CARBON DIOXIDE DEPOSITION AND AIR POLLUTION MONITORING SYSTEM BY ADABAS AND NATURAL SOFTWARE

Chasovskykh V., Usoltsev V., Voronov M.

Ural State Forest Engineering University, e-mail: vip@usfeu.ru, mstrk@yandex.ru

A system of spatial analysis of carbon deposition on forest cover using ADABAS and NATURAL software is suggested. The system gives a possibility for automatic actualization of data of forest biomass plots and of data of National Forest Inventory System (NFIS) that is synchronized with the interactive map-scheme of territorial arrangement of forest cover carbon. The value of carbon emanating or sink from atmosphere is determined as difference between the value of deposited carbon change and the value of its atmospheric concentration change in some time interval. This gives a possibility for monitoring the level of air pollution by carbon and other greenhouse gases.

Keywords: carbon dioxide, air pollution, air pollution

Nowadays, in condition of permanent productive capacity accretion of the enterprises all over the world, of steady impairment of ecological situation and explicit threat of ecocatastrophe, environmental pollution abatement represents its utter urgency. Unfortunately, environmental conditions in Russian Federation and in the world weren't being radically changed for the better during the last 10 years. And among the factors, which pose the main ecological threats, there are the following: increasing of technical catastrophe risk; foodstuff pollution; water quality degradation; renewable natural resources degradation; global climate fluctuation and air pollution by industrial gases involving greenhouse ones.

Pollution damage becomes more and more perceptible with every passing year. As Russian ecologists say [1, 2, 3] the biggest share in the total volume of gases ejection, that causes the greenhouse effect, belongs to CO_2, and power engineering (its fossil fuel firing) is the main source of it (Fig. 1).

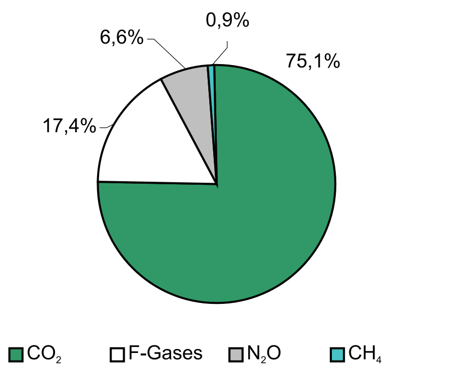

Fig. 1. Gases shares in the total volume of ejection that causes the greenhouse effect in 2006

The gravest consequence of its dissemination is air temperature rise due to greenhouse effect. For the purpose of solution of this problem, the Protocol of the United Nations Framework Convention on Climate Change was signed in Kyoto (Japan) in December 1997. This Protocol, among other things, includes quantitative obligations of developed and transitional economies countries to restrain and decrease greenhouse gases pollution, first of all CO_2, in atmosphere for 2008-2012. 23rd of October 2004 Russian Federation State Duma resolved to ratify the Kyoto Protocol.

In terms of the Protocol requirements implementation, an environment pollution monitoring system design seems expedient. At the heart of this system there is the idea to measure Russian Federation environment pollution level on the basis of the quantity analysis of CO_2, which is deposited by Ural region ecosystems. Based on professor Usoltsev's researches, the carbon deposition spatial analysis information system (CDSAIS) is designed by means of ADABAS and Natural software. Monitoring is supposed to be carried out by CDSAIS results processing with the help of dedicated system in ADABAS and Natural environment. Now CDSAIS includes data of the whole Ural region forestry units. Also, there are possibilities of supplement CDSAIS DB with data of other regions and further extension of the system coverage to state scale.

Within CDSAIS on the base of ADABAS software the experimental data of forest biomass and the data of National Forest Inventory System (NFIS) were combined with replicating the data into NATURAL software according to the following stages:

1) plot biomass factual data;

2) regression models of biomass fractions, which include NFIS indices as regressors;

3) geographical distribution matrixes of areas covered by forest for prevailing wood species;

4) geographical distribution matrixes of carbon pool where NFIS indices are the inputs for these matrices;

5) geographical distribution map-schemes of carbon pool in forest biomass for Ural region.

