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Impact of Tansmigration Development UPT.Waleh SP.2 on Carbon Emissions

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Abstract:
This article is the result of a research on the impact evaluation of transmigration development on carbon emissions in UPT Waleh SP.2, Central Halmahera Regency, North Maluku. Where the opening of transmigration land has the potential to change ecosystems, including vegetation cover, biomass, and greenhouse gas emissions, which can affect environmental sustainability. The objective of this study was to analyze changes in the ecosystem due to transmigration development, particularly on vegetation cover, carbon biomass, and carbon emissions. For this purpose, remote sensing technology and GIS-based spatial analysis were used with four main indicators: NDVI for vegetation cover, AGB for carbon biomass, CO as an emission indicator, and NPP for carbon absorption capacity. The results showed a decrease in NDVI, AGB, and NPP, as well as an increase in CO. Decreases in NDVI and AGB reflect vegetation degradation and biomass loss, while increases in CO are caused by human activities such as biomass burning and the use of motorized vehicles. The decrease in NPP indicates a decrease in the capacity of vegetation to absorb carbon.
Keywords: *AGB,CO_2, NDVI, NPP, Transmigration*

INTRODUCTION

This research was designed as an effort to understand and manage the impact of transmigration development on the environment, with a focus on carbon emissions management in the UPT Waleh SP.2 area, Central Halmahera Regency, North Maluku Province. This area is one of the areas designated by the government as a location for the development of transmigration programmes, with the aim of supporting population distribution, regional development, and improving the welfare of local communities.

This study aims to analyse the impact of transmigration development on carbon emissions, which is often one of the main environmental issues in land use change. Four main indicators are used to measure this impact, namely NDVI (Normalised Difference Vegetation Index), AGB (Above Ground Biomass), CO (Carbon Monoxide), and NPP (Net Primary Productivity). Through these indicators, the project was able to identify ecosystem changes, such as vegetation degradation, decreased carbon biomass, increased emissions from human activities, and the ability of vegetation to sequester carbon.

RESEARCH METHOD

This research uses quantitative methods based on remote sensing technology and geographic information systems (GIS). Data on natural resources and their environment can be collected by remote sensing (Handayani and Setiyadi, 2003). Remote sensing is essential for large area-based estimation (Galidaki et.al., 2017). This approach allows monitoring and analysing land cover change and carbon emissions only through freely available satellite image data, and spatial processing and analysis with GIS. The research focuses on four main variables: normalised difference vegetation index (NDVI), above ground biomass (AGB), carbon monoxide (CO), and net primary productivity (NPP) to assess the impact of transmigration development in UPT Waleh SP.2 on carbon emissions. This research method is expected to provide an in-depth understanding of the impact of transmigration development on ecosystems, especially related to carbon emissions. By using satellite data and spatial analysis, this research is able to provide accurate and comprehensive results in analysing environmental changes in the study area. The research location is in UPT Waleh SP.2, North Weda District, Central Halmahera Regency, North Maluku Province which is located between 0°26'45" LU - 0°28' LU and 128°13' East - 128°45' East.

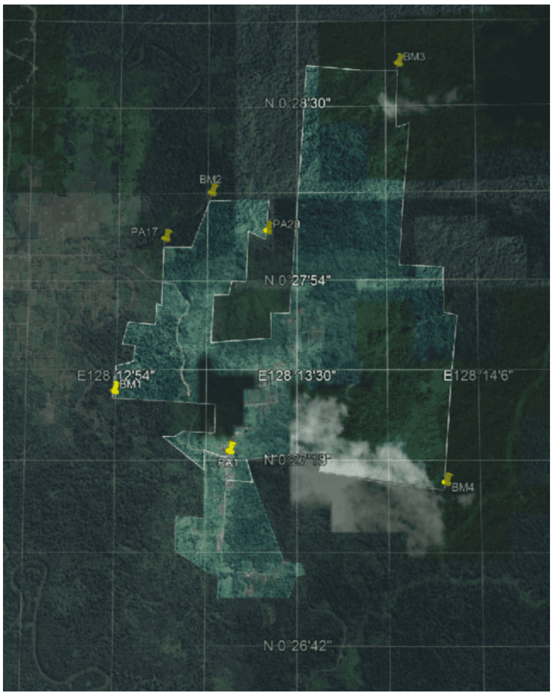

Figure 1: Research location UPT.WalehSp.2, Weda Utara Sub-district, Central Halmahera Regency, North Maluku Province

This area was chosen as the research site because it used to be, in 2010, a virgin forest. Then in 2011-2012, transmigration development was carried out so that this forest experienced a significant change in land use, namely the forest was converted into yard land and 100 ha of business land.

