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FORECASTED TRENDS IN CHANGES OF VEGETATION IN THE EUROPEAN PART OF RUSSIA IN CONNECTION WITH GLOBAL WARMING

ABSTRACT. The paper discusses connections between zonal boundaries of vegetation and productivity of forest stands and some climatic parameters. It also suggests mathematical-cartographic models of these connections. The models are used to forecast changes in the boundaries of the vegetation sub-zones and of forest stands productivity in the European Part of Russia and on the adjacent areas for 2046–2065 under one of the scenarios of global warming.

KEY WORDS: Zoning of vegetation, growth of timber, global warming, climatic parameters, forecasts, mathematical-cartographic model.

INTRODUCTION AND BACKGROUND

The most important feature of the modern climate is global warming. It can be traced as a background process throughout the XXth century and it has become most prominent beginning in the 1970s. Climate warming is detected from meteorological observations (for a rigorous analysis, only data of the measurements of non-urbanized areas are used) and is supported by indirect evidence, of which the principal one is the rise in the oceans' level and melting of mountain glaciers. The major challenge for the modern science is the question of the climate forecast and identification of the environmental response to these changes. This paper discusses some issues related to changes in the vegetation cover (VC) occurring under the influence of current trends of climate change and a projection of its dynamics in the European Part of Russia.

It is best to consider feedbacks of VC to climatic changes under an integrated approach. This approach involves, first of all, ideas of the planetary homeostasis (i.e., the tendency of the natural system to reproduce itself, to restore the lost balance, and to overcome resistance of the external environment) that have been best reflected in the Gaia hypothesis [Lovelock, 1982]. However, with all its elegance, this concept of the biological control over the global climate must, apparently, be rejected – empirical and theoretical results show that the dynamics of the Earth's history for the global biota depended heavily on geophysical phenomena occurring on the planet [Budyko, et al., 1985].

The interaction between VC and climate can be assessed with varying level of detail. The VC properties (morphological, physical, and psychological) are considered together with soil parameters in current climate models in the calculations of various flows (heat, moisture, and carbon dioxide) between the atmosphere and the underlying surface. These are the so-called SVAT ("Soil-Vegetation-Atmosphere-Transfer") models that can be integrated or used individually. The resulting climate change calculations determine changes of the biophysical and biochemical processes in plants and soils, defining changes in species composition, length of the growing period, and the vegetation structure. The process of transition from inputs of climatic models to the VC parameters may occur at different levels of complexity. This may involve very simple regression relations and much more sophisticated models, such as EFIMOD (http://ecobas.org/www-server/rem/mdb/efimod.html; http://prezi.com/tprjzowtnuj3/2), BIOME 6000, etc. A common feature is a unidirectional approach; i.e., the information about the changes in VC is not interactively fed back to the climate model. At the same time, changes in the properties of VC influence the exchange of heat, H_2O, and CO_2 with the atmosphere, and these changes can effectively impact the thermodynamic field of the atmosphere. Thus, the so-called dynamic models of vegetation were developed. These include, for example, ORCHIDEE [Krinner, et al., 2005], JSBACH [Bathiany, et al., 2010], etc., that are interactively connected with the atmosphere component of climatic models. Such systems are already able to reflect feedback-based transient changes.

This paper treats changes in VC through static relations, i.e., regression equations. The use of the simplest approach is quite reasonable since the use of complex models does not often produce reasonable results due to requirements for very precise information of the VC parameters. VC is characterized through its zonal boundaries and productivity parameters of woody plants.

Shifts in zonal boundaries of vegetation are found in different regions of the world. With sufficient moisture, they are most likely where the temperature is the limiting factor [Turmanina, 1976]. Therefore, the most noticeable changes can be observed at the northern limit of the distribution of woody vegetation: with global warming, the forest boundary at high latitudes is expected to shift north [Turmanina, 1976; Velichko, 1992; Malkhazova, et al., 2011]. Modern research in the polar regions of Siberia has identified the spread of woody vegetation to the north. Thus, for the world's northernmost forests in Khatanga (Taimyr) over the last 30 years, a 65% increase of larch canopy closure and their shift into the tundra area at 3–20 m/yr have been detected [Kharuk, et al., 2006]. Unfortunately, similar data are not available for the southern regions of Russia.

Establishing the quantitative relationship between the zonal boundaries of VC and climatic parameters is associated frequently with an array of problems that relate to complex relations between VC and climate change, to uncertainty in dependencies between VC boundaries and climate, to vegetation system inertia, to multi-factorial nature of climatic impacts, and to uncertainty of the definition of the notion of "zonal boundaries" itself [Malkhazova, et al., 2011].

Quantitative analysis of the effect of climate on the *productivity of forest stands* is of particular importance for the assessment of resource-biosphere relationships. *Growth of timber* is an integral indicator of stand productivity. Growth of timber is defined by biological characteristics of the species and by the entire array of abiotic factors, among which, climate is of paramount importance. Warming, in conditions of the shortage of heat supply, leads, apparently, to an increase in productivity of forest stands in Russia and some European countries (0.5% per year from 1961 to 1998) [Alekseev and Markov, 2003].

The goals of this work included identification of climate indicators that are most associated with vegetation, establishment of forms of these relationships, and assessment of forecasted values of selected vegetation characteristics based on climatic models for the mid XXIth century [Kislov, et al., 2008; Kislov, 2011]. As a result, mathematical and cartographic models of relationships between vegetation zoning and productivity for the European Part of Russia (EPR) and some climatic parameters were built. These models were used to forecast possible changes in the boundaries of the vegetation sub-zones and in stand productivity in the EPR in the middle of the XXIth century caused by global warming.

MATERIALS AND METHODS

Climatic data. Information about the spatial distribution of climatic parameters used in the above-mentioned models characterizes the EPR and the adjacent areas. The territory is broken into a grid with a 2 S 2 deg. cell size.

The data for the period from 1961 to 1989 inclusively (that are called a «period of the modern climate» on the recommendation of the World Meteorological Organization) are the results of the NCAP/NCEP re-analysis [Kislov, 2011; Kislov, et al., 2011] interpolated to the nodes (the geometric centers of the cells) of the degree grid. For each node, a range of climate parameters was calculated. It was assumed, that their values for the node (point) can be extrapolated to the whole cell (polygon).

Structurally similar projections for 2046–2065 are based on the data of numerical experiments carried out with climatic models under the project CMIP3 (*Coupled Model Intercomparison Project*) of the WCRP (*World Climate Research Program*). For the characteristics of the future anthropogenic impacts, "A2" scenario (i.e., one of the most "harsh"scenarios of the IPCC (*Intergovernmental Panel on Climate Change*)) was adopted [Kislov, 2011; Kislov, et al., 2011].

Of a variety of available climatic parameter, the parameters selected for the analysis are as follows:

1) Effective air temperature (T > 10°C). The analysis considered a number of days with effective temperature and the annual sum of such temperatures. These indicators are considered the major climatic characteristics of plants growing season.

2) The hydrothermal coefficient (*HTC*) by Selyaninov:

$$HTC = Sum\_R/0.1 \cdot Sum\_T \qquad (1)$$

where: *Sum_R* is the total precipitation for the year; *Sum_T* is the sum of effective temperatures for the year.

Zoning of vegetation. Possible changes in the vegetation zones boundaries were assessed based on the map "Zones and types of vegetation belts of Russia and adjacent territories" [Zones and types..., 1992]. This map represents the most common understanding of the modern zoning of vegetation, while satisfying the fullest the requirements to scale and detail. It was assumed that the map represents the equilibrium of the zonal boundaries of vegetation and of the conditions for the "period of the modern climate".

Within the EPR, the following categories of the classification of flatland vegetation are used (zones and sub-zones, in accordance with the legend of the map (Fig. 1A)

A. Tundra zone. *Sub-zones*: A2 – arctic tundra (*only on some islands of the EPR, however, is considered in the numbering system*); A3 – northern hypoarctic (typical) tundra; A4 – southern hypoarctic (shrub) tundra.

B. Taiga zone. *Sub-zones:* B1 – forest tundra; B2 – northern taiga; B3 – middle taiga; B4 – southern taiga; B5 – sub-taiga (mixed forest).

C. Deciduous forest zone. *Sub-zones:* C1 – broadleaved forest; C2 – forest-steppe.

D. Steppe zone. *Sub-zones:* D1 – northern (bunch-grass-turf) steppe; D2 – middle (dry) steppe; D3 – southern (desert) steppe.

E. Desert zone. Sub-zones: E1 – northern desert; E2 – middle desert; E3 – southern desert (*not present in the study area under modern conditions, however, is present in the forecast – see below*).

The analysis was performed at the level of the vegetation *sub-zones*. Within the study area, they were numbered from north to south from "1" (A2) to "16" (E3).

Fig. 1A shows the distribution of the nodes and degree grid cells over the map of the modern zoning vegetation [Zones and types..., 1992]. The analysis was performed separately for the nodes and cells, as their spatial association with the vegetation sub-zones boundaries differed somewhat. Excluded from the analysis were the nodes and cells that were outside the boundaries of the vegetation units identified on the map, as well as the islands (except for the largest), mountain areas, and seas. Each node or cell was assigned a number of the sub-zone. It was assumed:

- for the nodes – the node is within the sub-zone;
- for the cells – more than 50% of the area of the cell is within the sub-zone, even if its geometric center (node) is located outside the sub-zone.

The analysis of the map (Fig. 1A) showed that a significant number of the nodes (at least 20%) are almost on the boundaries of the sub-zones. Approximately the same number of the cells is divided by these boundaries practically in half. If we consider that the accuracy of the zonal boundaries on the map is, to some extent, relative, it can be concluded that the assignment of specific nodes or cells to a particular sub-zone, in some cases, is rather arbitrarily, particularly in the northern areas where the latitudinal extent of the sub-zones is minimal. However, all the nodes and cells, with some assumptions, have been confined to specific sub-zones (Fig. 1B).

