Carbon Footprint Management Analysis in Climate Change Mitigation at Umbul Ponggok

Isna Aini Muthi'ah[1]
Hanin Istiqlaliyah*[1]
Salsabila Ramadianti[1]
Firdhya Afnan Septianingrum[1]
Ika Feni Setiyaningrum [2]

Affiliation ([1]Department of Environmental Science, UIN Raden Mas Said Surakarta [2]Center of Science and Technology, UIN Raden Mas Said Surakarta)

ABSTRACT

The global rise in temperature has become a major concern over the past decades, with global warming largely driven by human activities. One contributing factor comes from tourism activities, which can be identified through transportation modes, electricity use, and waste generation. Umbul Ponggok is a well-known tourist destination that attracts visitors from both within and outside Klaten Regency. However, the increasing number of tourist visits has contributed to higher carbon emissions. The accumulation of carbon emissions in the atmosphere, primarily from gases such as carbon dioxide (CO_2) and methane (CH_4), generates greenhouse effects that lead to various environmental problems. This study aims to analyze the sources of carbon footprint in Umbul Ponggok and identify effective environmental management strategies. The research employed an interactive qualitative approach through direct field engagement, combined with a descriptive quantitative method based on survey results. Mitigation efforts such as tree planting programs, village clean-up initiatives, and innovations toward renewable energy are expected to help reduce carbon emissions in the surrounding environment.

Keywords: carbon footprint, mitigation, climate change, Umbul Ponggok

Introduction

Climate change is a global environmental challenge and issue that occurs in the 21st century. Climate change is caused by carbon (CO2) emissions which are mostly produced by human activities, such as the use of fossil fuels, land clearing, the tourism sector, and others that have a negative impact on the environment (Sallsabila & Rochman, 2024). The resulting carbon emissions make the temperature conditions on earth increase. The earth's temperature is getting

* Corresponding author: haninistiqlaliyah@gmail.com

hotter is influenced by the high concentration of Greenhouse Gases (GHGs) in the atmosphere which is the cause of global warming (*global warming*) (Rahmayani, 2021).

Tourism is an activity that involves the process of a person's travel to a destination using transportation. The tourism sector in Indonesia is an important sector to be developed because it can have a positive impact on the lives of the surrounding community, especially on the economic system (Oktaviani & Yuliani, 2023). A more advanced economic development will provide an increase in community welfare and regional income (Satria & Maharani Wibowo, 2021). Although tourism can contribute to the country's economy, Indonesia faces challenges such as lack of attention to the environment (Maherty & Fardani, 2024). Activities in the tourism sector are the main contributors to the use of fossil fuels that produce carbon emissions. These carbon emissions can come from industrialization and transportation (Kusumaningtyas, 2024). Various activities in the tourism sector that produce carbon emissions, such as tourist vehicles, the use of energy to support facilities, and the consumption of food and services.

The increase in activities that produce emissions is likely to have a negative impact on the environment, such as ecosystem degradation to pollution (Sana, 2025). In addition, this increase in emissions causes global warming and increases the risk of global climate change (Irma & Gusmira, 2024). Therefore, tourism managers must carry out mitigation efforts that support the achievement of the Sustainable Development Goals, namely "Handling Climate Change" (Leontinus, 2022).

Mitigation is carrying out actions that aim to reduce activities that cause climate change (Leontinus, 2022) . Mitigation emphasizes the impact of policies in various sectors of the economy, including energy, transportation, and waste management. Mitigation efforts by the tourism sector in order to reduce carbon footprint can be implemented by managing natural resources wisely such as becoming ecotourism areas, as well as inviting visitors or local residents to start being aware of environmental issues (Ratnaningsih, 2023).

One of the tourist areas that is the choice of tourist destination is Umbul Ponggok, which is located in Ponggok Village, Polanharjo District. Umbul Ponggok is often used as the main destination when visiting Klaten and has become one of the most famous tourist attractions (Wulandari, 2022). Different from other umbul, Umbul Ponggok offers clear underwater beauty, so it is used for *selfie underwater, diving,* and *snorkling.* The activity attracts more visitors who come to try or just look. This increase in the number of tourists has a positive impact on the economy, but there is also a negative impact because it has the potential to increase the carbon footprint.

There is a lack of awareness among managers and the surrounding community on how important environmental management is, especially climate change mitigation efforts. This lack of awareness is an important reason for further research. This research is important to provide the actual conditions of Umbul Ponggok management on the carbon footprint problem and how efforts are being made to implement carbon footprint reduction strategies. Thus, this research is expected to make a real contribution to climate change mitigation

efforts, so that the benefits produced remain in line with efforts to protect the environment.

