Overall, Scope 1 emissions totaled 53.57 tCO_2 which represents 67% of the total monthly CO_2 emissions. According to the International Energy Agency (n.d.), the vast majority of CO_2 emissions in the energy sector come from burning fossil fuels such as coal, oil, and natural gas for power generation or to fuel vehicles and machines. In the Philippines in 2021, coal accounted for 57% of total CO_2 emissions from fuel combustion. This parallels the findings in our study, where the primary sources of emissions (Scope 1) are related to combustion processes. This comparison highlights the significant influence of stationary combustion and fuel-related activities on overall CO_2 emissions, impacting both household-level assessments and broader national contexts.

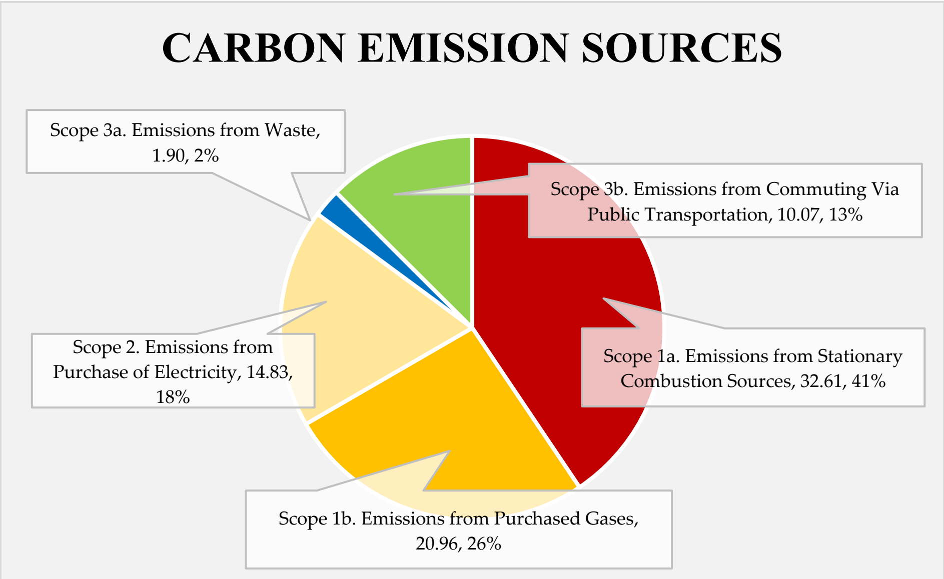

Figure 2. Carbon emission sources.

Scope 2 emissions, arising from the purchase of electricity, ranked third with a total of 14.83 tCO2/month. Fourth is Scope 3B emissions, stemming from commuting activities, which were notable at 10.07 tCO2/month. Finally, Scope 3A emissions from waste activities totaled 1.90 tCO2/month. In aggregate, these emissions across scopes sum up to 80.37 tCO2.

Variation in Carbon Emission Across Households

The total CO2 emissions across different categories reveals some interesting insights. There are significant differences in total emissions between provinces (Prob > F = 0.0165**, Table 10). Leyte stands out with the highest total emissions of 37.94 tCO2 (47% of the region's total CO2 emission), indicating potentially higher levels of domestic activity or population density contributing to carbon emissions (Table 11). The proportional sampling method used ensures that the data accurately reflects the larger population and possibly greater economic activities in Leyte compared to other provinces. This approach helps in understanding the true scale of emissions in more populous areas, providing a clear picture of regional disparities in carbon emissions. However, when considering the mean emissions per province, Biliran emerges with the highest average emissions of 0.34 tCO2, suggesting a more significant carbon footprint per household compared to other provinces.