Data Collection Methods

The data used comes from the following data:

a. Remote Sensing Data:
   - Landsat 8 and Sentinel-2 satellite images were used to measure NDVI and monitor vegetation changes during the period before and after transmigration development.
   - MODIS satellite imagery was used to calculate NPP and monitor carbon monoxide (CO) emissions released due to land clearing.
   - Above ground biomass (AGB) data were obtained through modelling algorithms implemented on satellite imagery, based on non-destructive measurement methods commonly available in global remote sensing databases.

b. Other Data Sources:
   Data on local climate and weather conditions were taken from relevant satellite databases such as the global land data assimilation system (GLDAS), which provides information on environmental factors that can affect carbon emissions.

Data Analysis Methods

Data collected from satellite image processing were analysed using a geographic information system (GIS) to map spatial changes in land cover and carbon emissions. GIS was used to integrate NDVI, AGB, CO, and NPP data into thematic maps depicting the impact of transmigration development on local ecosystems. A spatial overlay analysis was then conducted to combine data from multiple sources, allowing for a more detailed mapping of how land change affects carbon emissions in different study areas. The final step was data validation by comparing the results of the satellite image processing with and relevant literature on carbon emissions from deforestation and land conversion in similar areas. Data from the processed satellite imagery was verified by cross-checking data from the previous and following years. From the results of satellite image analysis and spatial data processing, the impact of transmigration development on carbon emissions in UPT Waleh SP.2 will be known.

RESULT AND DISCUSSION

Normalized Difference Vegetation Indeks (NDVI)

Normalised difference vegetation index (NDVI) is a vegetation indicator derived from the difference in light reflectance and absorption by plants in the process of photosynthesis. NDVI values are used to analyse vegetation cover and can be an indicator in carbon stock estimation. NDVI has a positive correlation with carbon stocks, where higher values indicate a greater capacity of vegetation to store carbon [1][2][3]. Studies conducted by [4] show that a decrease in NDVI value is directly proportional to a decrease in vegetation biomass, which in turn can increase carbon emissions from the ecosystem. The higher the NDVI value, the greater the absorption of red and blue light waves and reflection of green light, reflecting healthier and denser vegetation conditions. In addition, NDVI has a strong correlation with above ground biomass (AGB), so it can be used as an effective approach in estimating carbon stocks by land use type[5].

Figure 2 NDVI Map of UPT.Waleh Sp.2 in 2010 Using Landsat Image

In 2010, prior to transmigration development, the NDVI class value that dominated the UPT.Waleh SP.2 area was NDVI class 3, which is light green in colour, having a value between 0.3-0.45 covering an area of 346.0984090077481 Ha. This area indicates an area with moderate forest or vegetation cover. This can be seen in table 1 below.

Tabel 1. NDVI UPT. Waleh SP.2 classification in 2010

Class NDV I	Classificatio n Class	Colour	Luas Area (Ha)	Descriptio n
1	≤0,15	Red	9,4520829804514	Low Vegetation
2	0,15-0,3	Orang e	0,2681836395263	Emerging Vegetation
3	0,3-0,45	Light Green	346,098409007748 1	Medium Vegetation
4	≥0,45	Dark Green		Dense Vegetation
Total Area			355.818675627727	

Tabel 2. NDVI UPT. Waleh SP.2 2010

NDVI 2010			
Min	:	0,28629	
Max	:	0,516462	
Mean	:	0,39805	
Area	:	355,8186756277278	Ha

This minimum NDVI value (0.28629) indicates an area with thin vegetation or a transition area between bare soil and vegetation that is starting to grow. The vegetation condition in this section can be categorised as not very lush or less dense. The maximum NDVI value (0.516462) indicates the part of the area that has the most lush and dense vegetation. With an average of 0.398, the overall vegetation condition can be considered quite good, but still in the medium category. Further NDVI values for 2012 can be seen in the following figure and table.

