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Geographical and Ethical Integration in Climate Change Mitigation: A Case Study of Agricultural Land in Lembang, West Java

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Abstract: Climate change has become a real threat to sustainable living, driven by rising greenhouse gas (GHG) emissions from human activities, including agriculture. This study aims to estimate GHG emissions in the agricultural sector in Lembang subdistrict, an area with high agricultural cultivation intensity, and formulate mitigation strategies through an Islamic ethical approach. The study uses a descriptive-qualitative method, focusing on GHG emissions from the use of inorganic fertilizers and soil cultivation. Estimates of agricultural land area and distribution in each village were analyzed using QGIS. The estimation calculations refer to the Tier-1 method of the 2006 IPCC (Intergovernmental Panel on Climate Change) and the 2012 Ministry of Environment's National Greenhouse Gas Inventory Guidelines. Input data for mitigation strategies was obtained through interviews with farmers associated with the Walungan Foundation in Suntenjaya village. Based on the results of the calculation, GHG emissions in the Lembang subdistrict were estimated at 2,404.46 tons of CO2e per year, arising from the main agricultural commodities: tomatoes, cayenne pepper, and curly peppers. The highest estimated GHG emissions were from the villages of Suntenjaya, Cikidang, and Pagerwangi, which also had more extensive field/farmland than other villages. Based on these findings, a mitigation strategy was formulated by reducing fertilizer use in agriculture. Based on these findings, a mitigation strategy was formulated by reducing agricultural processes in terms of excessive urea fertilizer use, reducing intensive soil cultivation, and, from an ethical perspective, providing assistance and guidance to farmers with a spiritual and environmental awareness approach to maintaining the balance of nature.

Keywords: Climate Change Mitigation, Greenhouse Gas Emissions, Islamic Ethics, Soil Management, QGIS

Introduction

Excessive greenhouse gas emissions are the main cause of climate change. These greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). The increase in greenhouse gases causes global warming in altering the composition of gases in the atmosphere, so that the sun's heat energy that should be released into space is reflected to Earth (Sondakh et al., 2023). Various human activities, including agricultural, industrial, energy, and other sectors, can increase GHG emissions. According to Sondakh et al. (2023), although GHG emissions from the agricultural sector are lower than those from the energy sector, their potential to drive global warming remains substantial, necessitating serious management and reduction efforts. Artiningrum & Artifiani (2024) note that the agricultural sector contributed about 8% of total national GHG emissions in 2018, and could reach up to 24% in developing countries. Agricultural cultivation, livestock farming, and land cover changes in developing countries, including Indonesia, can increase GHG emissions and exacerbate the impacts of climate change.

Climate change can be viewed in the context of Islamic ethics. Based on the interpretation of Surah Ar-Rum verse 41, it does not directly explain the threat of climate change. However, it is seen as one of the phenomena of environmental damage caused by immoral acts and deviations from norms and ethics. This verse is in line with the understanding that excessive human activity can be a major factor driving climate change (Azmy, 2024). Muslims need to view climate change as a result of humans' failure to fully fulfill their role as caliphs in maintaining the balance of nature. According to Koehrsen (2021), Muslims should respond to climate change as an effort to restore balance to nature through the interpretation of Islamic teachings and various environmental initiatives. This approach is based on Islamic principles such as Tawhid (the oneness of God), Mizan (balance), and Khalifa (humans as caliphs on earth), which are manifested through environmental conservation actions.

Through the scientific context of geography, climate change becomes a relevant object because it concerns the interaction between humans and the environment. Haggett (1983) states that geography is an integrative discipline that combines physical and social aspects in the study of humans, places, and the environment. Thus, an environmental approach in geography is highly relevant in analyzing the impact of human activities on climate change. Over time, one branch of geography, namely geographic information systems (GIS), has become a key technological tool for researching climate change using spatial principles.

Analysis and estimation of greenhouse gas emissions are crucial as a basis for policy formulation and regional and spatial planning, because the quantification of emissions, whether based on territory or consumption, is recognized as providing a more comprehensive understanding of emission patterns and supporting local decision-making in assessing the impact of spatial policies (Lylykangkas et al., 2023). Through GIS, detailed analysis and mapping of GHG emissions distribution can be carried out. Several studies have shown that spatial characteristics in GIS can help stakeholders manage carbon emissions using spatial-based methods, while increasing carbon sequestration potential at the micro- to medium-scale (Hasanah & Wu, 2023). For this reason, the issues of climate change, Islamic ethical approaches, and GIS technology can be combined into a new approach in formulating climate change mitigation strategies based on GHG estimates.

