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Assessing greenhouse gas and related air pollutant emissions from road traffic counts: A case study for Mauritius

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ABSTRACT

The road transport sector is one of the major contributors of greenhouse gases and other air pollutants emissions. Regional emissions levels from road vehicles were investigated, in Mauritius, by applying a fuel-based approach. We estimated fuel consumption and air emissions based on traffic counts on the various types of classified roads at three different regional set ups, namely urban, semi urban and rural. The Relative Development Index (RDI), a composite index calculated from socio-economic and environmental indicators was used to classify regions. Our results show that the urban motorways were the most polluting due to heavy traffic. Some rural areas had important pollution levels as well. Our analysis of variance (ANOVA), however, showed little difference in emissions among road types and regions. The study can provide a simple tool for researchers in countries where data are very scarce, as is the case for many developing countries.

Introduction

Greenhouse gases (GHGs) have been recognised to be responsible for global warming and climate change (IPCC, 2007b). Due to intense anthropogenic activities in recent years, especially those requiring fossil fuels, GHG emissions are increasing with an accelerating rate. This has urged many countries to put global warming high up on their sustainable development agenda. Sustainable development can be monitored with results of emission calculations. Emission calculations would also assist developing countries to shift to lower-carbon paths (World Bank, 2010), while promoting development and reducing poverty. At the international level, the United Nations Framework Convention on Climate Change (UNFCCC) keeps watch on climate change with the ultimate objective to stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system (UNFCCC, 2014). Under this convention, industrialized countries (referred to Annex I countries under the UNFCCC (UNFCCC, 2014)) have to report regularly on their climate change policies and measures, including issues governed by the Kyoto Protocol (for countries which have ratified it). They must also submit an annual inventory of their greenhouse gas emissions, including data for their base year (normally 1990) and all the years since. Developing countries (Non-Annex I Parties, i.e. countries in this category under the UNFCCC (UNFCCC, 2014)) report in more general terms on their actions both to address climate change and to adapt to its impacts - but less regularly than Annex I Parties do, and their reporting is contingent on their getting funding for the preparation of the reports, particularly in the case of the Least Developed Countries. Beside the UNFCCC, the Inter-governmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change (IPCC, 2014). It was established

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by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts (IPCC, 2014). Regarding air pollution, the World Health Organisation keeps a database (WHO, 2014) to monitor pollution around the world. Moreover, each country has its own way to monitor GHG emissions and air pollution.

While being important for studying climate change mitigation on the backdrop of heavy reliance on fossil fuels, GHG emissions are also challenging to measure. Calculations of emissions, as proposed in our study, are an easy alternative. Emissions of GHGs such as carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) are ever increasing and other gases such as oxides of nitrogen (NO_x), carbon monoxide (CO), and sulphur dioxide (SO_2) often accompany the release of these GHGs. Fuel combustions in industries, transportation and households are important sources of air pollutant emissions which also have health impacts. Primary pollutions, such as pollution from motor vehicles, are those that are directly emitted as such into the atmosphere, whereas secondary pollution results from chemical reactions among pollutants after they have been released into the air (Boamah et al., 2012). Both of these pollutions are known as being responsible for climate change and a large number of deaths and cases of respiratory diseases (Boamah et al., 2012).

Air pollution from motor vehicles and fossil fuel power plants, in many cities around the world, is increasingly reaching levels that threaten people's health (World Nuclear Association, 2013). The transport sector is known to share a big chunk of fossil energy use. Automobiles alone emit roughly 10% of global CO_2 emissions (DeCicco and Fung, 2006). The combined share of electricity and heat generation and transport represented nearly two thirds of global CO_2 emissions in 2010 (IEA, 2012). In many countries, with improved standards of living and technological advancements, there is a phenomenal increase in the number of vehicles. For instance in Brazil, which is a fast developing country, this increase in vehicles has resulted in heavy emissions in 2010, where the transport sector contributed 43% while the industrial sector shared 29%. These are likely to grow the most over the coming years (IEA, 2012).

Understanding the level of atmospheric emissions from road traffic is vital for bringing in mitigation of climate change as well as air quality monitoring plans, amongst others. Air pollution could be better understood if the distribution of road traffic emissions is known together with the factors involved such as land use, congestion, socio-economic status and others, affecting emissions at particular locations. There remain important research questions regarding road traffic emissions and it is clear that policy makers will require tools, particularly at the local levels, to assess the scale of transport induced air quality problems (Rayfield et al., 1998).

While for industries, emissions are frequently measured directly using continuous emission monitoring systems (CEMs), for mobile sources, models and simple estimations from a very large and diverse population of engines are helpful (Dallmann and Harley, 2009) though complex. Most of the road vehicles are powered by internal combustion engines that burn gasoline, diesel or other fossil fuels. Complex methods involves vehicle cohorts (counts by characteristics such as age, engine capacity, fuel used etc.) and are difficult to administer with costly instruments and other resources. Calculations of GHG emissions inventories are usually carried out at national level in most countries whereas other air pollutants are usually measured at city levels. The GHG inventories thus prepared are suitable for reporting. However, the variations within regions and road classes have been largely ignored mainly due to the difficulty in collecting, processing, and analyzing data at smaller geographic scales. With the increasing availability of count data useful for emission studies and the special capabilities of spatially referenced data, spatial variations of emissions within regions can now be analyzed (Dai and Rocke, 2000). For GHG emissions calculations, fuel based approaches include the top down (simple fuel consumption based) and bottom up methods (complex fuel consumed at sites etc). The latter include the ASIF (activity, modal structure, energy intensity, fuel carbon content) method which considers travel activity by passenger kilometers, the modal share by ratios of passenger kilometers, the fuel intensity by liters per passenger kilometer and the fuel emission factor by CO_2 emissions per liter of fuel (Loo and Li, 2012).

Our study complements international efforts to provide simple tools to study air emissions from the road in relation to climate change and other environmental issues. It focusses on mobile sources of air emissions that occur on the road and looks for the pollutants distributions originating from vehicles (all types of road vehicles) in the different classes of roads in Mauritius. We thus assessed the global warming and health related air pollutants at specific locations and road classes. We developed a simple technique to assess road traffic air emissions based on traffic counts and our results from the quantification of pollutants in specific road types and settlements will assist policy makers to set air pollution and climate change mitigation strategies and action plans. The results will as well assist adoption of cleaner vehicles for carbon abatement. The results could also subsequently provide options to engage in economic gains through projects like the Clean Development Mechanism (CDM) in the transport sector.

Transport models lacking spatial details are unsuitable for estimating air pollution exposures because polluted sites will not be precisely spotted. It would therefore be more appropriate to estimate the total emissions from detailed local levels. This could then be related to coarse spatial models where changes in emissions within locations can be spotted. Many theories and models have been used to study land-use, transport and air-quality via using spatial information sciences (Demirel et al., 2008). Air pollution monitoring network assessment includes quantifying ambient concentrations of air pollutants in the various areas, identifying the contribution of road transport emissions to the ambient hazardous air pollutant, GHG emissions and providing support to the regulatory community in developing mitigation plans, and supporting air quality and/or human health exposure modelling (Demirel et al., 2008).

The European Union (EU) regulation specifies that each vehicle manufacturer must achieve a fleet-average CO_2 emission target of 130 g/km by 2015 for all new cars registered (Giorgos et al., 2011). Our proposed method can be experimented to