Distributed inventory: analysis of uncertainty sources. Ukraine case study

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Abstract

Geoinformation technologies for greenhouse gases distributed inventory, which are based on IPCC methodologies and special software, linking input data, inventory models, and visualisation means, have been proposed. Problems concerning uncertainty and verification for distributed inventory have been discussed. These technologies open new possibilities for qualitative and quantitative "distributed" presentation of uncertainty problem on regional level, and give additional possibilities for decision makers.

1 Introduction

The Kyoto Protocol defines obligations of the parties on greenhouse gas emission reductions comparing to the base year. According to the Protocol each party must develop national system for estimation of anthropogenic emissions and removals of greenhouse gases (GHG). Intergovernmental Panel on Climate Change (IPCC) developed general methodologies for estimation of GHG emissions and removals published as IPCC Guidelines and corresponding software [1]. Universality is a positive feature of the IPCC methodologies. Just because of universality the methodologies can be used by experts of many countries, notwithstanding the countries lie in different parts of the globe and have different economical development. It is one of the reasons why the IPCC Guidelines are important on the stage of the formation of the Kyoto protocol mechanisms.

But for the future the positive feature could be a factor decreasing a little bit the efficiency of GHG inventories and thus restraining of utilisation of the Kyoto mechanisms in practice. That is because of their universality the IPCC methodologies cannot consider regional peculiarities of different countries that increases inventory uncertainty. Besides, in most of large area countries different sources and absorbers of GHGs are distributed in space very non-uniformly. For instance, that completely relates to Ukraine (area 603 th.sq.km), which consists of 25 administrative units (oblasts). IPCC methodologies for GHG inventory give the results for entire countries and thus cannot be an effective tool for those who make strategic economical and political decisions on regional development inside a country. Integrated information on actual spatial distribution of GHG sources and absorbers would serve an efficient instrument helping in making of well-considered decisions in economical and environmental perspectives.

2 Basic approach

Proposed information technology for distributed inventory of GHGs is based on geoinformation system (GIS), IPCC methodologies and special software linking input data, inventory models, IPCC methodologies and GIS. Usage of digital maps and geoinformation approaches gives the possibility to make, first of all, territory distributed inventory (in fact, the inventory relates to an area unit), but usage of IPCC methodologies and software provides compatibility and comparability of the inventory results with traditional approaches. Besides, usage of region specific emission factors and activity data will increase quality of the GHG inventory [2].

On the highest inventory level (country level) both input data and inventory results are "concentrated" and they make sense for entire country. If all necessary data, which relate to corresponding chapters of the IPCC Guidelines - Energy, Industrial Processes etc., are available for country, than the IPCC Guidelines give the possibility to calculate GHG emissions and removals (output data of the model). In this case the methodology, presented in the IPCC Guidelines, can be regarded as a mathematical model of inventory on the highest level. We have mathematical expressions mapping input data into output data, which are necessary for making an inventory process for the whole country. Used input data are taken mainly from statistical yearbooks, results of scientific researches, etc.

On the middle inventory level (level of administrative regions) the parameters of mathematical models are concentrated as well. Ukraine, for example, includes 25 administrative regions (oblasts). For each of them, in principle, similar methodology of the IPCC Guidelines can be applied as described above. This is not surprising because a country could be as large as administrative unit of Ukraine. For such region an inventory model based on IPCC Guidelines is also applicable. The model has input and output data as well, but in this case it is more difficult to obtain all necessary input data for calculations. In this case a situation is similar to the mathematical model of the highest level. Input data are obtained from statistical yearbooks, because the most of statistical information is published for administrative regions, and from results of scientific researches representing regional peculiarities of some parameters used by the IPCC Guidelines. There could be a situation when a parameter is known for country but not for regions. In this case some assumptions and additional information for obtaining the algorithm for determination of necessary parameters for regions can be used.

On the lowest inventory model both input and output data are represented in the form of georeferenced database. This inventory level is used for elementary plots of size, e.g. 10*10 km. For such plots, in principle, the similar approach as described above can be applied. On the analogy of the previous inventory levels corresponding mathematical model is defined with IPCC Guidelines. But in contrast to the previous inventory levels the input and output data for an elementary plot are not lumped. In some cases one can calculate GHG emissions and removals peculiar to an elementary plot directly using IPCC Guidelines with corresponding emission factors, e.g. emissions of a power generating plant, cement production, chemical plants, fertilised field, planted forest etc. But in some cases it is more efficient to distribute results obtained for region using spatial distribution of activity data, e.g. GHG emissions from gas flaring used for building heating and cooking. The GHG emission distribution in this case correlates with population density which is obtained from spatial analysis of digital map [3, 4]. In the worst case, if one can not derive detailed data on GHG emissions in region, the total emission quantity on all elementary plots within the region can be distributed uniformly.