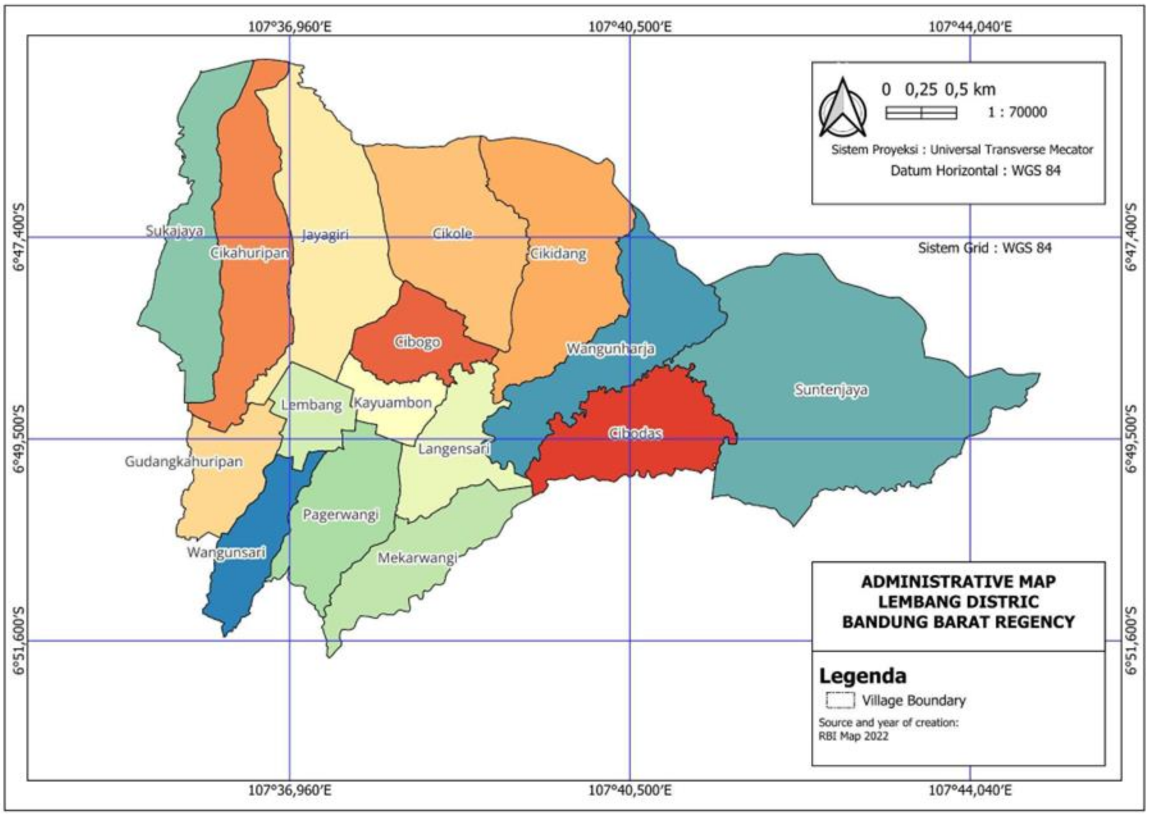

Figure 1. Administrative Map of Villages in Lembang Subsubdistrict in 2022
Source: Author, 2025

Lembang is one of the sub-subdistricts in West Bandung Regency, geographically located in the northern part of Bandung City. It has hilly terrain and is located in a climate zone that supports this area becoming a leading region in horticultural production, especially vegetables, fruits, and other seasonal crops. As food demand increases, the intensity of agricultural activities in this region continues to rise and has the potential to grow uncontrollably. Uncontrolled agricultural practices, such as excessive use of nitrogen fertilizers (urea), intensive soil cultivation, and biomass burning, can increase greenhouse gas (GHG) emissions, which cumulatively contribute to global climate change.

Based on this background, multidisciplinary research with a geographical and ethical approach is needed in the Lembang sub-subdistrict, serving as a representative case study location for GHG emission estimates in the agricultural sector. This area was chosen because it has a high proportion of agricultural land cover, enabling a comprehensive spatial analysis of GHG emissions. This study aims to map the distribution of estimated agricultural-sector GHG emissions in the Lembang subsubdistrict and formulate recommendations for climate change mitigation strategies using a GIS and an ethical approach. It is recommended that this research serve as the basis for spatial planning and development in the West Bandung Regency.

Methods

A. Research Design

This research was conducted in the Lembang sub-subdistrict, West Bandung regency, West Java province, which comprises 16 villages and has a total area of approximately 98 km². Lembang has a population of 191,644, with most of the community working as farmers (BPS, 2024).

Agricultural land-cover data were obtained from the website tanahair.indonesia.go.id in 2022. Agricultural land cover was analyzed in QGIS to produce a detailed map of emissions. Emission factors were based on Tier-1 of the IPCC. Meanwhile, information on agricultural practices was collected from structured interviews with representatives of the Walungan Foundation farmer group in Suntenjaya Village. Literature study of Islamic ethics in dealing with climate change.

