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Communication

Development of a greenhouse gas accounting GIS-based tool to support local policy making—application to an Italian municipality

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HIGHLIGHTS

- We developed a GIS-based tool for local (municipal) GHG accounting.
- All emissions (carbon sources) and removals (carbon sinks) are geo-referenced.
- The tool can be used with different levels of input data (less or more accurate).
- The town of Spoleto (Italy) was chosen to apply and validate both methodologies.
- The tool is effective to monitor the energy and environmental policies of the municipality.

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ABSTRACT

Climate change is the issue of the century and, according to Agenda 21, local actions are essential to impact global mitigation of greenhouse gases (GHG) emissions ("*think globally*, *act locally*"). However, in order to plan and implement effective, sustainable actions, local authorities need detailed information on their GHG emissions and their sources. This paper presents the work that led to the development of a GIS-based tool for local GHG accounting, which provides data for local decision-makers in an innovative manner different from traditional GHG inventories. The original aspects of the study are the geo-referencing of all results and the possibility of calculating all emissions (carbon sources) and removals (carbon sinks) with input data of different accuracy.

1. Introduction

Climate change is the defining issue of the 21st century. The Kyoto Protocol sets binding targets for industrial countries to reduce greenhouse gas (GHG) emissions, and furthermore establishes timing and procedures to achieve them. The EU Renewable Energy and Climate Change Package sets the climate change reduction goal by 2020: 20 percent reduction in GHG emissions, 20 percent cut in energy consumption through improved energy efficiency, and 20 percent increase in the use of renewable energy (Directive, 2009).

However, to overcome the GHG emission problem that is to achieve the reduction targets, it is necessary to act not only at international and national levels, but also at regional and local levels. In fact, urban areas which occupy only 2% of total Earth's surface, are responsible with their various sectors for 75% of global energy consumption and 80% of the world's greenhouse gas emissions. (Anna Kajumulo). It is therefore important for the local governments to take advantage of easy-to-use tools to monitor GHG emissions for the purposes of planning and implementing more sustainable actions, strategies, and good practices.

Moreover, according to the strategy defined by the European Commission, the so-called Italian Digital Agenda was launched in March 2012. The Agenda promotes (through the actions "open data" and "e-government") the digitalization of data owned by local authorities, including municipalities, which have to become gradually public through web-platforms and web-sites, smart phones applications and so on. Data concerning environmental issues are considered priority in the Agenda.

This paper describes the development of a new GIS-based tool for local GHG accounting. All CO_2 emissions and removals are not only accounted for, but are also spatially geo-referenced.

The purpose of the work is to develop a technical tool for screening the environmental pressures from different sectors (industrial, residential, transports, etc.) at municipal level, estimating GHG emission with different accuracy input data. The tool is not an analytic calculator for municipalities pollution evaluation. Rather, it aims to facilitate low-carbon policy-making, supporting

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local authorities in environmental issues identification and therefore in planning special actions on specific areas. The tool in fact allows to simulate the efficiency of planned actions (re-forestation, sustainable mobility, renewable energy plants, energy refurbishment of buildings) by calculating their effect on the area considered and therefore to perform costs/benefits analysis. Finally, the results given by the tool may be implemented on a web-site, thus making environmental data public.

Two areas representative of the whole territory of Spoleto, a city in central Italy, were chosen for a first application of this methodology.

2. Literature review

The ability and responsibility to reduce the GHG emissions are increasing at sub-national levels, and the interest in climate governance at this scale has resulted in a number of campaigns, such as the "Cities for Climate Protection" (CCP) (Betsill and Bulkeley, 2006; Wheeler, 2008), as well in the development of local GHG inventories (Dodman, 2009; ICLEI, 2008), and also in the investigation of the methods to build up them (Larsen and Hertwich, 2009).

