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Carbon Footprint Analysis of Residental Activities in the Kuta Alam Banda Aceh

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Abstract

Global warming is a phenomenon caused by the greenhouse effect. Increasing global temperature will lead to climate change, which human activities influence. Settlement as an area with various activities is one of the sources of greenhouse gases. Banda Aceh City, the capital of Aceh Province, has a population of 268,148 people. The large number of residents who engage in various activities in their daily lives will undoubtedly affect the carbon emissions produced. A study was conducted to calculate the carbon footprint generated in the Kuta Alam Sub-district Banda Aceh as the study area. Kuta Alam sub-district has a population of 53,679 from 11 villages. This study calculated carbon footprints in the cooking fuel, electricity, and transportation sectors. The results show that the CO_2 emission in the cooking fuel sector is Beurawe village, which produces emissions of 59.358 TonCO_2 / month; in the electricity sector is Bandar Baru village, which produces emissions of 628.753 TonCO_2 / month, in the transportation sector is Bandar Baru village which produces emissions of 444.795 TonCO_2 / month. The largest total emitter is Bandar Baru village, 1073.548 TonCO_2 / month, while the lowest emitter is Kota Baru village, which produces emissions of 307.825 TonCO_2 / month.

Keywords: Carbon Footprint, Settlement, CO_2

1. Introduction

Global warming is a phenomenon resulting from the amount of greenhouse gases that increase global temperatures each year. Caused by greenhouse gases, global warming has increased in recent decades and has become a concern of the world community in various parts of the world as global warming. Carbon dioxide (CO_2) emissions released into the ambient air are the most significant contributor to greenhouse gas emissions. Greenhouse gas emissions can be generated from various activities of natural origin (one of which is caused by erupting volcanoes) and human activities. According to the Intergovernmental Panel on Climate Change (IPCC) report, human activities accelerate the concentration of greenhouse gases in the atmosphere (Yulianto P. Prihatmaji, 2016).

Some economic activities provided by humans will cause climate change. In Indonesia, climate change mainly comes from several industries, such as the agricultural industry, which in the process will produce Dinitro Oxide (N_2O) exhaust gas; the livestock industry will produce Methane (CH_4) exhaust gas, and the transportation sector will produce Carbon Monoxide (CO) gas. Other natural elements can also cause climate change due to exhaust gases, such as forest fires and factories for smoke. Climate change is caused by the impacts arising from activities carried out by humans, both directly and indirectly. The various activities carried out by humans mostly come from settlement activities (Rachmawati, 2015).

Banda Aceh City, the capital of Aceh Province, has a population that engages in various activities. The city has nine sub-districts with a population of 270,321 people (BPS, 2020). The Kuta Alam Sub-district is the sub-district with the largest population It has about 53,671 people, and the large number of residents who engage in various activities in it will undoubtedly affect the CO_2 emissions. To control greenhouse gas emissions for the long term, it is necessary first to track the average amount of emissions released at this time. In Kuta Alam sub-district, there needs to be more information on the amount of emissions released into the air. A study was conducted to identify the carbon footprint generated from residential activities in the area.

One of the problems that occurs every year is the problem of air pollution. Air pollution is also caused by the development of technology and science and frequent forest fires (Jainal Abidin, 2019). A situation where there is a physical, biological, or chemical substance in the atmospheric layer is called air pollution, which, if the amount is excessive, can cause harm to the health of the body of living things on Earth. The classification of air pollution is divided into primary pollution and secondary pollution. Polluting substances that directly arise from air pollution sources are primary pollutants, such as carbon dioxide (CO_2) produced from the combustion process. Secondary pollution is a substance formed in the atmosphere due to the reaction of primary pollutants, such as ozone formation.

Greenhouse gases are gases in the atmosphere, either natural or anthropogenic, that absorb and emit infrared radiation. The Earth's surface will receive some radiation from the sun through short waves. It will be re-emitted by the atmosphere in the form of infrared radiation in the atmosphere, which will then be absorbed by GHGs, which will cause the heat effect or greenhouse effect (Yuliana, 2017). Greenhouse gases impact the environment and health. One impact is an increase in the Earth's temperature, which can cause droughts and decrease crop yields, leading to food supply shortages (Harvard School of Public Health, 2011). Rising temperatures can also cause glaciers to melt and sea levels to rise. It has been predicted that the Earth's average sea level will rise by 0.09 to 0.88 meters from 1990 to 2010, affecting ecosystems within the ocean (MenLHK).

