International Journal of Environmental Impacts
Vol. 7, No. 4, December, 2024, pp. 685-692
Journal homepage: http://iieta.org/journals/ijei

Identification and Mapping of Plant Types in the Household Environment to Increase Carbon Absorption in East Lombok, Indonesia

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https://doi.org/10.18280/ijei.070409

Received: 20 September 2024
Revised: 20 November 2024
Accepted: 30 November 2024
Available online: 31 December 2024

Keywords:
carbon absorption, emission, household emission, plant types

ABSTRACT

Identifying and mapping plant types in the household environment that contribute to carbon uptake is the goal of this research. The research method used exploratory descriptive by exploring and collecting information from respondents and field observation about plant types that play a role in carbon absorption and sources of carbon emissions produced in households (LPG, electricity, and transportation emissions). Primary data was collected from four sub-districts (Suralaga, Labuhan Haji, Sakra, Sukamulia) with 75 respondents per sub-district. Data was analyzed quantitatively descriptively, which describes the amount of carbon emissions produced by households, plant types, and the amount of carbon uptake by various plant types. The results show that plants with the highest carbon uptake and also mostly found at research locations are Mango (*Mangifera indica)* at 445.3, followed by Matoa (*Pometia pinnata*) at 39.76, Jackfruit (*Artocarpus heterophyllus*) at 26.51 and the rest is a combination of several types of fruit plant, such as Srikaya (*Annona squamosa*), Soursop (*Annona muricata*), Coconut (*Cocos nucifera*), Banana (*Musa acuminata*), Guava (*Syzygium*), Sapodilla (*Manilkara zapota*), Papaya (*Carica papaya*), Longan (*Dimocarpus longan),* Rambutan (*Nephelium lappaceum*), Oranges (*Citrus*), and Avocados (*Persea americana*). The results of the analysis show that these trees cannot fulfill the carbon absorption resulting from LPG emissions, electricity emissions and transportation emissions from households, even though all calculation shows that it still unbalanced, and needs more plants to be planted. These findings can be used as a basis for making policies to regulate CO_2 emissions originating from households.

1. INTRODUCTION

Global warming is an important issue that is being discussed throughout the world. Change [1] predicts that by 2100 an increase in atmospheric CO_2 will reach 700 ppm. The impacts of global warming have been felt for some time, such as disruption of ecological balance, rising sea levels, extreme weather, and natural disasters [2]. Global warming also has a negative impact on human health, causing crop failure because of long droughts, and decreasing the body's resistance to viruses and infections. Apart from that, it causes a decrease in global agricultural production due to low rainfall, seasonal fluctuations, and rising temperatures [3].

The biggest contributor to global warming is CO_2 at 25% [4]. The amount of CO_2 will continue to increase gradually in line with human activities. Burning, industrial activities, and motorized vehicles play a role in releasing CO_2, including land burning and deforestation [5]. Greenhouse gas emissions are produced by various human activities, one of which comes from households. According to Al Latifa et al. [6] the household sector contributes direct CO_2 emissions of 3.8% and indirect CO_2 emissions of 20.7%. CO_2 emissions produced by households are influenced by several things such as the number and type of electronic equipment used, electrical power, the number of family members living [7], and the use of fuel in cooking [8].

Various policies have been issued by the government to reduce CO_2 emissions, including through green economy policies. Several countries in the world reduce carbon emissions by imposing carbon taxes, formulating energy efficiency standards for electrical equipment, establishing markets for carbon dioxide [9, 10] taxing vehicles based on the CO_2 emissions produced [11]. Some efforts that can also be made to reduce emissions are by providing insight and knowledge to the community through counseling, waste management, implementing wastewater management installations (IPAL), and tree planting efforts [12].

Trees have a very important role in the carbon cycle and absorb CO_2 during photosynthesis. Plants absorb CO_2 naturally through the carbon cycle [3]. Plants will reduce carbon in the atmosphere through the process of photosynthesis and store it in their tissues [13]. According to Ariyanti et al. [14], the larger the diameter of the constituent trees and the greater the number of constituent individuals, the greater the carbon dioxide absorption process, which will provide a greater carbon storage value. Meanwhile, Suhartati et al. [15] biomass accumulation and carbon absorption depend on tree age, the older the tree, the higher the biomass. Plants can also reduce heat through the transpiration process and reduce CO_2 concentrations in the environment by absorbing CO_2 during the day [16].

