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Spatial GHG Inventory: Analysis of Uncertainty Sources. A Case Study for Ukraine

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Abstract A geoinformation technology for creating spatially distributed greenhouse gas inventories based on a methodology provided by the Intergovernmental Panel on Climate Change and special software linking input data, inventory models, and a means for visualization are proposed. This technology opens up new possibilities for qualitative and quantitative spatially distributed presentations of inventory uncertainty at the regional level. Problems concerning uncertainty and verification of the distributed inventory are discussed. A Monte Carlo analysis of uncertainties in the energy sector at the regional level is performed, and a number of simulations concerning the effectiveness of uncertainty reduction in some regions are carried out. Uncertainties in activity data have a considerable influence on overall inventory uncertainty, for example, the inventory uncertainty in the energy sector declines from 3.2 to 2.0% when the uncertainty of energy-related statistical data on fuels combusted in the energy industries declines from 10 to 5%. Within the energy sector, the 'energy industries' subsector has the greatest impact on inventory uncertainty. The relative uncertainty in the energy sector inventory can be reduced from 2.19 to 1.47% if the uncertainty of specific statistical data on fuel consumption decreases from 10 to 5%. The 'energy industries' subsector has the greatest influence in the Donetsk oblast. Reducing the uncertainty of statistical data on electricity generation in just three regions – the Donetsk, Dnipropetrovsk, and Luhansk oblasts – from 7.5 to 4.0% results in a decline from 2.6 to 1.6% in the uncertainty in the national energy sector inventory.

Keywords energy sector · geoinformation system · greenhouse gas · greenhouse gas inventory · multilevel model · spatial analysis · uncertainty

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1 Introduction

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) defines obligations for its parties to reduce their greenhouse gas (GHG) emissions compared with those of a base year. According to the Protocol, each party must develop a national system for estimating anthropogenic emissions and sinks of GHGs. The Intergov-

ernmental Panel on Climate Change (IPCC) has developed a general methodology for estimating GHG emissions and sinks, which has been published in the Revised 1996 IPCC Guidelines (IPCC, 1997a) and corresponding software (IPCC, 1997b). A positive feature of the IPCC methodology is its universality, which allows it to be used by experts in many countries, notwithstanding these countries' different locations around the world and their different levels of economic development. This is one reason why the IPCC Guidelines have been so important during the formation of the Kyoto Protocol mechanisms.

In the future, however, this universality could slightly decrease the efficiency of GHG inventories and thus limit the use of the Kyoto mechanisms. Because of its universality, the IPCC methodology cannot consider regional disparities within countries, which could thus increase inventory uncertainty. Moreover, in most large countries, the various GHG sources and sinks are distributed nonuniformly across the territory. This is the case with Ukraine, for instance, which has an area of 603,000 square kilometers and comprises 25 administrative units (oblasts). The IPCC GHG inventory methodology gives results for entire countries and thus cannot be an effective tool for those making strategic economic and political decisions on regional development within a country.

Integrated information on the actual spatial distribution of GHG sources and sinks would aid in making well-considered economic and environmental decisions. Neighboring countries are interested in real information on ecological conditions near their borders. Geographically explicit data are needed for modeling GHG fluxes. Moreover, spatially distributed analysis of GHGs and their uncertainties can help to identify cost-effective ways of reducing uncertainty.

GHG inventories for regions within a country and the use of geographical information systems (GIS) to increase inventory quality and usability are becoming more widespread. In Portugal, for example, the national GHG inventory was carried out by region and the emissions were spatially analyzed for emission-reduction purposes (Seixas et al., 2002). There have also been efforts to disaggregate GHG emissions on a spatial grid and to produce the georeferenced maps necessary for modeling. For example, the project CARBOEUROPE-GHG (Synthesis of the European Greenhouse Gas Budget; see http://gaia.agraria.unitus.it/ceuroghg/projghg.html) disaggregates GHG emissions to a 50×50 km grid. The project currently concentrates on the 15 original European Union (EU) member countries; however, the plan is to ultimately study the new EU countries as well, and to obtain disaggregated GHG emissions for Ukraine and Russia for full coverage of the continent. Another project is aimed at spatial disaggregation of the 1990 emissions inventory data to a 20×20 km grid for Africa south of the equator (Fleming & van der Merwe, 2000).

This article discusses bottom-up inventory analysis. We examine carbon dioxide (CO_2) emissions and their uncertainties in two dimensions – energy subsectors and spatial distribution – and determine which dimension is the most influential. A similar analysis has been performed for the Netherlands by Vreuls (2004), who considers more GHG gases and sources but omits spatial analysis. We agree with Gillenwater, Sussman, and Cohen (2007) that the uncertainty inherent in the uncertainty estimates is rather large. Nevertheless, we think that the uncertainty estimates should be used to aid policy making. Examples of practical ways of coping with the uncertainties in GHG emissions estimates when trading or comparing national GHG emissions are listed in the conclusions by Monni, Syri, Pipatti, and Savolainen (2007); valuable theoretical work is also offered by Nahorski, Horabik, and Jonas (2007).

The basic approach to carrying out a multilevel, spatially distributed inventory is considered in Section 2 of this chapter, and the geoinformation technology developed to carry out such an inventory is discussed in Section 3. Sections 4 and 5 illustrate the application of the technology for the analysis of GHG emissions in the energy sector at the regional and plot levels, respectively, while Section 6 is devoted to simulations and analysis of the uncertainties and uncertainty reduction measures. Conclusions are presented in the final section.

2 Basic Approach

The IPCC methodology (IPCC, 1997a) covers a number of human activities associated with GHG emissions and sinks – in particular, fossil fuel combustion, industry and agriculture, land-use change, and deforestation. On the basis of this methodology, we have developed a geoinformation technology that presents