According to the proposed approach the distributed inventory is carried out consequently for certain class of objects (region, district or an elementary plot). Information obtained from layers of digital map and statistical data for regions and districts is used as input data. As a result of such distributed inventory the new layers of digital map which correspond to economy sectors from the IPCC methodologies are formed. From the country point of view it is not longer the lumped inventory but distributed inventory model where input and output data are stored in georeferenced database. If one sums inventory results for all elementary plots in the boundaries of Ukraine he obtains general inventory for country [5, 6].

3 Information technologies

An approach presented in section 2 is an information technology, which combines electronic maps, geoinfomation systems, and IPCC Methodology. Figure 1 illustrates this technology in more details were corresponding layers of digital map are reflected. Here information of corresponding layers of digital map together with statistical data and data of scientific researches serve as input data. The databases (new layers of digital map) corresponding to certain sectors of IPCC methodology (energy, industry, etc.) are created using this information.

Further we perform inventory using IPCC methodology in order for all elementary plots of selected model. In that way we form the new layers of digital map, which correspond to results of GHG inventory: emission of carbon dioxide, methane etc. Finally we obtain the layer of digital map, which corresponds to the total GHG emission in CO_2 equivalent. Thus, results in proposed approach of distributed inventory are produced in the form of layers of digital map of Ukraine. Inventory results of lower level include the information about specific emission/absorption of GHG per unit area in the country.

Digital map of Ukraine produced by ISGEO (http://www.isgeo.kiev.ua) was chosen for usage in the information technology of GHG inventory. The map is a spatial database made on the topographical basis of 1:500 000 scale. On a logical level the database is organized in the form of separate tables, which contain cartographic objects and classifiers. Physically the database is realized in the format of MapInfo system. With the purpose of GHG inventorying in the information technology the following segments were adapted: settlements (inhabited localities and their population); road network and constructions, forested lands, hydrology, bounds of oblasts, vegetation and soil.

Statistical data published by the State Committee of Statistics of Ukraine in a number of statistical collections is a major source of input information for

GHG inventory. The statistical data are issued for many economy sectors, where information is aggregated for oblasts. Besides, regional statistical collections exist. This allows easily make a step from country GHG inventory to inventory for oblasts. On the basis of statistical collections one can obtain corresponding input data for proper infill of input worksheets of IPCC methodology by economy sectors.

Proposed geoinformation system consists of two basic parts (modules): GHGinvent and GHGmap. The module GHGinvent is a programming module, which performs GHG inventory according to user defined inventory model (level). The main function of GHGinvent is infilling of input data into corresponding Excel tables of IPCC Methodology [1]. Input data are organized in the form of database infilling corresponding cells of tables of IPCC methodology by means of module GHGinvent. This module forms initial inventory tables of GHG by results of IPCC methodology according to model defined.

The basic functions of the module GHGmap are organizing of queries to resulting inventory tables, forming of new geoinformation layers with inventory results and their reflection on the map of Ukraine. The inventory tables organized by module GHGinvent together with topographical information of digital map of Ukraineserve as input data for module GHGmap. Proposed information technology is complicated enough for software implementation because a number of software components of different kinds have to interact correctly to provide correct performance of the whole information system. Such a complex of software includes: databases of input information filled by operator [7]; Ecxel tables of IPCC methodology filled by program according to inventory model defined; database tables, which are compatible with MapInfo for inventory results reflecting on the digital map of Ukraine.

4 Distributed inventory results and uncertainty

The most of CO_2 emissions falls on Donetska oblast (26,89% of total emissions of Ukraine). Half of total emissions (51,84%) falls on three oblasts of Ukraine (Donetska, Luhanska, Dnipropetrovska). Main part of carbon dioxide emissions occurs in the sector of fuel combustion for energy production. Difference between results of carbon dioxide emissions obtained following base and sectoral approaches comes to 10%. Discrepancy of emission estimations by base and sectoral approaches can be explained in the following way: Ukrainian statistical data by sectors are zero in such cases when their values are less than minimal order number represented by the table. This phenomenon takes place in both cases: when fuel-energy resources are divided by oblasts, or by branches of economical activity. Therefore, total emissions do not always equal to the sum of individual components. Small discrepancy of calculated emission values in the oblasts lets us conclude about mutual consistency of statistical data on fuels used in fuel-energy complex of Ukraine.

In 2000 the most emissions were observed in Donetska (109669 Gg of CO_2 equivalent), Dnipropetrovska (56607) and Luhanska (41964) regions. In a number of oblasts carbon sinks exceed emissions values, in particular: Volynska (2348), Zakarpatska (4821), Rivnenska (1828), Chernivetska (92) and Chernigivska (1897) oblasts. Emission level is determined mainly by Energy sector, and sink level by sector of Land Use Change and Forestry.

