

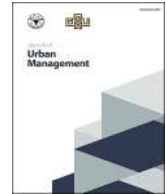
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Case Report

Carbon footprint assessment as a tool to support urban planning: A proposal for the territory of Sant'Anastasia municipality in Italy

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ABSTRACT

The increasing global awareness of climate change issues has led to the creation of numerous strategies to monitor and reduce emissions at local and international levels. At the present, cities have the chance to conduct their own local emission inventories, which enable them to formulate plans for air quality management integrated with the main territorial planning instruments. This study aims to provide a methodology for defining territorial strategies by applying the Intergovernmental Panel on Climate Change (IPCC) emission evaluation tool for the carbon footprint assessment of the municipality of Sant'Anastasia, in Italy. Using a comprehensive methodology, that combines results from the use of the IPCC Inventory Software and Geographic Information Systems (GIS), this research offers novel insights into the integration of urban land use analysis for the development of mitigation strategies within the framework of the Strategic Environmental Assessment (SEA).

1. Introduction

Climate change is emerging as one of the most serious global challenges of our time, calling for the development of skills and tools suitable for the high complexity of the phenomena associated with it. Among the determining agents of this process, urban areas emerge as the place where it is estimated that, by 2050, about 65–70 % of the world's population will live (UNDESA, 2019), and where over two-thirds of the world's energy is currently consumed, contributing to 70 % of global greenhouse gas emissions (Seto et al., 2014; IPCC, 2022). At the same time, cities are particularly vulnerable to the impacts of climate change, due to numerous factors, such as increasing urbanization and the complexity of the phenomena related to it. The consequences of this interaction between urban activities and climate change are multiple, including extreme weather events, sea-level rise, loss of biodiversity, and alterations in ecological balances (UNFCCC, 2015). This underlines that focusing on the mitigation of emissions linked to urban areas is crucial for proper territorial planning aimed at addressing one of the main factors of climate change. To this end, urban planning and the efficient use of its tools represent a fundamental step towards achieving municipal mitigation targets.

A growing number of cities (Kona et al., 2021), including the municipality of Sant'Anastasia in Italy, have voluntarily joined transnational networks active in climate action, such as the Covenant of Mayors. The Covenant of Mayors has gained significant traction among Italian mayors, achieving the highest number of signatory cities in Europe (Pietrapertosa et al., 2019). With its own council resolution no. 13 of May 11, 2011, the Municipality of Sant'Anastasia joined the Covenant of Mayors, and with council

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Abbreviations

[SEA]	Strategic Environmental Assessment
[GIS]	Geographic Information System
[IPCC]	Intergovernmental Panel on Climate Change
[COP]	Conference of the Parties
[GHG]	Greenhouse Gases
[LCA]	Life Cycle Assessment
[IOA]	Input-Output Approach
[SEAP]	Sustainable Energy Action Plan
[IPPU]	Industrial Processes and Product Use
[AFOLU]	Agriculture, Forestry and Other Land Use
[ISTAT]	Italian National Institute of Statistics
[CLC]	Corine Land Cover
[ISPRA]	Italian Institute for Environmental Protection and Research

resolution no. 17 of September 9, 2014, it adopted its own Sustainable Energy Action Plan. In 2017, the new Covenant of Mayors for Climate and Energy was established, committing to reduce CO₂ emissions by at least 40 % by 2030 and to adopt an integrated approach to address climate change mitigation and adaptation.

The aim of this study is to adopt, within the Strategic Environmental Assessment (SEA) procedure related to the Municipal Urban Plan, an innovative emissions calculation model for the municipality of Sant'Anastasia. For this purpose, the methodology proposed by the IPCC (Intergovernmental Panel on Climate Change) 2006 Guidelines was followed, including the updated Guidelines presented during the 28th Conference of the Parties (COP28), in Dubai by the IPCC Technical Committee. To do so, the designated IPCC Inventory Software was used, and the subsequent processing of the results with a Geographic Information System (GIS) allowed for the



Fig. 1. Location of Sant'Anastasia municipality in Italy and in the Campania Region.

creation of illustrative maps showing the spatial distribution of emissions for each key category in the municipal territory. This paper offers novel insights on the integration of an emission accounting and visualization procedure into strategic local environmental planning, as it was possible to evaluate the best mitigation strategies for the emission containment objectives of the municipality to integrate within the SEA procedure, defining policy recommendations for the Municipal Urban Plan.

This paper is structured in the following sections: Section 1 introduces the case study of Sant'Anastasia, providing a brief overview of current legislation for the study area, the theoretical framework and literature reviewed for the purpose of this study, including other local inventories taken as reference and the choice of the method employed in the research; Section 2 provides a description of the materials and methods used in the research, focusing on the methodology, software programs and data sources used for the evaluation of local emissions; Section 3 shows the results obtained from the use of the IPCC Inventory Software and spreadsheets, the evaluation matrix for municipal strategies and the spatial maps produced with the use of the Geographic Information System; Section 4 discusses the findings and their feasibility for integration into the Strategic Environmental Assessment; Section 5 concludes the study and suggests future research and planning implications.

1.1. Study area

The municipality of Sant'Anastasia is located in the Metropolitan City of Naples (Campania Region, Italy) and is partially included in the Vesuvius National Park (Fig. 1). Although the municipal area is not large (just under 19 km²) the territory is rather varied, extending as a strip of land from 34 m above sea level in the north up to 1131 m in the south. The territory is primarily urbanized, with a dense town centre. The urban pattern of Sant'Anastasia is represented by historical settlements connected to the infrastructural network by an upstream growth as well as by the urbanization of the valley area. With a population of 26,270 inhabitants, the municipality has a density of 1,400 inhabitants/km² (Fig. 2).

The economy of Sant'Anastasia is diverse, driven by a mix of small-scale commerce, agriculture, and light industry. There is also a growing service sector, particularly in retail, local services, and tourism due to its proximity to Vesuvius and Naples. Historically, agriculture played a significant role in the town's economy, and remnants of such activity are still present today: the volcanic soil supports vineyards, orchards (notably for apricots), and small-scale vegetable farming. Agricultural activities are mostly located on the outskirts of urbanized areas, while the majority of green areas are found on the slopes of Vesuvius National Park (Fig. 3).

In the municipality of Sant'Anastasia, there are no primary energy sources (oil, natural gas). Regarding energy production from secondary sources (oil derivatives), there are no energy transformation activities occurring within the municipal territory. As for power generation plants fuelled by renewable energy sources (wind farms, hydroelectric plants, photovoltaic and solar thermal systems), no

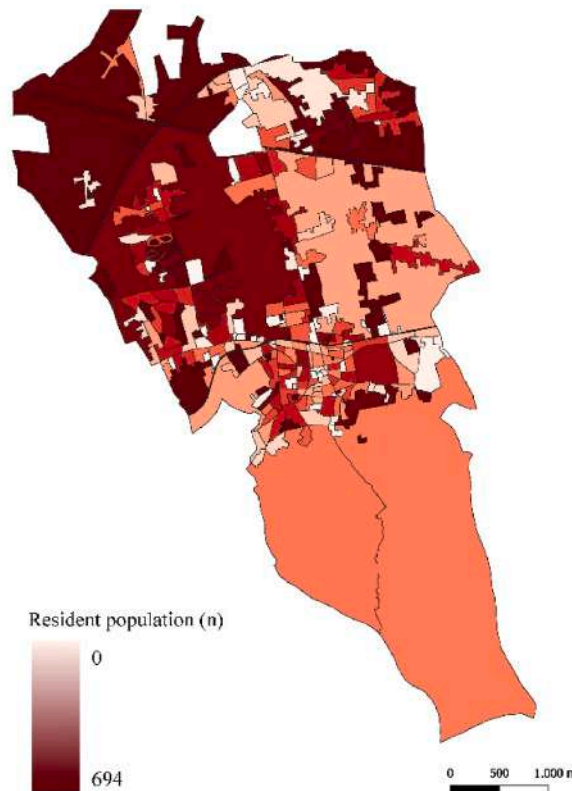


Fig. 2. Resident population distribution in census areas (ISTAT, 2011).