Global warming is an increase in the average temperature of the atmosphere, the Earth's surface, and the sea. This drastic increase in temperature is caused by burning fossil fuels such as petroleum (which has been processed into gasoline, kerosene, avtur, and others), coal, and other natural gases that cannot be renewed (Rusbiantoro, 2008). According to the Intergovernmental Panel on Climate Change (IPCC), the global average temperature has increased significantly since the middle of the 20th century. This increase is most likely due to an increase in the concentration of greenhouse gases caused by various human activities. Some of the impacts of global warming are melting ice in the north and south, Increased extreme weather intensity, various endangered flora and fauna, and increased sea water levels.

fluctuating air pressure, fluctuating temperatures, wind direction, and speed can cause ocean currents to change. The city of Banda Aceh has an area where 70% of the area is at an altitude of 10 meters above sea level and is a flood-prone plain from the overflow of the Krueng Aceh River. The terrain narrows and undulates upstream with elevations up to 50 m above sea level. Steep hills flank the west and east at more than 500 m in height, making it similar to a cone with its mouth facing the sea. The coastal area of Banda Aceh City is broadly divided into plains from part of the Kuta Raja sub-district to the Kuta Alam sub-district and part of the Meuraxa Sub-district in the western coastal area. Based on the study by a team from Syiah Kuala University (TDMRC) from 2016 to 2019 show that every year, the sea level around the Malacca Strait and the Andaman Sea has increased by 7 mm. If this continues, it will directly impact communities in coastal areas, such as flooding, erosion, and tsunamis (TDMRC, 2019).

Settlement is part of an environment outside the protected area, including rural and urban areas that act as a living environment or place to live and become an area for various activities. While housing is a group of houses that are part of urban and rural settlements, it will be equipped with infrastructure, facilities, and public utilities to support the house and make its condition livable. Settlement can be implemented as a human settlement that shows a particular purpose (Lilik et al., 2017). According to the Ministry of the Republic of Indonesia, 1992 (Akmalia, 2021), the government divided housing criteria into superficial, medium, and luxury houses. Due to the environmental aspects, the government seeks to regulate each housing and settlement area by developing five main principles of the concept of environmentally sound housing and settlement: maintain and enrich the existing ecosystem, efficient in using existing energy, waste, and pollution control, maintaining the continuity of local socio-cultural systems, and improve understanding of environmental concepts.

Carbon is an element with many compounds and isotopes. Almost everything on earth contains carbon, so the waste produced due to the cycle of objects made from raw materials does not escape the long-term carbon cycle. Any energy wasted in each cycle will release emissions (Sewiko, 2016). Carbon footprint is the total calculation of greenhouse gases (GHGs), including Carbon dioxide (CO_2), nitrous oxide gas (N_2O), methane gas (CH_4), Hydrofluorocarbons (HFCs), Sulphur Hexafluoride (SF_6), and Perfluorocarbons (PFCs) originated from daily human activities. Carbon footprints are used to measure GHG emissions that contribute to global warming. Carbon footprint includes activities from individuals, groups, companies, governments, and the industrial sector (IPB, 2019). Carbon footprint is a method to estimate the amount of greenhouse gas emissions in the carbon equation from the cross-cycling of the production process of basic materials used in industry disposal in the final product (Carbon Trust, 2007). The direct combustion of fossil fuels, such as transportation, causes the primary carbon footprint. The carbon footprint of motor vehicles can be calculated from the type of fuel used and the amount of greenhouse gas emissions or Global Warming Potential (GWP). Besides motorized vehicles, LPG is also included in the primary carbon footprint potential. The primary carbon footprint is calculated by converting emissions data into carbon dioxide equivalent (CO_2e) (Ministry of Environment and Forestry, 2017).

Emission factors and calorific values are needed to calculate the emissions produced in each activity and determine the value of each emission released. The emission factor is a coefficient that shows the amount of emissions per unit of activity. The activity data used in the calculation is adjusted to the GHG emission source category (Mineral, 2017). The emission factor values and Volumecalorific Value of each fuel type refer to the provisions set by the IPCC (2006), as shown in Table 1 and Table 2.