Growth of timber. The analysis was based on the data on stocks and growth of forests from the statistical materials of the State Accounting of the Forest Fund (SAFF) for 1963–1990. Of a large number of forest

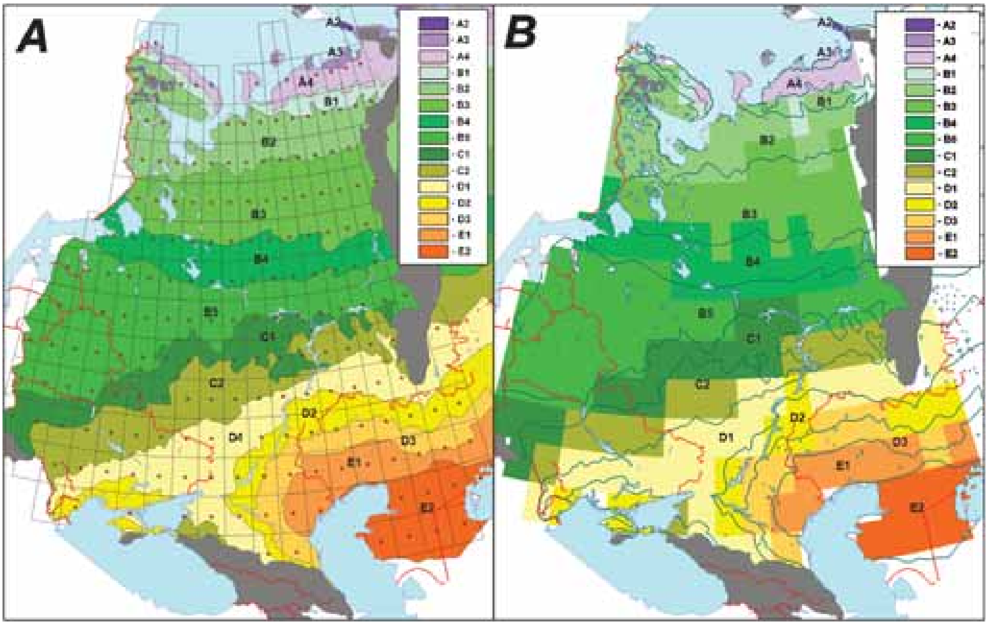

Fig. 1. A – the cells (polygons) and the nodes (points) of the degree grid used as the locations of the climatic data when superimposed with the map of the current zoning of vegetation.
B – sub-zonal locations of the grid cells.
A2-E2 – vegetation sub-zones (see text). Gray color indicates mountain areas

taxation parameters in the data of SAFF for all groups of tree species, the following parameters were selected for the analysis:

The total stock of timber is the amount of raw stem wood of all the trees of the forest stand. It depends on many factors, including, the forested area, the average age of the stand, etc.

The total average annual growth of timber is the parameter that characterizes the annual increase of the stem stock of the forest on average for the entire period of its life. This is an integral stand productivity index that reflects conditions of its development, including climatic.

To analyze the relationships between climate and productivity parameters, 36 administrative regions of the Russian Federation within the EPR were selected. Most of them are located entirely within the forest area, but there are others where the forested land occupies a relatively small area (Belgorod, Orel, Kursk Oblast, etc.). Therefore, the analysis was carried out for all the regions and separately for those fully located within the forest areas.

The data of SAFF were recalculated to arrive at the units of "m^3/ha of forested area." Thus, the parameters for the "average stock" and "average growth" of trees were obtained; then they were used to calculate the average long-term values for 1961–1988 for each of the selected Russian administrative regions.

The map of the administrative regions was superimposed with the degree grid (see above). The multi-year weighted average (for the area) climatic parameters were calculated for each administrative region of the Russian Federation; the calculations were made considering the set of the grid cells that cover each region and the proportion of the cells' area for the region.

Then, the relationships were assessed (Pearson correlation coefficients of the pairs) between:

– the values of climatic parameters and the sub-zonal locations of the nodes and cells (numbers of sub-zones); the results are shown in Table 1;

– the values of climatic and productivity parameters; the results are shown in Table 2.

The linear regression equations calculated for these indicators were then used to support and build the forecast models.

Data processing and calculations were carried out with *MS Visual FoxPro* and *STATISTIKA* software. Cartographic work was carried out in the *MapInfo Professional* GIS environment.

RESULTS AND DISCUSSION

Zoning of vegetation

Table 1 shows that the level of relationships between the climatic parameters and numbers of the sub-zones is very high. It is somewhat lower for HTC, but is especially high for effective temperature: 0.97 both for the cells and the nodes. This provided the basis for the calculation of the regression

Table 1. Correlation coefficients of the climatic parameters and the numbers of vegetation sub-zones*

Parameter	Sub-zonal locations (sub-zones numbers) of the nodes and the cells of the grid	
	nodes	cells
HTC by Selyaninov	–0.81	–0.79
Number of days with T0C > 100	0.92	0.92
SumT0C > 100	0.97	0.97

*All correlation coefficients are significant at $p < 0.01$.

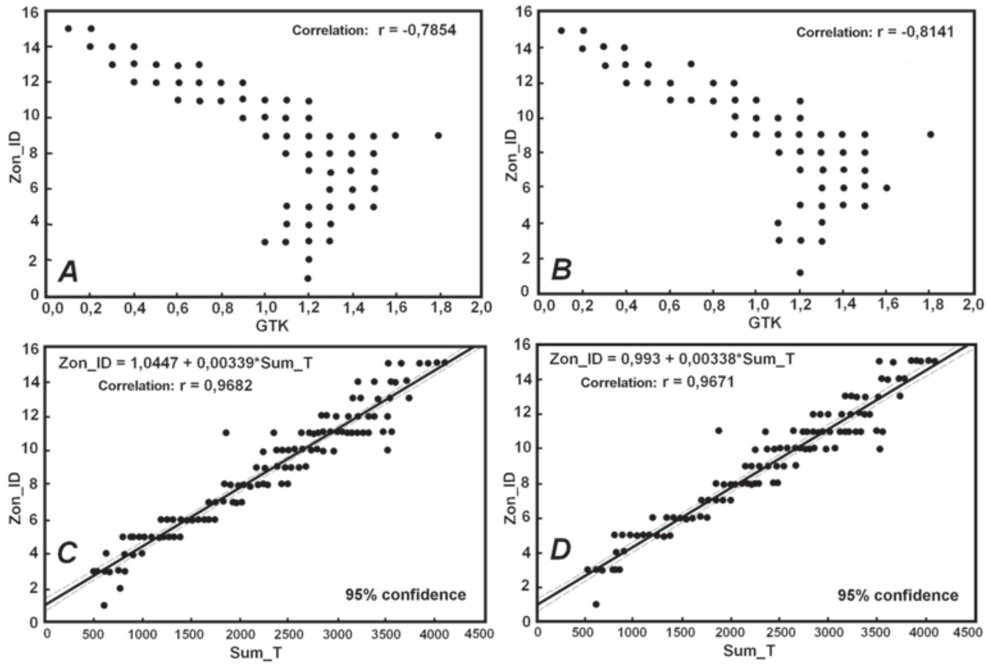

Fig. 2. The relationships between the order numbers of the vegetation sub-zones (Zon_ID), HTC by Selyaninov (HTC), and the sum of effective temperatures (Sum_T).

***A, B** – HTC (**A** – for the cells, **B** – for the nodes), **C, D** – the sum of effective temperatures (**C** – for the cells, **D** – for sthe nodes)*

relationships between the sub-zonal locations of the grid's nodes and cells and the climatic parameters (Fig. 2).

Fig. 2 shows nonlinear relationships for the HTC parameter; however, these relationships were not analyzed at the current stage; therefore, HTC was not used in the forecast.

We can also see that the sum of effective temperatures actually shows a linear relationship with the vegetation zoning. A similar pattern was obtained for the number of days with effective temperature, although in this case, the strength of the relationship was somewhat lower (Table 1), so the graphs for the last case are not given.

Thus, the sum of effective temperatures appeared to be the best parameter of all climatic parameters considered for the forecast of possible changes of the vegetation sub-zone boundaries in the EPR in the middle of the XXIth century; this parameter had the tightest connection with the vegetation zoning (Fig. 2, Table 1).

The relationships betweens the sub-zonal locations of the nodes and cells of the grid and the values of the sum of effective temperatures parameter are described by two regression equations (Fig. 2). Modification of some of these formulas (averaging the values of the coefficients for the nodes and cells) allowed arriving at the following equation applicable both to the cells and the nodes.

$$Zon\_ID = 1 + 0.0034 \cdot Sum\_T, \quad (2)$$

where: *Zon_ID* is the serial number of the sub-zone (1–15),

Sum_T is the sum of effective temperatures.

Using the existing forecast values *Sum_T* in equation (2) made it possible to determine the potential location of each cell of the degree grid for 2046–2065 in the zoning system, defined by the sum of effective

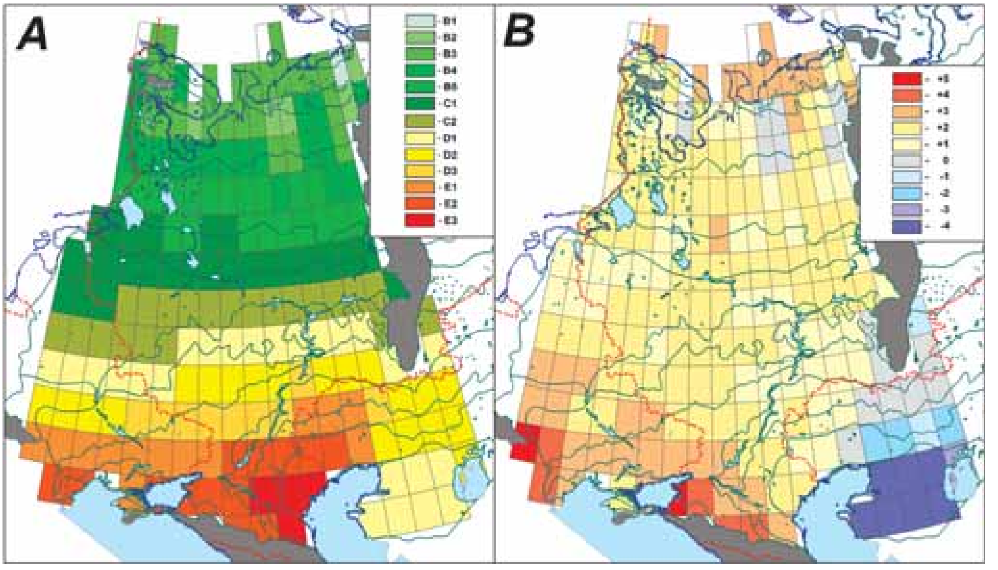

Fig. 3. A – 2046–2065 potential sub-zonal locations of the grid cells defined by the sum of effective temperatures. B – projected "shifts" – potential changes of the sub-zonal locations of the degree grid cells for 2046–2065 determined by the sum of effective temperatures.

*B1–E3 – parameters of the vegetation sub-zones (see text and Fig. 1), corresponding to the grid cells according to the forecasted temperature conditions for 2046–2065. The values of a "shift" (change in the number of the sub-zones): (+) – shift of the sub-zonal boundaries to the north (warming), (–) – shift of the sub-zonal boundaries to the south (cooling), (0) – no "shift." For **A** and **B**: "empty" cells indicate that the forecasted results are not reliable; green lines – the modern boundaries of vegetation sub-zones (see Fig. 1)*

temperatures. The same can be applied to the nodes, but in this case, the cartographic representation of the results is less evident.

Obviously, the time interval between the "period of the modern climate" (1961–1989) and the forecast period (2046–2065) is not sufficient to predict the real change of zoning boundaries, that, if at all possible, may manifest itself only locally. One can only talk about the potential conditions that determine the character of vegetation in the middle of the XXIth century. In any case, the inertia of vegetation as a system would not allow it to reach the state of equilibrium with changing climatic conditions by the middle of the XXIth century.

Considering this discussion and using equation 2, the potential locations of specific cells of the grid in the vegetation sub-zones system that correspond to the forecasted 2046–2065 changes in the thermal conditions were calculated and presented in a map format (Fig. 3A).