Table 1. Data Types and Data Sources

Data Type	Data Source
RBI Map of Lembang Subdistrict	Portal Tanah Air
Agricultural Land Area in Lembang	RBI Analysis with QGIS
Leading Horticultural Commodities	Central Bureau of Statistics (BPS)
Fertilizer Usage	Interviews with Lembang Farmers and Ministry of Agriculture Recommendations
Land Cultivation	Interviews with Lembang Farmers
Local Mitigation Efforts	Interviews with Lembang Farmers

Spatial data derived from the Indonesian Topographic Map (RBI) were analyzed in QGIS and then visualized at a 1:100.000 scale. Literature data on the Islamic ethical perspective on climate change mitigation efforts were analyzed from various recent research sources.

B. Analysis Method

1. Spatial Analysis of GHG Emissions in Lembang Subsubdistrict

Spatial analysis of GHG emissions was conducted in stages, starting with the administrative map of Lembang Subsubdistrict, land cover maps and agricultural land cover as the basis for calculating GHG emissions. The second stage involved calculating estimated GHG emissions using emission factors in the IPCC Tier-1 standard. The analysis method is described in detail as follows:

2. Spatial Analysis of Land Cover

Determining the area of cropland in the Lembang subsubdistrict in stages, starting with land cover analysis, followed by agricultural land cover analysis. Specifically, the results of the agricultural land cover analysis are distributed based on village administrative boundaries and calculate the area in each village. The area of cropland in each village is the basis for calculating GHG emissions, especially in determining the amount of urea fertilizer used in agricultural activities.

3. Calculation of CO_2 Emissions from Fertilizer Use

The GHG calculation method follows the Tier-1 IPCC guidelines, which use emission factors. The formula for calculating CO_2 emissions from fertilizer use is as follows:

$$CO_2\text{-Emission} = (M_{Urea} \times EF_{Urea})$$

Where:

CO_2 Emission = annual C emissions from Urea application, tons of CO_2 per year

M_{Urea} = Amount of Urea fertilizer applied, tons per year

EF_{Urea} = IPCC default Urea emission factor 0.2 tons of C per ton of Urea

According to KLH (2012), the use of urea fertilizer in agricultural cultivation releases CO_2 that was bound during the fertilizer's manufacture. Urea ($CO(NH_2)_2$) is converted into ammonium (NH_4^+), hydroxyl ions (OH^-), and bicarbonate (HCO_3^-) in the presence of water and the enzyme urease. Similar to the reaction of soil when lime is added, the bicarbonate formed then decomposes into CO_2 and water. CO_2 emission data were calculated from fertilizer use for three main horticultural commodities in Lembang. According to Tinaprilla (2008), the leading commodity in Lembang is red chili, which is financially beneficial to farmers. This is also mentioned in BPS (2024), which states that the three main commodities with the highest harvest area in Lembang, as mentioned in BPS data (2023), are tomatoes, cayenne pepper, and curly chili.

Table 2. Harvested Area of Vegetable Crops in Lembang Subdistrict, 2023

Crop Type	Harvested Area (ha)	% of Total Area
Tomato	110	33.9%
Bird’s Eye Chili	116	35.6%
Curly Chili	99	39.5%

Source: BPS (2024)

The use of urea fertilizer based on national recommendations for these three leading commodities is detailed as follows:

Table 3. Urea Fertilizer Recommendations

Crop Type	Urea (kg/ha)
Tomato	200
Bird's Eye Chili	200 – 300
Curly Chili	250 (Recommended)

The data in **Table 3** above are corroborated by interview results, which show that most farmers in Lembang use fertilizer doses that exceed national recommendations, so the maximum recommendation is used in calculate CO2 emissions from urea fertilizer use.

4. Calculation of Direct N_2O Emissions from Managed Soil

The process of converting land into agricultural soil causes N_2O emissions in the soil. According to KLH (2012), an increase in soil-available N in the soil increases nitrification and denitrification, which produce N_2O. The following is the formula for calculating direct N_2O emissions from soil management.

$$N_2O\text{-}_{Direct} = N_2O\text{-}N_{\ N\ input} + N_2O\text{-}N_{\ OS} + N_2O\text{-}N_{\ PRP})$$

explanation:

$N_2O–N_{\ N\ input}$ = **$\{[(F_{syn} + F_{cow} + F_{residue}) \times EF_1] + [(F_{sym} + F_{cow} + F_{wood}) \times EF_{1FS}]\}$**

$N_2O–N_{\ OS}$ = **$\{(F_{OS,CG,Temp}\ x\ EF_{2CG,Temp}) + (F_{OS,CG.Trop}\ x\ EF_{OS,F,Temp,NR}\ x\ ) + (F_{OS,F,Temp,NR}\ x\ E_{2F,Temp,NR}) + (F_{OS,G,Temp,NP}\ x\ EF_{2F,Temp,NP}) + (F_{OS,F,Trop}\ x\ E_{F2F,Trop})\}$**

$N_2O–N_{FPR}$ = **$[(F_{FRP,CPP}\ x\ EF_{3PRP,CPP}) + (FPRP,SO\ x\ EF_{3PRP,SO})]$**

$N_2O\text{-}_{Direct}$ = Annual direct N_2O emissions from N inputs to managed soils, kg N_2O-N per year