Table 1. Emission Factors and Calorific Value of Combustion of Motor Vehicles

Oil fuel	Emission factor (Kg/Tj)	Calorific Value (Tj/L)
Gasoline (Premium, Pertamax, Pertalite)	69300	33×10^{-6}
Solar	74100	36×10^{-6}

Source: IPCC 2006

Table 2. Emission Factors and Calorific Value of Combustion of LPG

Cooking fuel	Emission Factor (Kg/Tj)	Calorific value (Tj/Kg)
LPG	63100	0,0000473
kerosene	71900	0,0000438

Source: IPCC 2006

The secondary carbon footprint is an indirect CO_2 emission and is the carbon footprint of the product cycle process. Secondary carbon footprints are generated from household electronic equipment, which can function using electricity (Astari, 2012). One example of a secondary carbon footprint is the use of electricity. Electricity use consumption can be calculated using information on the number of kWh of electricity used within one year, depending on the power plant used. The secondary carbon footprint calculation method is similar to the primary carbon footprint calculation by converting emission data into CO_2e (Ministry of Environment and Forestry, 2017).

Table 3. Emission Factors of Electricity Consumption

	Emission factor (Ton CO_2/MWh)
consumption	0,93

The IPCC is a scientific panel consisting of climate change scientists worldwide. It was established by two UN organizations, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), in 1988. The IPCC evaluates the risk of climate change due to human activities, which will be considered in making decisions at the UNFCCC session (MenLHK).

2. Materials and Methods

This research uses the quantitative descriptive approach. The methods describe, explain, and summarize various variables based on events that can be photographed, interviewed, observed, and explained through documentation. The population in this study is the total number of households in Kuta Alam Subdistrict. Data was collected from the population as a sample. Determination of the number of samples using Stratified Random Sampling or stratified random samples to determine the number of samples in each village; hence not all populations will be tested, but a certain number will be determined using the Slovin method

$$n = \frac{N}{1+N\alpha^2} \quad (1)$$

Where :
n = number of samples for each village
N = total population
α = degree of error used

Equation (1) using an error degree of 10%, the number of samples in the study area is obtained:

$$n = \frac{12561}{1+12561(10\%)^2} = 99{,}2 \quad (2)$$

The number of samples to be studied in this study is 99.2 households, rounded up to 100 households. The following is the number of samples taken per village.

$$\text{Sample per village} = \frac{family\ number\ pervillage}{total\ family\ number}\ x\ total\ sampel \quad (3)$$

$$\text{Sampel village} = \frac{839}{12561}\ x\ 100 = \frac{86.500}{12561} = 6{,}88 \gg 7$$

Table 4. Number of samples in each village

No.	village	House number	Sample total
1.	Peunayong	839	7
2.	Laksana	1370	11
3.	Keuramat	1330	11
4.	Kuta Alam	1021	8
5.	Beurawe	1300	10
6.	Kota Baru	340	3
7.	Bandar Baru	1556	12
8.	Mulia	1291	10
9.	Lampulo	1294	10
10.	Lamdingin	840	7
11.	Lambaro Skep	1380	11
	Total	12561	100

After all data is obtained, primary data processing will be carried out. Primary data includes the amount of cooking fuel used and the amount of fuel used, and secondary data includes the amount of electricity used. Data processing is carried out to determine the total emissions generated by residential activities in Kuta Alam Subdistrict. The calculation for each emission uses CO_2 emissions based on cooking fuel consumption

3. Results and Discussion

Respondents to this research were taken from eleven villages in Kuta Alam sub-district, Banda Aceh City. These consisted of Laksana, Beurawe, Keuramat, Lamdingin, Lampulo, Lambaro Skep, Kota Baru, Mulia, Bandar Baru, Peunayong and Kuta Alam. The number of respondents surveyed by calculating the Slovin formula was 100. Cooking fuel is obtained from using LPG gas and kerosene on average per month. The average use will be calculated yearly to determine the CO_2 emissions produced. The following are the results of calculating Carbon Emissions from the Cooking Fuel Sector. Figure 2. Perform data on the transportation sector. Fuel use in motor vehicles and cars is obtained in this sector.

