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GHG emissions inventory at urban scale: the Sassari case study

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Abstract

Within current initiatives dedicated to provide information on the status of greenhouse gases emissions, the town of Sassari represents a pilot site for estimating the net exchange of carbon dioxide (emissions and sinks) at municipal level in Sardinia (Italy). A spatial and temporal high resolution greenhouse gas emissions inventory for the urban area of Sassari is currently under construction in line with European and international standard protocols to establish a baseline for tracking emission trends. This paper presents the preliminary results of the development of a simplified local emissions inventory where estimates of the atmospheric emissions are collected and cataloged by type of greenhouse gases, productive activity and emissive source on annual basis.

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Keywords: GHG emission inventory; carbon dioxide; municipal level; Sassari; Italy

1. Introduction

The European Union has indicated the fight against climate change due to greenhouse gas releases as a strategic priority to prevent the most severe impacts. The largest source of these emissions comes from human activities within urban areas that account for more than 70% of the world's emissions [1, 2]. Several local governments intend to support the European strategic policies and contribute to better assess the driving factors and sectors behind greenhouse gases (GHG) emissions at urban scale [3]. Planning for mitigation actions at the community scale starts with the compilation of a GHG inventory that, within a wide range of measurement tools, provides information on the current status of GHG emissions across a specific local government's jurisdiction. An inventory is also the first step toward developing a comprehensive emissions reduction strategy [4].

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One of the main challenges of completing community-scale inventories is addressing the complexities associated with reducing the spatial area of analysis for GHG inventories from the national to the community level. Using the so called Scope-based approach allows local governments to handle attribution of emissions that occur outside the community boundary as a result of activity or consumption within the community from stationary and mobile units, waste and industrial process and product use emissions [5].

In this context, Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC) has been established to integrate with existing GHG inventorying protocols and standards for communities [1].

The Scope definitions of GPC account for all direct emission sources from activities taking place within the community's geopolitical boundary, the energy-related indirect emissions that result from consumption of grid-supplied electricity, heating and/or cooling, within the community's geopolitical boundary, and all other indirect emissions that occur as a result of activities within the community's geopolitical boundary.

1.1. Objectives

The project aims to provide information at urban scale on the current status of emissions and removals of carbon dioxide (CO_2) by direct measurements (micrometeorological techniques) and through a simplified local inventory of GHG emissions. The inventory was developed adopting a standardized procedure based on European and national guidelines, and harmonized with the experiences of other Italian towns. Specific purposes of this accurate accounting are (i) to obtain an appropriate allocation of CO_2 and other GHG emissions at the fine building and hourly scales, (ii) to create GHG emissions baseline, and (iii) to compare inventory estimates with direct measurements results, which are needed for constructing future emission scenarios and for assessing possible strategies to reduce their impact.

Identification of data to be collected will be based on two main criteria: (i) relevance, GHG emissions should reflect emissions occurring as a result of activities and consumption from within the Sassari community's geopolitical boundaries, and (ii) completeness, all significant emissions sources included should be accounted for. Data collection can be performed using different approaches (1) bottom-up, where emissions are determined starting from individual processes or plants and then aggregated at a higher level; (2) top-down, where emissions derive from upper level aggregates (national/regional) that are then downscaled to local areas; (3) mixed approach, a combination of top-down/bottom-up scheme. In this project, GHG emissions quantification will be based on a mixed approach, using the top-down or bottom-up approach when it is appropriate and can be made, and having in mind to find a trade-off among level of detail, time consumption and expected accuracy.

A calculation-based methodology will be used to quantify most of the GHG emissions. This type of methodology is based on a linear relationship between source activity and emission, following a relation that can be generally outlined as follows:

$$E_i = A \cdot FE_i \qquad (1)$$

where Ei is the emission of the GHG_i (g $year^{-1}$), A is the activity indicator (i.e. fuel consumption, amount produced, etc.), FE_i is the emission factor for the GHG_i (i.e. g t^{-1} of fuel type, kg kg^{-1} of solvent, g $inhabitant^{-1}$) [1].

The reliability of the estimates will deeply depend on the accuracy of the "emission factors", which are specific for each type of GHG source. An estimate of the data quality will be also assigned for each emission factor, thus providing a range of error [6].