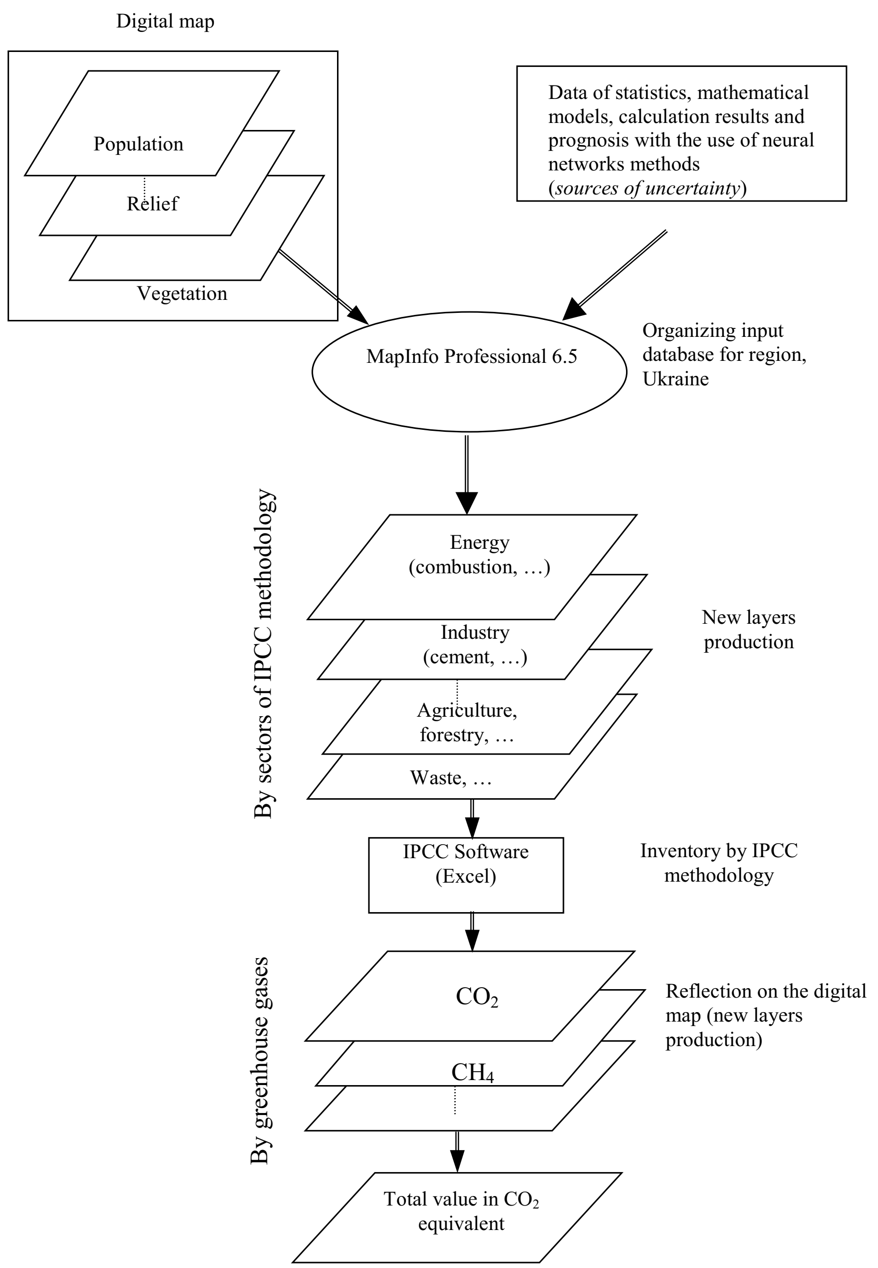

Figure 1: Geoinformation approach to GHG inventory

The least CO_2 emissions occur at the natural gas combustion because its emission factor is the least (about two times less than for coal). So, thermal power stations transition from coal to natural gas and black oil utilization can solve GHG problem of the energy sector of Ukraine. Taking into account significant contribution of thermoelectric power stations into total GHG balance of

Ukraine it is necessary to reconsider plan of development of domestic sources of power supply. Increasing efficiency of power equipment will accelerate solving the problem. Transition to nuclear energy can assist in solving this problem too, but this transition should be applied guardedly and gradually according to the level of scientific-technical progress of Ukraine.