Analyzing by community type, there is higher total emissions in rural areas, primarily attributed to the larger sample size in these communities compared to urban areas. In the dataset, rural areas consist of 206 households, whereas urban areas comprise 179 households. This difference in sample size significantly impacts the total emissions calculated for each community type. Thus, interpreting mean emissions is meaningful because it provides a standardized measure of emissions per household, allowing for a fair comparison between different community types regardless of sample size. When examining mean emissions, a different story emerges. The mean emissions are higher in urban areas (0.2154627) compared to rural areas (0.2029143). The difference between groups is statistically significant (Prob > |z| = 0.0454**, Table 11). This discrepancy highlights important behavioral and lifestyle differences between the two community types. Households in rural areas tend to minimize travel to city centers due to the higher cost and lower availability of transportation. They often opt to do grocery shopping and other errands less frequently, typically once a week, to save money, time, and effort. This reduced frequency of travel results in lower transportation-related emissions. Additionally, rural households might rely more on local food production and consumption, further reducing the need for transportation-related emissions. In contrast, urban residents benefit from more accessible and affordable public transportation options. This convenience encourages more frequent travel for shopping, education, dining, and leisure activities, leading to higher transportation emissions. The frequent use of transportation in urban areas thus contributes to the higher mean emissions observed. This comparison underscores the significant impact of transportation availability and lifestyle choices on overall carbon emissions between urban and rural areas.

The amount of CO2 emissions by household family type reveals intriguing disparities in carbon footprints. While nuclear families exhibit a higher total emission compared to extended families, extended families have a higher mean emission per household. The difference between groups is statistically significant (Prob > |z| = 0.0019***, Table 11). This suggests that while extended families collectively contribute less to the overall emissions compared to nuclear families, individual households within the extended family setup have a higher average emission. This difference could be attributed to various factors such as household size, consumption patterns, and lifestyle choices. Nuclear families may have a smaller total emission due to their smaller household size, but individual households within extended families may have higher emissions per household due to shared resources and potentially higher energy needs.

In terms of educational attainment, while there is some variation in emissions across different education levels, the differences are not as pronounced. Households with members attaining college-level and above education tend to have slightly higher mean emissions compared to those with elementary or high school-level education. This aligns with the expectation that higher education levels are often associated with higher income levels and potentially more affluent lifestyles, which can lead to increased consumption and energy usage. When categorizing education into two elementary and high schools and above, a statistically significant difference is observed (Prob > |z| = 0.0018***, Table 11).

Similarly, employed individuals tend to have higher mean emissions compared to unemployed individuals, reflecting the influence of economic activity and lifestyle choices on carbon emissions. The difference between groups is statistically significant (Prob > |z| = 0.0129**, Table 11).

Lastly, there is significant difference in carbon emissions between income groups (1 & 2) (Prob > |z| = 0.0000***, Table 11). Income Group 1 shows a higher total sum of emissions (69.04643), while Income Group 2 exhibits a higher mean emission rate (0.3329922). This suggests that although Income Group 1 emits more in total, individuals in Income Group 2 emit more per capita on average. The data aligns with the EKC hypothesis, suggesting that as incomes rise, average emissions per capita initially increase due to increased consumption before potentially declining with further economic development and environmental policy implementation.

Table 10. Test of differences: one-way ANOVA.

Variables	F	Prob > F	Is there a statistically significant difference in CO_2 emissions between group means?
Province	2.81	0.0165**	YES
Location Ecological Setting	1.20	0.3011	NO

Source: Author's Estimation using Stata 14.
*** p<0.01, ** p<0.05, * p<0.1

Table 11. Test of differences: Rank-Sum (Mann-Whitney U) test.

Variables	Z	Prob > |Z|		Is there a statistically significant difference in CO_2 emissions between groups?
Community Type	-2.0010	0.0454	**	YES
Civil Status	-1.5160	0.1296		NO
Family Type	-3.1100	0.0019	***	YES
Sex	1.6050	0.1085		NO
Education	-3.1190	0.0018	***	YES
Employment Status	-2.4860	0.0129	**	YES
Income Group	-4.4660	0.0000	***	YES
Religion	0.2460	0.8059		NO

Source: Author's Estimation using Stata 14.
*** p<0.01, ** p<0.05, * p<0.1

Existence of the Environmental Kuznets Curve

To examine the existence of EKC, let's begin by visualizing the data. First, let's analyze the data in terms of income and carbon emissions per capita. Examining distinct income groups can help validate the EKC hypothesis by revealing how environmental impacts vary at different stages of economic development. Income groups were defined based on methods from the Philippine Institute for Development Studies (2022), Consequently, three income groups were identified. Households earning below poverty threshold (PHP 13,797) are categorized as poor or low-income. Middle-income households are defined as those earning between two to twelve times the poverty threshold, i.e., between ₱27,594 and ₱165,564 per month. High-income households are those earning above PHP 165,564. Notably, no high-income households were present in the sample. The lowest-income group exhibits lower mean per capita emissions at 0.04tCO2 compared to 0.07 tCO2 for the middle-income group (Table 12). The scatterplot's fitted curve shows a pattern consistent with the initial stages of the EKC hypothesis, indicating that per capita carbon emissions tend to increase with income.