$N_2O\text{-}N_{N\ Input}$ = Annual direct N_2O emissions from N inputs to managed soils, kg N_2O–N per year

$N_2O–N_{OS}$ = Annual direct N_2O emissions from organic soil management, kg N_2O–N per year

$N_2O–N_{PRP}$ = Annual direct N_2O emissions from urine or manure inputs to pastures or grazing lands, kg N_2O–N per year

F_{SN} = Annual amount of synthetic N fertilizer applied to soil, kg N per year

F_{ON} = Annual amount of manure, compost, urine, livestock manure, and other organic materials applied to the soil, kg N per year

F_{CR}	= Annual amount of crop residues (above and below ground), including crop residues that sequester N and are counted as additional N fertilizer, kg N per year
F_{SOM}	= Annual amount of N in mineralized soil, related to the loss of soil organic matter due to changes in land cover or land management, kg N per year
F_{PRP}	= Annual amount of N in urine and manure deposited on pastures or grazing lands, kg N per year (CPP: Cattle, Poultry, and Pigs, and SO: Sheep, and other livestock)
F_{OS}	= Area of managed/drained organic soil, ha (CG, F, Temp, Trop, NR and NO are abbreviations for Cropland and Grassland, Forest Land, Temperature, Tropical, Nutrient Rich and Nutrient Poor)
EF_1	= Emission factor for N_2O emissions from N inputs for dry land, kg N_2O–N per kg N input
EF_{1FR}	= Emission factor for N_2O emissions from N inputs for irrigated rice fields, kg N_2O–N per kg N input
EF_{1FR}	= Emission factor for direct N_2O emissions from managed organic matter (FS = Organic N input) for water-saturated soils, kg N_2O–N per kg N input
$EF_{2CG, F, Temp, Trop, R, P}$	= Emission factors for N_2O emissions from N inputs from managed/drained organic soils N inputs for irrigated rice fields, kg N_2O-N per (ha year); (CG, F, Temp, Trop, NR, and NO are abbreviations for Cropland and Grassland, Forest Land, Temperature, Tropical, Nutrient Rich, and Nutrient Poor)
EF_{3PRP}	= Emission factors for N_2O emissions from urine and manure deposited on pastures or grazing lands, kg N_2O-N per (kg N input); (CPP: cattle, poultry, and pigs; SO: sheep and other livestock)

Source: KLH (2020)

Based on the above formula, once the N_2O N emission value has been obtained, it must be converted e CO_2-e emissions by multiplying it by 44/28.

In this study, the source of nitrogen added to the land was assumed to be urea fertilizer. The urea fertilizer dosage used was based on national recommendations and verified through interviews with farmers in Lembang.

Table 4. Amount N Synthesis from Urea Fertilizer

Plant Type	Urea (kg/ha)	N Content	Total N (kg/ha)
Tomato	200	46%	92
Bird's Eye Chili	300	46%	138
Curly Chili	250	46%	115

In this study, N_2O emission estimates consider only direct N_2O emissions.

5. **Spatial Analysis of GHG Emissions Distribution in Lembang Subsubdistrict**

Spatial analysis was conducted by first creating digital maps in QGIS using data from administrative boundary maps of villages in Lembang, then adding new fields based on GHG emission calculations for each village. The results of the analysis were used to identify which villages contributed significantly to GHG emissions and to recommend appropriate climate change mitigation strategies, taking ethical considerations into account.

Results and Discussion

Analysis of Carbon Emissions Distribution in Lembang Subdistrict

Spatial analysis using QGIS software on Indonesian Land Cover (RBI) data for 2022, taken from the portal https://tanahair.indonesia.go.id/. Data visualization standards for land cover maps studied by Wiweka et al. (2012), particularly for the categories of forest, village settlements, fields/farmland, and plantations.

Based on **Table 5**, the results of the land cover map analysis in Lembang subsubdistrict show that most of the area is dominated by forests, fields/farmlands, and village settlements.

Table 5. Analysis of land cover in the Lembang sub-subdistrict in 2022

Land Cover Category	Area (ha)	Percentage of Total Area
Forest	3,061	31%
Cropland	4,070	41%
Plantation	882	9%
Urban Area	1,164	12%
Grassland	809	8%

Land cover, such as fields/farmland, dominates 41% of the total land area in Lembang. This reinforces the fact that Lembang uses land intensively for agriculture. The second largest percentage of land area is forest, as most of the northern part of Lembang is covered by hills and mountains.