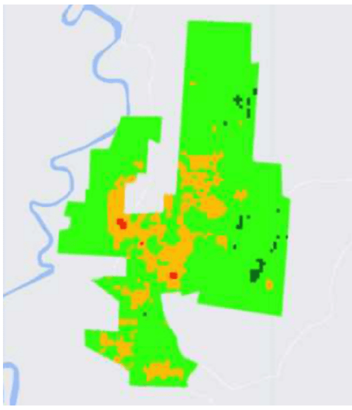

Figure 3 NDVI Map of UPT.Waleh Sp.2 Year 2012 Using Landsat Image

Tabel 3. Klasifikasi NDVI UPT. Waleh SP.2 Tahun 2012

Kelas NDVI	Nilai Klasifikasi	Warna	Luas Area (Ha)	Keterangan
1	≤0,15	Merah	1,0727365249633	Vegetasi Rendah
2	0,15-0,3	Orange	62,1146000136121	Vegetasi mulai Bertumbuh
3	0,3-0,45	Hijau Muda	288,5674065498426	Vegetasi Sedang
4	≥0,45	Hijau Tua	4,0639325393018	Vegetasi Lebat
	Total Luas		355.8186756277278	

Transmigration development UPT. Waleh SP. 2 is carried out in areas that have vegetation levels ranging from low to medium levels. This can be seen from the increase in the area of NDVI class 1 to class 2 and the decrease in the area of NDVI class 3. For NDVI values in 2024 can be seen in Figure 4, Tables 5 and 6.

Tabel 4. NDVI UPT. Waleh SP.2 Tahun 2012

NDVI 2012			
Min	:	0,1319	
Max	:	0,50765	
Mean	:	0,3525	
Area	:	355,8186756277278	Ha

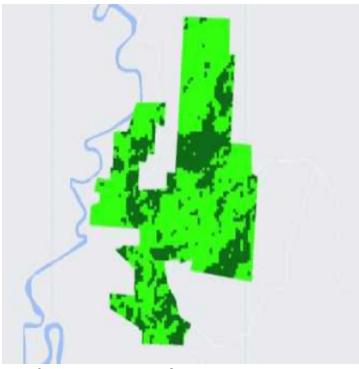

Figure 4 NDVI Map of UPT.Waleh Sp.2 Year 2024 Using Landsat Image

Tabel 5. Klasifikasi NDVI UPT. Waleh SP.2 Tahun 2024

Kelas NDVI	Nilai Klasifikasi	Warna	Luas Area (Ha)	Keterangan
1	≤0,15	Merah	-	Vegetasi Rendah
2	0,15-0,3	Orange	0,0893947631835	Vegetasi Mulai Bertumbuh
3	0,3-0,45	Hijau Muda	241,6711142054355	Vegetasi Sedang
4	≥0,45	Hijau Tua	114,0581666590889	Vegetasi Lebat
	Total Luas		355.8186756277278	

In 2024, there is a very significant increase in NDVI class 4, 114,0581666590889 Ha, which indicates that the vegetation in the area is quite green and lush. This indicates an increase in the density of vegetation in the area. NDVI class 3, with moderate vegetation, still has the largest area, while NDVI class 4 has increased very rapidly.

Tabel 6. NDVI UPT. Waleh SP.2 Tahun 2012

NDVI 2024			
Min	:	0.29051416935347024	
Max	:	0.5222779248577705	
Mean	:	0.43103149641267335	
Area	:	355,8186756277278	Ha

Above Ground Biomass (AGB)

Above ground biomass (AGB) refers to the dry mass of living or dead matter from trees and woody plants above the ground. AGB plays an important role in storing carbon, especially in tropical forests. The density of AGB in an area is measured in units of weight per area (tonnes/ha) and is used as a key indicator in the estimation of terrestrial ecosystem carbon stocks. AGB values can be used to estimate the amount of carbon stored in vegetation, making it an important parameter in the analysis of land use change, deforestation and climate change mitigation.