Once all GHG emissions data will be collected and processed, the quantification of GHG emissions will be based on statistical data, proxies and estimates by successive approximations. The procedures and tools developed will meet the following criteria: (1) simple and concise structure, in a simple web based format (e.g. Excel worksheet, also usable via browsers without installing software); (2) flexible (easy to upgrade or integrate with new subcategories by the users); (3) applicable in different territorial contexts; (4) easy data entry and accessible understood structure by the users; (5) possibility of comparison with regional or national data or indicators; (6) possibility of inclusion of both detailed and approximate data based on estimates.

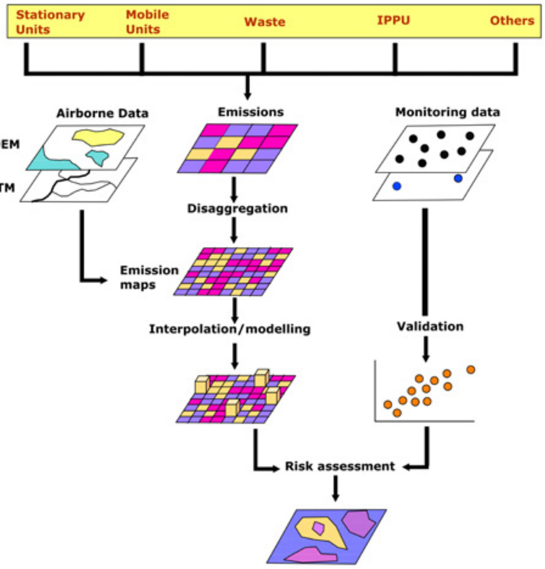

Fig. 1. Flow diagram of the main components of the project.

2. Study area

The city of Sassari is located in the North-West part of Sardinia Island (West Mediterranean, Italy) and lies at 225 meters above sea level (masl) on the Nurra plain, a karst plateau gently North-dipping and degrading towards the sea (Gulf of Asinara). It is delimited by the Mannu Stream on the West and the steep cliffs of Bunnari valley on the South and East. Sassari is the 2nd most populous city in Sardinia (behind Cagliari) with a 2010 population of about 130,000 according to the last census, with the majority of the population living in the "compact city" (72.7% of the surface). Sassari town has an asymmetrical urban structure and is built over a hill surrounded by a olive grove strip and cross-cut in two parts from a NW-SE oriented dry canyon. The older city-center is located in the NW part of the urbanized area and a number of residential-commercial areas grew over time towards SE. A commercial-industrial area occupies the West part of the urban zone.

The climate is typical of the Mediterranean, with warm winters and dry summers (maximum, T_{max}, and minimum, T_{min}, temperatures in August and January, respectively). The average annual temperature (1965-2012) is 15.9 °C (mean T_{min} 11.8 °C; mean T_{max} 19.8 °C). The number of average annual heating and cooling degree days are about 1580 and 720, respectively. The average annual precipitation is around 615 mm (1986-2007) and the average daily value of the air relative humidity ranges between 70% in summer and 79% in winter. Major direction of weak wind is South while stronger wind comes from North-West and North [7].

3. Methods

The key element of the methodologies used to construct this GHG emissions inventory is the Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC) (March 2012) that identifies four main types of emission sources: (i) Stationary Units, (ii) Mobile Units, (iii) Waste, and (iv) Industrial Process and Product Use Emissions.

The development of the GHG emissions account for Sassari town consists in the collection of a range of alternative data sources (primary data, IPCC emission factors, national and local statistics, etc.) selected on the basis of their relevance and completeness, and using 2010 as baseline year and a mix of data collection approaches (top-down, bottom-up or mixed).

GPC protocol also defines three standard scopes for downscaling emissions from the national to the community level and allows handling the attribution of releases that occur outside the community boundary as a result of activity or consumption within it. The procedures for data processing have simple and concise structure, and are applicable in different communities giving the possibility of comparing results from other national contexts.

As one of the main tasks of the project is to obtain an appropriate allocation of GHG emissions at the fine building and hourly scales, the completion of the GHG emission inventory will be followed by downscaling emissions across the Sassari town area. For this purpose, the Hestia Project method will be used [8]. This approach combines a series of data sets and simulation tools for estimation down to the individual building scale, road segments and electricity production facilities at the hourly time scale and for allocating these non-point sources CO_2 emissions.