For greater clarity, we calculated "shifts" of corresponding values of the sub-zonal locations of the grid cells. The "shift" means the difference between the forecasted and the modern values of the sub-zone numbers (1–16) of the current cell. The "shift" can be positive (the forecasted value is greater than the modern – "warming"), negative (the forecasted value is less than the modern – "cooling"), or "zero" (no change forecasted) (Fig. 3B).

The map in Fig. 3A (in comparison with Fig. 1) shows the tendency of the northern shift of the sub-zonal boundaries in the future for almost the entire territory under the discussion. The exception is the individual cells in the northern EPR, for which the results of the forecast are considered less reliable.

Fig. 3B (in comparison with Fig. 1, 3A) shows that for tundra and forest-tundra of the EPR, the forecasted trends in the "shifts" of the sub-zonal boundaries correspond to the established ideas. The development of favorable, for forest vegetation, conditions is expected. In this case, in the north of the territory for individual cells, there are very significant "shifts" leading to a situation where, for example, on the Kola Peninsula, the forecasted temperature conditions in some places will support the growth of southern taiga or mixed forests (Fig. 3A).

Negative "shifts" within the study area are forecasted primarily outside of Russia, for the northwest of Kazakhstan; within Russia – for the southern Urals (Fig. 3B).

Growth of timber

The results of the calculations of the Pearson correlation coefficients of pair values presented above (Table 2) show that the most significant connection between vegetation productivity and climate exists only for the pair "the total average annual growth of timber – the sum of effective temperatures". In this case, the connection becomes stronger if only the forest regions are included (Table 2, Fig. 4). Accordingly, these parameters were used to predict trends in vegetation productivity for the period 2046–2065 in the EPR.

The relationship between the total average annual growth of timber (*GT*) and the sum of effective temperatures established in the calculations can be expressed by the following equation of the linear regression with the correlation coefficient equal to 0.92 (see Table 2):

$$GT = -2{,}007 + 0{,}0026\ S\ Sum\_T, \qquad (3)$$

where: *GT* is the average growth of timber (m^3/ha); *Sum_T* is the sum of active temperatures.

Table 2. Correlation coefficients of climatic and productivity parameters for the selected regions of the EPR

Pairs of parameters	All regions (*n* = 36)	Forest (*n* = 23)*
Average stock of timber –> HTC	0.10	0.17
Average stock of timber –> Sum of *T* > 10°C	**0.39**	**0.65**
Average growth of timber –> HTC	–0.29	–0.16
Average growth of timber –> Sum of *T* > 10°C	**0.80**	**0.92**

*Forest steppe and steppe regions are excluded.
In Italics – correlation is insignificant. In Bold – correlation is significant at $p < 0.05$. Normal font – correlation is significant at $p < 0.5$.

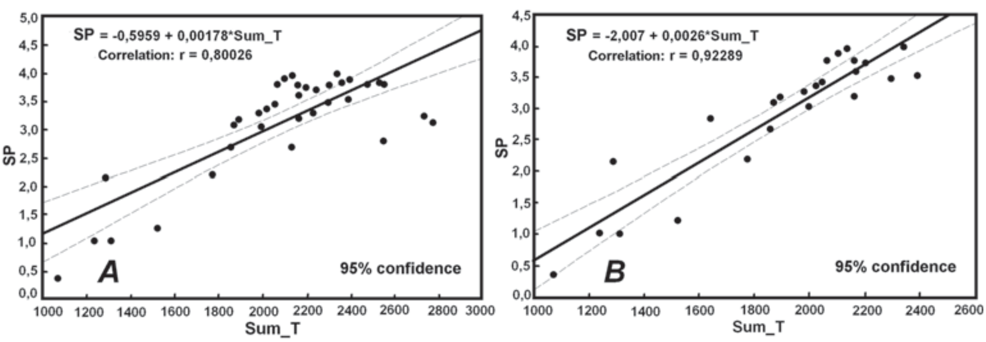

Fig. 4. The relationships of the average growth of timber (GT) and the sum of effective temperatures (Sum_T) for the regions of the EPR.

A – all regions, B – only the "forest" regions

Table 3. The forecasted for 2046-2065 changes in the timber annual growth for the "forest" regions of the EPR

Administrative regions of the Russian Federation	Average annual growth of timber (m3/ha)		"Shift"*
	1961–1990	2045–2065	
Arkhangelsk Oblast	1.03	2.51	1.48
Bryanks Oblast	4	5.54	1.54
Vladimir Oblast	3.7	4.98	1.21
Vologda Oblast	2.2	3.72	1.52
Ivanovo Oblast	3.8	4.68	0.88
Kaluga Oblast	3.97	5.12	1.15
Kirov Oblast	2.7	4.07	1.37
Kostroma Oblast	3.11	4.14	1.03
Leningrad Oblast	2.85	3.81	0.96
Moscow Oblast	3.73	4.96	1.23
Murmansk Oblast	0.38	1.91	1.53
Nizhnyi Novgorod Oblast	3.6	4.82	1.22
Novgorod Oblast	3.2	4.17	0.97
Perm Oblast	2.16	3.82	1.66
Pskov Oblast	3.05	4.43	1.38
Smolensk Oblast	3.9	4.78	0.88
Tver Oblast	3.3	4.4	1.1
Yaroslavl Oblast	3.43	4.46	1.03
Republic of Karelia	1.25	2.55	1.3
Republic of Komi	1.04	2.42	1.38
Republic of Mari El	3.2	4.82	1.62
Republic of Udmurt	3.38	4.54	1.16
Republic of Chuvash	3.49	5.14	1.65

* "Shift" means the change between the forecasted and the current values of the growth of timber parameter, m^3/ha .

Using forecasted values of *Sum_T* for the EPR for 2045–2065 in equation (3), we can calculate the potential value of the average annual growth of timber for each analyzed point in the territory. Additionally, we calculated the "shifts" in the values of the average annual growth of timber defined both for the forecasted and the modern periods (Table 3, Fig. 5).

The results show a general trend in the productivity growth of the stands, resulting in higher values of the forecasted average growth of timber for 2046–2065 compared with the current climate. Particularly significant increase in the growth and thus its maximum values are forecasted for the southern and eastern parts of the territory. Thus, the greatest "shifts" in the productivity are expected for the Middle Volga region (Republic of Mari El – 1.62 m^3/ha, Republic of Chuvash – 1.65 m^3/ha) and the Middle Urals (Perm Oblast – 1.66 m^3/ha).

It should be noted that this forecast is possible only in conditions of sufficient moisture supply in these areas, that is, if an increase in annual precipitation occurs. The

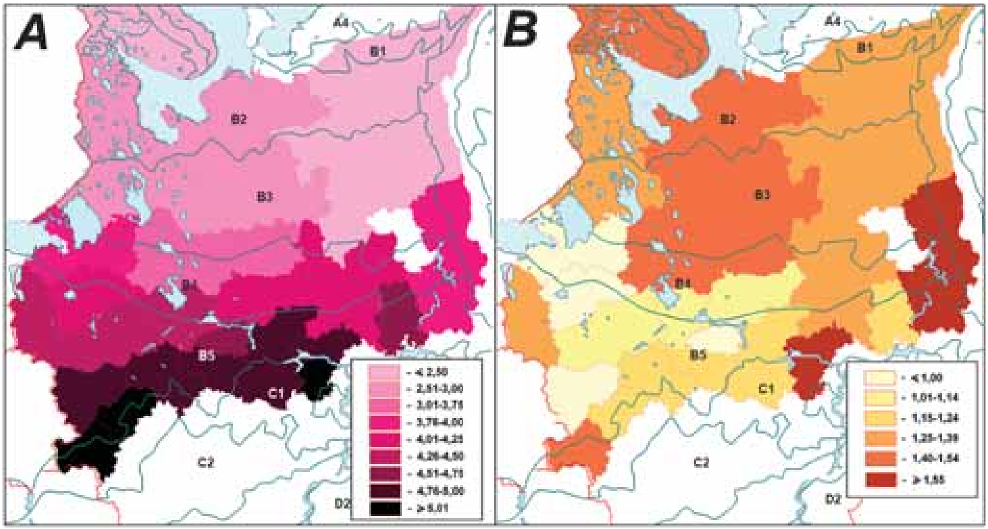

Fig. 5. A – 2046–2065 forecasted average growth of timber (m^3/ha). B – Forecasted "shifts" of the average values of growth of timber in comparison with the period of "the modern climate" (only for "forest" regions of the EPR). Explanations are in the text.

There are no data for the Komi-Permyak AO (the "white spot" on the map). Vegetation zones and sub-zones (boundaries and parameters) – see above

noticeable "shifts" are also projected for the most northern regions – the Murmansk and Arkhangelsk regions. If, at the present time, the average increase is small and is 0.38, and 1.03 m^3/ha, respectively, in 2046–2065, the growth is forecasted to increase by 1.5 m^3/ha, i.e., 2.5–3 times (Table 3). This is consistent with the established current ideas that the most significant changes in forest vegetation will occur at the northern limit of its distribution, where the conditions for the existence of forest are extreme, and that specifically temperature is a limiting factor in the development of trees and in their productivity.

CONCLUSION

The results of the analysis show that the forecasted "shifts" of the sub-zonal boundaries of vegetation associated with the thermal conditions of the growing season can have both positive ("warming" – "shift" in the conditions determining the northern shift of the existing sub-zonal boundaries: almost the entire EPR) and zero (there is no "shift": the individual cells in the EPR) trends. In some regions of the south part of the study area, the "shifts," according to the forecasted changes in the temperature conditions, can have even a negative trend.

For the growth of timber parameter for the entire territory under the discussion, only positive "shifts" are forecasted. However, it should be kept in mind that this parameter is not tightly connected with the climatic conditions. It is known, that growth of timber for each forest species increases along with better climatic conditions only to some point after which the growth slows down [Romanovsky and Schekalev, 2009].

The results obtained demonstrate the relationships between the vegetation parameters and the sum of effective temperatures only. It can be assumed that the results are reliable only if current, for the area, conditions of sufficient moisture supply are preserved. The analysis performed earlier [Kislov, et al., 2008; Kislov, 2011] shows that in the EPR (except for its southern border), warming occurring simultaneously with the growth of precipitation maintains moisture supply that is close to the modern conditions. This confirms the representativeness of the results.

It must be stressed that the forecast considers, especially with respect to the zonal boundaries, trends of changes and not the changes themselves. It is possible that the real "shifts" of these boundaries in the EPR by the middle of the XXIth century will be manifested only locally because of insufficient succession rates. This, however, does not mean that the impacts of climate change on the discussed territory are small. In fact, it means that most of the plant communities in the area will exist in temperature conditions not characteristic to the area, for indefinitely long period. In the short term, it is highly desirable to attempt to assess the possible consequences of such non-equilibrium state of the ecosystems. ■

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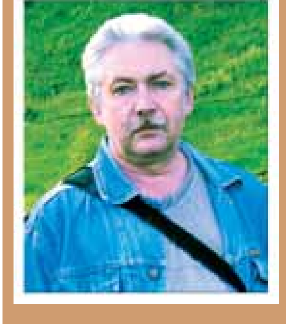

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MIDDLE PLEISTOCENE SMALL MAMMAL FAUNAS OF EASTERN AND WESTERN EUROPE: CHRONOLOGY, CORRELATION

ABSTRACT. Many new very important Middle Pleistocene small mammal localities of Europe were discovered during the last decades. These new data permit to divide the Middle Pleistocene geological sequences of Eastern and Western Europe and carried out the correlation between them. However, there are some difficulties connected with the incongruity of mammal appearance in different parts of Europe. In this paper we would like to discuss all these problems using Middle Pleistocene small mammal data and to present the possible biostratigraphical scheme for the whole Europe.