Table 12. Summary of Income Per Capita and Carbon Emission Per Capita by Income Group

Table 12. Summary of income per capita and carbon emission per capita by income group.

Income group	Frequency	Income per capita	CO_2 emissions per capita
1	351	1695.952	0.0433467
2	34	9380.673	0.0674329
3	0	-	-

However, due to the absence of households in the high-income group in our sample, the scatterplot does not capture emissions dynamics at higher income levels. Thus, based solely on the scatterplot, we cannot confidently determine whether the later phase of the EKC, where emissions decline after a certain point as income continues to grow, exists. Therefore, further data including higher income groups is necessary to conclusively confirm this pattern.

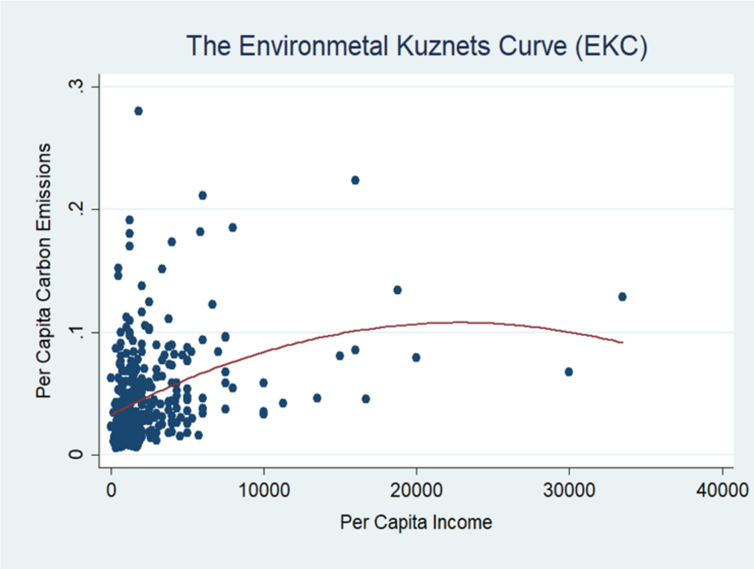

Figure 3. The environment Kuznet curve.

The visualization of EKC using aggregate data did not fully confirm the pattern, prompting further investigation. Therefore, disaggregation by community type and education level was performed to assess whether EKC trends become more evident or reliable. As can be observed in the scatterplots (Figure 6-7), both exhibit a similar pattern to the overall visualization of carbon emissions, even without disaggregation.

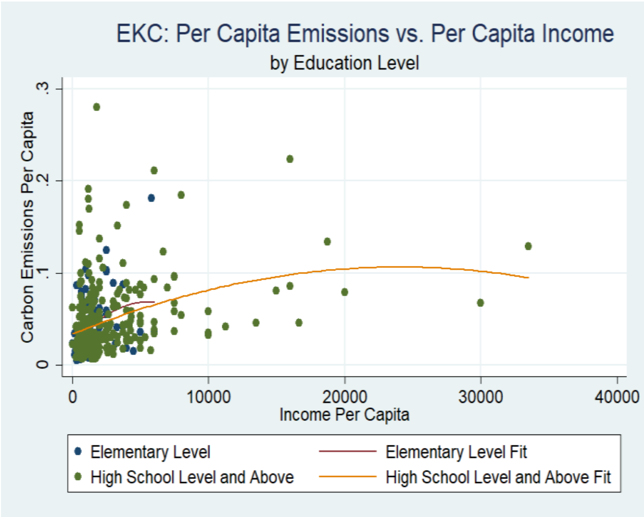

Figure 4. EKC by community type.