Fig. 2. Downscaling approach in the Hestia project.

4. Results

On the basis of the Global Protocol guidelines, the categories identified in each of the four main groups of emissions types (Stationary Units, Mobile Units, Waste and Industrial Process and Product Use Emissions) in the town of Sassari are listed in Figure 3.

4.1. Stationary units

Stationary Units emissions include those produced by consumption of fuels combusted on-site or indirectly by heating and/or cooling of buildings and grid-delivered electricity. About this category, no specific agencies collect the whole energy consumption data in Sassari, so most of them are fragmentary and not spatially allocated.

Climate influences the building conditioning mainly in winter and summer. Most of the residential structures are without natural gas services lines and are meeting all their energy needs through fuel combustion and electricity. In the city center most of the buildings have individual heating/cooling systems, while in the rest of the urban area, centralized heating generators in each building are fueled by heating oils.

Grid-supplied electricity is provided off-site by a power station (Eon Power Station - Fiumesanto) located outside of municipality boundary, around 10 km NW from the city, and burns fossil fuels (coal and oils). Power station's production data are available at yearly scale.

Only recently a 195 km long gas pipe-line was built around the city, but the service is not available in the whole streets. Data on natural gas consumption have already acquired for 2010 from MEDEA gas service, divided in residential, commercial and institutional users. Distribution of pipe network is not available yet.

Wood and other biomass are also used in some building. Commercial and industrial activities burn fuels, as coal, wood, wood residual, heating oils, and so on, for their purposes (pizza shops, smith activities, etc.).

The spatial disaggregation of these GHG emissions is on the basis of individual building types. Their parameters such as year construction, building materials, unoccupied housing stock, occupied housing stock distinguished by intended use are provided by census (Italian Institute of Statistics, ISTAT). Building age reflects extremely different building typology and three main groups can be recognized: before 1900, before 1950 and post-1950.

Data on the geo-location and size of the buildings in Sassari, provided by Regional Authorities, includes building footprint, elevation data for land surface (digital elevation model – DEM) and building height (digital surface model – DSM) with resolution 1 m x 1 m.

The total building volume has been calculated for each of the about 40,000 buildings of the city from a combination of DEM and DSM in ArcGIS 9 environment [9]. A centroid of each building footprint was defined on the digital elevation map and the building height was estimated subtracting the DEM elevations from the DSM elevations. Then, the total building volume for each building in Sassari was obtained multiplying the building footprint by the building height.

Stationary Units	Mobile Units	Waste
Residential building	**On-Road transportation**	**Solid waste disposal**
Building types (year, heating, etc.)	Private cars	Landfilled municipal solid waste (MSW)
Commercial Facilities	Pubblic cars	Special wastes
Store Centers	Light trucks	**Biological treatment of waste**
Shops	Heavy trucks	Composting
Institutional Facilities	Motorcycles	**Wastewater treatment and discharge**
Hospital	mopeds	Anaerobic digestion
Municipal buildins	Motorhomes	Aerobically treatment
County buildings	ATP Bus	**IPPU**
Regional buildings	ARST Bus	**Industrial Processes and Product Uses**
Public Light	**Railways**	Calcrete uses
Bank buildings	Trains	Consumption of cement, lime and soda ash
Energy generation (undirect emissions)	Metro	Chemical production
Grid-supplied electricity	**Aviation**	Consumption of petroleum products
Energy Use in Industrial Activities	Helicopters	Limestone uses
Bakery	**Off-Road**	Lubrificants uses
Smiths	Go-kart	Bitume, road oil and other petroleum diluents
	Brush-cutters	Solvents (kerosene and other aromatics)
	Tractors	Paraffin waxes
	Construction equipments	Nitrous oxide
	Landscape equipments	

Fig. 3. Inventory categories of GHG emissions in the town of Sassari.