The visualization of the land cover map of Lembang sub-subdistrict can be seen in **Figure 2** below:

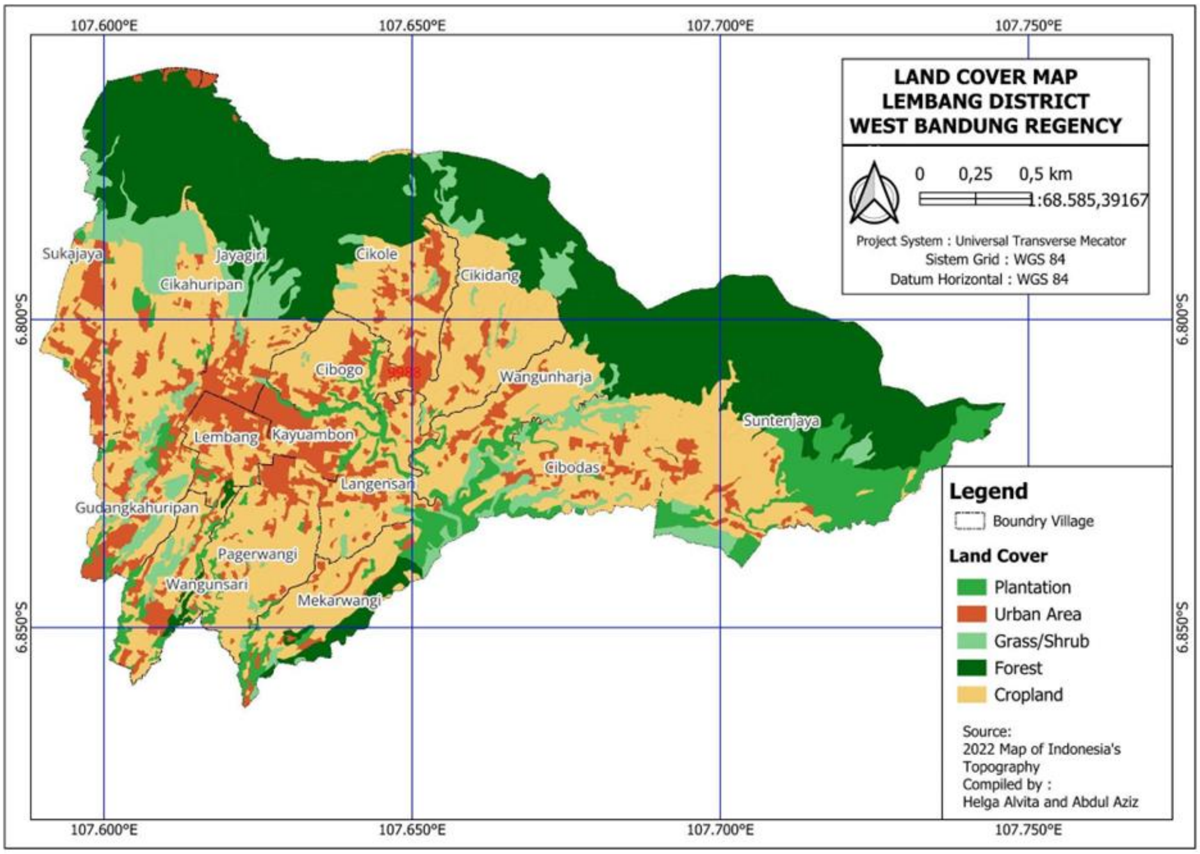

Figure 2. Map of Land Cover in Lembang Subdistrict in 2022
(Author, 2025)

The estimation of GHG emissions in this study is based on the area of land cover classified in fields/farmlands, using data on agricultural land potential that emits GHGs. According to Wiweka et al. (2012), fields/farmlands are dry-land areas that depend on rainwater irrigation, are planted with seasonal or annual crops, and are separated from the surrounding environment around houses and villages. Crops grown on dry fields are generally horticultural crops (ornamental plants and vegetables). Based on **Table 5**, the total area of dry field land cover is 4,070 hectares, or about 41.5% of the Lembang subsubdistrict.