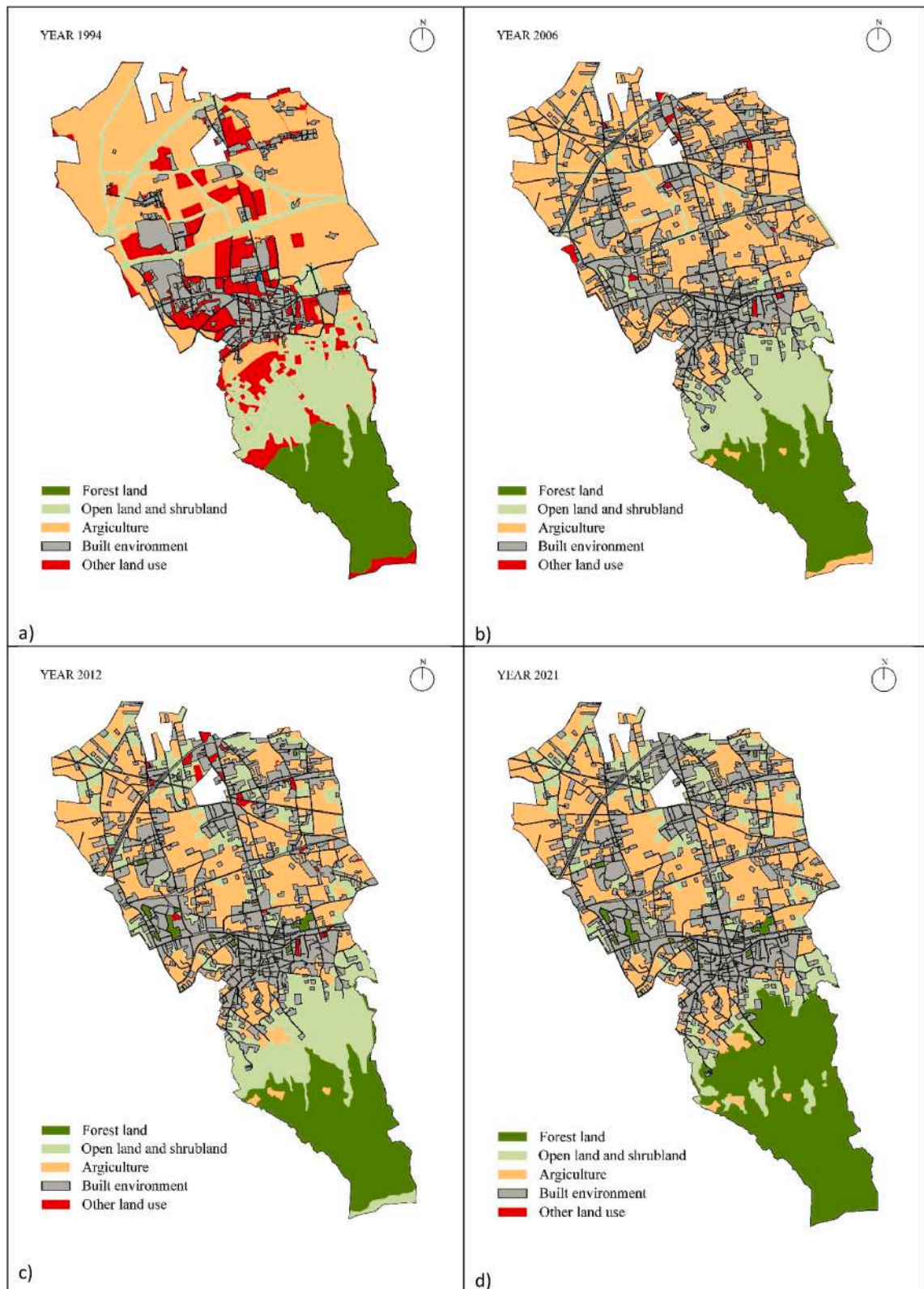


Fig. 3. Land use evolution through years: (a) 1994; (b) 2006; (c) 2012; (d) 2021.

such plants are present either. With regard to the energy sector, in 2014 the municipality of Sant'Anastasia joined the Covenant of Mayors, consequently developing its own Sustainable Energy Action Plan, which includes a local emissions inventory for the sector. The regulatory framework for carbon accounting in the municipality of Sant'Anastasia is governed by the Regional Plan for the Restoration and Maintenance of Air Quality, which identifies the municipality as a 'remediation area', where at least one pollutant exceeds both the limit and the tolerance margin set by the legislation. The municipality has recently been undergoing the process of Strategic Environmental Assessment (SEA), related to the municipal plan, which represents a major opportunity to study the integration of local inventories in such procedures, which is the main focus of the current study.

1.2. Theoretical framework

The main theoretical reference employed in carrying out a local inventory integrated into the SEA procedure in this study was the *European Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment*, which explicitly states the need to integrate Greenhouse Gases (GHG) accounting into environmental assessments for proper planning of mitigation measures. To achieve this goal, through the compilation of an inventory of local emissions, the prescriptions outlined in the IPCC 2006 Guidelines for conducting local inventories were followed, according to the 2019 Refinement.

A local emission inventory is a comprehensive record of the quantity of pollutants emitted from various sources within a specific geographic area, such as a city or region. The concept of carbon footprint was formulated on the basis of the ecological footprint (Ercin & Hoekstra, 2012), differentiating itself by the quantitative analysis of environmental impacts (Radu et al., 2013). In fact, although the ecological footprint includes an evaluation component of the carbon footprint, as an indicator of environmental sustainability, it still has limitations in the analysis of elements such as land use and the depletion of renewable resources, which are better expressed in local inventories using the carbon footprint indicator (Zhang et al., 2017).

According to the definition proposed by Wiedmann and Minx (2007), 'the carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product' (p. 14). Different carbon footprint assessment methodologies have been developed by a variety of international institutions and organizations, both private and public. The main carbon footprint calculation methodologies that emerged from a review of the literature are as follows: the IPCC methodology, a global reference for greenhouse gas quantification, mainly applied to national and local inventories; the Life Cycle Assessment (LCA), an analysis of the life cycle of a product or service that provide detailed information on emissions at every stage of the life cycle; and the Input-Output Approach (IOA), a top-down model that measures emissions resulting from exchanges between different entities.

In general, the main differences in the practical application of carbon footprint accounting methodologies lie in the definition of the boundaries of the system being analysed, in the allocation of emission sources, in the quality of the necessary data, and in the reporting and verification procedures for the results (Mirabella & Allacker, 2021). To categorize inventory approaches by complexity, three method tiers are identified (IPCC, 2006): Tier 1, Tier 2, and Tier 3. Tier 1 uses national activity data and default emission/removal factors from global databases, requiring minimal data and involving high uncertainty. Tier 2 also uses the basic Tier 1 structure but applies local data for better accuracy. Tier 3 includes advanced models and measurement systems, often using subnational and GIS-based data, offering the highest accuracy.

1.3. Choice of method

For the choice of method to conduct a local emissions inventory for the municipality of Sant'Anastasia, the initial focus was on recognizing the emission sectors commonly involved in municipal emissions. From the analysis of the previous local emissions inventory, included in the 2014 Sustainable Energy Action Plan (SEAP), it was noted that the only sector included in the document was that of Energy and Transportation. Therefore, with the purpose of integrating the previous inventory with the categories included in the IPCC methodology of Agriculture, Land Use and Waste, the main evaluation software taken into consideration were those capable of processing such categories independently of the other sectors. Other factors taken into account were their use worldwide and in Italy, focusing on their application in urban planning. This phase mostly involved distinguishing between local and national inventories, alongside assessing carbon footprint calculations aimed at developing local inventories rather than interregional models (Yang et al., 2018) and financing infrastructure projects (Fang et al., 2023). Internationally, the main methodology employed for local inventories differs in each country (Arioli et al., 2020), with the hybrid-LCA method being prevalent in the US (Ramaswami et al., 2008, 2012) while in South-Asia many regional models are developed autonomously within the national frameworks (Chen et al., 2016; Lin et al., 2017; Ramachandra & Shwetmala, 2012). In Europe, the IPCC method is the most used, particularly in conjunction with the development of local inventories for SEAPs (Heidrich et al., 2016; Harris et al., 2020). Focusing on the Italian context, three studies were taken as a reference, all employing the IPCC methodology (Lombardi et al., 2018; Pulselli et al., 2019; Marchi et al., 2023), or following simplified Tier 1 procedures (Sanna et al., 2014). Additionally, two studies were recognized for using the LCA methodology (Genta et al., 2022) or flow models (Marchi et al., 2012). Only a few of the Italian emissions inventories employed GIS for the spatialization of GHG emissions, in order to obtain a distribution model representative of the main emission sources in the territory (Asdrubali et al., 2013; Genta et al., 2022; Marchi et al., 2023). Nonetheless GIS is the most relevant tool for spatial visualization in Italy. Its relevance can be attributed to the widespread use of this software, given its compatibility, in municipal land use planning (Dell'Acqua & Verde, 2021; Verde et al., 2021; Roy et al., 2023).

Despite the main criticisms on the use of the carbon footprint or the IPCC methodology for the evaluation of local emissions (Hunt & Watkiss, 2011; Giampietro & Saltelli, 2014; Dahal & Niemelä, 2017; Lombardi et al., 2017), this methodological framework was

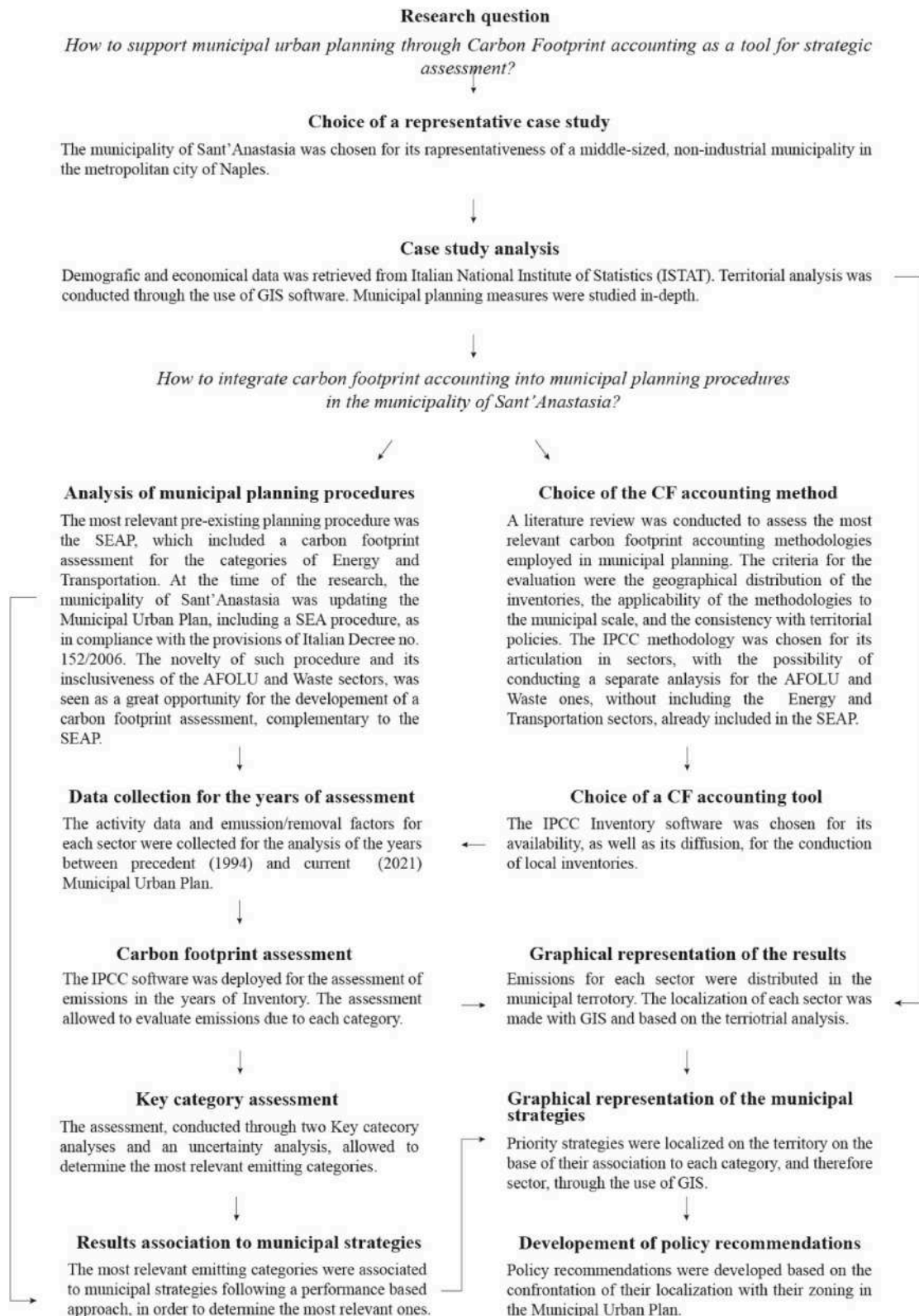


Fig. 4. Methodological flowchart.

chosen to conduct a local inventory for the municipality of Sant'Anastasia for its national representation and comprehensive approach for quantifying emissions from standard sectors, including Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) and Waste management, complementary that of Energy and Transportation. For the implementation of the Municipal Urban Plan, graphical representation was developed with the use of GIS.