This research focuses on the management analysis of the carbon footprint generated from activities that occur in Umbul Ponggok. And with this study, it can identify solutions to reduce carbon footprint by empowering the resources owned. Through this research, it is hoped that it can be beneficial for all parties who have contributed. This small step of research can provide motivation and awareness for managers in managing systems and programs that are not only environmentally friendly, but can also contribute more to overcoming current climate change. For the surrounding community, it is also hoped that their awareness will play an active role in protecting the surrounding environment.

The results of the study in (2021) by Rahmayani shows that tourism and economic growth have a significant negative influence on CO2 emissions. As a result, the tourism industry has contributed 8% of carbon dioxide to the earth. Meanwhile, fossil energy consumption does not show a significant effect on CO2 emissions. Recent studies by Sallsabila & Rochman year (2024) shows that tourism activities in Umbul Ponggok also contribute to the carbon footprint, which is sourced from activities such as electricity consumption, tourist transportation, waste produced and food consumption. The findings of this study are that tourist transportation is the largest contributor to CO2 emissions with a coefficient value of 0.832.

Strategies that need to be carried out in the management of Umbul Ponggok tourism according to the results of research by There year (2025) is sustainable tourism management to reduce adverse impacts on the environment. This research shows that the main strategies in sustainable tourism management include the implementation of ecotourism-based conservation policies, efficient waste and energy management, empowerment of local communities, and education for tourists on responsible tourism practices. In addition, collaboration between the government, the private sector, and the community in implementing strict regulations related to environmental carrying capacity and ecological impact monitoring is a key factor in ensuring the sustainability of natural tourist destinations.

Method

This research method uses a mixed approach (*mixed methods)*, i.e. qualitative and quantitative to obtain more comprehensive data (Puspitasari et al., 2024). The qualitative method refers to the collection of data directly from *Browse* (people) and *Place* (place) in the environment under study. Qualitative research aims to gain a deep understanding of human and social problems (Fadli, 2021). The approach taken is field research, which is research carried out at the research location directly by interviewing sources and observing to obtain information or data in the form of facts and opinions. Meanwhile, quantitative methods are used to analyze data in the form of numbers or statistics. According to Puspitasari et al. (2024) Quantitative data is obtained through variable measurement. In this study, quantitative data was obtained from the calculation of the carbon footprint produced from Umbul Ponggok. Emission results are

obtained by multiplying the amount of energy consumption by the emission factor of each type of waste (Reza et al., 2024).

$$Emissions = Energy\ Consumption \times Emission\ Factors$$

This research was carried out in Ponggok Village, precisely at the Umbul Ponggok tourist location. The choice of this research location was for the reason that Umbul Ponggok is one of the most visited tours by tourists. Umbul Ponggok is also different from other Umbul, Umbul Ponggok offers clear underwater beauty, so it can be used for *underwater selfies, diving,* and *snorkeling.*

The types of data in this study are in the form of primary data and secondary data. The collection technique in obtaining primary data is by conducting observations and interviews. The data collection through this interview is by obtaining in-depth information on the designated resource persons, namely the manager of Umbul Ponggok, the surrounding community, and tourists who visit. And supported by documentation in the form of photos, notes, and other results obtained from direct observation activities at the location. Meanwhile, secondary data uses secondary data collection techniques obtained from written documents related to Umbul Ponggok and literature studies related to the desired information.

Results

Tourist Vehicle Emission Data

Umbul Ponggok is visited by tourists who use various modes of transportation, both private vehicles such as cars and motorcycles, as well as public vehicles, such as buses. The visit of tourists from various regions also contributes to the carbon footprint in the Umbul Ponggok tourist area.

Table 1. Monthly passenger vehicle emission data

Types of Transportation	Mileage (km)	Emission Factor (KgCO2)	Total Emissions (KgCO2)
Motor	50	0,35	105.000
Private car	50	0,088	33.000
Bus	50	0,008	600
Total overall emissions			138.600

Landfill Emission Data

The number of tourists who come to Umbul Ponggok will increase the volume of waste produced. Dense tourism activities have significant potential to add waste, both in the form of organic and inorganic waste. The waste produced will contribute to carbon emissions, if not handled properly.