An example of applications created in ADABAS and NATURAL software is displayed on Fig. 2.

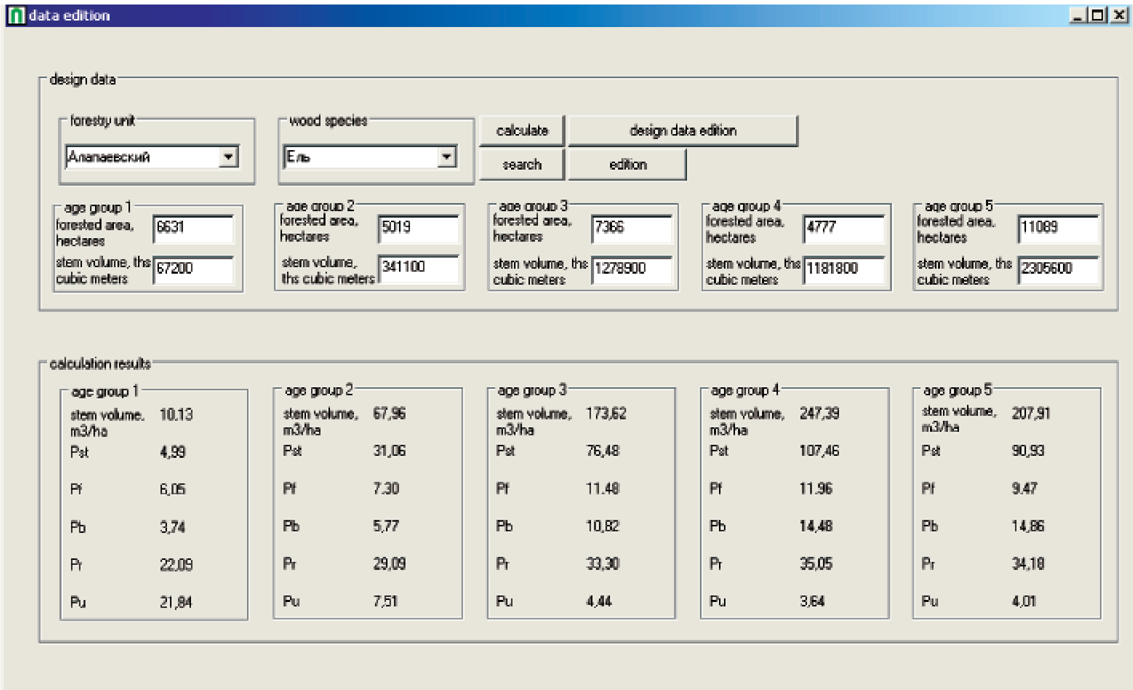

Fig. 2. Data edition application

In CDSAIS format the equations of biomass quantity dependence upon age and stand volume are calculated for each fraction: stems (P_{st}), foliage (P_f), branches (P_b), roots (P_r) and understory P_u.

The coefficients for biomass dependence equations (BDE) are calculated with the help of Tchebyshev's method [4] (formulas 1-7):