The practical impossibility of employing other, more complex methodologies, such as the hybrid LCA or the IOA, stemmed from the amount of work and unavailable data necessary to carry out the evaluation, as well as the availability of an emission calculation software for the process. The use of these complex methodologies is mostly suited for detailed analyses (LCA), or for the implementation of flow models (IOA) (Lombardi et al., 2017), therefore these methodologies were considered poorly suited for sectoral integrations into the local inventory. For the municipality of Sant'Anastasia, a Tier 2 approach was applied, using the IPCC Inventory software. Emissions/removals for each sector were estimated by multiplying local activity data (AD) with emission (EF) or removal factors (RF). The emissions/removal factors represent average pollutant quantities per activity unit, based on technical sources and monitoring data (ISPRA, 2023), or on calculations made by software, such as the IPCC Inventory one.

2. Materials and methods

2.1. Methodology

The carbon footprint assessment for the municipality of Sant'Anastasia followed the methodology outlined in the methodological flowchart in Fig. 4.

For conducting the local emissions inventory of the municipality of Sant'Anastasia, multiple software programs were used, as in Italy there is no official tool for carbon footprint accounting in local planning. For the first phase of emissions calculation, the tool employed was the one provided by the IPCC and developed in 2006, in accordance with the IPCC Guidelines, presented in its latest updated version at COP28 in December 2023. The basic principle of this software for estimating CO₂ emissions or absorptions involves combining information on the extent of human activity (activity data) with coefficients that quantify emissions or absorptions per unit of activity. The values obtained from the use of the software were subjected to uncertainty analysis using the IPCC spreadsheet, attached to the 2019 Refinement, following the standard procedure reported in the document. The emission trend analysis was conducted for the key categories of Agriculture, Land Use and Waste sectors. Subsequently, following the *Approach 1* (IPCC, 2019), two Key category analyses were carried out using the IPCC Inventory software. The approach for the identification of key categories assesses their influence on the variation of carbon fluxes between natural and anthropogenic carbon stocks. When inventory estimates are available for several years, it is good practice to assess the contribution of each category both in reference to the base year and with regard to the evolution of the results over time. For the analysis of the key categories for the year 2021, the appropriate tool available in the IPCC Inventory Software was used. The formula used is as follows:

$$L_{x,t} = \frac{|E_{x,t}|}{\sum_i |E_{i,t}|}$$

where.

$L_{x,t}$ = Level identified for category or subcategory x in inventory year (t);

$|E_{x,t}|$ = Absolute value of estimated emissions or removals for category or subcategory x in year t;

$\sum_i |E_{i,t}|$ = Total contributions, i.e., the sum of absolute values of emissions and removals for all i categories (i = 1, ..., x, n) in year t.

The first assessment illustrated which category was the one mostly affected by changes in carbon stocks over time. To find a correspondence between the key categories and the municipal strategies, a second Key category assessment, evaluating the most impactful categories depending from Land Use changes introduced by the Municipal Urban Plan, was carried out for the year 2021. The formula used is as follows:

$$T_{x,t} = \frac{E_{x,t} - E_{x,0}}{\sum_i E_{i,t} - \sum_i E_{i,0}}$$

where.

$T_{x,t}$ = Trends of category or subcategory x in the inventory year (t), compared with the reference year (0);

$E_{x,t}$ and $E_{x,0}$ = Absolute value of estimated emissions or removals for category or subcategory x in year t and year 0;

$\sum_i E_{i,t} - \sum_i E_{i,0}$ = Difference between emission and removal values for all i categories (i = 1, ..., x, n) between year t and year 0.

The 'impact hierarchy' of the emission categories obtained in this way was used to develop an evaluation matrix of priority intervention areas, following a performance-based approach (De Toro et al., 2020). Such methodology aims at defining territorial strategies, assigned to each category according to their priority order, and located within the municipal territory.

For the localization of emissions in the municipal territory, the GIS was used to interpret the spatial distribution of emissions. Emissions due to energy consumption were represented in the form of an area, using for this purpose the 2011 census sections of the

Italian National Institute of Statistics (Italian acronym ISTAT) and the related data on the total resident population. The map includes the road transport network in linear form, for the localization of emissions due to wheeled vehicles. The same procedure was applied to the Waste sector, to obtain a distribution of the results provided by the IPCC software. For the AFOLU sector, the localization of emissions and removals was derived from the integration of Corine Land Cover (CLC) with the territorial mapping included in the Municipal Urban Plan. To do so, two different and successively overlapping estimates were made using GIS software: for the first one, the emissions from livestock farming were reported as positive contributions and distributed homogeneously in agricultural areas; for the second assessment, data on removals for each land use category (including agricultural land, obtained by difference with previously calculated emissions) were distributed equally in the reference territorial areas. The difference between emissions and removals in the agricultural sector was integrated with the results obtained from the IPCC software for the Land Use category, in order to draw a combined map for the AFOLU sector.

Finally, all three maps in vector format (Energy and Transportation, Agriculture, Forestry and Land Use, and Waste) were converted to raster format to proceed with the operations of Map Algebra. The raster format was obtained by dividing the analysed territory into cells (as pixels) of equal size (100×100 m), as in the reference study of [Marchi et al. \(2023\)](#). In the present study, an attempt was made to rasterize at higher resolutions, but at the municipal scale such trials exceeded the computing capacity of the software. The final output of the operations was a single map representing the spatial distribution of the GHG emissions balance of the municipality of Sant'Anastasia. The final results of this study are presented in Section 3. To obtain this map, the prioritized municipal strategies were located within the distribution areas of the corresponding emission categories and, subsequently, these locations were superimposed on the overall territorial distribution of emissions to highlight, also with respect to the latter, the spatial correspondence of the identified strategies.

2.2. Assumptions regarding the use of software and data for the current study

The IPCC software dedicated to carbon footprint assessment provides varying levels of detail, depending on the specificity of the data and the emission factors entered. With the purpose of developing a local inventory for the municipality of Sant'Anastasia, a comprehensive Tier 2 methodology was used, given the availability of local activity data and the lack of locally referenced emission factors.

Calculations regarding the Energy and Transportation sector were excluded, taking as reference for the subsequent phase of territorial mapping the results already provided by the 2014 Sustainable Energy Action Plan (SEAP). Furthermore, there are no relevant industries located in the municipality. For this reason, the Industrial Processes and Product Use (IPPU) sector was not included in the evaluation, nor were small-scale emissions due to commercial activities. The latter were already accounted for in the Energy and Transportation sector, included in the SEAP, nevertheless the localization of the artisanal/commercial activities was included in the territorial analysis. Beyond the results already available for the Energy and Transport category in the Sustainable Energy Action Plan, most of the data collection phase focused on the Agriculture, Forestry and Other Land Use (AFOLU) and Waste sectors. For these two categories, data were gathered from the 1990, 2000, 2010 and 2020 ISTAT agricultural censuses; the 1990, 2000, 2006, 2012 and 2018 CLC maps; forestry and waste management authorities ([Arma dei Carabinieri, 2015](#); [Regione Campania, 2016](#); [ISPRA, 2023](#)). With regard to the waste sector, there was no data available for the Campania Region before 2006; for this reason, the evaluation only covers the AFOLU sector in the years between 1994 and 2006, adding the Waste sector subsequently.

Each sector's data were analysed separately, employing specific emission factors and activity data to calculate its contribution to the overall carbon footprint. This assessment acknowledges certain limitations, particularly regarding data availability and the specificity of emission factors for the category of Agriculture. For this category, the emission factors were provided by the 2023 National Emission Report, produced by the Italian Institute for Environmental Protection and Research (Italian acronym ISPRA), both for emissions evaluation and for uncertainty analysis. The national emission factors were applied without being reconverted to local ones, due to the complexity of this conversion, also considering the minor discrepancy previously associated with the rescaling of these factors from the national to the local level in the case study of Sant'Anastasia, as observed in the Sustainable Energy Action Plan of 2014. In addition, it should be noted that, if the exact location of the farms by number of animals in the livestock subcategory had been known, the location of the emissions attributable to the agricultural sector could have been graphically represented in a more precise, punctual form, and not as an area. Unfortunately, these data were not available. Similarly, if data on emissions and removals were localized with respect to crop type, it would have been possible to obtain a more precise spatialization of the results in the combined AFOLU sector maps.

Regarding the Land Use category, assumptions were made to fill gaps during the software calculation of removal factors, as the estimation of carbon stock capacity for shrublands was based on their biomass, obtained by comparison with carbon density attributable to woodland.

For the Waste sector, activity data were retrieved from the regional database for the years from 2006 to 2014, while data from 2015 to 2021 were retrieved from ISPRA. Unfortunately, no data was available for the years from 1994 to 2005, therefore emissions calculation for these years is missing.

The software was used to allow administrations to have an effective territorial monitoring system while implementing the mandatory SEA procedures included in the Municipal Urban Plan, as required by the 2021 European Guidelines for integrating carbon footprint assessment into SEA procedures.

3. Results

The use of the IPCC methodology allowed the development of a systematic analysis of emission trends for the municipality of Sant'Anastasia, fully reported in [Appendix A](#), covering the years from 1994 (year of the previous Municipal Urban Plan) to 2021, when the Municipality of Sant'Anastasia started drafting the new Plan and the SEA procedure attached to it. [Figs. 5 and 6](#) describe the emission trends as obtained using the IPCC software, respectively for the Land Use Change and Waste categories.