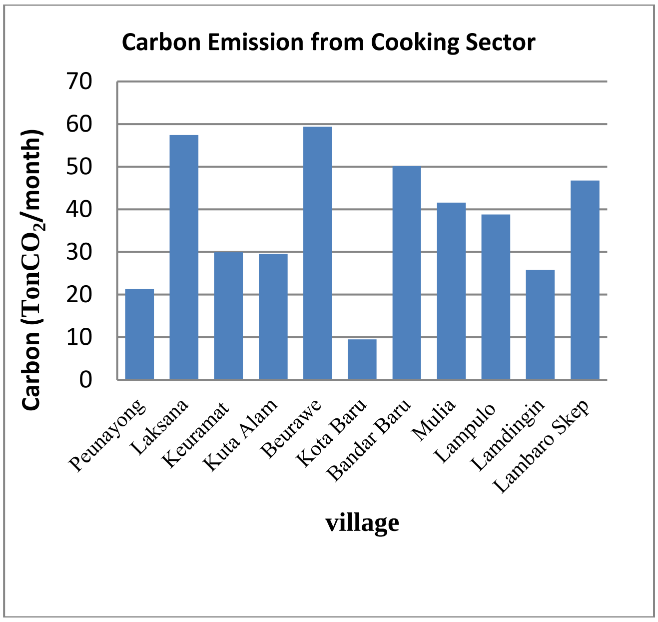

Figure 1. Carbon Emission from the Cooking Sector

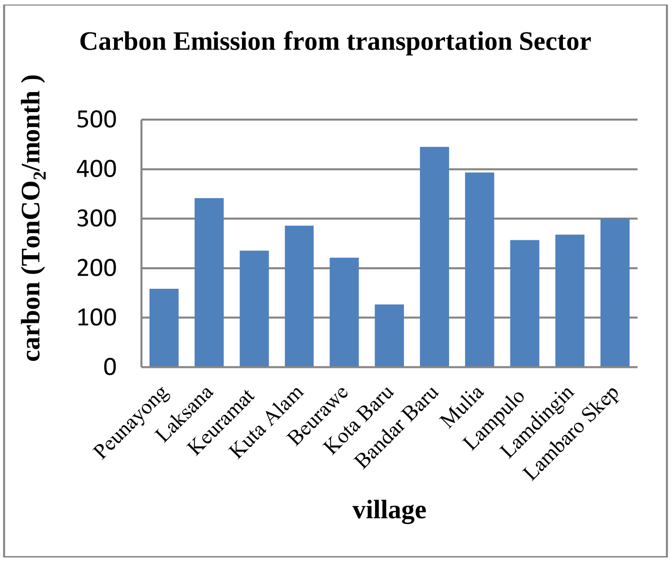

Figure 2. Carbon Emission from the Transportation Sector

The last data obtained is data on the electricity use of each household per month. This data is obtained using 450 VA, 900 VA, 1300 VA, 2200 VA, and 35000 VA.

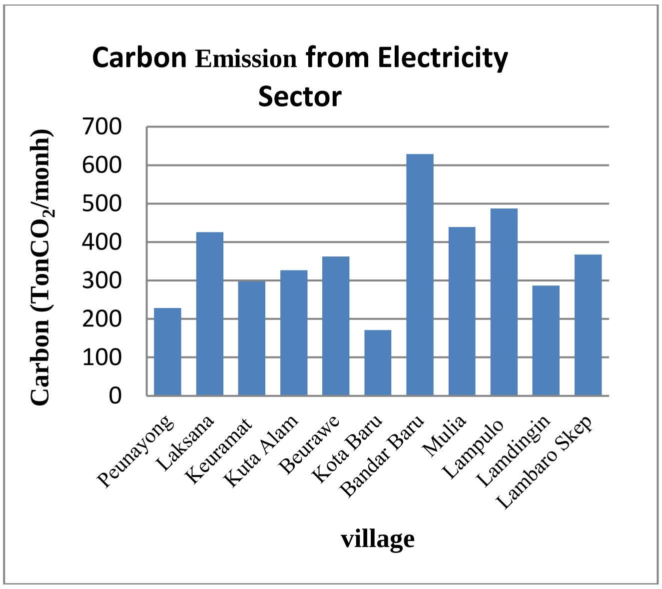

Figure 3. Carbon Emission from the Electricity Sector

After obtaining the results of the amount of emissions from each sector in each village, the next step is to map the distribution of emissions. In this study, the number of classes used for coloring is grouped into three classes, each representing the range of emission values obtained. Hence, the range for emission values was calculated using the following formula (Akmalia, 2021).