KEY WORDS: small mammals, Middle Pleistocene, Europe, correlation

MATERIALS AND METHODS

In this article we use the Western European stratigraphical scheme. According this scheme the beginning of the Middle Pleistocene corresponding to the boundary of palaeomagnetic epochs Matuyama–Brunhes (~0.8 mln. yrs. BP) and the end of Middle Pleistocene falls to the beginning of Eemian (=Mikulian) Interglacial (about 0,135 mln. BP). The Early and Middle Neopleistocene of the Russian stratigraphical scheme correspond to the Middle Pleistocene of Western European stratigraphical scheme.

Eastern Europe

Dniester, Danube and Prut basins. One of the most complete sections of the Middle Pleistocene is the Kolkotova Balka section near the Tiraspol town (Moldova, Dniester basin). The deposits corresponding to the whole Middle Pleistocene are opened up in this outcrop. The several layers with mammal faunas were discovered here: the lowest 3 layers with small and large mammal fauna were found in the fluvial deposits of different facies. The fauna of these fluvial layers describe as the stratotype of Tiraspolian mammalian complex [Alexandrova, 1976; Pleistocene of Tiraspol, 1971] which correspond to the Il'inkian Horizon of Russian stratigraphical scheme with *Mimomys savini, Prolagurus posterius – Lagurus transiens, Microtus (Stenocranius) hintoni-gregaloides*, *Microtus arvaloides, Microtus ratticepoides (=oeconomus)* and others; 2) above the fluvial deposits of the Dniester River underlies the horizon of the Vorona fossil soil with small mammal fauna which is correlated with the Muchkap Interglacial. Fauna includes *Lagurus transiens* (archaic morphotype), *Microtus gregalis* and others; 3) uppermost the loess deposits lie covered the horizon of the Inzhava fossil soil, synchronous to Likhvin Interglacial with *Lagurus transiens – L. lagurus*, *Microtus (S.) gregalis*, *Microtus* ex gr. *agrestis* и др.

[Mikhailesku, Markova, 1992; Markova, 2007]. So the faunas of this key section reflected the natural events of the most part of the Middle Pleistocene (Fig. 1). These faunas expressed the significant evolutional changes in different phylogenetic lines of Arvicolidae: *Prolagurus – Lagurus, Microtus (Stenocranius) hintoni-gregaloides – M. (S). gregalis* and others. The different taphonomy of Kolkotova Balka main horizons (fluvial deposits and fossil soils) didn't permit to reveal the transition between the rooted voles of *Mimomys* genus (the ancestral form of water vole *Arvicola*) and the un-rooted voles of *Arvicola* genus. All localities with *Mimomys* were found in fluvial older deposits. The different fossil soils overlying the fluvial deposits didn't include the remains of water voles *Arvicola* (or its ancestor form *Mimomys intermedius*) what could be explained by their taphonomy.

There are several other very principal Middle Pleistocene small mammal localities situated on the south-west of the Russian Plain in Prut and Danube River basins. The faunas were described in Nagornoe, Suvorovo, Ozernoe, Plavni and many others localities. These localities as a rule characterize only one stage of Middle Pleistocene: Il'inka Interglacial, Muchkap Interglacial, Likhvin Interglacial and Kamenka Interglacial. Most of them include the fauna of the Likhvin Interglacial. The significance of these materials for stratigraphy also is very high. All of these localities were found in the liman and lake deposits and include not only mammal remains but also brackish-water mollusks what permits to carry out the straight correlation between the continental and marine deposits of the Russian Plain and the Black Sea [Mikhailesku, Markova, 1992].

Dnieper basin. There are several Middle Pleistocene localities of small mammals are known from the Dnieper basin, mostly from the middle part of basin. They are connected with the fluvial deposits of IV terrace of Dnieper. The localities Gunki and Pivikha are situated on the left bank of Dnieper; the Chigirin locality is situated on the right bank [Markova, 1982] (Fig.1).

Gunki locality was studied by the several methods (geological, pedological, palynological, malacological methods). Also the palaeomagnetic investigation of deposits had been done [Velichko et al., 1982]. This outcrop includes the deposits of second part of the Middle Pleistocene and the Upper Pleistocene. The Dnieper (=Zaalian) till is registered here. The Romny and Kamenka paleosols were described below the Dnieper till. Fluvial thickness occurred below the loess-paleosol sequence. The fluvial deposits of IV terrace are correlated with the Likhvin Interglacial by the palynological and mammalian data. The small mammal remains were discovered in the 3 facieses of alluvium close by age. The rich fauna didn't include the teeth of rooted voles *Mimomys* and *Borsodia*. There are no also remains of archaic voles (with "pitymys" triangles) such as *Microtus (Terricola) arvaloides* and *Microtus (Stenocranius) gregaloides*. Steppe lemmings are presented by the remains of *Lagurus* genus with *Lagurus transiens* morphotypes (which are more abundant) and *Lagurus lagurus* ones. The *Microtus* genus includes the voles *Microtus arvalis, M. oeconomus* and *M. (S.) gregalis*. The palynological data indicate the Likhvin age of the deposits [Gubonina, 1982]. Malacological materials show on Early Euksinian age of mollusk fauna. Gunki section is a unique one by the completeness of the palaeontological data [Markova, 1982]. The localities Pivikha and Chigirin include similar small mammal faunas by the species composition [Markova, 2006].

Don and Desna basins. The complicated mammalian succession was described by the materials of Middle Pleistocene small mammal faunas from Don and Desna basins. The earliest of them are correlated with the beginning of Middle Pleistocene, the latest is referred to the Dnieper (=Saalian) Glaciation [Agadjanian et al., 2008; Markova, 2007]. The small mammal materials related as well as to the interglacials so to the glaciations (Don Glaciation, Oka Glaciation and Dnieper Glaciation).

In last years the small mammal faunas with archaic *Arvicola* were found in the deposits related to interval, which follows Muchkap interglacial and cooling which is next after

STRATIGRAPHY		PALAEOMAGNETIC	MIS	Biostratigraphy: Western Europe – Glaciations, Interglacials	Western Europe – Stages	Western Europe – Small mammal localities	Eastern Europe – Glaciations, Interglacials	Eastern Europe – Loesses, paleosols	Eastern Europe – Small mammal localities
PLEISTOCENE	LATE MIDDLE PLEISTOCENE	BRUNHES	8	Volstonian (=Saalian) Glaciation	Cold Interval	Ussel Armagier Plaidter-Hummerich I Ariendorf 2	Dnieper Glaciation	Dnieper loess	Berezovo, Chekalin (Fl. deposits), Alpatievo, Pavlovka0na-Desne
			8 (cont.)				Romny warming.	Romny paleospol	
			8 (cont.)			Ariendorf 1	Cooling	Loess	
			9		Hoogoven (=Reinsdorf) Interglacial	**Schöningen (Reinsdorf) Kärlich H**	Kamenka Interglacial	Kamenka paleosol	Priluki, Uzunlar, Rasskazovo, Plavni
			10		Cooling		Cooling	Borisoglebsk loess	Topka
			11	Hoxnian (=Holsteinian) Interglacial	Holsteinian Interglacial	**Schöningen (lower layer)** Niide	Likhvin Interglacial	Inzhava paleosol	Chekalin, Gunki, Chigirin, Pivikha, Ozernoe, Rybnaya Sloboda **Kolkotova Balka (Inzhava soil)**
	EARLY MIDDLE PLEISTOCENE		12	Anglian (=Elsterian) Glaciation			Oka Glaciation	Oka till	Mikhailovka 2
			13	«Cromerian complex»	Interglcial IV	Boxgrove, Mauer, Miesenheim Westbury-sub-Mendip	Ikoretsk Interglacial	Optimum	Mastyuzhenka, Shekhman **(first appear.of *Arvicola cantianus*)**
			14		Glaciation C	Kärlich G		Cooling	
			14 (cont.)		Interglacial III		Muchkap Interglacial		
			14 (cont.)					Cooling	
			15			Mosbach, Izernia **(first appear.of *Arvicola cantianus*)**			
			15 (cont.)					Cooling.	
			15 (cont.)			Little Okley, Süssenborn, Pakefield		Konakhovka warming	Posevkino, Perevoz, **Kolkotova Balka (Vorona paleosol),** Konakhovka loc. and others
			15 (cont.)					Cooling	
			15 (cont.)					Glazovo warming	Illovaisky Kordon
			16		Glaciation B	**Kärlich F**	Don Glaciation	Don till	Bogdanovka, Zmeevka Troitsa I
			17		Interglacial II	**Kärlich C-F** West Runton	Il'inka Interglacial	Il'inka paleosol complex	**Kolkotova Balka (fluvial dep.)** Novokhopersk Uryv 4, Il'inka
			18		Glaciation A				
		Matuyama	19		Interglacial I	**Kärlich B**	Petropavlovka cooling	Loess	Karai-Dubina Petropavlovka

Fig. 1. Middle Pleistocene biostratigraphical scheme of Europe

Muchkap (Mastuzhenka, Ikorets, Shekhnan-1 localities) and Oka glaciation.

The faunas of this evolutional level were described earlier in Western Europe (Mosbach, Miesenheim, Kärlich Kä G and others). These faunas don't' contain the remains of *Mimomys* genus, but include the representatives of archaic un-rooted voles of *Arvicola* genus. The Ikoretzk Interglacial was described by these new materials from the Russian Plain [Iosifova et al., 2009].

Volga basin. The small mammal fauna, similar by the species composition to the numerous faunas of the Likhvin Interglacial from other river basins of the Russian Plain (Danube, Prut, Dniester, Dnieper and Don basins) was found by Dr. V.P. Udartsev in the fluvial deposits of Rybnaya Sloboda section situated near the mouth of Kama River (right tributary of Volga) [Markova, 2004]. The Kamenka fossil soil is located higher in this section. The Rybnaya Sloboda fauna includes *Arvicola cantiana, Lagurus transiens-lagurus, Clethrionomys rufocanus* and others. In lower Volga basin (Chernyi Yar locality) more evolved fauna was described with more progressive *Arvicola* and *Lagurus* [Alexandrova, 1976]. Similar fauna of small mammals was found near Spasskoe village in the middle Volga basin [Markova, 2007].