The ability to absorb CO_2 by plants can show the balance of absorption capacity against the carbon dioxide (CO_2) emissions produced [17]. By knowing the level of carbon emissions in a place and the amount of carbon uptake by plants, it is hoped that this will become the basis for determining policies to mitigate carbon emissions. This research aims to describe plant types in the household environment that play a role in carbon uptake in East Lombok Regency.

2. METHODS

The research method used exploratory descriptive, by collecting information from respondents directly about plant types that play a role in carbon uptake and carbon emissions produced in households. Observed sources of household carbon emissions comprise LPG fuel use, transportation use, and electricity use. The data in this research is primary data, collected from four sub-districts (Suralaga, Labuhan Haji, Sakra and Sukamulia) with 75 respondents each. The sample size was set the same considering that all areas have the same characteristics, namely as buffer areas for the central government in East Lombok. Apart from that, the population density in the four sampling locations is also relatively same, around 2000 people per square km, and the environmental characteristics, especially land use, are almost uniform.

The basis for selecting households used as sample respondents was determined purposively, considering having a yard that could be planted with trees or other types of plants. This is known from the initial survey conducted before research activities were performed.

The questionnaire design contains two components. The first component relates to the question of sources of direct emissions produced from households as LPG fuel, and fuel oil for transport needs. The second component related to the question of indirect emission sources comes from the amount of electricity used. We used an open questionnaire type because we wanted to know the details of the emission sources of each house and the amount of emissions produced directly or indirectly. The average time needed for the interview is around one to one and a half hours for each household. The total time taken to interview all respondents was eight days.

Data was analyzed quantitatively descriptively, which describes the amount of carbon emissions produced by households, types of plants, and the amount of carbon uptake produced by various plants found by field observation. We use absorption values for plant types based on published values or derived from literature reviews in referenced literature. The amount of carbon uptake by plants at household gets from calculating it yourself based on the number of existing trees. The carbon absorption of one tree in a household is from the average calculation of the carbon absorption of household yard plant species [18].

2.1 Calculation of total carbon emissions

The carbon gas emission footprint resulting from household activities in this study uses the multiplication of activity data with emission factors. Activity data is as energy per unit time. Emissions of carbon dioxide gas originate from a combination of direct and indirect sources. Direct emissions are calculated based on energy consumption from motor vehicle fuel consumption and the use of liquid petroleum gas (LPG) as energy for providing household food. The calculation of the amount of carbon dioxide emissions from transportation and household LPG use follows the rules of the 2019 IPCC Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

$$\text{Transportation } CO_2 \text{ Emission}=\Sigma(\text{number of vehicle units fossil fuel consumption} \times \text{heating value} \times \text{fuel emission factor}) \tag{1}$$

$$\text{Liquid Petroleum Gas (LPG) } CO_2 \text{ Emission}=\Sigma(\text{number of LPG consumption} \times \text{LPG emission factor}) \tag{2}$$

The calorific value was used to convert fuel units into energy units (joules). This calorific value varies according to the type of fuel used. The heating value used in this research refers to regulations issued by the Ministry of Energy and Mineral Resources for direct and indirect emissions. The calorific value of LPG is 43.8.10-6 TJ/kg. Next, it is multiplied by the specific emission factor (63100) [19].

Calculation of secondary CO_2 emissions from electricity is done by multiplying it by the electricity network emission factor for the Lombok area, which is 1.61 tons CO_2/MW.

$$\text{Electrical } CO_2 \text{ emission}=\Sigma(\text{number of electrical consumption} \times \text{electrical emission factor}) \tag{3}$$

$$\text{Total } CO_2 \text{ emission}=\Sigma \text{ Direct Emission}+\Sigma \text{ Indirect Emission} \tag{4}$$

2.2 Calculation of carbon uptake

Calculation of carbon uptake uses a simple formula by multiplying the number of existing trees by the carbon uptake value based on tree type as seen in Table 1 [18]. Evaluation of household scale carbon uptake performed by comparing estimated carbon emissions and carbon uptake value based on the number and type of trees found at the sampling location.