$$
\begin{aligned}
r^{(2,2)}_{(j_1)(j_2)1} &= r_{101}\varepsilon_{1(j_1)} + \frac{\delta_1}{\gamma_1}\left(\varepsilon_{2(j_2)} - r_{110}\varepsilon_{1(j_1)}\right) + \\
&+ \frac{d_1}{c_1}\left[\varepsilon_{1(j_1)}\varepsilon_{2(j_2)} - r_{210}\varepsilon_{1(j_1)} - r_{110} - \frac{\gamma_2}{\gamma_1}\left(\varepsilon_{2(j_2)} - r_{110}\varepsilon_{1(j_1)}\right)\right] + \\
&+ \frac{\begin{vmatrix} c_1 & d_1 \\ c_2 & d_2 \end{vmatrix}}{\begin{vmatrix} c_1 & c_2 \\ c_2 & c_3 \end{vmatrix}}\left\{\varepsilon^2_{1(j_j)} - r_{300}\varepsilon_{1(j_1)} - 1 - \frac{\gamma_4}{\gamma_1}\left(\varepsilon_{2(j_2)} - r_{110}\varepsilon_{1(j_1)}\right) - \right. \\
&\left. - \frac{c_2}{c_1}\left[\varepsilon_{1(j_1)}\varepsilon_{2(j_2)} - r_{210}\varepsilon_{1(j_1)} - r_{110} - \frac{\gamma_2}{\gamma_1}\left(\varepsilon_{2(j_2)} - r_{110}\varepsilon_{1(j_1)}\right)\right]\right\}.
\end{aligned}
\qquad (1)
$$

Basic error:

$$
\frac{\sigma^{(2.2)^2}_{3.12}}{\sigma_3^2} = 1 - r_{101}^2 - \frac{\delta_1^2}{\gamma_1 c_1} - \frac{\begin{vmatrix} c_1 & d_1 \\ c_2 & d_2 \end{vmatrix}}{c_1 \cdot \begin{vmatrix} c_1 & c_2 \\ c_2 & c_3 \end{vmatrix}} - \frac{\begin{vmatrix} c_1 & c_2 & d_1 \\ c_2 & c_3 & d_2 \\ c_4 & c_5 & d_3 \end{vmatrix}}{\begin{vmatrix} c_1 & c_2 \\ c_2 & c_3 \end{vmatrix} \cdot \begin{vmatrix} c_1 & c_2 & c_4 \\ c_2 & c_3 & c_5 \\ c_4 & c_5 & c_6 \end{vmatrix}}, \qquad (2)
$$

where

$$\begin{cases} \gamma_1 = 1 - r_{110}^2 \\ \gamma_2 = r_{120} - r_{210}r_{110} \\ \gamma_3 = r_{220} - r_{210}^2 - r_{110}^2 \\ \gamma_4 = r_{210} - r_{110}r_{300} \\ \gamma_5 = r_{310} - r_{210}r_{300} - r_{110} \\ \gamma_6 = r_{400} - r_{300}^2 - 1 \\ \gamma_7 = r_{030} - r_{120}r_{110} \\ \gamma_8 = r_{130} - r_{210}r_{120} - r_{110} \\ \gamma_9 = r_{220} - r_{120}r_{300} - 1 \\ \gamma_{10} = r_{040} - r_{120}^2 - 1 \end{cases} \quad (3)$$

$$\begin{cases} \delta_1 = r_{011} - r_{110}r_{101} \\ \delta_2 = r_{111} - r_{210}r_{101} \\ \delta_3 = r_{201} - r_{300}r_{101} \\ \delta_4 = r_{021} - r_{120}r_{101} \end{cases} \quad (4)$$

$$\begin{cases} c_1 = \gamma_1\gamma_3 - \gamma_2^2 \\ c_2 = \gamma_1\gamma_5 - \gamma_2\gamma_4 \\ c_3 = \gamma_1\gamma_6 - \gamma_4^2 \\ c_4 = \gamma_1\gamma_8 - \gamma_2\gamma_7 \\ c_5 = \gamma_1\gamma_9 - \gamma_4\gamma_7 \\ c_6 = \gamma_1\gamma_{10} - \gamma_7^2 \end{cases} \quad (5)$$

$$\begin{cases} d_1 = \gamma_1\delta_2 - \gamma_2\delta_1 \\ d_2 = \gamma_1\delta_3 - \gamma_4\delta_1 \\ d_3 = \gamma_1\delta_4 - \gamma_7\delta_1 \end{cases} \quad (6)$$

$$\varepsilon_{1(j_i)} = \frac{X_{1(j_i)} - \bar{X}_1}{\bar{\sigma}_1} \quad (7)$$

Then, by combination of PDE with occupied forested area data and stand volume ones, provided by the NFIS, carbon pool of all fractions for each forest forming species of Russian territorial entities is calculated using the conversion coefficient 0,5 [5]. The results of calculating may be shown as a map-scheme for the whole country or for any of its region (Fig. 3). Annual carbon deposition is calculated as multiplication of carbon pool values by the corresponding coefficient [6].