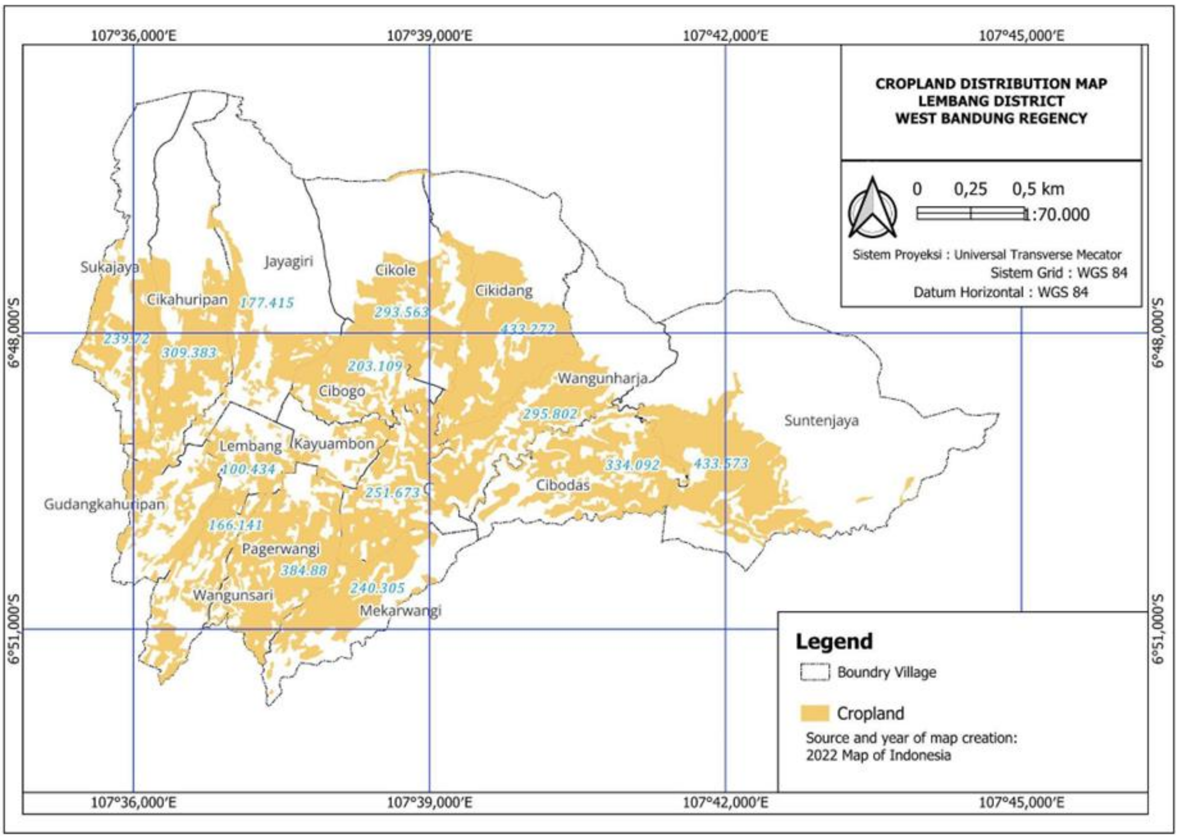

Figure 3. Map of Cropland Distribution in Lembang in 2022
(Author, 2025)

Most of the cropland is located in the southern part of the Lembang sub-subdistrict, because plantations and forests already cover the northern part. The villages with the largest agricultural areas are Suntenjaya, Cikidang, and Pagerwangi. Meanwhile, the smallest agricultural area is in the village of Lembang. According to Mustikaningrum et al. (2021), in a study on climate change inventory and mitigation in Tuban subdistrict, the larger the agricultural land area, the greater the potential for GHG emissions.

Estimated GHG emissions from the agricultural sector in the Lembang subdistrict

Based on the results of spatial analysis, the total area of Cropland is 4,070 ha. Then, the proportion of the planted area of the three commodities based on **Table 6** is as follows:

Table 6. Planting Area of land cover in Lembang in 2022 processed through QGIS

Town	Field Area (ha)*			
	Tomato	Bird's Eye Chili	Curly Chili	Total
Cibodas	113,08	119,25	101,77	334,092
Cibogo	68,74	72,49	61,87	203,109
Cikahuripan	104,71	110,43	94,24	309,383
Cikidang	146,65	154,64	131,98	433,272
Cikole	99,36	104,78	89,42	293,563

Town	Field Area (ha)*			
	Tomato	Bird's Eye Chili	Curly Chili	Total
Gudangkahuripan	50,09	52,83	45,09	148,003
Jayagiri	60,05	63,32	54,04	177,415
Kayuambon	19,95	21,04	17,96	58,947
Langensari	85,18	89,83	76,66	251,673
Lembang	33,99	35,85	30,59	100,434
Mekarwangi	81,4	85,84	73,02	240.505
Pagerwangi	130,27	137,37	117,24	384,88
Sukajaya	81,14	85,56	73,02	239,72
Suntenjaya	146,75	154,75	132,07	433,573
Wangunharja	100,12	105,58	90,11	295,802
Wangunsari	56,23	59,3	50,61	166,141
Total	**1377,71**	**1452,86**	**1239,94**	**4070,51**

Source:

*Table 1: Harvest area of leading commodities in Lembang

**Results of spatial analysis of RBI data for West Bandung Regency 2022

After obtaining the total area of land for each commodity in each village, a more detailed estimate of GHG emissions was calculated as follows:

Table 7. Calculation of GHG Emissions in Lembang Subdistrict

Town	GHG Estimation (tons CO_2 per year)		
	CO2 Emissions from Application of Urea	Direct N2O Emissions from Soil Management	GHG Emissions Total
Cibodas	16,77	180,58	197,35
Cibogo	10,19	109,78	119,98
Cikahuripan	15,53	167,23	182,75
Cikidang	21,74	234,19	255,93
Cikole	14,73	158,68	173,41
Gudangkahuripan	7,43	80	87,43
Jayagiri	8,9	95,9	104,8
Kayuambon	2,96	31,86	34,82
Langensari	12,63	136,03	148,66
Lembang	5,04	54,29	59,33
Mekarwangi	12,07	130	142,07
Pagerwangi	19,32	208,03	227,35

Town	GHG Estimation (tons CO_2 per year)		
	CO2 Emissions from Application of Urea	Direct N2O Emissions from Soil Management	GHG Emissions Total
Sukajaya	12,03	129,57	141,6
Suntenjaya	21,76	234,35	256,11
Wangunharja	14,84	159,89	174,73
Wangunsari	8,34	89,8	98,14
Total	204,28	2200,18	2402,46

Based on **Table 7**, the estimated GHG emissions from the agricultural sector in Lembang are 2,404.46 tons of CO2e per year. N2O emissions contribute significantly to potential climate change because they are estimated to account for almost 90% of total GHG emissions. Conventional tillage increases CO_2 emissions through soil disturbance and decomposition of organic matter, while minimum tillage and no-till systems reduce CO_2 emissions and also reduce N_2O and CH_4 emissions.