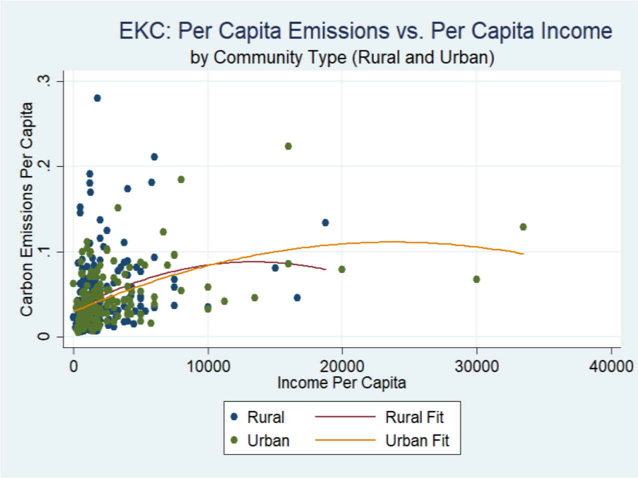

Figure 5. EKC by education level.

Regression Analysis

To further explore the EKC, regression analysis was conducted across three model iterations. Model 1 established a baseline relationship between log_INC, log_INCSQ, and the dependent variable log_CO2 without considering additional factors. However, neither log_INC nor log_INCSQ were statistically significant in Model 1, suggesting their impact on explaining variation in the dependent variable is limited without accounting for other factors. Although income variables are not significant in this model, the result still aligns with the EKC hypothesis, as there is a positive coefficient for the log_INC and a negative coefficient for the log_INCSQ.

Model 2 extended the analysis by including additional explanatory variables. Here, both log_INC and log_INCSQ became significant, indicating their effects are detectable when controlling for these additional factors. Results for Model 2 with significant positive coefficient for log_INC and negative coefficient for log_INCSQ suggest the existence of the Environmental Kuznets Curve (EKC) at the household level depicting an inverse U-shaped typed of relation with carbon emissions. This suggests that an increase in household income is associated with a reduction in emissions in the long run. Additionally, variables such as CT (urban living), KWH (electricity consumption), FUELS (fuel consumption), and PT (public transportation) were found to be statistically significant.

The same is true in Model 3 with province specific fixed effects to control for unobserved heterogeneity across 6 provinces, showing that the same variables remain significant, indicating a reliable relationship. Despite minor variations in coefficients due to the fixed effects absorbing some of the variations that would otherwise be explained by the independent variables, the significant results for log_INC and log_INCSQ persisted. This consistency across models provides robust evidence of the presence of EKC. Results suggests that as households in Region 8 become more affluent the carbon emission is expected to reduce. This implies that households are getting richer their choices are becoming more environment friendly as reflected in the reduction in emission.

Overall, the model explains a substantial portion of the variation in carbon emissions (R-squared = 0.74) and controls for province-specific factors, ensuring that the relationships are robust and not driven by unobserved heterogeneity across provinces.

Table 13. Regression models.

Dependent variable: LOG_CO_2

Independent variables	**Model 1 (Baseline)**	**Model 2 (Pooled OLS)**	**Model 3 (Fixed effects - Province)**
log_INC	0.715	0.835 ***	0.836 ***

	(0.562)		(0.319)		(0.321)	
log_INCSQ	-0.0234		-0.0425	**	-0.0423	**
	(0.0313)		(0.0178)		(0.0179)	
FT			0.0673		0.0739	
			(0.0447)		(0.0451)	
CT			0.136	***	0.138	***
			(0.0404)		(0.041)	
EDUC			0.0377		0.0296	
			(0.0518)		(0.0524)	
CCA			0.0401		0.034	
			(0.0652)		(0.0661)	
KWH			0.00472	***	0.00467	***
			(0.00044)		(0.00044)	
FUELS			0.017	***	0.0172	***
			(0.00069)		(0.00072)	
WG			-0.00043		-0.00043	
			(0.00116)		(0.00116)	
PT			0.001	***	0.00101	***
			(0.00012)		(0.00012)	
Constant	-6.278	**	-6.794	***	-6.81	***
	(2.504)		(1.433)		(1.441)	
Observations	372		372		372	
R-squared	0.143		0.744		0.744	
No. of provinces					6	

Source: Author's Estimation using Stata 14.
Note: Standard errors are in parentheses. Other values represent coefficients.
*** p<0.01, ** p<0.05, * p<0.1