Western Europe

The Central and Western European small mammal record is from a number of geographically scattered, in many cases isolated localities. Rich, well-known early Middle Pleistocene assemblages are from localities such as Voigtstedt (Gemany) and West Runton (England) [Maul, Parfitt, 2010]. Long sequences are almost non-existent. An exception is the Kärlich sequence, exposed in a quarry located in the Neuwied Basin (Germany), with on top of the Tertiary clays Quaternary deposits gravels of the Rhine and Moselle rivers and an alternation of loess, loess-like, and slope deposits and tephras (ashes, pumices) which originate from extinct volcanoes located in the neighbouring East Eifel volcanic field dating from the late Early Pleistocene to the Holocene [Boenigk, Frechen, 2001]. Several stratified mammalian faunas, within which the *Mimomys – Arvicola* transition occurs, were collected from the Pleistocene sequence (Kärlich main section – Kä A – H) exposed in the Kärlich pit. The older faunas Kä C – F are characterised by the presence of *Mimomys savini*; the oldest representatives of the water vole, *Arvicola terrestris cantiana*, were recovered in the rich fauna from Kä G. The faunal assemblages from the Kärlich sequence together with the faunas from the same region (Miesenheim I and Ariendorf) form a reference for the early Middle Pleistocene faunal history to which faunas such as Mauer and Mosbach (Germany) can be correlated [van Kolfschoten, 1990].

Both the *Microtus (Stenocranius) hintoni-gregaloides – M. (S). gregalis* and the *Microtus (Terricola) arvaloides – Microtus arvalis* lineage as well as the *Mimomys-Arvicola* lineage offer the possibility to correlate the Eastern and the Central European faunas. The faunal sequences indicate that in Central Europe, *Mimomys savini* occurs in the earliest Middle Pleistocene faunas and that the *Mimomys – Arvicola* transition occurs long before the Elsterian (=Oka Glaciation). The loess deposits of Kärlich F correlated with the Don Glaciation is the uppermost unit with *Mimomys* remains. Two *Arvicola* faunas (Kärlich G and Miesenheim I) are referred to two different interglacials with a pre-Elsterian age.

Central European faunas dating to the Elsterian (Oka) Glaciation are poorly known. The same applies to the Holsteinian (Likhvin) faunas. The Schöningen locality (Germany) yielded an extensive collection of small mammal remains dated to post-Elsterian age [van Kolfschoten, 2012]. The oldest assemblage from this site most probably has a Holsteinian age; however, this assemblage is rather poor. The mammal fauna from the so-called Reinsdorf Interglacial (locally defined), the second interglacial after the Elsterian, is very rich. This fauna is characterised by the presence (in a low quantity) of early Middle Pleistocene relicts (*Talpa minor* and

Drepanosorex) as well as rather primitive water vole *Arvicola* molars indicating that the age of the fauna predates many well-known late Middle Pleistocene faunas such as Weimar-Ehringsdorf (Germany) and Maastricht-Belvédère (The Netherlands) [van Kolfschoten, 1985] with a more advanced *Arvicola* record and with relicts.

DISCUSSION

The phylogenetic lines *Microtus (Stenocranius) hintoni-gregaloides – M. (S). gregalis, Microtus (Terricola) arvaloides – Microtus arvalis* and *Mimomys – Arvicola* are the base for the correlation of Eastern and Western Pleistocene small mammal faunas. The analysis of the Middle Pleistocene mammalian sequence of Central and Western Europe indicates that *Mimomys savini* was discovered in earliest Middle Pleistocene faunas. The *Mimomys – Arvicola* transition was found in Western Europe long before the Elsterian (=Oka) Glaciation. The loess deposits of Kärlich F are correlated with the Don Glaciation of Eastern Europe and are the latest sediments with *Mimomys* remains (Fig. 1).

Two localities with archaic *Arvicola* (Kärlich G and Miesenheim I) are referred to two different interglacials. Both of them are related to pre-Elsterian time. The faunas, synchronous to the Elsterian Glaciation, are practically unknown in Western Europe. The faunas of the Holsteinian (=Likhvin) Interglacial are very rare in this part of Europe.

Schöningen locality (Germany) includes the rich collection of small mammal remains corresponding to post-Elsterian deposits. The earliest layer with small mammal remains in Schöningen, possibly related to Holsteinian Interglacial. Unfortunately this locality contains only few small mammal bones.

The rich strata with small mammals in Schöningen is synchronous to the Reinsdorf Interglacial (this Interglacil was distinguished only in this region). This fauna corresponds to the younger Interglacial then Holsteinian warm phase. Possibly it could be synchronous to the Kamenka Interglacial of Eastern Europe. The Reinsdorf fauna includes few relics of the first half of Middle Pleistocene – *Talpa minor* and *Drepanosorex* and also archaic *Arvicola cantianus*. That permits to conclude that this fauna are earlier then late Middle Pleistocene faunas of Weimar-Eringsdorf (Germany) and Maastricht-Belv@édère (the Netherlands) with more progressive water voles [van Kolfschoten, 1990].

Thus, we can reveal the evolutional succession of small mammal faunas in Western and Eastern Europe during Middle Pleistocene based on the morphological changes in the different phylogenetic lines. These transformations have the similar trends in the different parts of Europe. The revealed succession of small mammal faunas indicates significant similarities of the Middle Pleistocene faunas belonged to the large stratigraphical divisions in different European regions. Unfortunately now only few full Middle Pleistocene sections with the significant succession of heterochronous mammalian faunas are known both on the Russian Plain and in Western Europe. The fullest picture was revealed to the Dniester and Don River basins of the Russian Plain and also for the Neuwied and Rhine River basins of Central Europe.

Unfortunately the mammals of the one of the most important phylogenetic line *Prolagurus – Lagurus*, which gives a lot of information about the stratigraphical position of the Eastern European faunas, are absent in Western Europe. So, we need to base only on *Mimomys – Arvicola* and *Microtus* members.

We need to mention some differences in the first appearance of new small mammal taxa in Western and Eastern Europe. So, there are un-known Central European faunas with *Mimomys* remains which correspond to the complicated interval between the cold stage synchronous to the Don Glaciation and the Elster Glaciation. Only archaic water voles *Arvicola cantianus* were discovered in these faunas. On the contrary there are several important well-known mammal localities in Eastern Europe (in the Dniester and Don basins) with evolved *Mimomus (M. savini*) which related to the Muchkap Interglacial. This Interglacial took place between the Don and Oka Glaciations. The first un-rooted water voles *Arvicola cantianus* appeared only in the very end of this complicated interval during the Ikoretsk Interglacial. Till now this phase was revealed only in the Don basin.

The future studies of small mammal faunas from the different regions of Europe and also the correlation of main stratigraphical horizons with mammal localities permit to establish most reliable correlations of Middle Pleistocene small mammal faunas of Eastern and Western Europe.

Described analysis of the Middle Pleistocene small mammal faunas could help to reconstruct and to date the natural events of Middle Pleistocene for the territory of whole Europe and to reveal the similarities and un-similarities in Arvicolidae evolution in the different parts of Europe. ■

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SPREADING OF ANTARCTIC BOTTOM WATER IN THE ATLANTIC OCEAN

ABSTRACT. This paper describes the transport of bottom water from its source region in the Weddell Sea through the abyssal channels of the Atlantic Ocean. The research brings together the recent observations and historical data. A strong flow of Antarctic Bottom Water through the Vema Channel is analyzed. The mean speed of the flow is 30 cm/s. A temperature increase was found in the deep Vema Channel, which has been observed for 30 years already. The flow of bottom water in the northern part of the Brazil Basin splits. Part of the water flows through the Romanche and Chain fracture zones. The other part flows to the North American Basin. Part of the latter flow propagates through the Vema Fracture Zone into the Northeast Atlantic. The properties of bottom water in the Kane Gap and Discovery Gap are also analyzed.

KEY WORDS: Abyssal channels, Vema, Romanche, Chain, Kane, bottom water

INTRODUCTION

Antarctic Bottom Water (AABW) is formed over the Antarctic slope as a result of mixing of the cold and heavy Antarctic Shelf Water with the lighter, warmer, and more saline Circumpolar Deep Water [Orsi et al., 1999]. In the region of origin, Antarctic Shelf Water is formed in the autumn-winter season over the Antarctic shelf due to cooling of the relatively fresh Antarctic Surface Water to nearly freezing point temperature and increased salinity caused by ice formation. The resulting water mass with increased density descends and reaches the ocean floor. In the Atlantic Ocean the regions of dominating Antarctic Bottom Water formation are in the southern and western parts of the Weddell Sea.

Antarctic Bottom Water represents the coldest and deepest layer of the South Atlantic. A commonly accepted definition describes AABW as water with potential temperature cooler than 2°C [Wüst, 1936]. This layer can occupy a layer 1000 m thick and even more at the bottom of the Atlantic Ocean. The thickness decreases in the northern direction up to complete wedging-out at the bottom in the North Atlantic.

Generally, propagation of Antarctic waters in the bottom layer of the Atlantic Ocean is confined to depressions in the bottom topography. The pathways of AABW in the Atlantic Ocean are shown in Fig. 1. The general flow of these waters can be presented as follows [Morozov et al., 2010].

There are several channels for the flow of Antarctic Bottom Water from the Weddell Sea. It propagates to the north through the passages in the South Scotia Ridge, through the South Sandwich Trench, and South Sandwich Abyssal Plain. Part of Antarctic Bottom Water flows to the west to the Drake Passage. The other part of Antarctic Bottom

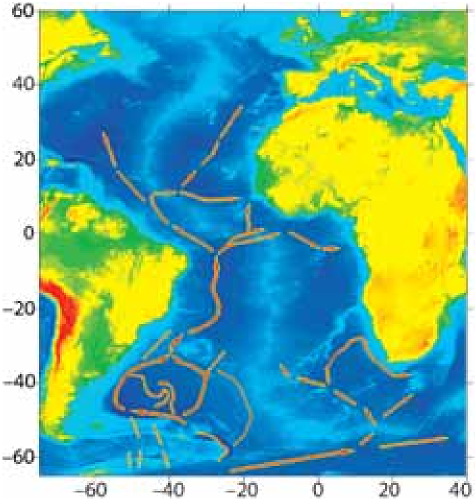

Fig. 1. Scheme of Antarctic Bottom Water propagation in the Atlantic Ocean

Water propagates through the Georgia and Northeast Georgia passages to the Georgia Basin. Then, Antarctic Bottom Water flows to the Argentine Basin through the Falkland Gap in the Falkland Ridge.

It is commonly accepted that AABW propagates from the Argentine Basin to the Brazil Basin in three places: through the Vema Channel, Hunter Channel, and over the Santos Plateau. In the northern part of the Brazil Basin, the flow of AABW splits. A part of the flow is transported to the eastern basin through the Romanche and Chain fracture zones, influencing the waters of the bottom layer in the Southeast Atlantic. The other part flows through the Equatorial Channel, propagating further to the Northeast Atlantic through the Vema Fracture Zone and to the North American Basin in the west, where it is entrained into the cyclonic gyre within its northward spreading zone, reaching the Newfoundland Bank.