Range = (highest value-lowest value)/n (4)

Where,
Highest value = highest emission value
Lowest value = lowest emission value
N = number of class colors used

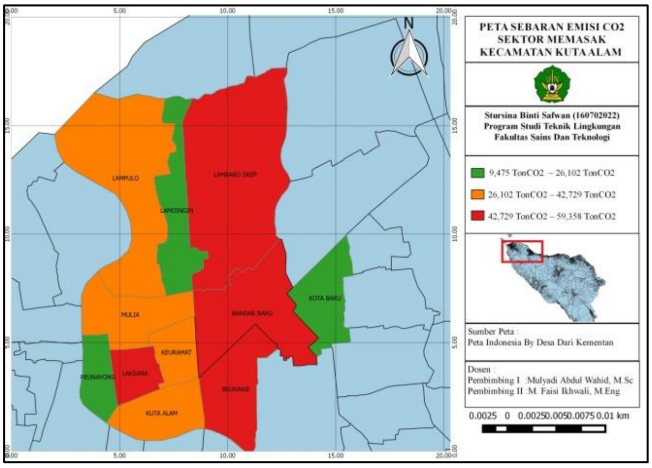

Figure 4. The CO_2 emission mapping per month of the cooking fuel sector

The CO_2 emission mapping per month is divided into three categories. Figure. 4 shows cooking fuel sector emissions where the green-colored urban villages produce emission values ranging from 9,475 $TonCO_2$ to 26,102 $TonCO_2$. Orange-colored villages produce emission values of 26,102 $TonCO_2$ - 42,729 TonCO2; red-colored villages produce the highest cooking sector emission values with a range of 42,729 $TonCO_2$ - 59,358 $TonCO_2$. The village with the highest emission value produced is Beurawe Village. This emission is due to the community's use of cooking fuel, which is increasing compared to other villages in the sub-district. The village with the lowest CO_2 emission value is Kota Baru. Kota Baru is the district with the lowest number of households in the sub-district, so the use of cooking fuel is lower than in other villages.

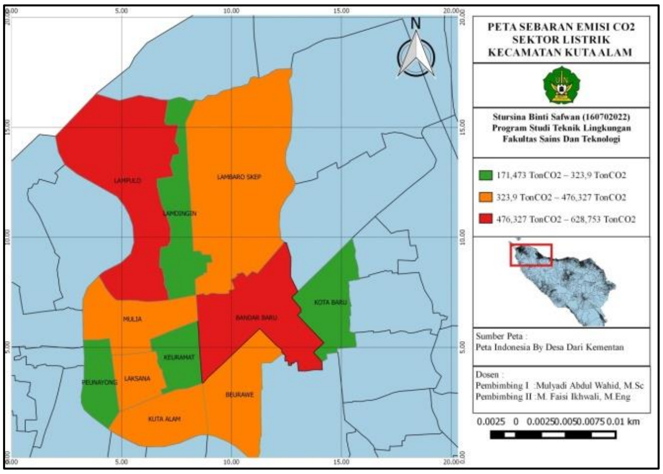

Figure 5. The CO_2emission mapping per month of the electricity sector

Figure. 5 shows that urban villages whose color is green produce emission values with a range of 171.473 $TonCO_2$ - 323.9 $TonCO_2$. Orange-colored urban villages produce emission values with a range of 323.9 $TonCO_2$- 476.327 $TonCO_2$, and red-colored urban villages produce the highest emission value of the electricity use sector with a range of 476.327 $TonCO_2$- 628.753 $TonCO_2$. The urban village that produces the highest CO_2 emission value in the electricity use sector is the Bandar Baru urban village. The emission is high because Bandar Baru urban village has the most significant number of households in the Kuta Alam Subdistrict, so electricity and the resulting emissions are higher than in other urban villages. Meanwhile, the urban village with the lowest CO_2 emission value is the Kota Baru urban village, which produces CO_2 emissions of 171.473 $TonCO_2$. This emission is partly due to the small number of households, so electricity use and emissions are lower.