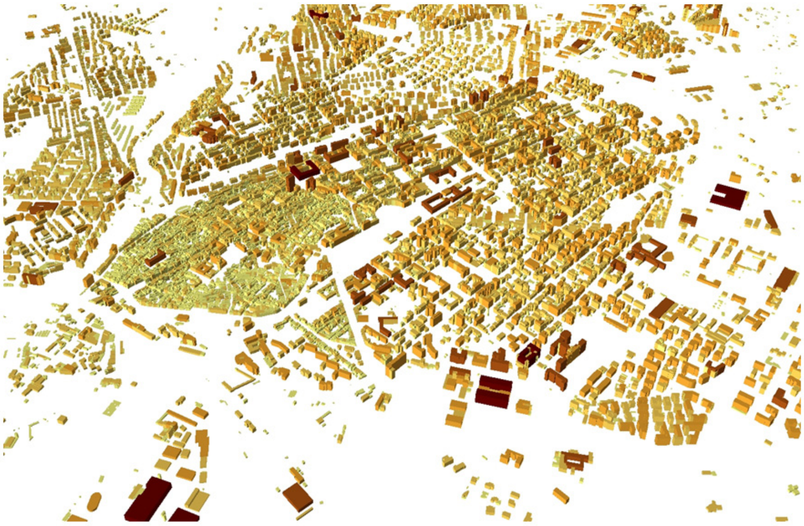

Fig. 4. Total building volume sketch map as calculated by the combination of DEM and DSM.

4.2. Mobile units

The municipality of Sassari is one of the Sardinian areas where the fuel consumption for road transportation purposes is higher. This is due to a road system strongly radial, with a monocentric plan and thoroughfares that spread in all directions out of the city [10].

Private traffic density on Sassari urban roads was estimated during the project MOSES (2010) at the 8 major entrances of the city and in the main intersections [7]. Vehicle fleet has an amount of about 110,000 units. Data are available from the Public Vehicle Database (PRA) but no dataset are available for off-road category.

About public service (managed by ATP), 23 bus lines (3,650,000 km during 2010) and 2.5 km city-railway (4 trains) serve transportation within the city, with an average frequency of 15 minutes (18 km h^{-1} speed). Connections with the main urban centers of Sardinia are provided by several ARST S.p.A. bus lines that transit in the community boundaries.

The city is also venue of the rail link between the main town of Sardinia region (Cagliari to the South and Olbia to the East, managed by Trenitalia) and among other important urbanized area of the province (Alghero, Sorso and Nulvi, managed by ARST S.p.A.).

Water bone navigation doesn't occur within the geopolitical boundary, and beside airport is located outside the local jurisdiction, aviation emission must be accounted related to helicopters operating air travels (fire rescue, health service, etc.) within the city.

Annual fossil fuel consumption (in volume) associated with on-road transportation (diesel, gasoline, gas) has already been collected through Dogane service, ATP and ARST public transport services.

4.3. Waste

Waste section includes GHG emissions associated with the disposal of municipal solid waste and wastewater handling and treatment.

Those emissions associated with disposal of municipal solid waste (MSW) refer to bury waste at landfill site (no incineration is performed) located 15 km far from the urban area, while wastewater treatment is carried out in a facility close to it.

Data on monthly mass of waste landfilled and biologically treated divided by composition have already acquired from the Environmental Local Authority of Sassari.

Municipal wastewater is treated in two different ways by Abbanoa S.p.A.: in presence and in absence of oxygen, aerobically and anaerobically, respectively. Data are not available yet.

4.4. Industrial processes and product uses

Among this category, different types of GHG emissions related to the economic sectors have been provided by census (Italian Institute of Statistics, ISTAT), but data collection and quantification is still in progress.

5. Conclusions

The quantification of GHG emissions represents an accurate set of means and tools to quantitatively estimate CO_2 and other GHG emissions at municipal level and at fine spatial and time scales. In addition, it can be used to construct future scenarios of GHG emissions and to identify possible adaptation and mitigation strategies. In the case study of Sassari, the first step of the project achieved the classification of the urban emissions, collected and catalogued by greenhouse gas, productive activity and emissive source (baseline year 2010).

An appropriate GHG emissions allocation over detailed spatial and temporal scales will be attained on the basis of specific indicators (population, industrial employees, amount of product, etc.) and of geo-location and size of all buildings, using appropriate models, that enable to properly geo-referenced them in relation to their uses.

The main advantage of neighbourhood-level quantification consists in the identification of the main productive sources and emissive activities within the urban boundaries that mostly contribute to the current GHG emissions and then focus the efforts on possible mitigation.

One of the main challenges in developing a local scale GHG inventory derives from the little availability of data from the Italian Statistical System and poor coordination among the different private and public institutions that manage and should provide data useful for emissions inventory purposes.

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