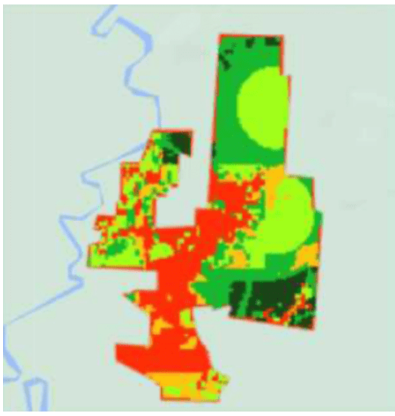

Figure 5. AGB map of UPT.Waleh Sp.2 in 2010 using Landsat image

Tabel 7. Klasifikasi AGB UPT. Waleh SP.2 Tahun 2010

Kelas AGB	Ton/Ha	Warna	Luas Area	
1	≤ 15	Merah	111.45012601541863	Ha
2	15 - 20	Orang e	35.83330206877436	Ha
3	20 - 70	Hijau Muda	92.93884740940442	Ha
4	70 -250	Hijau Daun	87.97943469767513	Ha
5	≥ 250	Hijau Tua	27.61696543647628	Ha
	Min		1.3544380068778992	Ton/Ha

In 2010, the area with the highest AGB value, having the most woody mass per hectare, was in AGB class 5 with an area of 27,61696543647628 ha, which has biomass densities ranging from 250 tonnes/ha and above. The largest area, 111,45012601541863 ha, belongs to AGB class 1 with biomass density values between 0-15 tonnes/ha. The average AGB lies between 70-250 tonnes/ha with an area of 87,97943469767513 ha. Vegetation in this area tends to be in moderate to high condition.

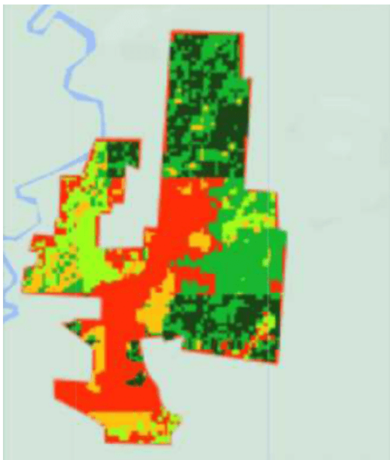

Figure 6. AGB map of UPT.Waleh Sp.2 in 2012 using Landsat image

Tabel 7. Klasifikasi AGB UPT. Waleh SP.2 Tahun 2012

Kelas AGB	Ton/Ha	Warna	Luas Area	
1	≤ 15	Merah	115.9755990558894	Ha
2	15 - 20	Orange	38.08363137465248	Ha
3	20 - 70	Hijau Muda	38.86269659492655	Ha
4	70 -250	Hijau Daun	97.08231840550721	Ha
5	≥ 250	Hijau Tua	65.81443019677465	Ha
	Min		1.6373655200004578	Ton/Ha
	Max		426.229111	Ton/Ha

In 2012, the areas with the highest AGB values belonged to class 5 with biomass densities ranging from 250 tonnes/ha and above, with an area of 65,81443019677465 ha. While the largest area, 115,9755990558894 ha, belongs to AGB class 1 with biomass density values between 0-15 tonnes/ha. The average AGB is between 70-250 tonnes/ha with an area of 97,08231840550721 ha. Vegetation in this area tends to be in moderate to high condition.

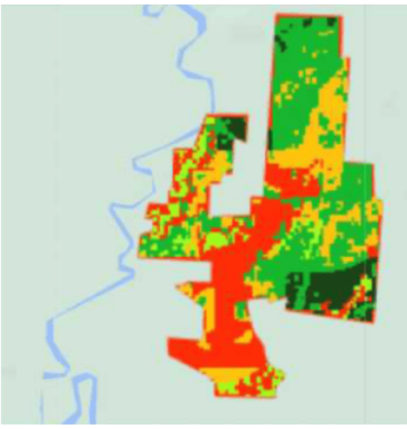

Figure 7. AGB map of UPT.Waleh Sp.2 Year 2024 Using Landsat Image

In 2024, the area that has the highest AGB value, having the most woody mass per hectare, is in AGB class 5 with an area of 27,485152851287314 ha, which has a biomass density ranging from 250 tonnes/ha and above. The average AGB lies in the biomass density between 70-250 tonnes/ha with an area of 120,16271230883366 ha. This AGB class has the largest area. Vegetation in this area tends to be in moderate to high condition.