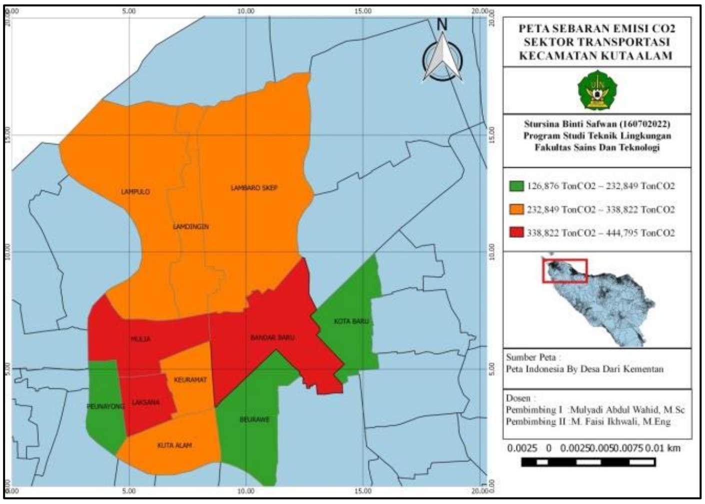

Figure 6. The CO_2 emission mapping per month of the transportation sector

The Mapping of the distribution of CO_2 emissions/month in the transportation sector is shown in Figure. 6, it is known that the area produces emissions ranging from 126,876 $TonCO_2$ to 232,849 $TonCO_2$ in green villages. The orange-colored urban village produces emission values with a range of 232,849 $TonCO_2$ - 338,822 $TonCO_2$, and the red-colored urban village produces the highest municipal sector emission value with a range of 338,822 $TonCO_2$ - 444,795 $TonCO_2$. In the transportation use sector, the village that produces the highest CO_2 emissions is Bandar Baru village. Several things might cause this village to be the largest emitter of transportation emissions.

In addition to having many households, the community as respondents in this study also has more vehicles, motorcycles, and cars than other villages. Therefore, Bandar Baru urban village produces a higher carbon emission value. The lowest carbon emission in the transportation sector is in Kota Baru urban village, which produces carbon emissions of 126.876 TonCO_2.

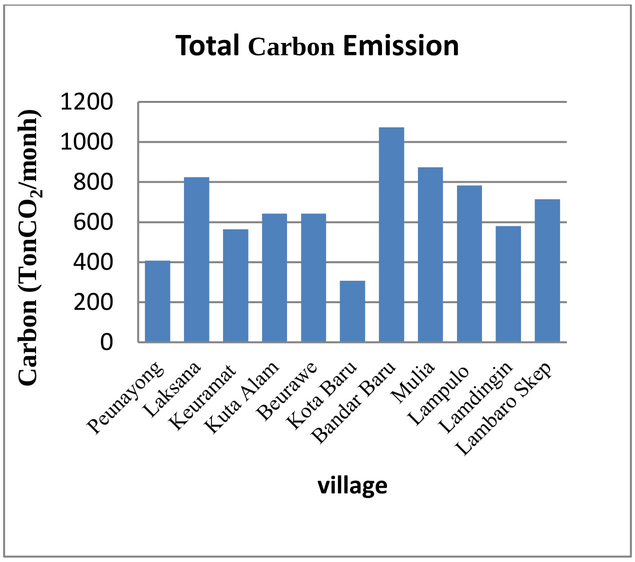

Figure 7. The CO_2emission mapping per month of the cooking fuel sector

The Mapping of total carbon emissions in the Kuta Alam Subdistrict is a mapping that results from calculations in the cooking fuel, electricity, and transportation sectors, which are totaled based on urban villages. In the Mapping of total carbon emissions to determine the value, grouping is also carried out based on the range of each village in Kuta Alam Subdistrict, which is marked with green for villages that produce low carbon emissions, orange for villages that produce medium emissions and finally for villages that produce high carbon emissions colored in red. Based on the calculations to determine groups based on color, Figure 8 presents a mapping of total carbon emissions from household activities in Kuta Alam Subdistrict, Banda Aceh City, which is presented in Figure. 8.