Interpretation of the Key Regression Coefficients

A 1% increase in income is associated with an approximate 0.836% increase in total carbon emissions, holding other factors constant. The high significance level ($p < 0.01$) indicates a strong positive relationship between income and carbon emissions. The negative coefficient for the squared term of log income suggests a diminishing marginal effect of income on carbon emissions. Simply put,

the rate of increase in carbon emissions diminishes as income increases. This coefficient is significant at the 0.05 level ($p < 0.05$).
Living in an urban community (CT) is associated with a 0.138% increase in total carbon emissions, holding other factors constant. This variable is highly significant ($p < 0.01$), indicating a strong positive association between urban and carbon emissions.

For each additional unit of electricity consumption (KWH), total carbon emissions increase by approximately 0.467%, holding other factors constant. This relationship is highly significant ($p < 0.01$), showing a positive impact of electricity consumption on carbon emissions.
Each additional liter of fuel consumption is associated with a 1.72% increase in total carbon emissions, holding other factors constant. This variable is highly significant ($p < 0.01$), indicating a positive relationship between fuel consumption and carbon emissions.

Each additional kilometer traveled using public transportation is associated with a 0.101% increase in total carbon emissions, holding other factors constant. This relationship is highly significant ($p < 0.01$), suggesting a positive impact of public transportation usage on carbon emissions.
The constant term of -6.81 represents the baseline level of emissions when all the independent variables are minimal or zero. The coefficient is highly significant ($p < 0.01$), which means that this intercept term is statistically significant. The negative constant term does not directly indicate a decrease in emissions. Instead, it indicates a very low level of emissions when the log-transformed value is back-transformed (exponentiated). For example, e-6.81 $\approx$ 0.00109. It represents a very small positive number, indicating very low baseline emissions.

The Potential of Net Zero Emission Among Households

In the overall assessment, the calculated total emissions amount to 80.37 tCO2/month or 964.42 tCO2 annually. Normalizing these emissions by household, the average emissions per household is about 0.21 tCO2 per month or 2.51 tCO2 annually. Similarly, when normalized by capita, the average emissions per capita stood at 0.04 tCO2 per month or 0.50 tCO2 annually.

Table 14. Total annual and monthly emissions.

	Monthly estimates	Annual estimates

	kgCO₂	tCO₂	kgCO₂	tCO₂
Total CO_2	80,368.1670	80.3682	96,4418.0036	964.4180
CO_2 per HH	208.7485	0.2087	2,504.9818	2.5050
CO_2 per Capita	40.16400148	0.0417	481.9680	0.5010

According to the International Energy Agency (2023), the global CO2 emissions per capita in 2021 were 4.3 tCO2, and for the Philippines, it was 1.2 tCO2. Meanwhile, a study on community-level carbon emission quantification found that an individual emits 685.26 kgCO2 per year (GC AAB FPH 2024). These figures are higher than the estimated CO2 per capita emission in this study at 481.97 kgCO2 or 0.5 tCO2 annually which possibly reflects localized factors. Eastern Visayas, has a lower population density and is just a subset of the Philippine population. Furthermore, our estimates focus solely on household consumption and practices, excluding industrial or commercial activities that contribute to higher per capita emissions. This results in emissions that are significantly lower compared to community-level, broader national, or global averages.

To identify the potential for net zero emissions among households, an analysis of CO2 sequestration was conducted through the tree planting initiatives that the households participated in over the past 5 years. A total of 2,877 trees were planted, with each tree sequestering approximately 0.06 tCO2, resulting in the sequestration of 172.62 tCO2. Taking into consideration that not all planted trees grew or survived, based on the Department of Environment and Natural Resources report, which indicated a 78% survival rate of trees planted under the NGP from 2011 to 2016 (PIDS 2023) we can estimate the effective CO2 sequestration. Out of 2,877 trees, we assume that only 78%, or 2,244 trees grew, and sequestered CO2 at the same rate of 0.06 tCO2 per tree. Therefore, the effective CO2 sequestration was reduced to 134.64 tCO2.

Table 15. Carbon sequestration.