In order to display the results as interactive maps, the synchronization of database and applications with map editor GIS Panorama 2008. Calculating algorithms, methods of biomass data obtaining on plots and CDSAIS DB features are considered in [7, 8]. DBMS ADABAS and NATURAL development environment features and description are considered in [9-12].

Environmental pollution monitoring necessitates permanent measuring of atmospheric CO_2 concentration. In Russia such measuring is run at Teriberka station (69°12‘ N., 35°06‘ E.) According to Teriberka station data [1] during the period of 1997-2007 the following values of CO_2 and carbon concentration and its annual growth were obtained (Table).

Methane, CO_2 and carbon air concentration and its annual growth during the period of 1997-2007 according to Teriberka station data [1]

Year	CH_4 concentration		CH_4 concentration change		CO_2 concentration		CO_2 concentration change	
	CH_4, billion^{-1}	Involving C, billion^{-1}	ΔCH_4 annual growth, billion^{-1}	Involving C, billion^{-1}	CO_2, million^{-1}	Involving C, million^{-1}	ΔCO_2 annual growth, million^{-1}	Involving C, million^{-1}
1997	1857,4	1393	16,9	13	365,9	98,8	2,5	0,7
1998	1871,3	1403	13,9	10	368,3	99,4	2,4	0,6
1999	1872,5	1404	1,2	1	370,8	100,1	2,5	0,7
2000	1867,4	1400	–5,1	–4	371,5	100,3	0,7	0,2
2001	1865,0	1399	–2,4	–1	373,2	100,8	1,7	0,5
2002	1862,6	1397	–2,4	–2	375,5	101,4	2,4	0,6
2003	1879,2	1409	16,7	12	377,6	102,0	2,1	0,6
2004	1871,7	1404	–7,5	–5	379,3	102,4	1,7	0,4
2005	1870,7	1403	–1,0	–1	381,4	103,0	2,0	0,6
2006	1871,3	1403	0,5	0	384,4	103,8	3,0	0,8
2007	1877,7	1408	6,4	5	384,6	103,9	0,2	0,1