Table 1. Absorption capacity by plants variety [18]

No.	Plants	Absorption Capacity (kg CO_2/year)
1	Mango (*Mangifera indica*)	445.30
2	Jackfruit (*Artocarpus heterophyllus*)	126.51
3	Srikaya (*Annona squamosa*)	77.96
4	Coconut (*Cocos nucifera*)	48.03
5	Kind of Bananas (*Musa acuminate*)	48.03
6	Guava (*Psidium guajava*)	44.55
7	Sapodilla (*Manilkara zapota*)	12.70
8	Papaya (*Carica papaya*)	36.19
9	Longan (*Dimocarpus longan*)	12.70
10	Avocado (*Persea americana*)	0.63
11	Matoa (*Pometia pinnata*)	329.76
12	Soursop (*Annona muricata*)	75.29
13	Kind of Orange (*Citrus*)	1.55
14	Rambutan (*Nephelium lappaceum*)	2.19

3. RESULT AND DISCUSSION

The research encompasses four sub-districts in the East Lombok Regency as seen in Figure 1.

This location is an area that circles the Selong sub-district, which is the location of the district capital. The four sub-districts in question are in direct proximity to the district capital, which gives them urban attributes while also being significantly impacted by the activities in the city center. Land use in the research area is dominated by agriculture, both paddy and non-rice paddy fields, as seen in Table 2.