VEMA CHANNEL

The depth in the Vema Channel exceeds 4600 m as compared to the background depths of 4200 m. Based on moored current-meter observations in combination with

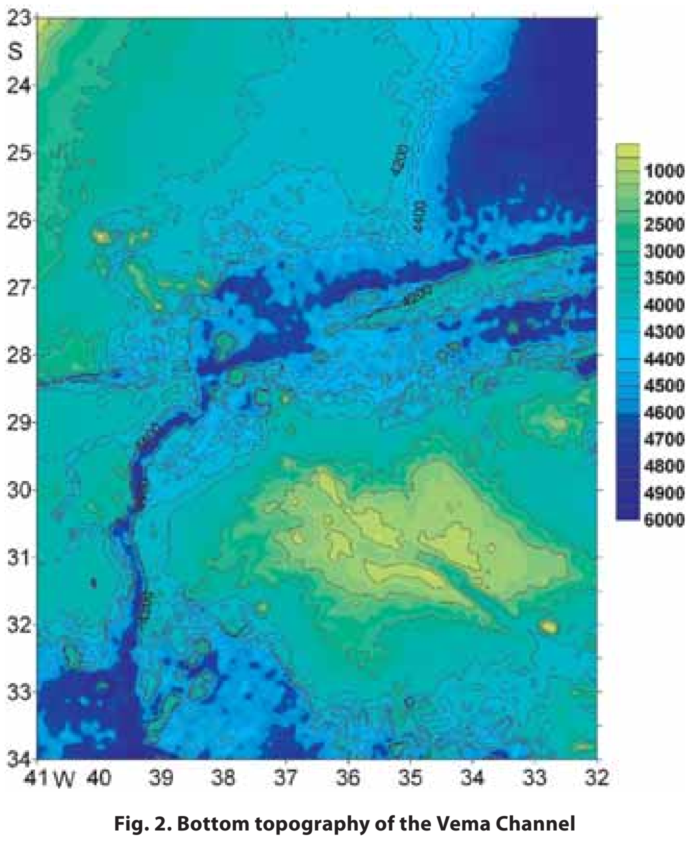

Fig. 2. Bottom topography of the Vema Channel

geostrophic velocity computations from hydrographic stations, the total Antarctic Bottom Water transport across the Rio Grande Rise and Santos Plateau is estimated at 6.9 Sv [Hogg et al., 1999]. On the average, two thirds of this volume passes through the Vema Channel. The rest part flows over the Santos Plateau and through the Hunter Channel.

The bottom topography around the Vema Channel is shown in Fig. 2. The Vema Channel is the deepest one among the passages existing for Antarctic Bottom Water. Therefore, the coldest water (Weddell Sea Deep Water) can exit the Argentine Basin in the equatorward direction only through this channel [Zenk et al., 1993].

According to the moored measurements (two moorings), the mean transport of Antarctic Bottom Water (layer below 2°C isotherm) through the Vema Channel is estimated at 3.5 Sv. The mean velocities are 30 cm s^{-1} and the highest reach 60 cm s^{-1}. (Fig. 3).

However, the instantaneous transport measured by LADCP instruments (five sections across the channel in the middle part of the channel) appears lower and fluctuates between 2.5 and 3.5 Sv. Usually, the jet core is vertically mixed in a layer approximately 150 m thick. Owing to the Ekman friction the coldest core of the flow in the Vema Channel is usually displaced to the eastern slope of the channel.

In 2010, we carried out the measurements of currents in the region where Antarctic Bottom Water outflows from the Vema Channel to the Brazil Basin at latitude of 26°40′ S. Let us compare the sections at the standard section (31°12′ S) and in the northern part of the channel. The sections are presented in Fig. 4. The red line shows the location of the zero isotherm of potential temperature. In the narrow passage in the northern part of the channel (the Vema Extension), where the channel becomes deeper and narrower, the isotherms of the potential temperature greater than 0°C do not reach the slopes of the channel as in the south. This means that the flow with a temperature of θ = 2°C and even with a temperature of θ = 0.2°C becomes wider. Using the available data we can compare only the

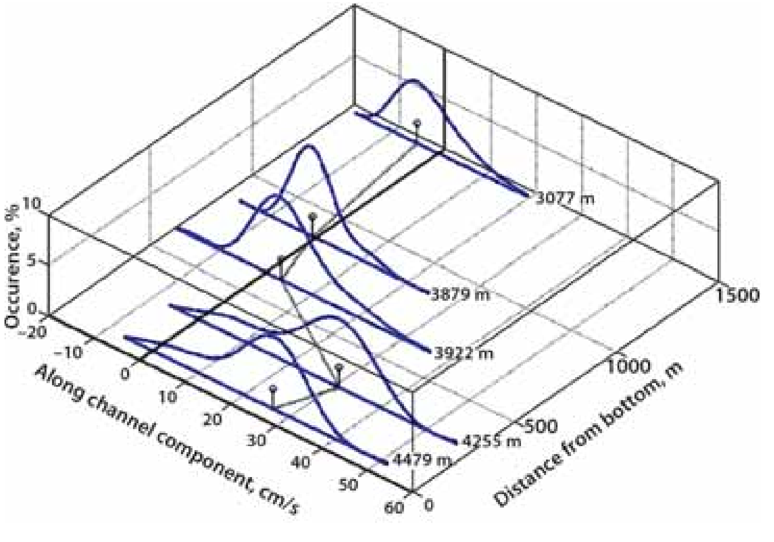

Fig. 3. Three-dimensional frequency distributions of mean speeds above the abyssal Vema Channel. Results from five moored current meters close to our standard section (31°12′ S) on the eastern flank are shown. In the x-y plain a year-long averaged speed profile is displayed as a stippled line with hair needles (means) as a function of the distance from the sea bed. Positive speed values point northwards. Collateral numbers indicate instrument depths (for details see [Zenk & Visbeck, 2012]).

Note the high speed core of AABW in the lowest 250 m and some rare current reversals caused by highly energetic eddies

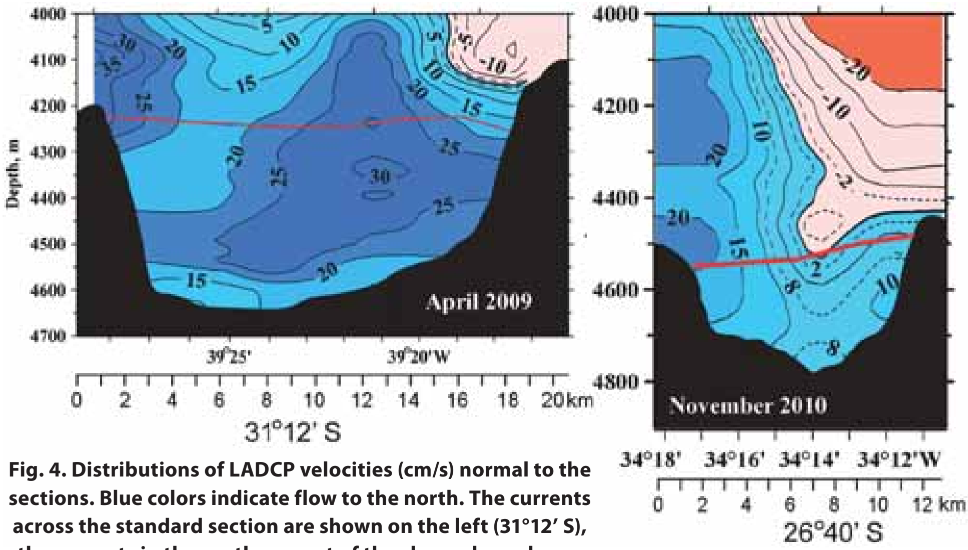

Fig. 4. Distributions of LADCP velocities (cm/s) normal to the sections. Blue colors indicate flow to the north. The currents across the standard section are shown on the left (31°12′ S), the currents in the northern part of the channel are shown on the right (26°40′ S). The red line shows isotherm 0°C

water flows with potential temperatures θ m 0°C. The mean velocities of the flow with such temperatures at the standard section are 23 cm/s, while at the northern section they decrease to 11 cm/s. Antarctic Bottom Water with higher temperatures flows above the western slope of the channel with velocities exceeding 20 cm/s. Unfortunately we could not extend the section farther to the west in the expedition in 2010 for a more precise calculation of the transport.

The square of the standard section for the water below 0°C is $6 \cdot 10^6$ m^2, while in the north the similar square is almost four times smaller ($1.4 \cdot 10^6$ m^2). The transport of this water across the standard section is 1.4 Sv, while the transport across the northern section is 0.16 Sv, which is almost 10 times smaller. Despite the fact that these sections were made not simultaneously, we relate this variability to the spatial variation of the flow. Thus a large amount of the coldest water does not reach the northern section remaining beyond the topographic obstacles and mixes with the overlying waters.

The decadal variability of the AABW flow in the Vema Channel is seen from the time series of 22 visits to the standard section of the Vema Channel from 1979 to 2009. During the period from 1979 to 2003, a temperature increase of the coldest temperature of the flow was observed. The temperature increased from –0.18°C to –0.12°C. In the end of 2004, this warming changed to temperature fluctuations with an amplitude of 0.02°C. Thus, we observed a general trend of warming of Weddell Sea Deep Water in the Vema Channel with slight fluctuations over a period greater than 30 years [Zenk & Morozov, 2007].

ROMANCHE AND CHAIN FRACTURE ZONES

Only three channels in the Mid-Atlantic Ridge exist that allow the propagation of Antarctic Bottom Water to the northern latitudes of the East Atlantic. These channels are: the Romanche and Chain fracture zones (at the equator) and the Vema Fracture Zone (11° N) [Messias et al., 1999; McCartney et al., 1991]. Other small and shallower passages are less significant and do not allow the propagation of the coldest bottom waters.

The Romanche Fracture Zone is a deep passage in the Mid-Atlantic Ridge 800 km long and 10 to 40 km wide. Together with the Chain Fracture Zone they form an equatorial pathway for Antarctic Bottom Water to the East Atlantic. The Chain Fracture Zone is located south of the equator, 200 km south of the Romanche

Fracture Zone. Both fracture zones allow the water flow from the Brazil and Guinea basins.

The Antarctic Bottom Water (θ < 2°C) flow through the Romanche and Chain fracture zones is estimated at 0.5 Sv in each channel [Messias et al., 1999]. The mean velocities are 10–20 cm s^{-1}. Velocities measured by current meters on moorings in 1991–1992 and on the same section across the fracture zone using LADCP in 2005 and 2009 are very close. The bottom water passing through the Romanche and Chain fracture zones spreads only to the southeastern and equatorial parts of the Atlantic. Its further propagation to the north is almost limited by the Kane Gap at 9° N.

VEMA FRACTURE ZONE

The Vema Fracture Zone is located at 11°N between 43.5° and 41° W. It connects the Demerara and Gambia abyssal plains. The width of the fracture zone is 8–10 km and the maximum depth is approximately 5200 m, while three sills of the fracture zone have depths 4690, 4650, and 4710 m.

In 2006, an expedition with CTD and LADCP measurements onboard R/V *Akademik Ioffe* visited the region of the main sills. The Antarctic Bottom Water flow through the Vema Fracture Zone (11° N) based on the measurements with a lowered velocity profiler was estimated at 0.5 Sv. The mean velocity is 10 cm s^{-1}, while the greatest velocity reaches 30 cm s^{-1}. The Vema Fracture Zone is the main pathway for Antarctic Bottom Water to the Northeast Atlantic.