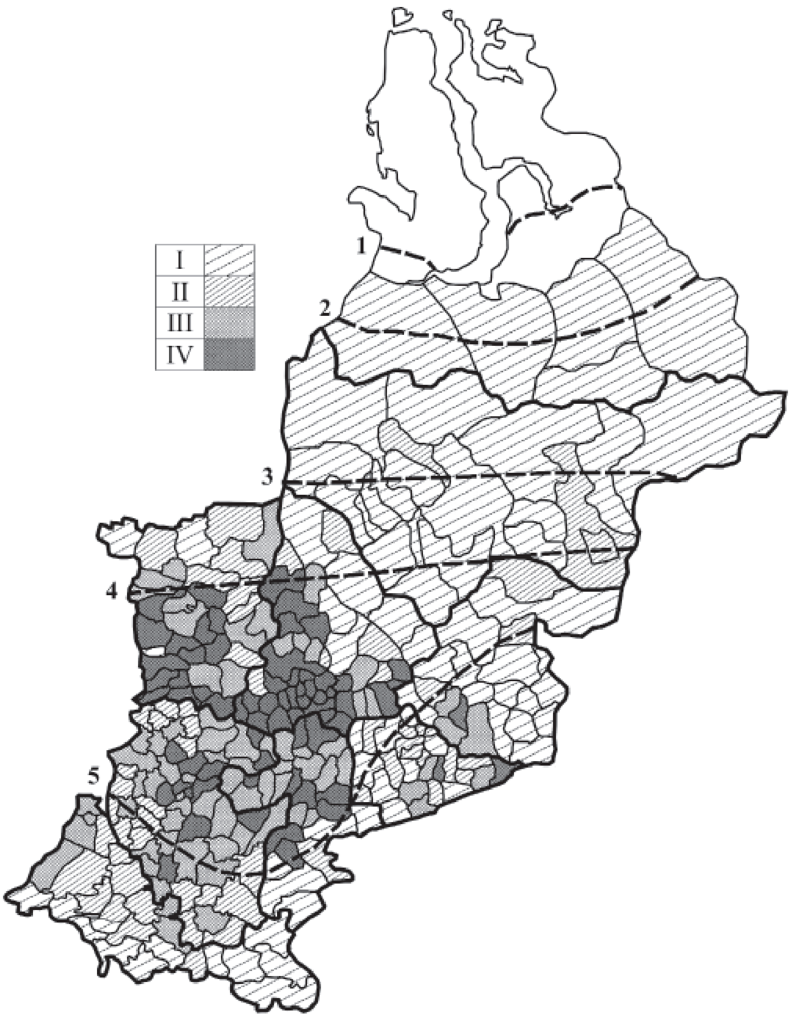

Fig. 3. Carbon pool distribution in forest biomass within forest area of Ural region. Carbon pool gradations, tons per hectare: I – 3,0-38,5; II – 38,5-46,5; III – 46,5-54,5; IV – 54,5-109,5. Firm line indicates the borders between forestry units, dotted line indicates the south borders of the natural zones: 1 – tundra, 2 – forest-tundra, 3 – north taiga, 4 – middle taiga and 5 – south taiga

In order to increase adequacy of monitoring, the creation of extra measuring stations on Russian territory is advisable. In this case, empirical data of regions pollution, rather than averaged data of Teriberka station, corrected by territorial coefficients, which define the pollution level in territorial entities, would be used for the calculation.

The algorithm of Environmental Pollution Monitoring Information System (EPMIS) is represented on the Fig. 4.

As it is showed with the model (Fig. 4), the difference between calculated value of carbon deposition for certain periods of time and CO_2 concentration data of Teriberka station is calculated. This difference per se is the excess of CO_2, which cannot be deposited by plants. This CO_2 excess, having accumulated in atmosphere, becomes the source of negative effects in environment, and on conditions that CO_2 emissions level remained the same it would result in irreversible consequences of planet scale.

Also, on the basis of maximum and critical CO_2 concentration limits and the comparison of this limits with the concentration values of CO_2 excess, future environmental CO_2 pollution forecast is available within EPMIS.

The means of EPMIS development environment gives the possibilities to display the results in the following forms:

– Interactive map (Fig. 3). For every region (forestry unit etc.), pointing mouse cursor at a territorial unit on the map, the deposited CO_2 quantity data, excessive CO_2 concentration data, maximum and critical CO_2 concentration limits excess data are displayed.