Once the emissions for each category were obtained, the calculation section in the IPCC software and the dedicated spreadsheet were used to evaluate both the impact of each category over time and for the reference year 2021. [Table 1](#) shows data for the year 2021. To estimate the uncertainty of the inventory ([Table 2](#)), the IPCC spreadsheet was used, based on the prescriptions of the 2019 Refinement (see Paragraph 1.2).

The uncertainty assessment was carried out for the total inventory, evaluating the partial contributions of the AFOLU sector (derived from the aggregation of Agriculture, Forestry, and Other Land Use), and the Waste sector. The results show great uncertainty related to the latter, and a minor contribution to total uncertainty from the AFOLU sector. The uncertainty in the total inventory was also calculated, amounting to 19.8 % with reference to the year 2021 and 28.9 % for the entire period (1994–2021) considered in the emissions inventory. This indicates that in 2021 the overall relative error of the inventory is $\pm 19.8\%$ compared to the estimated value. Over the entire reference period, instead, it amounted to $\pm 28.9\%$.

[Table 3](#) reports the results of the first Key category analysis conducted over the entire reference period (1994–2021), to identify the sectors mainly involved in emissions changes over time.

The second Key category analysis, reported in [Table 4](#), allowed to determine the sub-categories with the highest impact on emissions, which are the following:

1. Manure management, aggregated with the 3rd resulting category of Enteric fermentation.
2. Cropland remaining cropland.
4. Forest land remaining forest land.

Based on the results obtained through the key category analysis and assessment, it was possible to determine an order of priority for the mitigation strategies of the municipality prescribed by the current municipal regulatory tools ([Table 5](#)).

Such strategies, following the order of priority determined by the Key category analyses, are meant to be applied in the municipal territory on the basis of the distribution and intensity of each emission sector. To do so, the emissions related to each category in the year 2021 were mapped separately and subsequently overlaid through the Map Algebra procedure (see Paragraph 2.1). However, for the AFOLU sector, this operation was not directly feasible, as it was first necessary to evaluate the difference between positive and negative contributions in the sector, as reported in [Fig. 7](#). The overall emissions localization for each sector is shown in [Fig. 8](#).

The localization of emissions in the municipality shows a higher concentration in the downtown area, where the population is more densely settled, and consequently emissions related to energy consumption and waste production are higher. In particular, the red area in [Fig. 8 \(d\)](#), showing the highest level of emissions, is the one that has undergone the highest urbanization in the past years, where shrublands were replaced by residential and/or agricultural areas. The second area with a higher production of climate-altering emissions is located in the north-west quadrant of the municipal territory, corresponding to areas where arable farming is more

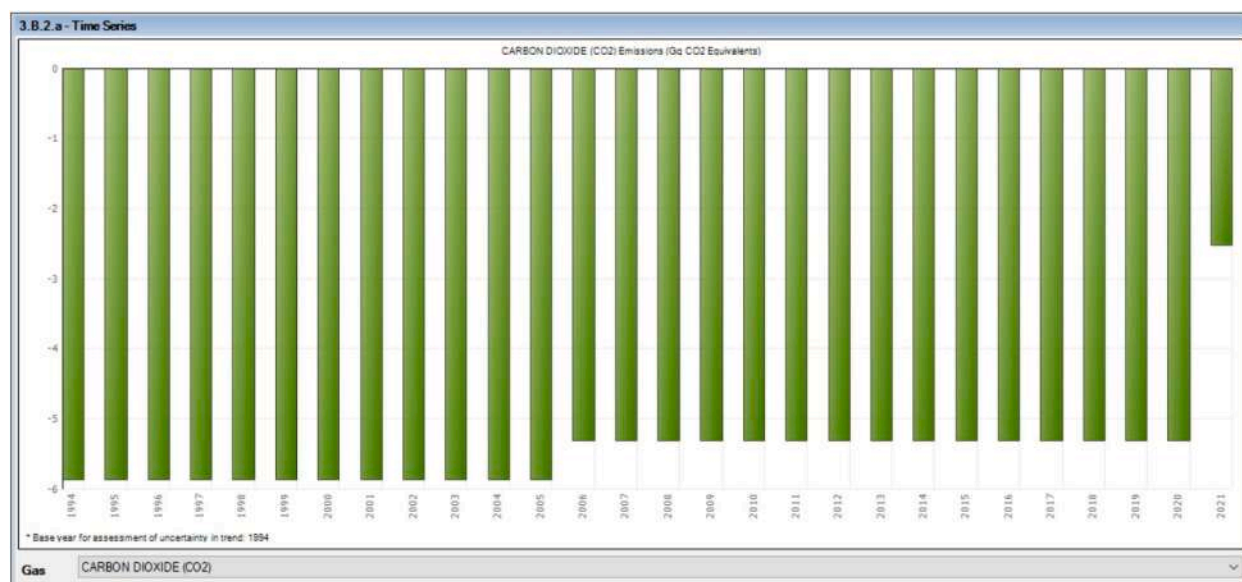


Fig. 5. CO₂ emission trend in the territory of Sant'Anastasia for the AFOLU sector.

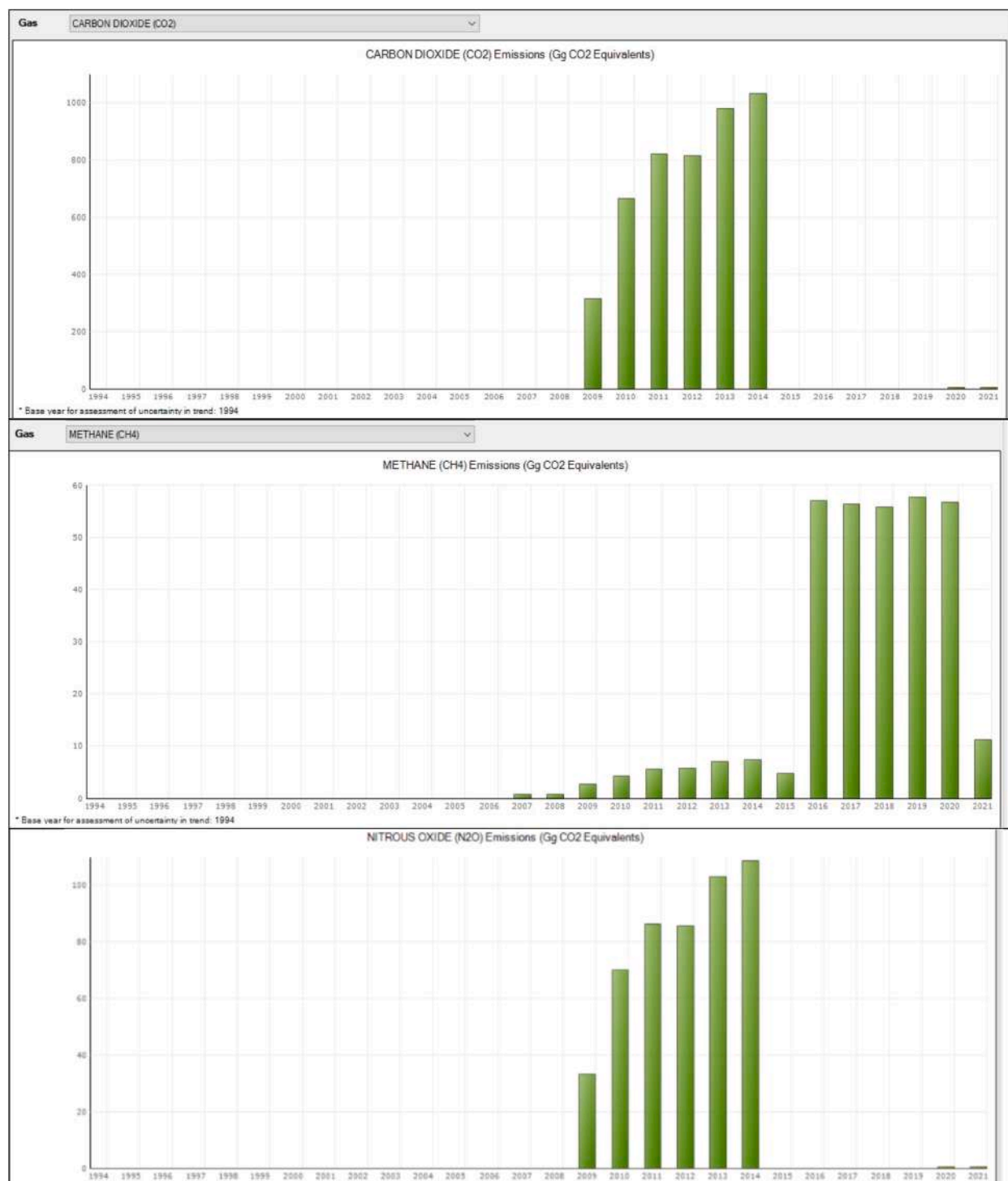


Fig. 6. CO₂, CH₄ and N₂O emission trend in the territory of Sant'Anastasia for the Waste sector.

prevalent and a similar process of urbanization has taken place, to complete the residential urban network. An interesting difference in carbon storage capacity can also be observed on the slopes of Mount Somma. The left side, which includes some agricultural production, shows a much lower carbon storage capacity compared to the adjacent forest area, highlighting the substantial differences in the contribution to removals provided by these two systems. On the other hand, the right side of the slope exhibits the highest storage capacity in the municipal area, although it is not sufficient to offset the emissions produced by the rest of the territory.

Table 1

Summary table of emissions for the Key categories of Agriculture, Forestry and Other Land Use and Waste, resulting from the difference between emissions and removals. Inventory year 2021.