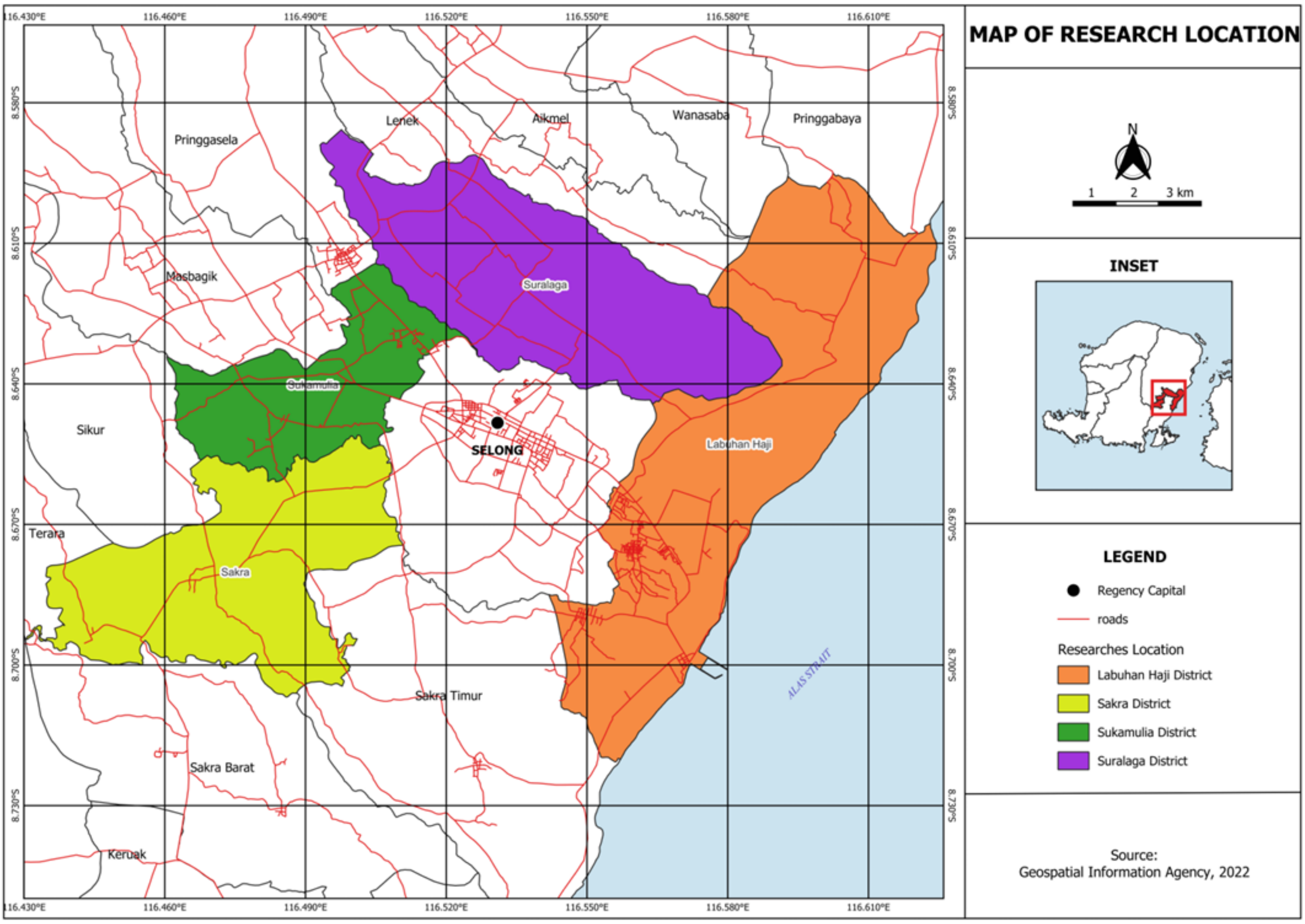

Figure 1. Research location map

Table 2 is used as comparative information regarding plant types other than those usually planted in household gardens, along with the land area. Limited land ownership and respondents' livelihoods, which are still centered on agricultural activities, have resulted in the empowerment of homesteads be one way possible land use increases internal productivity to fulfill needs for food. Therefore, planting perennial plants vegetables and herbs is common in people's yards. This has the potential to help carbon sequestration.

Table 2. Types of land use and area per sub-district in East Lombok Regency in 2020 (Hectares) [20]

Sub-District	Paddy Fields	Non-Paddy Fields	Non-Agriculture Land	Hectares
Sakra	1,584	176	748.2	2,509
Sukamulia	930.9	271	247.1	1,449
Suralaga	1,630.7	221.4	849.8	2,701.9
Labuhan Haji	1,744	1,985	1,228	4,957
Total	**5,889.6**	**2,653.4**	**3,073.1**	**11,616.9**

Based on the results, household scale carbon emission calculation data gained from primary emissions and secondary emissions then become total household emissions. Primary emissions gained from the use of LPG and the use of fossil fuels for motorized vehicles. Secondary emissions are calculated from electrical power used for household needs.

Calculations based on the 2019 IPCC method, the LPG emission factor based on the Guidelines for Implementing the Indonesian National Greenhouse Gas Inventory, 2012 is 63.1kg CO_2/tj with a calorific value of 47.3×10^{-6} tj/kg, and for the fuel type emission factor (*pertalite, pertamax, premium*) of 69.3kg CO_2/tj with a calorific value of 33×10^{-6} tj/liter. Electricity use emissions are calculated similarly, using an emission factor of 1.61kg CO_2/kWh, specific to Lombok Island and provided by the Ministry of Energy and Mineral Resources (ESDM). Calculation data for CO_2 emissions from households in four sub-districts in the East Lombok Regency can be seen in Table 3 and Figure 2.

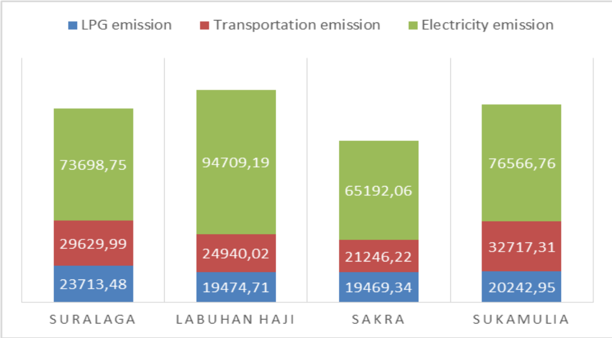

Figure 2. Distribution of household CO_2 emissions in East Lombok Regency in 2024 (kg CO_2/year)

Table 3 and Table 4 reveal that Labuhan Haji District has the largest emissions in the East Lombok Regency, followed by Sukamulia at second rank, only a slight difference with Suralaga as third and the fourth is Sakra (Figure 2). The most significant emissions are attributed to electricity, followed by transportation and LPG emissions. This is most likely caused by the lifestyle of the existing community, which is characterized by urbanism so that household electricity consumption is very high. The number of household equipment items that guarantee comfort and efficiency such as refrigerators, dispensers, air conditioners, smartphone chargers, washing machines and so on causes high electricity consumption.