PROPAGATION OF ANTARCTIC BOTTOM WATER TO THE NORTHEAST ATLANTIC

In this section we consider the flow of bottom waters to the Northeast Atlantic from the Vema, Romanche, and Chain fracture zones and their further propagation in the Northeast Atlantic basins. The present-day concept was for the first time suggested in [Mantyla and Reid, 1983]. They wrote that bottom waters propagating through the Romanche Fracture Zone influence only the equatorial and southeastern part of the Atlantic Ocean. The bottom water from

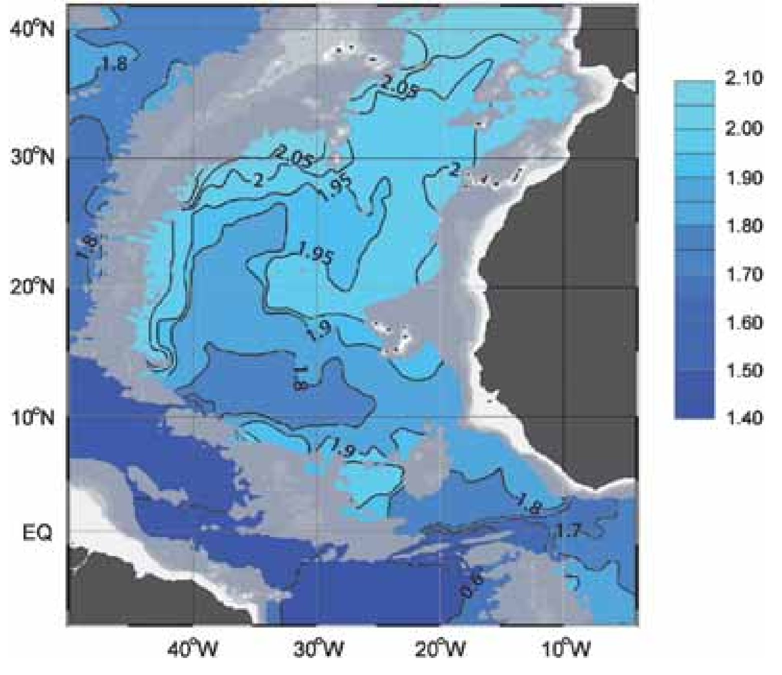

Fig. 5. Distribution of potential temperature (°C) at the bottom in the eastern part of the North Atlantic based on the WODB-2009 data. The data below 4000 m is presented. Gray shade shows the bottom topography above 4 km

these channels does not spread to the north through the Kane Gap, whereas the Vema Fracture Zone is the main pathway for bottom waters into the northeastern Atlantic.

The potential temperature of bottom waters in the Northeast Atlantic based on the recent and historical measurements is shown in Fig. 5.

One branch of the bottom water flow from the Vema Fracture Zone in the Gambia Abyssal Plane is directed to the north and waters of the Antarctic origin fill the deepest parts of the Northeast Atlantic basins including the Canary Basin. The flow reaches the Discovery Gap at 37°N. The second branch is directed from the Vema Fracture Zone to the southeast. This branch reaches the Kane Gap near the coast of Guinea.

The waters with θ = 1.80°C are located north and south of the Kane Gap. At the same time, isothermal surfaces θ = 2.00°C are not separated over the Kane Gap, which indicates that the exchange of Antarctic Bottom Water through this passage is possible. The large basin of the Northeast Atlantic including the Gambia Abyssal Plain and the Canary Basin is filled with bottom water that propagated through the Vema Fracture Zone. The bottom water that propagated through the Romanche Fracture Zone is localized in relatively small basins east of the fracture: the Sierra Leone and Guinea basins with a possible insignificant outflow to the Angola Basin.

Such localization seems surprising because Antarctic Bottom Water transports through the Romanche and Chain fracture zones are of the order of 1 Sv, which is almost the same as the water transport through the Vema Fracture Zone. We believe that this phenomenon may be explained by stronger mixing in the Romanche and Chain Fracture Zones compared to the Vema Fracture Zone caused by internal tidal waves.

KANE GAP

The Kane Gap is located between the Grimaldi Mountains, which are a part of the Sierra Leone Rise and the Guinea Plateau near the African Continent (Fig. 6). The gap connects Gambia Abyssal Plain (Cape Verde Basin) and Sierra Leone Basin. The sill depth in the gap is 4502 m.

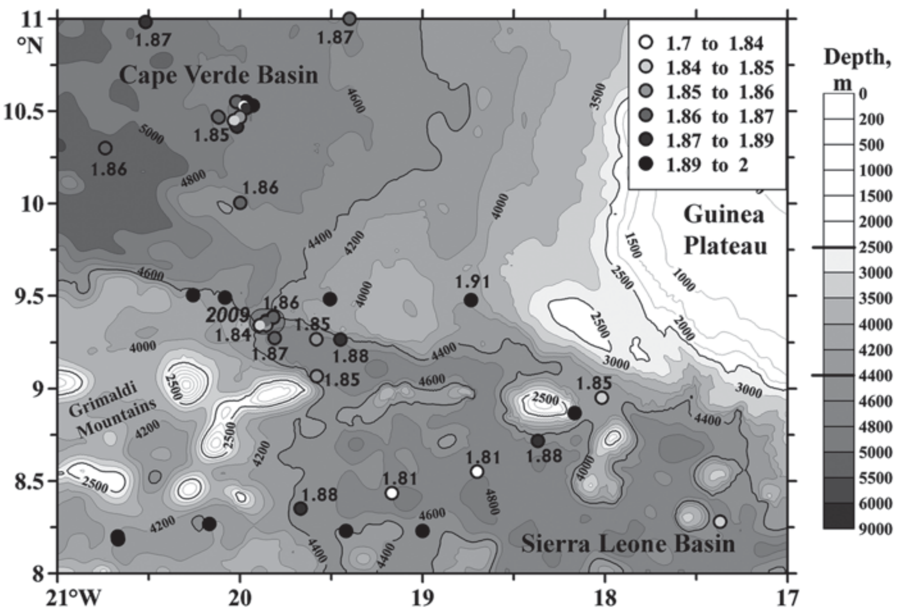

Fig. 6. Bottom topography (m) in the Kane Gap region showing locations of historical and recent stations near the main sill of the gap. Bottom potential temperatures (°C) are indicated at deepest stations

There are very few historical measurements in the Kane Gap. The scientists from the Shirshov Institute of Oceanology carried out CTD and currents measurements in this region in 2009–2011. In May 2009, the currents measured with LADCP were directed to the south at all depths below 2500 m. Thus, the bottom transport was directed from the Gambia Abyssal Plain to the Sierra Leone Basin. In October 2009, the measurements with a LADCP profiler demonstrated that the flow was directed to the northwest. Thus, the flow was opposite to the one recorded in May 2009.

The temperature stratification of the flow is similar to the flow in the Vema Channel. The coolest and densest water of the flow is displaced to the western wall of the gap due to the Ekman friction. Lower salinities are also recorded here at the foot of the western slope. Since the Kane Gap is located in the Northern Hemisphere, Ekman friction displaces the densest water to the left wall of the channel (southwestern slope in our case) (Fig. 7).

The total transport below 1.9°C potential temperature isotherm based on LADCP measurements fluctuates between zero and 0.2 Sv based on our measurements in different years. Thus, the bottom water from the Vema Fracture Zone influences at least the northern part of the Sierra Leone Basin, while the bottom water from the Romanche Fracture Zone can spread to the north through the Kane Gap and influence the adjacent southern region of Cape Verde Basin. However, the bottom water transport does not exceed 0.2 Sv and can be influenced by tides.

DISCOVERY GAP

The northward propagation of bottom waters from the Canary Basin to the northeastern Atlantic occurs through the Discovery Gap. This region is the boundary for the further northward transport of bottom water with potential temperatures below 2°C. This passage is considered the terminal point of AABW spreading to the north in the sense that this is the water with a potential temperature less than 2°C. This is a narrow passage in the East Azores Fracture Zone at 37°N between the Madeira and Iberian abyssal basins [Saunders, 1987]. The passage is 150 km long. Its narrowest place is located at 37°20′ N, 15°40′ W. The width of the narrowest gap is 10 km and the depth of the sill is 4800 m. The measured mean velocities were 5 cm s^{-1}. The flux of bottom water colder than potential temperature $\theta = 2.05$°C was estimated at 0.2 Sv. Numerous CTD measurements around the Discovery Gap indicate that water with potential temperature below 2°C does not propagate through this passage.

During the last 29 years since the previous measurements in 1982 the temperature at the bottom of the Discovery Gap decreased by 0.023°C from 2.025°C in 1982 to 2.002°C that we measured in 2011. Unlike the current measurements in 1982, the measurements in 2011 did not demonstrate clearly

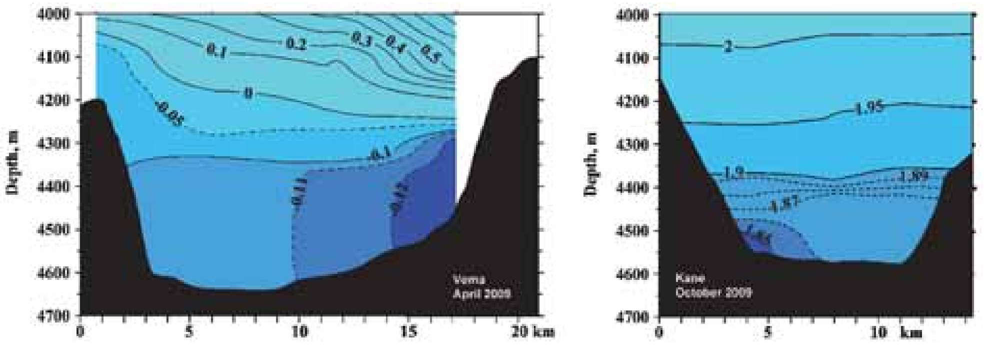

Fig. 7. Distribution of potential temperature (°C) across the Vema Channel and Kane Gap

manifested northerly flow of the bottom water. A fluctuating flow was observed in 2011. One core displaced to the eastern slope was directed to the northeast with velocities of approximately 5 cm/s and the second core with slightly greater velocities was directed to the southwest and displaced to the western slope.

CONCLUSIONS

We summarized the characteristics of the transport of bottom water from its source region in the Weddell Sea through the main abyssal channels of the Atlantic Ocean. The analysis is based on the recent CTD-sections and moored current meters as well as on the historical data. The main properties of the bottom flow in the Vema Channel include a flow with a mean speed of 30 cm/s. The measurements in the Vema Channel that have been continuing for 30 years already revealed a temperature increase and recent fluctuations in the temperature of the coldest water. After the flow of Antarctic Bottom Water passes the Brazil Basin it splits into two flows. Part of the water flows through the Romanche and Chain fracture zones to the east. The other part flows to the northwest to the North American Basin. Part of the latter flow propagates through the Vema Fracture Zone into the Northeast Atlantic. We analyze an unsteady flow of bottom water in the Kane Gap. The terminal point for the Antarctic Bottom Water flow is the Discovery Gap.