The first step of an effective policy for reducing GHG emissions is the knowledge of the emissions themselves. Many papers in the scientific literature can be found dealing with this topic, especially at a municipal level. Kennedy and Sgouridis (2011) address the question of rigorous classification and carbon accounting principles for Low and Zero Carbon Cities, while Larsen and Hertwich (2010) deal with the identification of important characteristics of municipal carbon footprints (CF). Many authors, such as Weidema et al. (2008); Wiedmann and Minx (2007) and Hammond (2007) focused their investigations on CF calculation methodology, while others presented various case studies. Lebel et al. (2007) looked at the metropolitan per capita carbon footprints in cities like Jakarta and Delhi. Gomes et al. (2008) determined the resulting carbon dioxide equivalent emissions (CO_{2eq}) for the Oeiras municipality, one of the largest in Portugal, and located in the metropolitan area of Lisbon. Some authors, such as Fengming et al; Xi et al. (2011), show how a clear inventory analysis of GHG emissions at city level can effectively help to identify the highest emitting sectors and activities, so as to be able to address reduction efforts and facilitate low-carbon policy-making.

GIS-based accounting is common for LULUCF (Land Use, Land Use Change and Forestry) and several countries already have Tier 3, Approach 3 accounting systems for this sector (for example, for reforestation and deforestation (Richards and Brack, 2004)). GIS-based models have been also developed to start the process of mapping individual anthropogenic CO_2 point sources (e.g., fossil-fired power plants, refineries) with specific geologic reservoirs (Dahowski et al., Shiozaki). Moreover, GIS-based tools have been developed for geo-referencing carbon sources and sinks (Chen et al., 2003; Ponce-Hernandez, 2004), and GIS is usually used to process the inputs of these models and to visualize the results obtained (Ponce-Hernandez, 2004; Ardö and Olsson, 2003). A recent study integrates process-based models with GIS to estimate carbon sequestration of terrestrial ecosystems in order to conduct land-use planning (Wang et al., 2010); another study proposes GIS-based approaches for quantifying and mapping economic values of carbon sink and stock of forest ecosystem (Deng et al., 2011).

Other authors focus on the spatial nature of GHG emissions ((Kuzyk, 2012), limited to the housing sector) and on their temporal variation (Monni and Syri, 2011), but so far, only a few papers deal with the problem of local governments–such as municipalities–often lacking specific information for CF evaluation of their territory.

3. Methodology

3.1. Municipality GHG emissions

The environmental indicator chosen for GHG accounting is the resulting value of CO_{2eq} emissions, calculated by multiplying specific emission factors and activity data for each considered sector. The accounting methodology considers specific data of different accuracy for each sector involved, as illustrated in the following pages. The emissions factors are obtained from scientific literature data. Equivalent emissions are calculated on the basis of the Global Warming Potential (GWP) of each greenhouse gas taken into account by the calculation tool (Table 1, (IPCC, 2007)).

The calculation tool processes GIS based information and returns them in graphical format. The tool links each GIS based element with its process direct GHG emissions (heating and electrical consumption), while the indirect GHG emissions (such as those related to freight and people transportation) are considered into

Table 1
Global Warming Potential of different GHG.

GHG	Global warming potential (GWP)		
	20 yrs	100 yrs	500 yrs
CO_2	1	1	1
CH_4	72	25	7.6
N_2O	289	298	153
HFC-23	12,000	14,800	12,200
HFC-134a	3.83	1.43	435
SF_6	16,300	22,800	32,600

Table 2
Items for each sector.

Sector	Items Considered
Agriculture–forestry	– Emissions from enteric fermentation in domestic livestock – Emissions from manure management – Emissions from agricultural soils – Emissions from nitrogen used in agriculture – Emissions from rice production – CO_2 absorption by vegetation – Electricity consumption – Diesel fuel consumption
Residential	– Heating – Electricity consumption – Domestic Hot Water (DHW) generation
Transport	– Inhabitants car trips – Commuters car trips – Tourists flows – Mopeds and motorcycles mobility – Public transport – Heavy duty vehicles
Waste	– Municipal Solid Waste (MSW) to landfill – MSW Separate collection – MSW to energy – Wastewater treatment
Energy	– Conventional fuel power plants – Renewable Energy
Industry	– Mining industries – Chemical industries – Iron and steel industries – Other industries