Table 3. Household CO_2 emissions in East Lombok Regency in 2023 (kg CO_2/year)

Sub-District	LPG	Transportation	Electricity
Suralaga	2,371.48	29,629.99	73,698.75
Labuhan Haji	19,474.71	24,940.02	94,709.19
Sakra	19,469.34	2,1246.22	65,192.06
Sukamulia	20,242.95	32,717.31	76,566.76
Total	**82,900.48**	**108,533.54**	**310,166.76**

Table 4. Total household CO_2 Emissions in East Lombok Regency in 2024 (tons CO_2/year)

Sub-District	Total Emission (kg CO_2/year)	Total Emission (ton CO_2/year)	Percentage (%)
Suralaga	127,042.23	127.04	25
Labuhan Haji	139,123.92	139.12	28
Sakra	105,907.61	105.91	21
Sukamulia	129,527.02	129.53	26
Total		**520.60**	**100**

The high use of LPG for daily cooking processes is because of national government policy since 2007 to conduct energy conversion on a household scale. LPG itself is a vital fuel which is currently much needed by the Indonesian people, especially since it implemented of the conversion program from kerosene to 3kg LPG cylinders. That data can be seen as a challenge to reduce the amount, even if it can be done at the zero emissions stage. A simple way to achieve this target by determine how much the surrounding environment can absorb carbon produced by household activities. Ideally, a household based on the standard concept of residential suitability should be able to create a safe and comfortable atmosphere with a green environment by planting vegetation in form of tree, herbs, flowers, shrubs and others (Figure 3).

Figure 3. Examples of plant types found at research location

There are various factors that influence the ability of a type of plant to absorb carbon emissions in the surrounding environment, especially the physiology and health of the tree itself. For example, stem condition, number of branches and leaves, leaf width and so on. In this research, we use the assumption that many vegetation or trees found in the field are in healthy condition, so that in the calculations we use the maximum carbon absorption capacity of that type of vegetation based on the reference used (Table 5).

Table 5. Number and dominated plant types

Sub-District	Number of Existing Trees	Plants Type Dominated
Sakra	179	***Mango***, jackfruit, papaya, banana, coconut
Sukamulia	105	***Mango,*** jackfruit, papaya, guava, banana, coconut
Suralaga	51	***Mango***, banana, longan, avocado
Labuhan Haji	139	***Coconut***, mango, guava, banana

In order to create a green environment, awareness is needed to green the environment by planting trees and other vegetation in the environment around settlements (Figure 4). At the research location, this has also become a community habit. However, with the increase in population and population pressure on land, this will play a role in land ownership. Not everyone can have land with sufficient area as a beautiful place to live, which also has its own space for planting. Figure 5 shows the imbalance between the number of existing trees and the number of households. This can already illustrate that the carbon emissions produced could not be absorbed by current environmental conditions, even though the existing data shows that the number of trees is greater than the number of respondents, except for the Sakra sub-district (Table 6). This can happen because one household may have more tree in their yard because they have a fairly large residential area.

The most common tree types found in the research location are mango, jackfruit, papaya, banana, and coconut. This type is very easy to find in people's yards because it is quite easy to cultivate has commercial value and is a fruit that is commonly consumed. There are several types of trees that produce fruit all year round, so they are popular among people to cultivate, such as bananas and papaya. This is an opportunity to be further developed as part of a strategy to reduce carbon emissions on a household scale.

Table 6. Average absorption/house and absorption balance per sub-district in 2023 (ton CO_2/year)

Sub-District	Absorption Estimation	Total Emission	Average Absorption /House	Absorption Balance

Suralaga	16.13	127.04	0.215	Unbalance
Labuhan Haji	9.46	139.12	0.126	Unbalance
Sakra	4.60	105.91	0.061	Unbalance
Sukamu -lia	12.52	129.53	0.167	Unbalance

The highest estimate of carbon emission absorption by existing household trees from 4 sub-districts in East Lombok Regency, as seen in Table 4 and Figure 5, come from Mango trees (Mangifera indica), followed by Matoa (Pometia pinnata), Jackfruit (Artocarpus heterophyllus), and other plants. In line with results of research by Hidayati et al. [21] which shows that Angsana (Pterocarpus indicus Willd) and Mango (Mangifera indica L.) are trees that have quite high carbon uptake potential. Meanwhile, the research results of Hidayati et al. [21] showed that the highest CO_2 absorption was found in the Matoa (Pometia pinnata) at 16.45µmol/m^2/s.