Greenhouse gas source and sink categories	Net CO ₂ (Gg)	CH ₄ (Gg)	NO ₂ (Gg)
Total local emission and removals	3.3495	1.0319	39.3250
4. Agriculture	0	0.4987	0
4A. Enteric fermentation	n.a.	0.0670	n.a.
4B. Manure management	n.a.	0.4317	0
4C. Rice cultivation	n.a.	0	n.a.
4D. Agricultural soils	n.a.	0	0
4E. Prescribed burning of savannas	0	0	0
4F. Field burning of agricultural residuals	0	0	0
4G. Other	n.a.	n.a.	n.a.
5. Forestry and Other Land Use	-2.4358	0	0
5A. Changes in forestry and other woody biomass stocks	-2.5936	n.a.	n.a.
5B. Forest and grassland conversion	0.1578	0	0
5C. Abandonment of management land	0	n.a.	n.a.
5D. CO ₂ emissions and removals form soils	0	n.a.	n.a.
5E. Other	0	0	0
6. Waste	5.7853	0.5332	39.3250
6A. Solid waste disposal on land	n.a.	0.1070	n.a.
6B. Wastewater handling	n.a.	0.0221	0
6C. Waste incinerator	5.7853	0.0012	0.0020
6D. Other	0	0.4029	39.3230

Table 2

Uncertainty assessment, calculated on the emission factors retrieved from [ISPRA \(2023\)](#).

Sector	Emissions/removals in base year 1994 (Gg CO ₂ equivalent)	Emissions/removals in year 2021 (Gg CO ₂ equivalent)	Contribution to total uncertainty by sector in year 2021 (%)	Contribution to total trend uncertainty (1994–2021) by sector (%)
AFOLU	5673.06	4314.96	11.67	11.67
Waste	0.00	12,201.31	88.14	88.18
Sum	5673.06	16,526.27	99.81	99.85

Municipal strategies were localized within the municipal territory, based on their correlation with key categories, to produce a map showing the localization of priority strategies ([Fig. 9](#)).

4. Discussion

The emission localization process proved to be a useful tool for policymaking, as it allowed the visualization and comprehension of the distribution of CO₂ emissions across the municipality, aiding in the identification of hotspot locations. On the basis of the results, which are consistent with those evaluated at the national level by ISPRA, the municipality of Sant’Anastasia demonstrates to be a representative case study for a medium-sized, predominantly residential, and non-industrialized municipality within a metropolitan area. In light of this, the evidence from the present study can serve as a useful tool for evaluating the impact of urbanization on local emissions and removals, and consequently for the localization of municipal strategies.

The analysis of emissions localization made it a priority to employ strategies related to the categories of ‘Forest land remaining forest land,’ ‘Land converted to forest land,’ ‘Fires,’ and ‘Land converted to cropland,’ which proved to be strategic in the localization charts ([Fig. 8](#)), as well as through the evaluation matrix conducted within the SEA framework ([Table 5](#)). In particular, the results were used as a basis for the promulgation of the ban on further soil consumption in the Municipal Urban Plan.

4.1. Result analysis

The results obtained from the analysis of the AFOLU sector show a progressive increase in emissions for the municipality of Sant’Anastasia during the years 1994–2021. This can be mainly ascribed to the increase in soil consumption and changes in its intended use, which have seen over time the reduction of the green areas with the most significant production of woody biomass, that is uncultivated and Mediterranean scrub areas. In 2021, there was the greatest reduction in the storage capacity of green areas, mainly due to the conversion of agricultural areas from perennial cultivation in favour of annual herbaceous crops. However, as part of the 2021 Municipal Urban Plan, an increase in wooded areas of more than 900 ha is expected, which should fix the negative trend in the next years ([Fig. 5](#)). Such temporal assumption creates difficulties in obtaining positive outcomes from the evaluation of carbon storage capacity for the AFOLU sector, as the inclusion of even a significant variation in areas allocated for forest or agricultural use requires several years of modelling to achieve positive values, based on the actual carbon storage capacity of growing plants and, subsequently, in their mature phase. This limitation applies only to new plantations or conversions from one land use type to another that ensures

Table 3

Outcome of the analysis of emissions trends for the municipality of Sant'Anastasia, year 2021. This is the first Key category analysis, which allows for the individuation of trends over the chosen period (1994–2021).

A	B	C	D	E	F	G	H
IPCC Category code ^a	IPCC Category	Greenhouse gas	1994 Year Estimate Ext (Gg CO ₂ Eq)	2021 Year Estimate Ext (Gg CO ₂ Eq)	Trend Assessment (T _{xt})	Contribution to Trend (%)	Cumulative Total of Column G
3.A.2	Manure management	Methane (CH ₄)	10.358084	9.065425	1110.960203	0.424410	0.424410
4.B	Biological treatment of solid waste	Nitrous oxide (N ₂ O)	0	12190.142400	672.388527	0.256866	0.681277
3.B.2.a	Cropland remaining cropland	Carbon dioxide (CO ₂)	-5.866861	-2.515821	629.027166	0.240301	0.921579
3.A.1	Enteric fermentation	Methane (CH ₄)	1.846418	1.406056	198.049912	0.075659	0.997239
3.B.1.a	Forest land remaining forest land	Carbon dioxide (CO ₂)	-0.058247	-0.058247	6.246926	0.002386	0.999625
4.B	Biological treatment of solid waste	Methane (CH ₄)	0	8.461383	0.466716	0.000178	0.999803
4.C	Incineration and open burning of waste	Carbon dioxide (CO ₂)	0	5.785266	0.319105	0.000121	0.999925
4.A	Solid waste disposal	Methane (CH ₄)	0	2.246462	0.123911	4.73368E-05	0.999973
4.C	Incineration and open burning of waste	Nitrous oxide (N ₂ O)	0	0.607600	0.033514	1.28032E-05	0.999985
4.D	Wastewater treatment and discharge	Methane (CH ₄)	0	0.463960	0.025591	9.77643E-06	0.999995
3.B.2.b	Land converted to cropland	Carbon dioxide (CO ₂)	0	0.157757	0.008701	3.32422E-06	0.9999907
4.C	Incineration and open burning of waste	Methane (CH ₄)	0	0.024613	0.001357	5.18652E-07	0.9999959
3.B.1.b	Land converted to forest land	Carbon dioxide (CO ₂)	0	-0.019499	0.001075	4.1089E-07	1

^a The assessment does not include category 1 (Energy and transport).

Table 4

Outcome of the second Key category assessment, year 2021. This assessment does not consider years before 2021 but solely focuses on the categories associated to the strategies included in the Municipal Urban Plan.

A	B	C	D	E	F	G
IPCC Category code ¹	IPCC Category	Greenhouse gas	1994 E _{x,t} (Gg CO ₂ Eq)	E _{x,t} (Gg CO ₂ Eq)	L _{x,t}	Cumulative Total of Column F
3.A.2	Manure Management	Methane (CH ₄)	10.358084	10.358084	0.571335	0.571335
3.B.2.a	Cropland remaining cropland	Carbon dioxide (CO ₂)	-5.866861	5.866861	0.323607	0.894942
3.A.1	Enteric fermentation	Methane (CH ₄)	1.846419	1.846419	0.101846	0.996787
3.B.1.a	Forest land remaining forest land	Carbon dioxide (CO ₂)	-0.058247	0.058247	0.003214	1

greater CO₂ absorption, whereas for deforestation activities or, in general, interventions that cause a reduction in carbon storage potential, the effects are recorded immediately by the software. Hence the negative assessment of green planning works observable in Fig. 5. Therefore, the effects of these forecasts have not been considered in this study and are proposed as a possible future investigation.

With regard to the Waste sector, the analysis differentiated by emitted gases shows a discontinuity in the nature and extent of the emissions produced by the municipality, mostly depending on the waste disposal methodology and, secondly, on the quantity of waste.

In the context of the 'waste crisis' happened in the Campania Region (Capone et al., 2006) direct carbon dioxide were observed during the period 2009–2014, the only years of activity with quantities recorded for the regional incinerator (located in Acerra at about 10 km from Sant'Anastasia), and in the years 2020–2021, for which ISPRA data on the fractions disposed of by type of plant were available. Since 2016, there has been a significant reduction (–90 %) in carbon dioxide emissions, mostly due to the inefficiency of the previous way of disposal, and an increase in the production of methane. The increase in CH₄ emissions is mostly attributable to the degradation of waste disposed in landfills, which is not increasing but has not been fully digested yet, prolonging the release of methane from previous stockings.

Table 5

Correlation between key categories and synthesised mitigation strategies. The “X” marks indicate in which local plan, regulation, or model each policy is included.

No.	Key categories	Mitigation strategies	Resolution 1894/2005 ^a	Resolution 167/2006 ^b	RGPUW ^c	IPCC AR6 ^d
1	Manure management	Monitoring of the strategies used by farmers for the management of wastewater.	X	X		X
2	Biological treatment of solid waste	Emissions monitoring; sustainable reduction of waste generation and hazardousness.			X	
3	Cropland remaining cropland	Protection of traditional crops, in particular orchards, avoiding the replacement of perennial woody plants with annual herbaceous ones, which have a lower carbon storage capacity in biomass.	X	X		X
4	Enteric fermentation	Improving animal diets efforts for the reduction of methane emissions caused by belching.				X
5	Wastewater treatment and discharge	Sustainable reduction of waste production and hazardousness; methane recovery.			X	
6	Solid waste disposal					
7	Forest land remaining forest land	Protection, monitoring, enhancement and restoration of natural ecosystems; fire prevention and extinguishing; support for the use of bioenergy.	X	X		X
8	Land converted to forest land					
9	Fires	Maintenance of the existing infrastructure system aimed at silvicultural management, fire prevention and extinguishing.	X	X		
10	Land converted to cropland	Implementation of strategies for managing and monitoring agricultural systems, particularly about the use of fertilizers and in the management of livestock, in favour of the improvement of agricultural and food technologies; incentivizing the switch to sustainable diets.	X	X		X

^a Resolution of the Regional Board of Campania no. 1894, year 2005, on ‘Plan of the Vesuvius National Park’.

^b Resolution of the Regional Board of Campania no. 167, year 2006, on ‘Measures for the Air Quality Management’.

^c Regional General Plan of Urban Waste (2016).

^d IPCC Sixth Assessment Report (AR6) (2022).

4.2. Limitations of the study and suggestions for future research

The main critical issue related to the conduct of a study on carbon emissions in the municipality of Sant’Anastasia proved to be the lack of homogeneous and easily available data and emission factors for all sectors, as well as the lack of a standardized methodology at the national level, allowing administrations and experts in this field to effectively use carbon footprint assessment as a planning and monitoring tool.