Distribution of estimated GHG emissions from the agricultural sector in the Lembang subdistrict

Visually, estimated GHG emissions can be seen in **Figure 4**, which shows the correlation between the area of the village and the area of cropland used in relation to the estimated GHG emissions. The villages of Suntenjaya, Cikidang, and Pagerwangi are among the three largest areas in the Lembang sub-subdistrict, and, based on GHG emission calculations, they also have high GHG emissions.

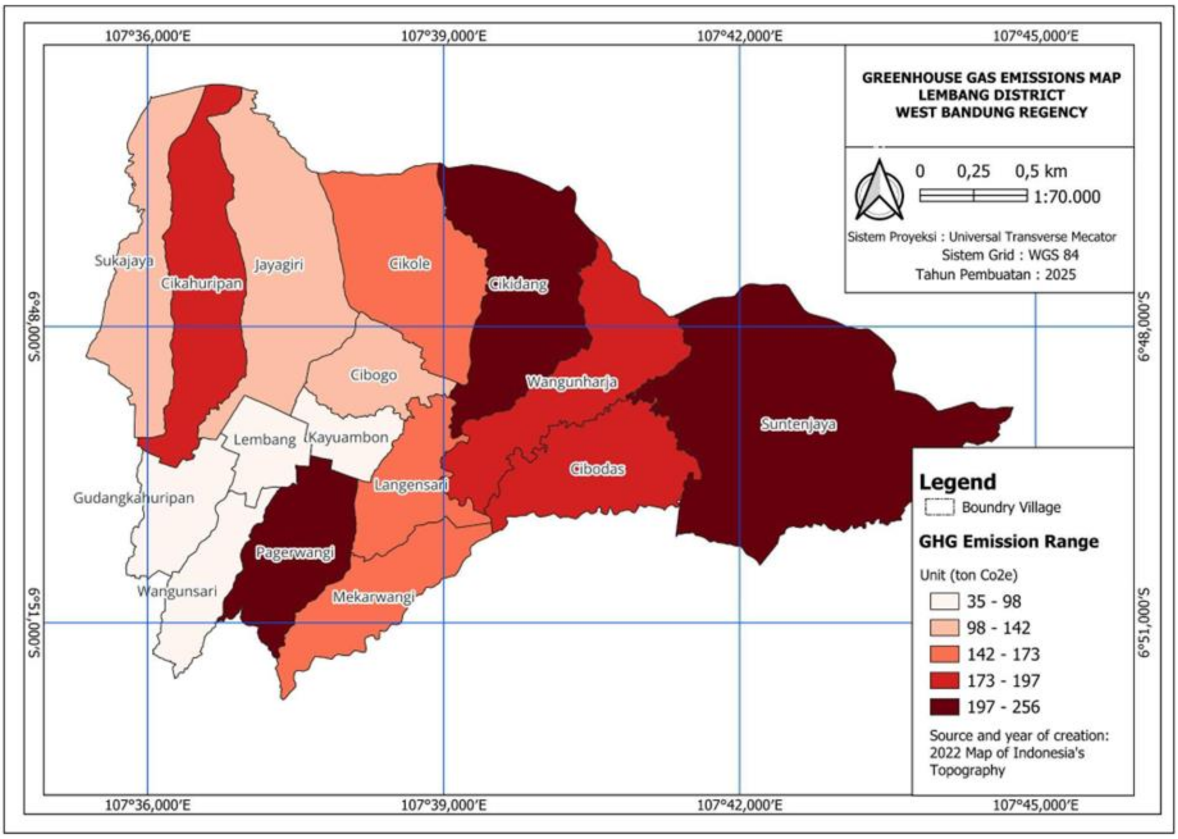

Figure 4. Map of Greenhouse Gas (GHG) Estimates for Lembang Subdistrict (Author, 2025)

Literature Study and Field Analysis: Climate Change Mitigation in Lembang Based on Ethics

Law No. 32 of 2009 emphasizes that increased global warming causes climate change that worsens environmental quality, thereby requiring environmental protection and management through the RPPLH, which covers the utilization of natural resources, environmental protection, and climate change adaptation and mitigation. This is in line with the 13th Sustainable Development Goal, which emphasizes strengthening resilience to climate disasters, integrating climate issues into policies, and improving education and mitigation capacity. Asta Cita point 8 also encourages harmony between the environment, culture, and religious tolerance to create a sustainable society. Meanwhile, from an Islamic perspective, the vision of rahmatan lil 'alamin (QS. Al-Anbiya: 107) and the responsibility as caliphs (QS. (Ar-Rum: 41) It becomes the moral foundation for Muslims to preserve nature as a form of universal love that unites spiritual, social, and ecological values. This is reinforced by Koehrsen (2021) in his research, who reports that Muslims respond to climate change an seek to balance nature through the interpretation of Islamic teachings and various environmental initiatives.