Table 2. Waste emission data per month

Types of Garbage	Composition	Weight (kg)	Emission Factor (KgCO2)	Total Emissions (KgCO2)
Organic	56%	655,2	0,21	137,6
Plastic	16%	187,2	2,5	468,0
Kertas	12%	140,4	1,2	168,5
Logam	5%	58,5	0,05	2,9
Other	11%	128,7	0,1	12,9

Data on the Calculation of the Carbon Footprint of the Third Source of Emissions

Umbul Ponggok as a fairly famous tourist destination, indirectly contributes to large carbon emissions. Activities that contribute to carbon emissions in Umbul Ponggok itself are categorized into 3 types of activities, namely, tourist transportation, electricity use, and waste.

Table 3. Overall calculation of carbon-emitting activities

Activity	Emisi (KgCO2)	Percentage(%)
Tourist Transportation	138.600	96,49
Electricity Use	4.250	2,96
Waste Management	789,9	0,55
Total Emissions	143.639,9	100

This section deals with the research findings (level one headings). The findings obtained from the research have to be supported by sufficient data. The research results and the discovery must be the answers, or the research hypothesis stated previously in the introduction part. The findings section consists of a description of the results of the data analysis to answer the research question(s). The findings should summarize (scientific) findings rather than providing data in great detail. Please highlight differences between your results or findings and the previous publications by other researchers.

Discussion

The Influence of Tourist Activities on Carbon Emissions

The tourism sector is recognized as a contributor to carbon emissions, especially from tourist vehicles, energy use for facilities, and consumption of food and services (Susanti et al., 2023). Tourism in Umbul Ponggok operates through a series of interconnected activities, where each activity carried out will have a

certain environmental impact. The contribution of carbon emissions in Umbul Ponggok comes from:

Carbon Emissions of Tourist Vehicles

The Umbul Ponggok tourist attraction is a destination destination for visitors from outside the city. The average visitor to Umbul Ponggok is at 15,000 per month. The tourists who visit, come by driving vehicles ranging from motorcycles, cars, and buses. Distribution of transportation modes: 40% motorcycles, 50% private cars, 10% buses. The average round-trip distance per traveler is 50 km. Carbon emission factors produced by modes of transportation are motorcycles of 0.035 kg CO2 e/km, private cars of 0.088 kg CO2 e/km, buses of 0.008 kg CO2 e/km (Trail, 2025). This transportation emission is calculated based on the distance traveled and the mode of transportation used when going to tourist attractions.

Carbon Emissions of Electricity Consumption

The source of electrical energy used is conventional electrical energy. The supply of conventional electrical energy comes from coal, oil, and natural gas so that it can help increase CO2 emissions (Buana & Riyanto, 2024). The use of electricity in Umbul Ponggok is calculated from management activities in the form of lighting and several electronic devices used during operational hours. To support operations, Umbul Ponggok still depends on electricity supply from PLN, which means that it still uses fossil or conventional fuels. The average electricity consumption in Umbul Ponggok is at 5,000 kWh/month. The calculation of carbon emissions from electricity use is calculated by multiplying electricity use by an emission factor of 0.85 based on the decision of Press Release No. 775.PR/STH.00.01/X/2022 by PT PLN (Persero) in Jakarta, October 13, 2022 (Trianto, 2022).