To establish a mitigation strategy referred back to previous years and defined within the municipal boundaries, numerous data gaps were found, particularly in the energy and waste sectors, which hindered the definition of emission trends and the consequent definition of mitigation targets. For calculations in the agriculture sector, national emission factors were employed without local calibration, following a Tier 2 approach. The development of local-specific emission factors calls for further analysis. For the purposes of this study, a sensitivity analysis for the manure management sector was conducted, converting national (ISPRA, 2023) to standard (IPCC, 2019) emission factors. Such analysis showed no difference in the emissions related to manure management, while minor discrepancies, up to the 3rd percentile, were found in emissions from enteric fermentation of dairy cows. Overall, the use of a Tier 2 methodology proved robust enough for the purposes of the current study.

The SEA can be a useful tool for assessing the impacts due to the AFOLU sector, given the high availability of time-based data on land use change. In addition, with regard to the Energy and Transportation sector, the integration of the SEAP into the compilation of a local emissions inventory could provide a useful tool for the definition of mitigation strategies. Within the SEAP, a biennial update of this document is prescribed, which has never been carried out for the municipality of Sant’Anastasia. It would therefore be necessary to update the previous document and conduct a study on the effectiveness of the mitigation strategies proposed therein. In the context of this study, the evaluation of the Energy and Transportation sector was not updated, as the primary objective of this analysis was to evaluate the possibilities to integrate the SEA into pre-existing municipal provisions. In addition, the data collection phase and the conversion of emission factors related to this category are particularly complex, and it would not have been possible to carry out the SEAP update operation without a significant slowdown in the SEA process, mainly aimed at Land Use.

Using the IPCC software, it was only possible to partially assess the effects on emissions and removals of agricultural and livestock management strategies, land use and waste. The main critical issues related to the operability of the software arose in the land use sector, in particular with regard to the conversion of green areas into built-up areas, for which the software does not provide the possibility of compiling data yet. Therefore, the analysis of land use transformations for urban planning purposes is partial and does not account for those emissions that can be attributed to the use of means and materials for building construction. For a better understanding of such emissions the IPCC methodology could be integrated with LCA or other Tier 3 methodologies. Results obtained through the use of a Tier 2 methodology showed sufficient discrepancy to allow the identification of a priority order for the best local mitigation strategies. Nevertheless, a comparative study of the application of these methodologies at the local level might allow for the

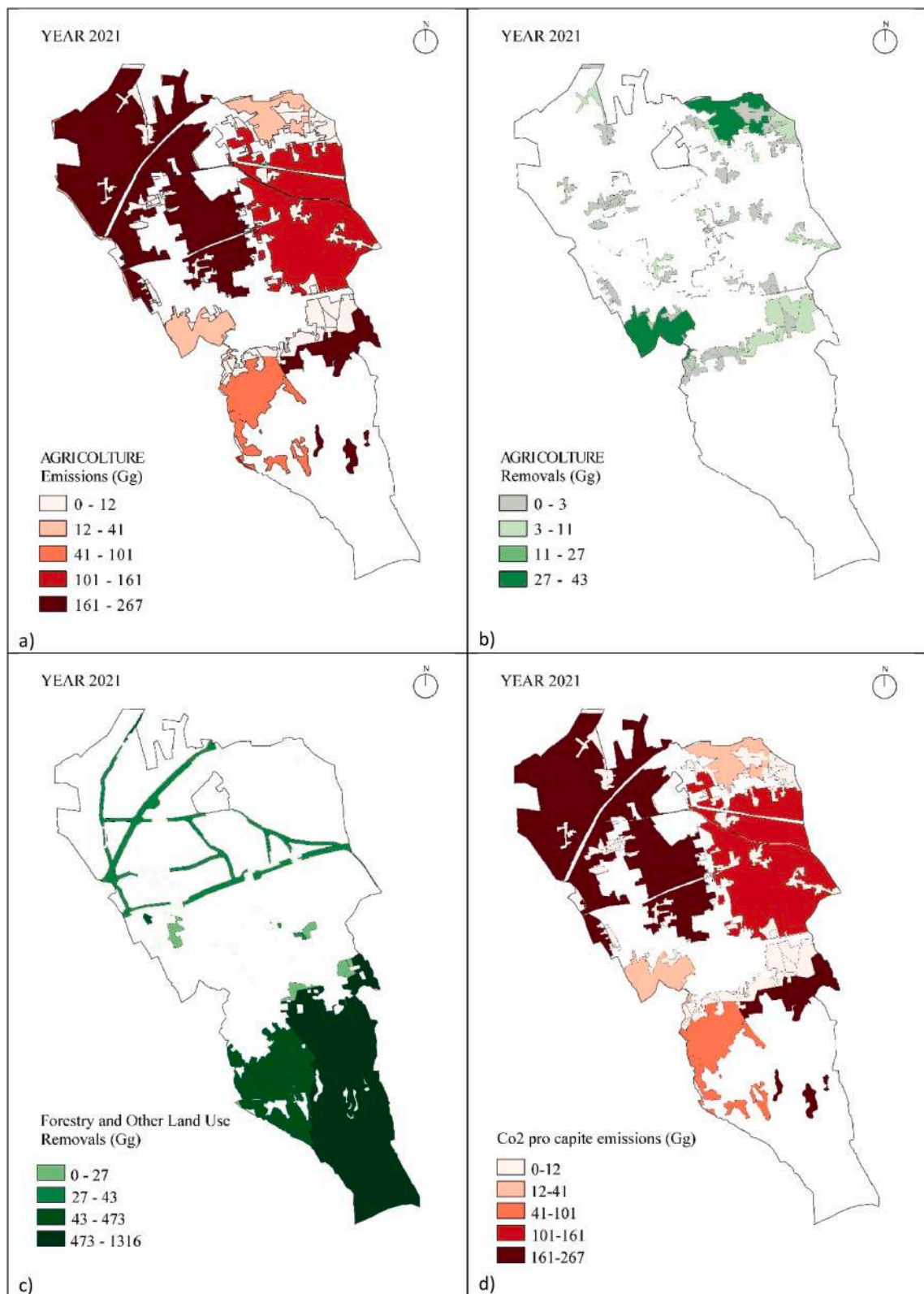


Fig. 7. Emissions localization for AFOLU sector: (a) CO₂ per capita emission for Agriculture; (b) CO₂ per capita removal for Agriculture; (c) CO₂ per capita removals for Land Use; (d) CO₂ per capita emission for AFOLU sector.

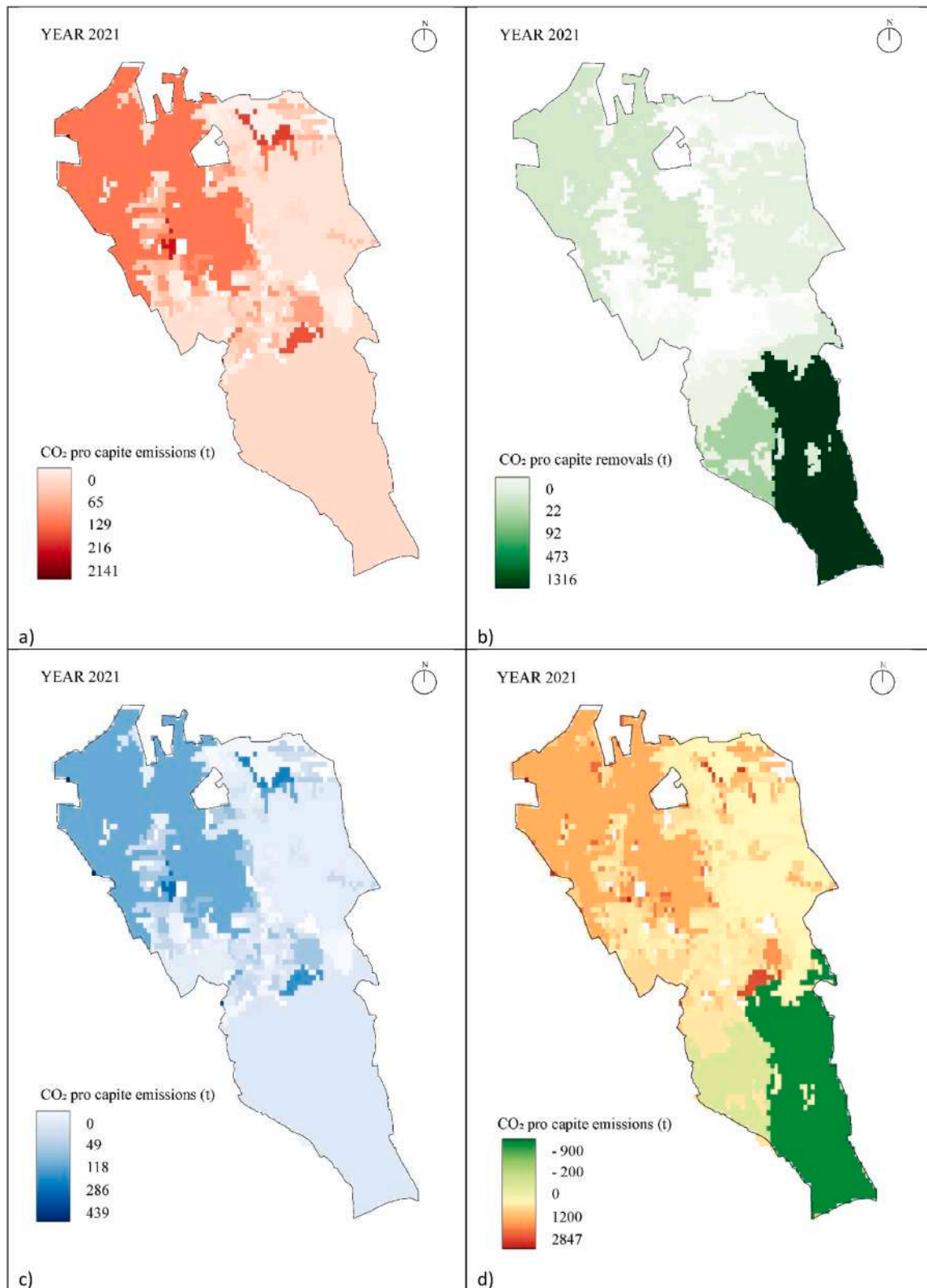


Fig. 8. Emissions localization for each sector: (a) CO₂ per capita emissions for Energy and Transportation; (b) CO₂ per capita removals for AFOLU sector; (c) CO₂ per capita removals for Waste sector; (d) cumulate CO₂ per capita emission.