The CO_2 uptake rate is influenced by the intensity of sunlight, stomatal conductivity, and chlorophyll content in the leaves [22]. CO_2 absorption is also influenced by the magnesium content in chlorophyll, total leaf area, leafage, and plant growth phase [23]. According to Yang et al. [24], the rate of photosynthesis is influenced by the number of leaves and leaf area, which correlates with CO_2 absorption. Apart from being able to absorb CO_2 from the atmosphere and storing it as biomass, trees can also reduce air pollutants directly by absorbing gas pollutants such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3) through leaf stomata from the air, and reducing indirectly by avoiding air pollutant emissions [25]. CO_2 will be absorbed by plants to be used in the photosynthesis process, affecting plant growth, increasing flowering and pod formation [26]. Several types of plants, such as legumes, can store carbon in their roots so they can be optimally used [27].

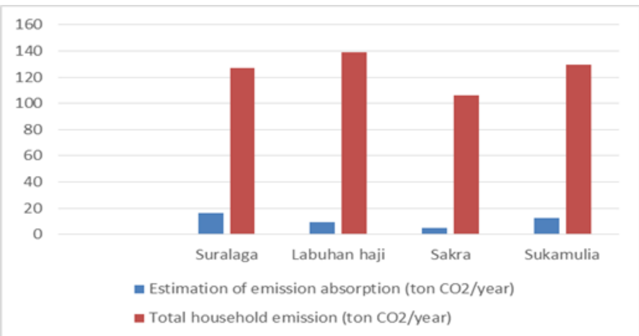

Figure 4. Comparison of total household CO_2 emissions with the estimated carbon absorption capacity of existing trees

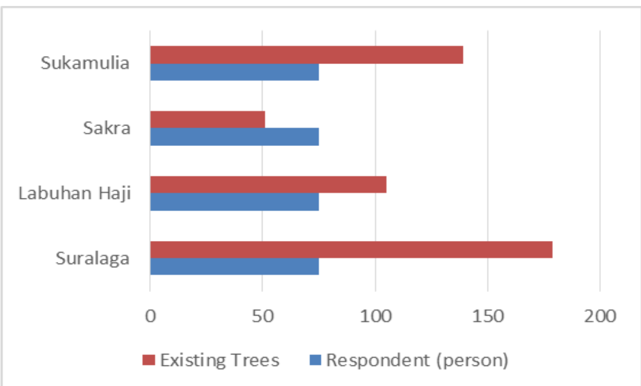

Figure 5. Number of households versus tree ownership

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Types of trees that are suitable for carbon mitigation objectives are types that have criteria to grow faster, so they can compete with nuisance plants in the field, have high adaptability, have pioneering qualities that provide opportunities for high success, and most importantly is that it has a high carbon absorption capacity. To effectively choose tree species for greenhouse gas mitigation, it is imperative to comprehend the ecological properties and physiological traits that differ among species [28]. There are similarities in the results with previous studies, especially with Fadhilah et al.'s research [18], but from the latest literature study, information was found that the most effective type of tree for absorbing carbon is the pine type because of its fast growth and large size and even though the tree has long been used for absorption. Carbon, native grasses, and herbaceous plants are increasingly popular for this purpose. Grasses such as Switchgrass and Miscanthus have complex root systems that are ideal for storing carbon in the soil.

Based on the data in Table 4, it is known that the total absorption of carbon emissions by existing household trees compared to the amount of emissions produced in four sub-districts in East Lombok Regency is not balanced, meaning that the amount of emissions produced is greater than the amount of carbon absorption. Referring to these findings, several efforts need to be made to overcome them, including through adaptation and mitigation [29]. There are simple things we can do to reduce carbon emissions around us, such as saving electricity, processing household waste into compost, not burning leafy waste, and using our yard by planting vegetables and ornamental plants.