Among Ukrainian regions (oblasts) cropland ecosystems are the most vulnerable to all climate change scenarios in Cherkaska oblast, and the least vulnerable cropland ecosystems are in Chernigivska oblast. Ecosystems of haylands and pastures are the most vulnerable under *base, min* and *tran* scenarios in Zaporizka oblast, and the least vulnerable ecosystems of haylands and pastures are in Chernigivska oblast. Under the *max* scenario conversely Chernigivska oblast is the most vulnerable, and Zaporizka is the least vulnerable. Oak forest ecosystems are the most vulnerable under all climate change scenarios in Cherkaska oblast, and the least vulnerable forest ecosystems are in Zaporizka oblast under *base* and *max* scenarios, and in Chernigivska oblast under *min* and *tran* scenarios.

According to the most favourable scenario of Ukrainian economy development the greenhouse gas emissions reach their 1990 level in 2011-2012. According to favourable scenario in 2013-2014, and for unfavourable scenario in 2020. It should be noted that unfavourable scenario corresponds to slow changes in economics, therefore this scenario is the most appropriate. It is necessary to invest money in reduction of power inputs of economics of Ukraine. First of all it concerns to thermoelectric stations, boiler-houses, steel and cast iron production.

Territorial approach to carbon dioxide inventory better takes into account differences of economical activity of the regions of Ukraine. Multilevel inventory is aimed to obtaining quantitative estimations for separate country regions. Estimations of distributed GHG emissions (on territorial basis) in the Energy sector will assist accelerating implementations of actions on reduction of emission levels, for example, means for GHG utilisation, catching carbon dioxide from exhausts, creation of favourable conditions for carbon absorbing by forests etc.

5 Positive features

Integrated information on actual spatial distribution of GHG sources and absorbers would be quite useful for decision makers. Such information and tools for information management would serve an efficient instrument helping in making of well-considered decisions in economical and environmental perspectives. There is a correlation between sustainable development of the territory and GHG emission values and structure. Positive aspects of proposed approach:

- information technologies for distributed inventory of GHGs reflect the real state of GHG emissions and sinks on regional level;

- in contrast to known approaches proposed technologies are based on utilisation of digital maps and IPCC methodologies combining transparency of the inventory and comfort of documenting;

- developed information technologies allow effective utilisation of earth remote sensing data, neural network technologies and approaches to estimation and prognosis of a number of parameters of distributed models of processes of GHG emitting and removing on region level;
- GHG emission structure and dynamics can be used as an indicator of region development, including sustainable development as well;
- in contrast to known approaches proposed technologies are effective for large area countries with non-uniform localisation of GHG sources and removals, the technology will be good instrument for decision-makers for regional management, carrying out of prognosis in accordance with development strategies as well as sustainable development strategies;
- information technologies of distributed inventory enable to define the most essential sources of uncertanty (as on kinds of activity, and also regional locations), it opens a capability for more effective utilization of investments on reduction of uncertainty just in these locales and in these kinds of activity.

Certainly, that for information technologies of distributed inventory some new problems take place concerning uncertainty and verification. But these technologies open new possibilities for qualitative and quantitative distributed presentation of uncertainty problem on regional level. Such information for Energy sector, Industry and Agriculture sectors, Land Use Change and Forestry sectors gives new additional possibilities for decision makers.

References

[1] IPCC Software (1977): IPCC Greenhouse Gas Inventory Software for the Workbook, IPCC.

[2] Bun R., M.Gusti, V.Dachuk, L.Kujii, B.Oleksiv, H.Striamets, S.Striamets, O.Tokar, Ya.Tsybrivskyy (2004), *Infpormation Technologies for Greenhouse Gas Inventory and Prognosys of Carbon Budget of Ukraine (R.Bun ed.)*, Lviv, SSRIII.

[3] Kujii L., B.Oleksiv (2003), Methods and means for realization of geoinformation system of greenhouse gases inventory, *Scientific Papers of the Institute for Modelling Problems in Energetics* **19**, 182-192.

[4] Tsybrivskyy Ya., Z.Klym (2003), Information technologies for greenhouse gas inventories: pilot analysis of emission sources in industry and agriculture of Ukraine, *Information Technologies and Systems* **1-2**, 183-194.

[5] Bun R., M.Gusti, V.Dachuk, B.Oleksiv, Ya.Tsybrivskyy (2003), Specialized computer system for multilevel inventory of greenhouse gases, *Herald of Technological University of Podillia* **3**, 77-81.

[6] Bun R., B.Oleksiv, Z.Klym, L.Kujii, Ya.Tsybrivskyy (2002), Geoinformation systems as a tool for carbon cycle monitoring and greenhouse gas inventory in the Western Region of Ukraine, *Proceedings of the International conference Mountains and People (in the context of sustainable development)*, Rakhiv, Vol. 2, 21-25.

[7] Bun R., B.Oleksiv (2003), Specialized database for information technologies of greenhouse gases inventory, *Information Technologies and Systems* **1-2**, 195-201.