YEAR 2021

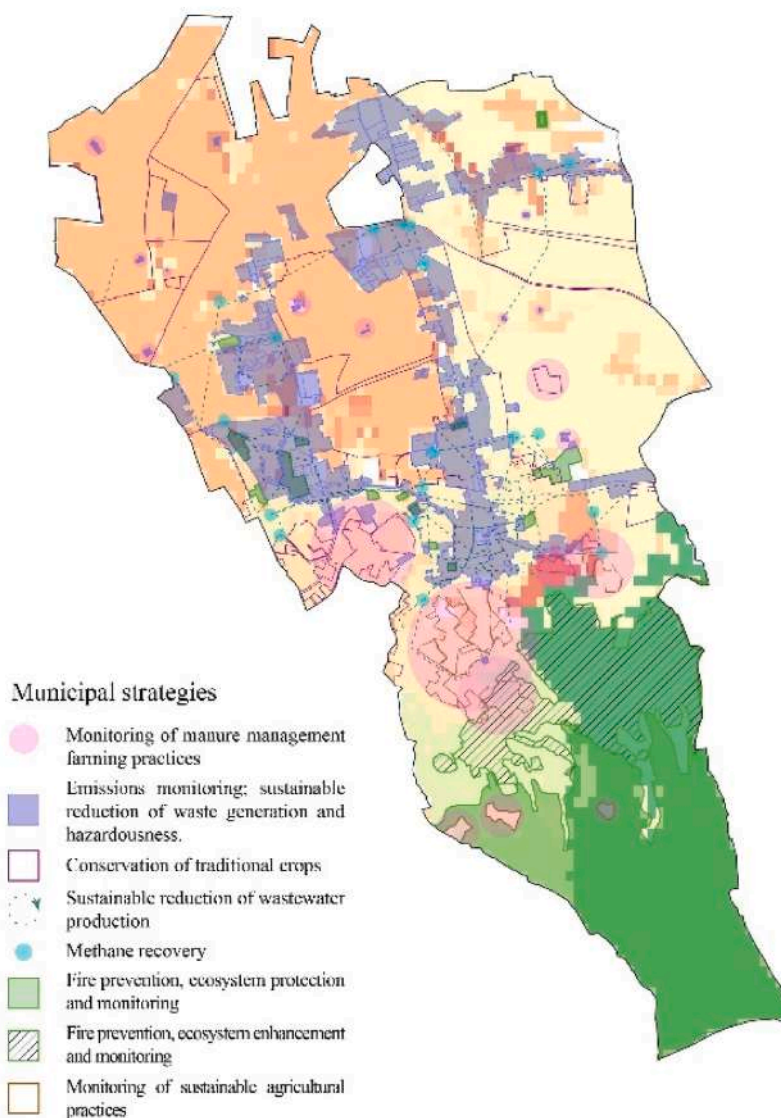


Fig. 9. Localization of municipal strategies.

determination of the uncertainty related to the use of a Tier 2 approach, compared to a more complex one.

Limitations of the current study are also acknowledged with regard to spatial analysis procedures, as the process of rasterization into pixels necessarily causes a standardization of parcels of territory included. Similarly, assuming homogeneous distributions for emissions due to livestock in agricultural areas has an impact on the accuracy of the location related strategies. Further analysis, also using GIS, could be developed (Infascelli et al., 2009). These strategies were illustrated in Fig. 9 within their buffer zone, with reduced accuracy. Future research in the sector might therefore be based on punctual data, using methods other than GIS, complementary to it as well (Roy et al., 2024), such as remote sensing (Rigillo et al., 2016) or high-resolution spatial models (Majumder et al., 2023). The use of these methodologies could be explored for a more detailed visualization of the results and consequently support more targeted mitigation strategies. Finally, it should be emphasized that the theoretical reference underpinning the present study was the *Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment*. Although the objective of integrating climate change mitigation strategies has been accomplished, further research could be undertaken regarding the possibilities of incorporating biodiversity protection within SEA.

5. Conclusions

The present study has allowed to understand the main sources of carbon dioxide emissions in the municipality of Sant'Anastasia, while providing a starting point for the designation of the best mitigation strategies in the implementation of the Municipal Urban Plan. Local level emissions accounting proved to be a useful tool, particularly if integrated into pre-existing or superordinate assessments, such as the regional emissions inventory. The methodology followed in this study can be replicated in other municipalities or general territorial analyses, even at a larger scale, given sufficient data and technical operativity.

Starting from an investigation of current legislation, environmental directives and tools, the experimentation conducted in the municipality began by integrating the most recent requirements of the academic and institutional world on carbon footprint assessment into the environmental assessments already carried out in the area. With the aim of developing a climate performance assessment, as indicated by the *Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment*, the complementarity of carbon footprint analysis for the AFOLU and Waste sectors with the prescriptions of the 2014 local SEAP emerged. The integration of this document with the compilation of a local emissions inventory provided results diversified by sector of intervention. Subsequently, using GIS, specific and cumulative emissions were represented in the municipal area. Through sensitivity, uncertainty and key category analyses, it was possible to prioritize emission categories in relation to which the most relevant strategic actions for mitigation could be identified.

Based on the results of this study, local policies should promote more advanced agricultural and manure management practices and monitoring, collecting precise data directly from local activities. For the Waste category, there is a need for more in-depth studies on the past and future destination of waste produced within the municipal limits, also for the purpose of determining extraterritorial impacts, which although already quantified in this study, cannot be recorded with respect to the precise destination of disposal. In addition, there is a need to rationalize the use of waste disposal plants that favour the emission of climate-altering gases alternative to carbon dioxide, as there is a risk of interpreting zero CO₂ emissions as an advantage, without taking into account the fact that the Global Warming Potential (GWP) of other gases such as methane and nitrogen peroxide is much higher than that of carbon dioxide (IPCC, 2014). With regard to forest fires, preventive measures should be implemented, mainly consisting of frequent, non-aggressive pruning and wood waste removal.

A final consideration concerns the standardization of methodologies for conducting local emission inventories. In the absence of clear and uniform standards, it becomes difficult to compare data between different local contexts and to assess the effectiveness of policies at the regional or national level.

The present study demonstrated the potential of integrating a local inventory of carbon dioxide emissions into the SEA procedure conducted at the municipal level. Some of the administrative barriers were resolved with the approval of the Municipal Urban Plan, while the main economic obstacles that arose were mainly related to the applicability of policies due to stakeholder involvement.

To maximize the effectiveness of the policies and actions undertaken, it is necessary to address the challenges related to environmental planning and monitoring. Only through an integrated and preventive approach we can hope to achieve the emission reduction targets set by international agreements, guaranteeing the validity of local urban planning in the face of the challenge of climate change.

CRedit authorship contribution statement

Pasquale De Toro: Writing – review & editing, Validation, Methodology, Conceptualization. **Paola Mautone:** Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation.

Informed consent statement

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Data availability statement

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Conflicts of interest

The authors declare no conflict of interest.

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APPENDIX A

IPCC Software results for each year (1994–2021)

Inventory Year: 1994							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	-5,92510822	0,5812	0	0	0	0	0
4 - Agriculture	0	0,5812	0	0	0	0	0
4A - Enteric Fermentation		0,0879		0	0	0	0
4B - Manure Management		0,4932	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,92510822	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,92510822			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0

Fig. A1. Estimated emissions for the year 1994.

Inventory Year: 1995							
Categories	Net CO2 (1)(2)	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,925108219	0,5812	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,5812	0	0	0	0	0
3.A - Livestock		0,5812	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A2. Estimated emissions for the year 1995.

Inventory Year: 1996

Categories	Net CO2 (1)(2)	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,925108219	0,5812	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,5812	0	0	0	0	0
3.A - Livestock		0,5812	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A3. Estimated emissions for the year 1996.

Inventory Year: 1997

Categories	Net CO2 (1)(2)	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,925108219	0,5812	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,5812	0	0	0	0	0
3.A - Livestock		0,5812	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A4. Estimated emissions for the year 1997.

Inventory Year: 1998

Categories	Net CO2 (1)(2)	CH4	N2O	NOx	CO	NMVOCs	SO2
Total National Emissions and Removals	-5,925108219	0,5812	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,5812	0	0	0	0	0
3.A - Livestock		0,5812	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A5. Estimated emissions for the year 1998.

Inventory Year: 1999

Categories	Net CO2 (1)(2)	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,925108219	0,5812	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,5812	0	0	0	0	0
3.A - Livestock		0,5812	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A6. Estimated emissions for the year 1999.

Inventory Year: 2000

Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	-5,92510822	0,4714	0	0	0	0	0
4 - Agriculture	0	0,4714	0	0	0	0	0
4A - Enteric Fermentation		0,0623		0	0	0	0
4B - Manure Management		0,4091	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,92510822	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,92510822			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	0	0	0	0	0	0	0
6A - Solid Waste Disposal on Land		0		0	0	0	0
6B - Wastewater Handling		0	0	0	0	0	0
6C - Waste Incineration	0	0	0	0	0	0	0
6D - Other (please specify)	0	0	0	0	0	0	0

Fig. A7. Estimated emissions for the year 2000.

Inventory Year: 2001							
Categories	Net CO2 (1)(2)	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,925108219	0,4714	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,4714	0	0	0	0	0
3.A - Livestock		0,4714	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A8. Estimated emissions for the year 2001.

Inventory Year: 2002							
Categories	Net CO2 (1)(2)	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,925108219	0,4714	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,4714	0	0	0	0	0
3.A - Livestock		0,4714	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A9. Estimated emissions for the year 2002.

Inventory Year: 2003							
Categories	Net CO2 (1)(2)	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,925108219	0,4714	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,4714	0	0	0	0	0
3.A - Livestock		0,4714	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A10. Estimated emissions for the year 2003.

Inventory Year: 2004

Categories	Net CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,925108219	0,4714	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,4714	0	0	0	0	0
3.A - Livestock		0,4714	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A11. Estimated emissions for the year 2004.