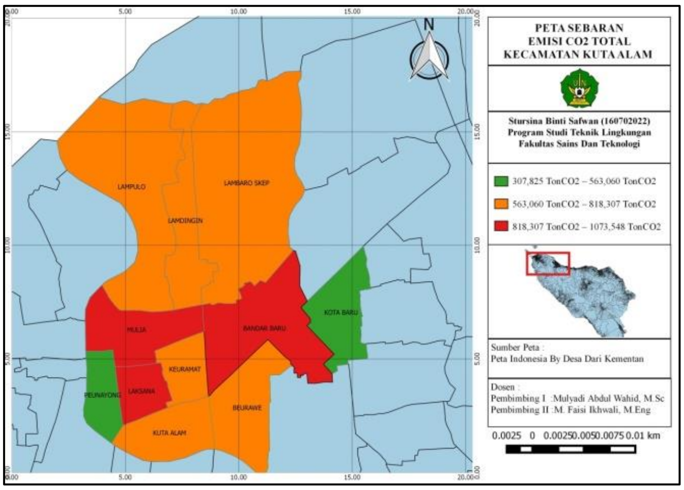

Figure 8. The Mapping of total carbon emissions from household activities in Kuta Alam

Based on Figure. 8, the villages that produce high CO_2 emissions are in the red color range, namely Laksana, Mulia, and Bandar Baru villages, which produce emissions with a range of 818.307 TonCO_2 - 1075.548 TonCO_2

/ month. Six villages produce carbon emissions in the range of 563,060 TonCO_2 - 818,307 TonCO_2, namely Beurawe, Keuramat, Kuta Alam, Lampulo, Lamdingin and Lambaro Skep. The villages that produce the most minor CO_2 emissions are Peunayong and Kota Baru, which produce CO_2 emissions in the range of 307,825 TonCO_2 - 563,060 TonCO_2 / month.

4. Conclusion

Based on the research and data processing that has been completed, it can be concluded that the village that produces the most significant carbon emissions in the cooking fuel sector is Beurawe, which produces CO_2 carbon gas emissions of 59.358 tons of CO_2 per month. The village that produces the most significant carbon emissions in the electricity sector is Bandar Baru, which produces CO_2 gas emissions of 628.753 TonCO_2 / Month, and the village that produces the most significant carbon emissions in the transportation sector is Bandar Baru, which is 444.795 TonCO_2 / Month. The urban village that produces the most significant total CO_2 gas emissions is Bandar Baru, which produces CO_2 gas emissions of 1073.548 TonCO_2 per month. Meanwhile, the district with the lowest gas emissions is Kota Baru, which produces 307.825 TonCO_2/ Month emissions. It is assumed that Bandar Baru has a smaller population than other districts.

Acknowledgments

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References

(NOAA), N. O. (2022). *Annual 2022 Global Climate Report.* National Center For Environmental Information.

(TDMRC), T. T. (2019). *Strategi Mitigasi Bencana Tsunami dan Banjir Rob yang Diperparah oleh Kenaikan Muka Air Laut Akibat Perubahan Iklim.* Pemerintah Kota Banda Aceh.

Admaja, W. K. (2018). Identifikasi Dan Analisis Jejak Karbon (Carbon Footprint) Dari Penggunaan Listrik Di Institute Teknologi Yogjakarta. *Jurnal Rekayasa Lingkungan*, Vol. 18 No. 2.

Akmalia, D. (2021). *Analisis Jejak Karbon Pada Aktivitas Pemukiman di Kecamatan Waru Kabupaten Sidoarjo.* Skripsi: UIN Sunan Ampel Surabaya.

Alwin, R. N. (2016). *Analisis Jejak Karbon dari Aktivitas Permukiman di Desa Ciherang, Dramaga dan Petir, Kabupaten Bogor, Jawa Barat.* Skripsi: Jawa Barat : Institute Pertanian Bogor.

Astari, R. G. (2012). *Studi Jejak Karbon Dari AKtivitas Pemukiman Di Kecamatan Pedemangan Kotamadya Jakarta Utara.* Depok: Universitas Indonesia.

BMKG. (2023). *Perubahan Iklim.*

BPS. (2020).

BPS. (2020). *Kecamatan Kuta Alam Dalam Angka 2020.* Banda Aceh: Badan Pusat Statistik Banda Aceh.

IPB, T. C. (2019). *Laporan Perhitungan Jejak Karbon.* Bogor: IPB University.