Tabel 8. Klasifikasi AGB UPT. Waleh SP.2 2024

Kelas AGB	Ton/Ha	Warna	Luas Area	
1	≤ 15	Merah	110.32480803585837	Ha
2	15 - 20	Orange	72.21648045957367	Ha
3	20 - 70	Hijau Muda	25.629521972195516	Ha
4	70 -250	Hijau Daun	120.16271230883366	Ha
5	≥ 250	Hijau Tua	27.485152851287314	Ha
	Min		1.6373655200004578	Ton/Ha
	Max		433.68253599999997	Ton/Ha

The average AGB value from 2010-2024 is in AGB class 4 which has a biomass density between 70-250 tonnes/ha. The more years increase, the wider the area. Where in 2010 it had an area of 87,97943469767513 ha, it increased to 97,08231840550721 ha in 2012. And in 2024 to 120,16271230883366 ha. This shows that the forest has increased biomass storage.

Carbon Monoxide (CO)

The main sources of carbon monoxide (CO) are fossil fuel combustion, biomass burning, and oxidation of methane and other hydrocarbons in the atmosphere. CO acts as an early marker of increased carbon emissions, especially in areas that have experienced massive land conversion. Deforestation due to transmigration development contributes to increased greenhouse gas emissions, including carbon dioxide (CO_2) and carbon monoxide (CO). Transmigration development, which often involves land clearing through burning or mechanical activities, can trigger elevated CO_2 levels, as observed in several transmigration areas in Indonesia. In the tropics, biomass burning plays a significant role in increasing carbon emissions, especially in areas with high deforestation activity. Therefore, this study analyses the extent to which transmigration development contributes to increased CO emissions, to understand its impact on ecosystem and atmospheric balance.

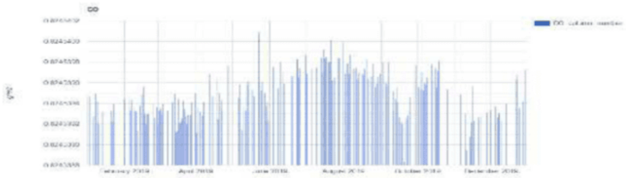

Figure 8. Graph of Carbon Monoxide (CO) UPT.Waleh Sp.2 2010

Tabel 9. Karbon Monoksida (CO) UPT. Waleh Sp.2 Tahun 2010

CO Tahun 2010			
Min	:	0.82453883	Gr/m²
Max	:	0.824541	Gr/m²
Mean	:	0.824539542	Gr/m²

The minimum CO value, 0.82453883 gr/m2 occurred between the end of November and the beginning of December. While the maximum CO value, 0.824541 gr/m2 occurred in June. But the difference between the minimum CO and maximum CO values is very small, it can be said to be almost the same. This shows that this area has a very stable and low CO emission level before development.

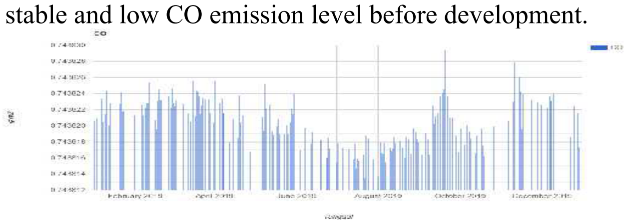

Figure 9. Graph of Carbon Monoxide (CO) UPT.Waleh Sp.2 2012

The minimum CO, 0.7438124 gr/m², occurred in early August. The minimum CO value decreased compared to 2010, which could indicate an improvement in air quality in some areas or a decrease in activities that produce CO, especially after land clearing. The maximum CO, 0.7438295 gr/m², occurred in early December. The maximum value also decreased compared to 2010, indicating that overall CO emissions decreased in this area. The average CO also decreased, indicating a decrease in emissions after the development of transmigration.

Tabel 10. Karbon Monoksida (CO) UPT. Waleh Sp.2 Tahun 2012

CO Tahun 2012			
Min	:	0.7438124	Gr/m²
Max	:	0.7438295	Gr/m²
Mean	:	0.7438210	Gr/m²

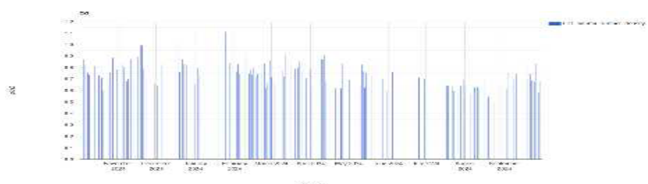

Figure 10. Graph of Carbon Monoxide (CO) UPT.Waleh Sp.2 2024

The minimum value of CO was 0.491 gr/m², a significant decrease compared to 2012. This indicates that certain areas experienced a significant decrease in CO emissions, possibly related to vegetation recovery or the cessation of development activities. The maximum value of CO was 1.163 gr/m², indicating that there were certain areas with activities that produced very high CO emissions. This may be due to new activities such as the use of vehicles or machinery in transmigration areas, or agricultural activities involving burning. The average CO increased slightly compared to 2012. Although there was a decrease in emissions in some areas, increases in other areas caused the average CO value to be higher than in 2012.