Inventory Year: 2005

Categories	Net CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,925108219	0,4714	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,925108219	0,4714	0	0	0	0	0
3.A - Livestock		0,4714	0	0	0	0	0
3.B - Land	-5,925108219			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A12. Estimated emissions for the year 2005.

Inventory Year: 2006

Categories	Net CO2 (1)(2)	CH4	N2O	NOx	CO	NMVOCs	SO2
Total Local Emissions and Removals	-5,368344995	0,4714	0	0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	-5,368344995	0,4714	0	0	0	0	0
3.A - Livestock		0,4714	0	0	0	0	0
3.B - Land	-5,368344995			0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	0	0	0	0	0	0	0
3.D - Other	0	0	0	0	0	0	0
4 - Waste	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		0		0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	0	0	0	0	0	0	0
4.D - Wastewater Treatment and Discharge		0	0	0	0	0	0
4.E - Other (please specify)	0	0	0	0	0	0	0

Fig. A13. Estimated emissions for the year 2006.

Inventory Year: 2007							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	-5,368345	0,5103	0	0	0	0	0
4 - Agriculture	0	0,4714	0	0	0	0	0
4A - Enteric Fermentation		0,0623		0	0	0	0
4B - Manure Management		0,4091	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	0	0,0389	0	0	0	0	0
6A - Solid Waste Disposal on Land		0,016		0	0	0	0
6B - Wastewater Handling		0,0228	0	0	0	0	0
6C - Waste Incineration	0	0	0	0	0	0	0
6D - Other (please specify)	0	0	0	0	0	0	0

Fig. A14. Estimated emissions for the year 2007.

Inventory Year: 2008							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	-5,368345	0,5112	0	0	0	0	0
4 - Agriculture	0	0,4714	0	0	0	0	0
4A - Enteric Fermentation		0,0623		0	0	0	0
4B - Manure Management		0,4091	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	0	0,0398	0	0	0	0	0
6A - Solid Waste Disposal on Land		0,0169		0	0	0	0
6B - Wastewater Handling		0,0228	0	0	0	0	0
6C - Waste Incineration	0	0	0	0	0	0	0
6D - Other (please specify)	0	0	0	0	0	0	0

Fig. A15. Estimated emissions for the year 2008.

Inventory Year: 2009							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	311,050322	0,6051	0,1072	0	0	0	0
4 - Agriculture	0	0,4714	0	0	0	0	0
4A - Enteric Fermentation		0,0623		0	0	0	0
4B - Manure Management		0,4091	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	316,418667	0,1337	0,1072	0	0	0	0
6A - Solid Waste Disposal on Land		0,0469		0	0	0	0
6B - Wastewater Handling		0,0227	0	0	0	0	0
6C - Waste Incineration	316,418667	0,0641	0,1072	0	0	0	0
6D - Other (please specify)	0	0	0	0	0	0	0

Fig. A16. Estimated emissions for the year 2009.

Inventory Year: 2010							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	662,003488	0,3793	0,2261	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	667,371833	0,2106	0,2261	0	0	0	0
6A - Solid Waste Disposal on Land		0,0527		0	0	0	0
6B - Wastewater Handling		0,0227	0	0	0	0	0
6C - Waste Incineration	667,371833	0,1352	0,2261	0	0	0	0
6D - Other (please specify)	0	0	0	0	0	0	0

Fig. A17. Estimated emissions for the year 2010.

Inventory Year: 2011							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	817,851488	0,4358	0,2789	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	823,219833	0,267	0,2789	0	0	0	0
6A - Solid Waste Disposal on Land		0,0787		0	0	0	0
6B - Wastewater Handling		0,0215	0	0	0	0	0
6C - Waste Incineration	823,219833	0,1668	0,2789	0	0	0	0
6D - Other (please specify)	0	0	0	0	0	0	0

Fig. A18. Estimated emissions for the year 2011.

Inventory Year: 2012							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	812,243322	0,4435	0,277	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	817,611667	0,2748	0,277	0	0	0	0
6A - Solid Waste Disposal on Land		0,0877		0	0	0	0
6B - Wastewater Handling		0,0215	0	0	0	0	0
6C - Waste Incineration	817,611667	0,1656	0,277	0	0	0	0
6D - Other (please specify)	0	0	0	0	0	0	0

Fig. A19. Estimated emissions for the year 2012.

Inventory Year: 2013							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	978,126988	0,5021	0,3332	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	983,495333	0,3333	0,3332	0	0	0	0
6A - Solid Waste Disposal on Land		0,1121		0	0	0	0
6B - Wastewater Handling		0,022	0	0	0	0	0
6C - Waste Incineration	983,495333	0,1993	0,3332	0	0	0	0
6D - Other (please specify)	0	0	0	0	0	0	0

Fig. A20. Estimated emissions for the year 2013.

Inventory Year: 2014							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	1030,96182	0,5212	0,3511	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	1036,33017	0,3525	0,3511	0	0	0	0
6A - Solid Waste Disposal on Land		0,1206		0	0	0	0
6B - Wastewater Handling		0,0219	0	0	0	0	0
6C - Waste Incineration	1036,33017	0,21	0,3511	0	0	0	0
6D - Other (please specify)	0	0	0	0	0	0	0

Fig. A21. Estimated emissions for the year 2014.

Inventory Year: 2015							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCS (Gg)	SOx (Gg)
Total Local Emissions and Removals	-5,368345	0,4001	6,6269	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	0	0,2314	6,6269	0	0	0	0
6A - Solid Waste Disposal on Land		0,1251		0	0	0	0
6B - Wastewater Handling		0,0218	0	0	0	0	0
6C - Waste Incineration	0	0	0	0	0	0	0
6D - Other (please specify)	0	0,0845	6,6269	0	0	0	0

Fig. A22. Estimated emissions for the year 2015.

Inventory Year: 2016							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCS (Gg)	SOx (Gg)
Total Local Emissions and Removals	-5,368345	2,887	339,152	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	0	2,7182	339,152	0	0	0	0
6A - Solid Waste Disposal on Land		0,1334		0	0	0	0
6B - Wastewater Handling		0,0219	0	0	0	0	0
6C - Waste Incineration	0	0	0	0	0	0	0
6D - Other (please specify)	0	2,563	339,152	0	0	0	0

Fig. A23. Estimated emissions for the year 2016.

Inventory Year: 2017							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCS (Gg)	SOx (Gg)
Total Local Emissions and Removals	28971,95541	2,8595	334,6431	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	28971,95541	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (Fires)	28977,32375	0	0	0	0	0	0
6 - Waste	0	2,6907	334,6431	0	0	0	0
6A - Solid Waste Disposal on Land		0,1189		0	0	0	0
6B - Wastewater Handling		0,0218	0	0	0	0	0
6C - Waste Incineration	0	0	0	0	0	0	0
6D - Other (please specify)	0	2,5501	334,6431	0	0	0	0

Fig. A24. Estimated emissions for the year 2017.

Inventory Year: 2018							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCS (Gg)	SOx (Gg)
Total Local Emissions and Removals	-5,368345	2,8273	325,584	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	0	2,6586	325,584	0	0	0	0
6A - Solid Waste Disposal on Land		0,1262		0	0	0	0
6B - Wastewater Handling		0,0212	0	0	0	0	0
6C - Waste Incineration	0	0	0	0	0	0	0
6D - Other (please specify)	0	2,5111	325,584	0	0	0	0

Fig. A25. Estimated emissions for the year 2018.

Inventory Year: 2019							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	-4,97282166	2,9195	334,9217	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	0,39552333	2,7508	334,9217	0	0	0	0
6A - Solid Waste Disposal on Land		0,1129		0	0	0	0
6B - Wastewater Handling		0,0211	0	0	0	0	0
6C - Waste Incineration	0,39552333	8E-05	0,000134	0	0	0	0
6D - Other (please specify)	0	2,6167	334,9216	0	0	0	0

Fig. A26. Estimated emissions for the year 2019.

Inventory Year: 2020							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total Local Emissions and Removals	0,41397	2,8759	326,5407	0	0	0	0
4 - Agriculture	0	0,1688	0	0	0	0	0
4A - Enteric Fermentation		0,0422		0	0	0	0
4B - Manure Management		0,1266	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-5,368345	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-5,368345			0	0	0	0
5B - Forest and Grassland Conversion	0	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (Fires)	0	0	0	0	0	0	0
6 - Waste	5,782315	2,7071	326,5407	0	0	0	0
6A - Solid Waste Disposal on Land		0,1194		0	0	0	0
6B - Wastewater Handling		0,021	0	0	0	0	0
6C - Waste Incineration	5,782315	0,0012	0,001959	0	0	0	0
6D - Other (please specify)	0	2,5656	326,5387	0	0	0	0

Fig. A27. Estimated emissions for the year 2020.

Inventory Year: 2021							
Greenhouse gas source and sink categories	Net CO2 (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCS (Gg)	SOx (Gg)
Total Local Emissions and Removals	3,3494563	1,0318	39,325	0	0	0	0
4 - Agriculture	0	0,4986	0	0	0	0	0
4A - Enteric Fermentation		0,067		0	0	0	0
4B - Manure Management		0,4317	0	0	0	0	0
4C - Rice Cultivation		0		0	0	0	0
4D - Agricultural Soils		0	0	0	0	0	0
4E - Prescribed Burning of Savannas	0	0	0	0	0	0	0
4F - Field Burning of Agricultural Residues	0	0	0	0	0	0	0
4G - Other (please specify)				0	0	0	0
5 - Land-Use Change & Forestry	-2,43581037	0	0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-2,59356784			0	0	0	0
5B - Forest and Grassland Conversion	0,15775747	0	0	0	0	0	0
5C - Abandonment of Managed Lands	0			0	0	0	0
5D - CO2 Emissions and Removals from Soil	0			0	0	0	0
5E - Other (please specify)	0	0	0	0	0	0	0
6 - Waste	5,78526667	0,5332	39,325	0	0	0	0
6A - Solid Waste Disposal on Land		0,107		0	0	0	0
6B - Wastewater Handling		0,0221	0	0	0	0	0
6C - Waste Incineration	5,78526667	0,0012	0,00196	0	0	0	0
6D - Other (please specify)	0	0,4029	39,323	0	0	0	0

Fig. A28. Estimated emissions for the year 2021.

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