Sequestration activity	No. of trees planted	tCO_2 sequestered/tree	Total tCO_2 sequestered
Tree Planting	2,877	0.06	172.6200
Tree Planting	2,244	0.06	134.6436

Given these estimates, the five-year tree planting effort offset slightly more than a month's worth of the region's total carbon emissions. While tree planting could have a greater impact on carbon sequestration, the current efforts by households are not enough to offset the scale of emissions they produce. However, the estimation of carbon offsets above could be underestimated. There are several domestic activities such as participation in environmental conservation/restoration, gardening, waste reduction, etc., which were documented but unfortunately not quantified in this study. These activities also contribute to reducing the carbon footprint and could result in additional offsets not accounted for in the current estimates.

To effectively offset the region's monthly carbon emission, the 385 respondents altogether must plant at least 20,607 trees every year. This translates to each household needing to plant at least 54 trees, or at least 11 trees per person each month (Table 17). The study's estimates are lower than those from the GHG Emissions Inventory 2023-2024 of Barangay Cogon in Ormoc City conducted under the Ako Ang Bukas (AAB) Program of Green Convergence, which determined that a total of 28,126 trees are needed to offset carbon emissions from 287 households, equating to about 98 trees per household.

Table 16. Required number of trees for planting to offset carbon emissions.

Total emission (per region, household, and per capita)	**Number of trees required for planting (Effective Sequestration Rate: 78% survival rate x 6% sequestration rate = 4.68%)**	
	Monthly	**Annual**
Total CO_2	1,717	20,607
CO_2 per HH	4	54
CO_2 per Capita	1	11

Perceptions of Households on Nature-Based Solutions

The data highlights significant awareness gaps and varying levels of engagement in sustainable practices among households in the region. While 87.79% are aware of climate change, only 32.73% are familiar with Nature-Based Solutions (NBS), indicating a need for targeted education on sustainable practices. Furthermore, 80.52% recognize CO2 emissions as a contributing factor, and 63.12% of households acknowledge that their activities contribute to CO2 emissions. Transportation is perceived as the largest contributor to CO2 emissions, followed by kitchen activities and waste management.

Attitudes towards sustainable practices vary widely, with strong adherence to segregating trash and moderate engagement in activities like practicing the 3Rs and reducing single-use plastics. However, less common practices such as composting and incentivizing garbage collectors show room for improvement.

Despite low awareness, a significant 78.7% of respondents apply NBS, particularly through tree planting (53.25%) and coastal clean-up drives (43.9%). This underscores a proactive community approach towards enhancing climate resilience and reducing carbon emissions. Household experiences reveal significant insights into what motivates participation in sustainable practices. Among 385 households, a majority (58.18%) participate in sustainability activities as volunteers, while 10.91% are motivated by cash-for-work systems, and 6.75% engage through organizational activities. Additionally, 24.16% of households benefit from protection against extreme heat and typhoons, while 31.95% report gaining access to clean water, and 53.77% enjoy fresh air. Other notable benefits include clean environments (41.3%), additional income (32.47%), and fresh fruits and vegetables (57.66%). These findings indicate that both intrinsic motivations (such as volunteerism and environmental benefits) and extrinsic incentives (like financial rewards) play crucial roles in encouraging sustainable behavior.

The data reveals several perceived barriers impacting sustainable transportation and waste management behaviors, which in turn influence carbon emissions. Out of 385 households 229 own vehicles, and only 193 of these vehicle owners still use public transportation. Overall 345 households use public transport. This highlights a significant opportunity for promoting sustainable travel modes. Using public transport is a more environmentally friendly choice, as it supports shared consumption and reduces individual carbon footprints compared to the higher emissions from private vehicle use. Key barriers to using public transport include the convenience of using private vehicles, uncertain availability, multiple transfers, long waiting times, small space, and high fare costs. Enhancing public transport infrastructure, reliability, and affordability could mitigate these barriers and promote its usage.