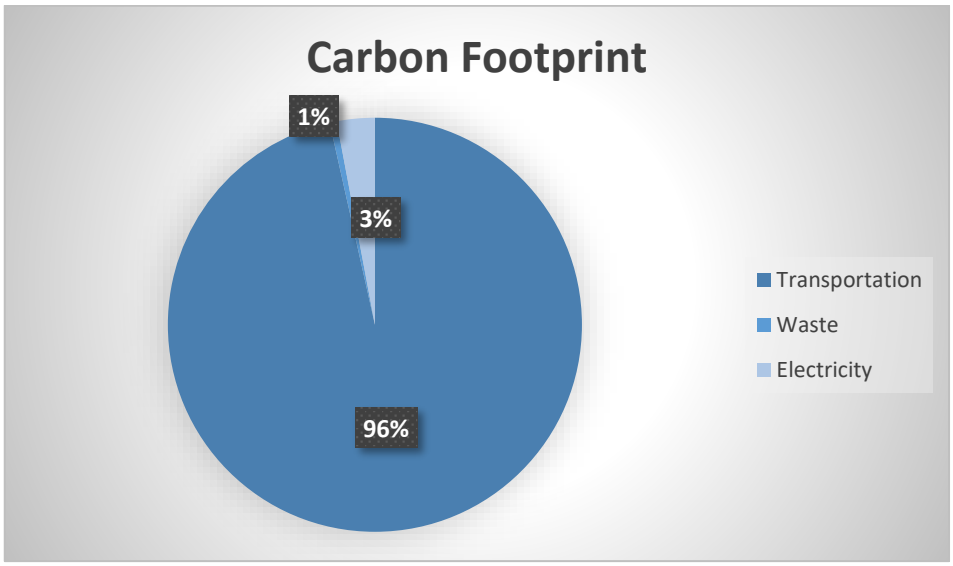
Carbon Emissions Waste Management

The increase in the number of tourists also has an impact on the volume of waste, both organic and inorganic waste produced in the Umbul Ponggok area. One type of waste that is the main contributor to environmental pollution is organic waste. Organic waste consists of food scraps, fallen leaves, plant remains, and more (Utami et al., 2023). If not managed properly, organic waste will go to waste in landfills that produce methane gas. Methane gas is one of the most dangerous, as it has a greater warming potential than carbon dioxide (CO2) (Sikki et al., 2024).

The inorganic waste produced is in the form of cracker bags, plastic bottles, soap wrappers, food wrappers and others. The inorganic waste that cannot be decomposed quickly causes a new problem in the form of an ever-increasing volume of waste without special treatment (Raharjo et al., 2022). A common treatment for inorganic waste is open combustion. This open burning produces carbon gases and pollutants that will increase air pollution in the atmosphere,

which will later affect climate change (Sa'diyah & Davina, 2025). Umbul Ponggok has many garbage cans that can accommodate 3-5 kg of garbage, with an average amount of garbage at 39 kg/day. The calculation of carbon emissions from waste can be calculated from the amount of waste produced multiplied by the MoEF's emission factors, namely 0.21 Kg CO2e for organic waste; 2.5 Kg CO2 for plastic waste; 1.2 Kg CO2 for paper waste; 0.05 Kg CO2 for metal waste; and 0.1 Kg CO2 for other waste (SIPSN, 2023).

Figure 1. Carbon Footprint in Umbul Ponggok



Based on the results of figure 1 calculations, it is known that the activities of transportation used by visitors have the highest contribution to carbon emissions, which is 138,600 Kg of CO2 with a percentage of 96.49% of the total carbon emissions. This is due to the large number of respondents who use private vehicles compared to using public transportation. The transportation category is the highest contributor to emissions, the use of conventional vehicles is still widely used by tourist visitors and managers. The use of these conventional vehicles will experience the imperfect combustion of fossil fuels that release harmful chemical gases such as C, CO2, N2O, NOx. These carbon emissions reinforce the greenhouse effect and the rise in the earth's temperature (Lulu et al., 2020).

The generation of waste in ponggok cannot be managed properly by tourists, waste is only collected at the Temporary Disposal Site (TPS), before being transported by the local waste carrier. Piles of garbage that are not immediately disposed of in the Final Disposal Site (TPA) can cause harmful chemicals contained in the waste, which will result in new problems in the environment (Hafizah et al., 2023). Environmental problems that can be caused, such as bad odors, damage to the soil landscape, emitting methane gas or other pollutants (Mahendra & Salsabila, 2024). Therefore, tourism managers have an important role in climate change mitigation efforts to support the Sustainable Development Goals. This increase in the number of tourists, while having a positive impact on the economy, also has the potential to increase the carbon footprint in the tourist environment.

Mitigation Efforts in Climate Change

Climate change is currently characterized by an increase in the earth's temperature, extreme weather, and rising sea levels. In order to reduce its impact, climate change mitigation needs to be carried out by all parties, both the government, resource managers, and the community. Mitigation includes various efforts to reduce greenhouse gas emissions through the transition to clean energy, waste management, and the protection of carbon-sequestring ecosystems. Efforts that can be made to reduce the impact of climate change, in climate change mitigation are as follows:

Tree Planting Program

The manager of Umbul Ponggok Village implements a unique program that has a positive impact on environmental sustainability, namely the tree planting program by every bride and groom who are going to get married. Planting this tree is one of the conservation efforts to maintain water resources so that they are preserved and always in good condition. Trees have vegetation that functions to absorb carbon emissions through photosynthesis (Ega et al., 2024). The process of absorbing emissions from the atmosphere and storing them as carbon is stored in the tree part of the trunk, leaves, and roots in the soil (Saputri & Sutrisno, 2025). The important role of trees is to reduce carbon concentrations in the environment.

Umbul Ponggok is committed not to cutting down large trees that already exist in the Umbul Ponggok area. This, too, encourages the preservation of nature, especially water resources in Umbul Ponggok. The big trees in Umbul Ponggok are like the ketapang tree (*Terminella catappa)* and the bodhi tree (*Ficus religiosa*), plays a role in reducing carbon emissions by sequestration. The average carbon sequestration of each tree is 14.18 tons/tree (Agumanis et al., 2021). However, the ability to absorb CO2 in the air is certainly different for each plant.