Jainal Abidin, F. A. (2019). Pengaruh Dampak Pencemaran Udara Terhadap Kesehatan Untuk Menambah Pemahaman Masyarakat Awam Tentang Bahaya Dari Polusi Udara. *Prosiding Seminar Nasional Fisika Universitas Riau IV (SNFUR 4) Pekanbaru*, ISBN: 978-979-792-691-5.

Lilik Anjar Setiawan, W. A. (2017). Tingkat Kualitas Permukiman (Studi Kasus: Permukiman Sekitar Tambang Galian C Kecamatan Weru Kabupaten Sukoharjo). Vol. 12 No.1.

MenLHK, M. L. (n.d.). *Knowledge Centre Perubahan Iklim.*

Mineral, K. E. (2017). *Kajian Penggunaan Faktor Emisi Lokal (Tier 2) Dalam Inventarisasi GRK Sektor Energi.* Jakarta Pusat: Pusat Data dan Teknologi Informasi ESDM Kementerian Energi dan Sumber Daya Mineral.

Mira Tri Wulandari, H. d. (2013). Kajian Emisi CO_2 Berdasarkan Penggunaan Energi Rumah Tangga Sebagai Penyebab Pemanasan Global (Studi Kasus Perumahan Sebantengan, Gedang Asri, Susukan RW 07 Kab. Semarang). *Seminar nasional Pengelolaan Sumberdaya Alam dan Lingkungan* , ISBN 978-602-17001-1-2.

Pratikto, W. A. (2002). *Tinjauan Dampak Global Warming Terhadap Lingkungan Pesisir dan Pulau-Pulau Kecil di Indonesia.* Bandung: Direktorat Jenderal Bina Marga.

Qibtiyah, E. M. (2014). *Pembiasaan Pola Makan Balita di Lingkungan Keluarga Sejahtera 1 Desa Cibodas*

Bungursari Purwakarta. Universitas Pendidikan Indonesia.

Rachmawati, V. (2015). *Penentuan Faktor Emisi Spesifik Untuk Estimasi Tapak Karbon dan Pemetaannya Dari Pemukiman dan Persampahan di Kabupaten Sukoharjo.* Tesis: Surabaya : Institute Teknologi Sepuluh November.

Rusbiantoro, D. (2008). *Global Warming for Beginner: pengantar Komprehensif tentang Pemanasan Global.* Yogjakarta: O2 Penembahan Yogyakarta.

Sasmita, A. (2018). Analisis Karbon Footprint Yang Dihasilkan Dari AKtivitas Rumah Tangga Di Kelurahan Limbungan Baru Kota Pekanbaru. *Jurnal Teknik Waktu*, Vol. 16 No. 1.

Sewiko, R. (2016). *Analisis Jejak Karbon Di Kawasan Wisata Pesisir Dan Laut (Studi Kasus Kawasan Wisata Pangandaran, Jawa Barat).* Jawa Barat :: Institute Pertanian Bogor.

Sutono, I. (2019). *Dampak Rumah Kaca.* Jawah Tengah: ALPRIN.

Umara Firman Rizi D, S. S. (2019). Analisis Dampak Diterapkannya Kebijakan Working From Home Saat Pendemi Covid-19 Terhadap Kondisi Kualitas Udara Di Jakarta. *Jurnal Meteorelogi Klimatologi dan Geofisika*, Vol 6 No.3.

Utina, R. (2015). *Pemanasan Global : Dampak dan Upaya Meminimalisasinya.* Dosen Biologi FMIPA: Universitas Negeri Gorontalo.

Wardhana, W. A. (2010). *Dampak Pemanasan Global : Bencana Mengancam Umat Manusia. Sebab, Akibat , dan Usaha Penanggulangannya.* Yogjakarta: Andi.

Yuliana, D. K. (2017). Tingkat Emisi Gas Rumah Kaca di Kabupaten Indramayu. *Jurnal Sains Dan Teknologi Mitigasi Bencana*, Vol. 12 No. 2.

Yulianto P. Prihatmaji, A. F. (2016). Analisis Carbon Footprint Gedung Perpustakaan Pusat , Rektorat dan Lab MIPA UII Berbasis Vegetasi Eksisting Sebagai Pereduksi Emisi Gas Rumah Kaca . *Asian Journal of Innovation and Entrepreneurship*, Vol. 01 No. 02.