In waste management, significant behavioral and infrastructural barriers are evident. Major obstacles include unwillingness and lack of interest to engage in proper waste disposal. Additionally, practical challenges such as lack of training, improper waste management, and unmanageable waste hinder effective waste management. Further issues include public indifference, no disposal areas, lack of awareness about health impacts, absence of recycling facilities, increasing population, ineffective government policies, lack of support from government offices, limited financial resources, and ineffective disposal facilities. Other waste issues mentioned include the irregular pick-up of garbage, leading to accumulated waste. To prevent the waste from spreading on the streets due to dogs dragging it, especially diapers, some households resort to burning or burying it. Meanwhile, biodegradable or wet wastes like food wastes, referred to as "pasaw," are often thrown into the sea. Lastly, they mentioned that the practice of other households disposing of their garbage along the street sides has become widespread. This is primarily due to the lack of streetlights, which provides a sense of anonymity and confidence to those dumping the trash, as they are not easily identified. Additionally, there are no CCTV cameras or penalties in place to deter this behavior, and even if there are, they are not strictly enforced.

5. CONCLUSION

The findings indicate that household carbon emissions are significantly influenced by both socio-economic factors and direct energy use. Socio-economic factors such as income and its squared term, community type (urban), electricity consumption, fuel consumption, and commuting activities using public transportation modes play a critical role in determining the level of carbon emissions. Understanding the influences of these variables can inform targeted policies and interventions aimed at reducing household carbon emissions. The quantified carbon emissions from household consumption and activities identified Scope 1 emissions, particularly from stationary combustion and purchased gases appear as the leading contributors to household carbon emissions totaling 53.57 tCO_2/month which account for 67% of the total household carbon emissions of the region. Followed by Scope 2 emissions from purchased electricity at 14.83 tCO_2/month. Lastly, Scope 3 emissions from waste generation and commuting amount to 11.97 tCO_2/month.

From the emission estimates, it was revealed that the per capita carbon emission level stood at 0.05 tCO_2 annually. Meanwhile, households in Eastern Visayas are living below the poverty threshold (average income of PHP 10,382.49 < PHP 13,797). Given these income and emission levels, the region faces a dual challenge of reducing poverty while managing its carbon emissions. This represents a dilemma regarding prioritization between poverty alleviation and carbon emission reduction.

“End poverty in all its forms everywhere” is the first of the United Nations Sustainable Development Goals; setting targets of eradicating extreme poverty by 2030 for all people everywhere. In parallel another United Nations process took place where 195 countries adopted the new Paris Agreement under the UNFCC aiming at keeping warming to well below 2 °C above pre-industrial levels in the long term while recognizing developing countries right to eradicate extreme poverty and develop sustainably (Hubacek et al 2017; UNFCCC 2015). Eastern Visayas, as one of the regions in the Philippines, a developing country, has the imperative to prioritize poverty alleviation. Key findings from Hubacek et al (2017) suggest that lifting people out of extreme poverty has minimal impact on global carbon emissions. The relatively small increase is understandable considering the low per capita carbon footprint of the extremely poor. Therefore, this finding indicates that the Philippines can pursue economic growth and poverty reduction sustainably without exacerbating climate change significantly. However, it underscores the need to prioritize reducing carbon footprints in our development efforts, emphasizing sustainability as a core principle.

In investigating the hypothesis of the Environmental Kuznets Curve (EKC), confirming its validity based solely on data visualization proved challenging for the author. The current data does not provide sufficient evidence to fully confirm the EKC pattern, as none of the households in the sample belong to the high-income group with incomes above PHP 165,564. The scatterplot supports the initial phase up to the middle phase, suggesting a potential turning point in the relationship between per capita income and carbon emissions. Moreover, the regression results extend this understanding by indicating that the EKC hypothesis holds. This is highlighted by the significant positive coefficient of log_INC and the negative coefficient of log_INCSQ, suggesting that beyond a certain point (income level at inflection point equals PHP 19,535.72), emissions start to decrease as income increases in the long run.

The regression analysis conducted in this study reveals several significant predictors of carbon emissions at the household level. Income and its squared term, community type (urban or rural), electricity consumption, fuel consumption, and commuting activities using public transportation modes emerged as influential factors shaping carbon emissions profiles. There is a need for behavioral interventions aimed at reducing electricity and fuel consumption among households and targeted interventions based on income levels and community types to effectively mitigate carbon emissions.