Appeal not to litter by tourism managers

The waste generated from tourism activities is collected first at a temporary disposal in Umbul Ponggok and then disposed of in the village landfill every 2-3 days. The Umbul Ponggok Tourism Manager has provided many garbage cans, with a total of about 13 garbage cans scattered around the pond and stalls. The garbage cans provided by the manager are carried out as an effort to encourage visitors not to litter. The procurement of cleaning tools and garbage cans is carried out, because this is one of the means and infrastructure to carry out and maintain cleanliness. The existence of the facilities provided can increase the awareness of tourist visitors and/or the management of the cleanliness of tourist sites and the environment. The most basic processing that can be done is sorted, recycled, and disposed of in its place (Zakaria et al., 2023). In addition, the management also made efforts by giving an appeal to tourists who came not to littering or polluting water sources.

Figure 2. Garbage Collection (Source: personal image)

The management already has an innovation plan to carry out the resulting waste management program, namely the "waste decomposition" program. This program aims to process the waste produced by sorting waste according to its type, such as inorganic waste in the form of plastic bottles or beverage cups and organic waste in the form of food waste, fallen leaves, and others. This program is very important to be realized, considering that efficient waste management can be one of the sustainable tourism management strategies to reduce environmental impact.

The Role of Bumdes "Tirta Mandiri" Ponggok Village

Village-Owned Enterprise (BUMDes) are village-owned businesses managed by the village by adjusting the needs and potential of the village (Humanika et al., 2023). Each village has potential and advantages that have the potential to improve the welfare of its community. Ponggok Village which has natural potential in the form of a spring water source that is used for tourism. Of course, cooperation is needed between managers and BUMDes in participating in protecting water sources and the environment. Protecting the environment is an important role that greatly affects the survival of both the health and the community's economy.

The effort made is by urging MSME owners (Micro, Small, and Medium Enterprises) to start reducing the use of single-use plastics and replacing them with leaves, such as banana leaves. This innovation in the use of leaves is carried out to participate in reducing the generation of plastic waste which is increasing while minimizing the impact of microplastics in the environment. This innovation has been implemented in several internal BUMDes events such as the appeal to reduce the use of plastic and began to be replaced with the use of leaves instead. This innovation supports responsible tourism practices and is in line with environmental impact mitigation efforts (Widyaningtyas, 2023).

Reducing PLN's Electricity Dependence

The use of conventional electricity derived from coal, oil, and natural gas can also increase CO2 gas emissions (Buana & Riyanto, 2024). The electricity used in Umbul Ponggok's operations still uses electricity consumption by relying on PLN (State Power Plant). Electricity consumption in Umbul Ponggok tourism is around 5000 kWh/month. Umbul Ponggok itself uses electricity as a support for electronic devices and as lighting at night at certain points.

The management of Umbul Ponggok is committed to reducing dependence on electricity supply from PLN by developing a Micro Hydro Power Plant (PLTMH). PLTMH functions as a power supply to be able to meet the needs of the community in the form of electricity (Ardo et al., 2022). Technically, micro hydro has three main components, namely: water, turbines and generators. Water with a certain capacity flowing in a special channel is channeled at a certain height through a rapid pipe to the installation house (power house) (Tria Melati et al., 2022).

Although the Umbul Ponggok location does not have an ideal elevation (height difference) for the hydro system, the management team still makes efforts to utilize the existing water flow by designing a mini microhydro prototype. This microhydro technology was chosen because it has the potential to produce clean energy without producing carbon emissions, while at the same time supporting climate change mitigation efforts through reducing the use of fossil fuels (Tria Melati et al., 2022).

The Umbul Ponggok tourism sector has been proven to contribute to carbon emissions, especially from tourist transportation, electricity consumption for operations, and food and services consumed. therefore, managers play an important role in climate change mitigation efforts to support Sustainable Development goals.

Conclusion

Based on the findings of the research that has been conducted, it can be concluded that tourism activities in Umbul Ponggok have a significant impact on increasing carbon emissions, especially from the visitor transportation sector which accounts for around 96.49% of total carbon emissions. Electricity consumption and waste management are other factors that need to be addressed related to climate change mitigation efforts. Nevertheless, the management of Umbul Ponggok shows concern and commitment to reducing environmental impact through a number of mitigation initiatives, such as tree planting programs, the provision of adequate garbage cans, an invitation not to litter, and a waste management plan with a sorting system. In addition, there are also planned initiatives to be implemented to develop alternative energy sources, such as microhydro, which is a positive step in reducing dependence on fossil-based energy.

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