Tabel 11. Karbon Monoksida (CO) UPT. Waleh Sp.2 Tahun 2024

CO Tahun 2024			
Min	:	0.491	Gr/m^2
Max	:	1.163	Gr/m^2
Mean	:	0.749845134	Gr/m^2

Net Primary Productivity (NPP)

Net Primary Production (NPP) is the carbon collected to form biomass in plants in a unit and time [6]. This result is supported by [7], who found that ecosystems with natural vegetation cover have higher NPP compared to developed transmigration areas, indicating reduced carbon absorption potential. NPP refers to the rate of processes such as the amount of leaf material production (NPP) per day, week, or year.

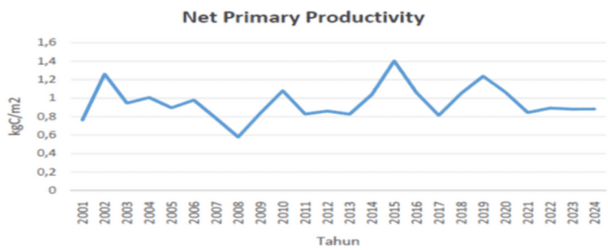

Figure 11. NPP Value of UPT.Waleh Sp.2 2010-2024

In 2010, before the development of transmigration, this area had a relatively high carbon productivity, 1.08 kgC/m2, indicating that the vegetation in the area was quite healthy and able to absorb large amounts of carbon. This NPP value indicates that the vegetation ecosystem in 2010 was quite efficient in storing carbon through the process of photosynthesis. After the development of transmigration, in 2012, there was a significant decrease in the NPP value, 0.861 kgC/m2 after the development of transmigration. This shows that vegetation productivity is decreasing, most likely due to land clearing (transmigration areas. In 2024, there was an increase in the NPP value of 0.993536272 kgC/m², compared to 2012. Although it has not fully returned to the pre-development level in 2010. This increase indicates that vegetation in the area is starting to recover, with an increasing ability to absorb carbon. However, the fact that the NPP has not reached the initial value of 1.08 kgC/m² indicates that despite the recovery, the area is still in a transition phase and has not fully recovered from the impacts of development.

Tabel 12.NPP UPT. Waleh Sp.2 Tahun 2010, 2012 dan 2024

NPP			
2024	:	0,883536272	KgC/m^2
2012	:	0,861	KgC/m^2
2010	:	1,08	KgC/m^2

CONCLUSION

Transmigration development in 2011-2012 had a significant impact on land cover, decreased biomass, and vegetation productivity, as indicated by a decrease in NDVI, AGB, and NPP, as well as a temporary decrease in CO emissions. In 2024, there were signs of environmental recovery, especially in terms of dense vegetation (NDVI class 4) and maximum AGB. However, this recovery has not yet fully returned the ecosystem to pre-development conditions, especially in terms of carbon productivity (NPP) and variations in carbon monoxide (CO) emissions.

Long-term impacts show that although transmigration development causes significant disruption to vegetation and ecosystems, recovery can occur gradually, although unevenly and depending on land management interventions. From the above ground biomass (AGB) data, it is known that the initial data in 2010 before transmigration development and the data in 2024 showed an average increase in carbon stocks of 1.495 tons/ha or 0.1495 kg/m2. But if seen from 2012, at the time of transmigration development, until 2024, on average there was a decrease in carbon reserves of 27.133 tons/ha or 2.7133 kg/m2. From carbon monoxide (CO) data, on average, it is known that there was a decrease in carbon emissions from 2010-2024 of 0.000074694 kg/m2. From net primary productivity (NPP) data, there was a decrease from 2010-2024 of 0.196463728 kgC/m2. From this it can be concluded that the development of transmigration UPT.Waleh SP.2, can reduce carbon emissions by 29.0969 tons/ha or 2.90969 kg/m2.

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