Careful consideration must be given to the choice of plant species in urban settlements in order to maximize their ability to absorb carbon dioxide (CO_2) [30]. Trees, in contrast to shrubs and ground covers, exhibit a greater biomass, affording them the capacity to absorb the greatest levels of CO_2 [31]. Considering the limitation of yards in certain households for tree planting, one viable alternative involves the use of potting media as a planting substrate. Of course, types of plants that can be planted are also limited in their ability to absorb carbon.

If you cannot plant in the yard because of limited land ownership, then the action you can take is to use indoor plants, according to research by Shishegaran et al. [32] which shows level of lighting dominates the ability to absorb CO_2. Several ornamental plants are effective at absorbing CO_2, such as Aloe vera, Snake Plants (*Sansieveria*), and ornamental plants. According to the Dubois et al. [33], Aloe vera has the best ability to absorb CO_2 compared to other plants tested.

The establishment of green open spaces is considered a viable solution to mitigate global warming. Green open space encompasses areas that are extended or grouped together, providing a more open environment and serving as a suitable location for the growth of both naturally occurring and intentionally planted vegetation. There is a suspicion that green open space can contribute to the mitigation of carbon dioxide. Green open spaces hold a significant function in enhancing the quality of life in urban areas, primarily as an effective air purifier.

Most of the studies about activities to reduce greenhouse gases for mitigation from the source of the industrial scale. It has not yet led to a reduction in household scale emissions comprehensively, try to compare it with estimation of existing trees at the house of respondent found. Things that can be done to reduce emissions on a household scale [34] are by planting trees or making vertical gardens or rooftop gardens [17]. Of course, use plant species that have high emission absorption capacity. Local governments can also require every resident to have at least one tall and shady tree.

Things that support the potential of the yard are tropical rainforest climate conditions and the high biodiversity in Indonesia, which should be able to support the yard's productivity. Yard has great potential as a support in meeting the needs of daily life because it has a production function. Production results from yard can be sold to increase income, especially those whose low economy. The social function of the yard is to provide a comfortable feeling for the living environment, a place for children to play, and also to relieve fatigue and relax in their free time. Yards planted with shade wood plants to fulfill this function or fruit trees, because apart from taking the fruit for personal consumption, it can also be sold. Likewise, if the yard is planted with vegetables. Types of vegetables that are most effective in helping reduce carbon emissions have not yet been studied further.

The initial findings from this research have been presented at a focus group discussion forum which was attended by academics, NGOs, Regional Planning and Development Agency, Environmental Service, and community leaders. There are several important points that must be underlined in order to make efforts to use home yard land a success to start steps to reduce carbon emissions on a household scale. The suggestions given are as a village/district scale pilot project. The ideal management concept is in the community, by increasing community capacity through an empowerment approach, especially for vulnerable groups (housewives and underprivileged families).

Regional regulations (PERDA) are considered very important, but it is recommended to start from "regent's regulations" as a first step by prioritizing pilot projects, perhaps at the village/district level to strengthen the discourse on preparing local policies related to this issue because of the long procedures preparing PERDA up to realize as a ratified PERDA.

4. CONCLUSIONS

Based on the results of the research and discussion, it can be concluded that the existing household trees that have been identified in four sub-districts in the East Lombok Regency cannot fulfill the carbon absorption resulting from LPG emissions, electricity emissions and transportation emissions. This could be because of the lack of trees and tree species that play a role in carbon absorption in each house.

To further increase the carbon absorption capacity of plant types that are commonly found in people's yards, more detailed information must be sought regarding the most effective plant types and, if possible, those that have a higher economic value than the current plant types. Of course, it still requires an evaluation of the suitability of the land if the recommended plant type is not a type that is familiar to the public. Here, the role of agricultural/plantation instructors and others becomes quite important as one party can contribute if assessed from the socio-economic aspect of the community.

ACKNOWLEDGMENT

This work is supported by Indonesian Ministry of Education, Culture, Research and Technology for The National Competitive Research Grant Funding for Applied Research in 2024 (Grant Number: 110/E5/PG.02.00.PL/2024 Date 11 June 2024), and also the community of East Lombok Regency who contributed as respondents in this research.

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