This study gains insightful findings on household perceptions and practices related to Nature-Based Solutions (NBS) and sustainable behaviors. Awareness levels regarding climate change and CO2 emissions are high among households in the study area, indicating a strong foundation for environmental education and awareness campaigns. For Nature-Based Solutions, despite the low level of awareness, a considerable number of households reported applying these methods, underscoring their perceived benefits in climate resilience and environmental sustainability. Households' motivations for engaging in sustainable practices are diverse, with intrinsic factors like environmental benefits and extrinsic incentives such as financial rewards and organizational initiatives playing crucial roles. While there is a positive attitude of households toward sustainability, barriers such as infrastructure limitations, behavioral challenges, and other socio-economic constraints hinder the broader adoption of environmentally friendly practices, such as sustainable public transport use and effective waste management.

However, despite these challenges, there exists potential for households to achieve net-zero emissions. The assessment of potential net-zero emissions highlights that current tree-planting initiatives while falling short in significantly offsetting household emissions, demonstrate initial steps toward reducing carbon footprints. To achieve meaningful carbon neutrality, each household would need to plant approximately four trees per month. This proactive step is essential in mitigating carbon footprints and advancing sustainability goals at the household level.

Based on the findings of this study, several recommendations are proposed to guide policy-makers and stakeholders in effectively reducing household carbon emissions and promoting sustainable practices:

Reduce Reliance on Wood

- Combusting wood for lighting and cooking emits the highest CO2 among all energy sources. It is recommended that households minimize their reliance on wood and transition to cleaner alternatives.

Promote Energy Efficiency

- Encourage households to conduct energy audits to identify areas where energy consumption can be reduced.
- Promote behavioral changes such as turning off lights and appliances when not in use, adjusting thermostat settings, and using energy-efficient appliances.

- Offer financial incentives or rebates for households that invest in energy-efficient appliances.
- Scale up the use of renewable energy technologies like solar and wind to reduce emissions from electricity consumption.
- Carpooling or car sharing reduces emissions by decreasing the number of vehicles on the road. This leads to lower overall fuel consumption and reduced carbon dioxide output per person, contributing to cleaner air and a smaller carbon footprint.

Invest in Infrastructure Improvements

- Expand access to reliable public transportation. Develop infrastructure for cycling and walking paths to reduce reliance on private vehicles and promote the use of electronic vehicles (EVs). EVs are a lower-carbon alternative to gasoline-powered vehicles (C2ES, n.d.). Also, the "potpot," an improvised bicycle that can accommodate up to two passengers, is popular in the region. It is suggested to use this mode of transportation when time is not a concern. According to the International Energy Agency (2021), substituting private vehicle commutes with cycling or public transportation could lead to an additional cumulative emissions reduction of 4% towards net zero.
- Enhance waste management systems, and install streetlights and CCTV cameras to deter illegal dumping. These enhancements can contribute to reducing emissions from commuting and waste generation.

Implement Awareness Campaigns

- Educate households about the environmental impact of their daily activities.
- Emphasize the environmental and economic benefits of reducing carbon emissions through reducing unnecessary travel, optimizing energy consumption, using sustainable transportation options, and practicing waste reduction, including recycling and composting.

Support Tree Planting Initiatives

- Comprehensive tree planting initiatives should be supported and monitored, ensuring proper maintenance and survival of trees to maximize their carbon offset potential.

Foster Partnerships

- Foster partnerships between government agencies, non-governmental organizations, academia, and local communities to leverage resources, expertise, and community networks.

- More organizational initiatives and incentives in encouraging households to participate in Nature-Based Solutions (NBS). By providing financial rewards, volunteer opportunities, and other forms of support, these partnerships can significantly enhance community engagement in environmental conservation and carbon reduction efforts.

Stricter Enforcement of Environmental Laws

- Implement stricter enforcement of environmental laws, impose sanctions for illegal dumping or littering, and set emission reduction targets.

Future Studies Recommendations

- For future similar studies, it is suggested that data for distance traveled via sea trips be accurately recorded and that emission factors be made available to include these trips in estimating Scope 3 emissions for commuting.
- Obtain the weight of recycled materials, as carbon emission reduction can be quantified from this activity. All these efforts are aimed at achieving more accurate emission quantification.
- Conduct further research on Environmental Kuznets Curve (EKC) dynamics, particularly gathering data from higher income groups and diverse regions to validate the hypothesis in data visualization. This would provide a deeper and clearer understanding of the relationship between economic growth and environmental impact, guiding long-term sustainable development strategies.

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