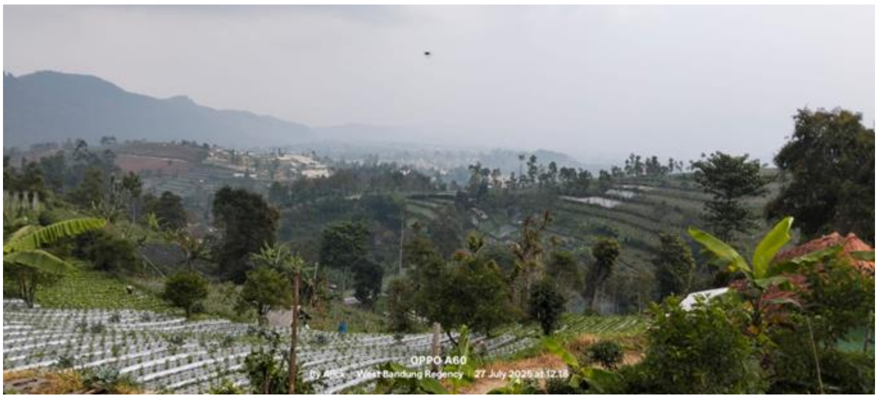

Figure 5. Overview of agricultural practices in Suntenjaya Lembang village, which carries out intensive soil cultivation and uses plastic mulch.

Looking at the results of the geographical analysis in the Lembang sub-district, most of the villages with the highest estimated GHG emissions are located in the easternmost (Suntenjaya village), northernmost (Cikidang village) and southernmost (Pagerwangi village) areas. After conducting a field survey in Suntenjaya village, it was found that farmers assisted by the Walungan Foundation have begun to take the initiative to practice environmentally friendly agricultural processes by avoiding the excessive use of synthetic fertilizers, using mulch from natural materials such as leaf litter, and implementing an intercropping system between seasonal vegetable crops and perennial crops that serve as a fence for agricultural areas. In addition, the foundation also regularly conducts outreach activities in the form of regular studies with segments of farmers' children, adult men, and farmers' wives. In our opinion, what the Walungan Foundation has done is in line with efforts to reduce GHG emissions. This is because the agricultural practices that are being implemented reduce the main factors that control emissions, namely synthetic fertilizers and excessive soil cultivation.

Based on literature reviews and interview results, several key factors can help reduce greenhouse gas (GHG) emissions from the agricultural sector. First, reducing the use of urea and synthetic nitrogen fertilizers is an important step, as Menegat et al. (2022) show that synthetic nitrogen-based fertilization contributes significantly to global emissions. Hence, fertilization optimization needs to be implemented immediately. Second, no-till and conservation tillage practices have been shown to reduce GHG emissions, with Wang et al. (2022) confirming that these systems increase soil carbon sequestration while reducing emissions from intensive tillage. Third, from an ethical and social perspective, assisting farmers with an environmental awareness approach is an equally important factor, as Lal (2024) explains that spiritual values and ecological ethics can strengthen farmers' commitment to maintaining the balance of nature. Thus, a combination of technical and ethical-spiritual approaches provides a more comprehensive mitigation strategy in addressing climate change in the agricultural sector.

Conclusion

The Lembang subdistrict, with its vast agricultural land covering 41% of the total subdistrict area, has the potential to contribute significantly to GHG emissions. Through Geographic Information System (GIS) analysis and GHG emission estimates, the Lembang subdistrict produces 2,404.46 tons of CO2 e per year from the agricultural sector. The villages of Suntenjaya, Cikidang, and Pagerwangi have the highest estimated GHG emissions. Therefore, efforts to reduce GHG emissions are needed, with recommendations including reducing agricultural practices such in excessive urea fertilizer use, reducing intensive soil cultivation, and, from an ethical perspective, providing assistance and guidance to farmers with a spiritual and environmental awareness approach to maintaining the balance of nature. This study has limitations in terms of the agricultural commodity data used to calculate greenhouse gas (GHG) emissions estimates. Lembang Subdistrict should have more than three agricultural commodities, but this study considers only three main commodities: tomatoes, cayenne pepper, and curly peppers. Furthermore, from an ethical analysis perspective, this study is limited because it relies solely on ethical data from one village in Lembang District. Further research should include other agricultural commodities, such as beans and potatoes, to make GHG estimation calculations more comprehensive. In addition, ethical analysis needs to be expanded by collecting data from more villages in Lembang Subdistrict to obtain more representative and in-depth information.

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