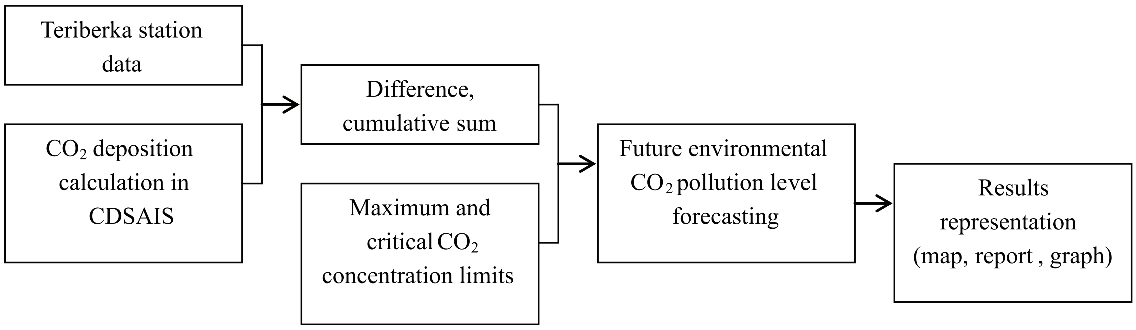

Fig. 4. The algorithm of Environmental Pollution Monitoring Information System (EPMIS)

– Report. The results can be displayed as reporting form.

– Graph. The deposited carbon mass changing, the CO_2 concentration growth dynamics, the fractions shares of plants of different age groups into the total deposited carbon mass, and also pollution level forecast can be displayed in the form of graph.

From the research many benefits were obtained. The main advantages of EPMIS are:

– The possibility of automated recalculating of deposited CO_2 data when: (a) forest biomass experimental data obtained on plots and (b) NFIS data are changed. Synchronization of databases changes with interactive maps.

– The possibility of changing maximum and critical CO_2 concentration limits data.

– The possibility of future environmental CO_2 pollution forecast.

This work has been supported by Russian Fund of Fundamental Researches (grant 07–07–96010) and by Ministry of Education and Science of Russia (State Contract № P1713 from 23 September 2009).

References

1. Federal Hydrometeorology and Environment Monitoring Service. – Russian Federation environment condition and pollution review of 2007. – M.: Publishing House «Rosgidromet», 2008. – 164 p.

2. Lozanovskaya I.N., Orlov D.S., Sadovnikova L.K. Ecology and biochemical contamination protection of biosphere. – M.: Publishing House «Vysshaya Shkola», 2006. – 334 p.

3. Revel P., Revel C. Our habitat. 4 volumes (translation from English). – M.: Publishing House «Mir», 1995. – 191 p.

4. Mitropolsky A.K. Statistic computing technique. – M.: Publishing House «Nauka», 1971. – 576 p.

5. Kobak K.I. Biotic components of carbon cycle. – Leningrad: Gidrometeoizdat, 1988. – 248 p.

6. Usoltsev V.A. Biological productivity of North Eurasian forests: methods, database and its applications. – Ekaterinburg: Ural Branch of RAS, 2007. – 636 p.

7. Usoltsev V.A. North Eurasian forests phytomass: database and geography. – Ekaterinburg: Ural Branch of RAS, 2001. – 707 p.

8. Usoltsev V.A., Chasovskykh V.P., Voronov M.P., Korets M.A., Tcherkashin V.P. et al. Forests carbon deposition ability appraisal: from tree plot to automated system of spatial analysis // Forest Measurement and Inventory. – Krasnoyarsk, 2008. – № 1 (39). – P. 183–190.

9. Chasovskykh V.P., Voronov M.P., Faterkin A.S. Information technologies in management: DMS ADABAS and applications design by NATURAL means. – Ekaterinburg: The Ural State Forest Engineering University, 2006. – 477 p.

10. Chasovskykh V.P., Voronov M.P. The research of system relations and regularities of timber enterprise corporative information system operation in ADABAS and NATURAL environment.– Ekaterinburg: The Ural State Forest Engineering University, 2008. – 120 p.

11. Chasovskykh V.P., Akchurina G.A., Slobodin A.V., Azarenok M.V. Voronov M.P. Management information technologies. – Ekaterinburg: The Ural State Forest Engineering University, 2008. – 402 p.

12. Chasovskykh M.P., Voronov M.P. Multi–level structure model as an instrument of CIS adjustment to enterprise activity // Modeling, Identification, Synthesis of Management Systems. Proc. of X International Science and Technical Conference. – Donetsk: Institute of Applied Mathematics and Mechanics NAS of Ukraine, 2007. – P. 67–79.