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CONTEMPORARY LAND REFORM POLICY AND PRACTICE IN SOUTH AFRICA AND ITS ENVIRONMENTAL IMPLICATIONS: NEW IDEAS, OLD PROBLEMS?

ABSTRACT. An extensive land reform programme is underway, which faces many challenges unique to the socio-political context of post-apartheid South Africa. The aim of this paper is to review the extent to which agrarian land reform policy, more particularly in respect to its land distribution element, incorporates environmental sustainability principles into resultant practice and whether or not this may lead to exacerbation of land degradation problems in the country. The paper briefly outlines the key land reform role-players, the policy and implementation process of land reform, and considers these in relation to the problem of land degradation. Ongoing problems of implementation with the land redistribution programme are discussed in relation to a number of significant challenges. The paper illustrates the lack of integration of environmental planning in the land reform process generally and points to the potentially deleterious impact of land reform on land degradation.

KEY WORDS: Land reform, land degradation, *apartheid*, environmental impact, agricultural policy, rural livelihoods

INTRODUCTION AND CONTEXT
LAND REFORM IN SOUTH AFRICA

Land reform is a highly topical and emotionally charged issue that has received particular attention in southern Africa but one that resonates across the continent as a whole [Cousins, 2009]. South Africa, as an emerging democracy with a well known history of conquest and dispossession of land in the colonial and *apartheid* eras, has embarked on a systematic land reform programme in order to redress previous political and economic imbalances. Since the demise of the *apartheid* system in the early 1990s, land reform has been a part of the restructuring process in South Africa, and was one of the cornerstones of African National Congress (ANC) policy when they formed the new democratic government in 1994 [Ibsen, 2000; Lemon, 2004]. The ANC's Reconstruction and Development Programme (RDP) envisaged a land reform programme that was integral to rural development:

A national land reform programme is the central and driving force of a programme of rural development [African National Congress, 1993, section 2.4.2].

Through a government programme of land reform since 1994, efforts are being made to redress the past inequity of access to land and resources, although it remains a hotly debated, emotive and contested issue and one that is further complicated by other social and health problems in the region [Drimie, 2003]. There has been much debate in both official government circles and in the media (see, for example, *Financial Mail*, 28th February 2012, in which progress is described as proceeding "...at a snail's pace"). There are, in addition, other concerns, particularly over the potential environmental impact of agrarian land reform if sustainability issues are not systematically incorporated into policy and practice [Wynberg and Sowman, 2007]. Thus, while there are clear political and economic imperatives to land reform, the fact that much of rural South Africa experiences a semi-arid climate and is highly susceptible to land degradation [Hoffman *et al*., 1999; Kakembo and Rowntree, 2003], strongly suggests that such environmental concerns need to be taken very seriously.

The model of land reform developed and adopted by the post-1994 democratic government has three elements: land ***restitution*** (the return to the previous owners of land taken away under racially discriminatory laws, limited to those removals that took place after the 1913 Land Act), land ***tenure reform*** (administration and legislation to improve tenure security and to accommodate diverse forms of land tenure, including communal tenure) and a market-led, demand-driven land ***redistribution*** programme that intends to achieve both political goals and economic growth in the agricultural sector [DLA, 1997; Turner and Ibsen, 2000]. The land redistribution programme initially aimed to obtain the transfer of 30% of historically white-owned agricultural land (including both private commercial and State agricultural land) by 2014 [ANC 1993]. This paper explores agrarian land reform in South Africa, in particular its land redistribution component, and assesses the policy, process and practice of land reform together with its possible impacts on the environment. In reviewing progress – or lack of it – in regard to land reform, it is argued that any process that lacks integrity in terms of the environment will ultimately fail to solve the social and economic problems it is aimed at addressing. The argument is made that, while land reform *per se* is absolutely key to rural development in the country, its implementation without significant consideration of the natural environmental constraints of the country, cannot resolve the serious inequities associated with the marginalisation South Africa's rural poor.

While land reform has been a cornerstone of national policy since the installation of the first democratic government in 1994, the proposed future trajectory for the programme is set out in the recent *Green Paper on Land Reform* issued by the Department of Rural Development and Land Reform [DRDLR, 2011]. The basic tenets of the policy are underpinned by the recognition that agrarian transformation is fundamental to future social cohesion and development in general as well as improved food sovereignty and food security in particular; such goals depend on more equitable access to and ownership of land. The strategy involves government support (subsidies and technical support) for people of so-called designated population groups, wishing to purchase agricultural land for farming purposes (each described as a "land reform project"). The extent to which the revised land reform policy, as set out in this Green Paper, redresses some of the shortcomings of the original, post-*apartheid* intentions provides an important focus for this paper.

Rural livelihoods in South Africa are acknowledged to be complex and dynamic systems and that '…undoing the social, economic and cultural effects of centuries of discrimination and exclusion on the basis of race, class and gender, will take time and an enduring national political effort [DRDLR, 2011]. However, the fact that agrarian livelihoods and, indeed, the livelihoods of the rural population in general, are directly dependent on natural resources highlights the significance of the environment to the process. This clearly has important implications for the conceptualisation, design and implementation of land reform policy and practice [Shackleton *et al*. 1999]. It is, therefore, essential that the planning of land reform, including restitution, redistribution and tenure reform, should systematically embrace an evaluation of the land and the available natural resources, and an assessment of the suitability of land for the envisaged land uses (the impacts of the land uses on the natural environment). Such evaluation should incorporate an inventory and assessment of the existing situation that focuses on the resources and services provided by the natural environment. Decisions made on a sound ecological basis, taking into account most recent theories of environmental degradation, are better able to avert the failure of these new settlements and promote more sustainable land reform projects. Sustainability within the land reform context is a measure of the extent to which land reform objectives (environmental, economic and social) can be met from a defined land use over a fixed period of time [Wynberg and Sowman, 2007].

Land degradation in rural South Africa

Land degradation has been recognised as a serious environmental problem and one that threatens global food and energy security [Reed *et al*., 2011]. The United Nations Environment Programme (UNEP) estimated that 73% of Africa's drylands are moderately to severely degraded [UNCCD, 1995]. As much as two-thirds of the continent is classified as drylands according to UNEP definitions, thus the International Convention to Combat Desertification (UNCCD) gives priority to Africa in a special annexure. It is important to note however, that the issue of land degradation and desertification remains the subject of much debate and uncertainty in spite of the recognition given to the issue by UNEP [Thomas and Middleton, 1994; McCann, 1999; Andersson *et al*., 2011]. Poverty, climate variability, political mismanagement, institutional issues and even unfair trading by developed countries are all identified as potential contributors to environmental degradation. In South Africa, any policy aimed at agrarian reform must surely include a consideration of the environment in its manifestation. Land reform, if inappropriately or improperly applied, can amplify environmental degradation and reduce the sustainability of the very resource that is targeted by the policy [see Wynberg and Sowman, 2007].

The status of land degradation in South Africa has been surveyed in a comprehensive review by Hoffman *et al*. [1999] and published by the Department of Environmental Affairs and Tourism (DEAT), as part of a National Action Plan in terms of the UNCCD (Fig. 1). Land degradation is considered in terms of severity, rate and extent of both soil

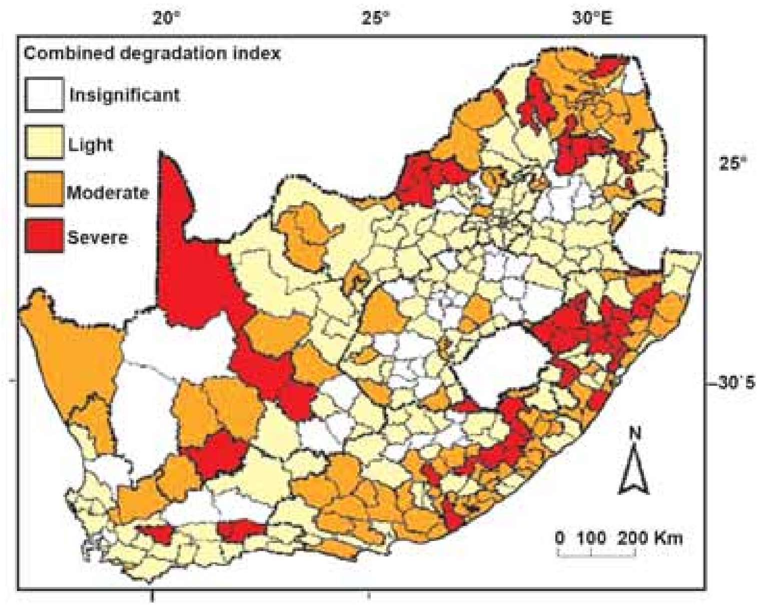

Fig. 1. Land degradation in South Africa illustrated by Hoffman *et al.'s* combined degradation index. Darker shading indicates areas of greatest degradation. The magisterial districts of South Africa are indicated.

Original data: Hoffman et al. [1999] and redrawn in Meadows and Hoffman [2003] degradation and vegetation degradation (loss of cover, change in species composition, bush encroachment, alien infestation and deforestation). The study [Hoffman and Ashwell, 2001] highlighted the overall severity of degradation in the communally farmed areas of the former so-called *Bantustans* (commonly referred to as the 'homelands'). This conclusion was contrary to the previously widely held view that the semi-arid eastern Karoo region was the most severely degraded as a result of overgrazing by commercial (white) farmers, although this is not to say that commercial farms were not also subject to degradation. There is evidently, however, a strong disparity between the Bantustans and commercial areas in terms of degradation and this is attributable to a number of factors including the history of land allocation in colonial and *apartheid* eras, issues of demography and settlement, land use policies, and access to government agricultural support [Hoffman and Ashwell, 2001:141].

Aim and objectives of the study

The overall aim of this paper is to review and reassess land reform policy (more particularly in regard to its land redistribution element) and practice and to reflect on the extent to which land degradation issues are dealt within contemporary agrarian transformation in South Africa. The degree to which environmental planning (in order to avoid further land degradation) is integrated into the land reform process is investigated. Finally, the question as to whether land redistribution may or may not aggravate or mitigate land degradation is briefly explored.

INSTITUTIONS ENGAGED IN LAND REFORM IN SOUTH AFRICA

The structure of governance in South Africa consists of three spheres, national, provincial and local government [Republic of South Africa, 1996]. There are nine provinces, each with a provincial legislature. National departments have provincial counterparts, although there is variation in these departments between provinces. In terms of the Constitution, there are certain functional areas of concurrent national and provincial competence; agriculture, environment and urban and rural development are such areas [Republic of South Africa, 1996]. The Constitution obligates the government to enable citizens to gain equitable access to land, and to produce the necessary legislative and policy reform [S.25 [4)]. In 1999, following the nation's second democratic elections, the then Department of Land Affairs (DLA) undertook a major review of the land reform programme, principally affecting land redistribution. The outcome of this review was the launch of a new programme entitled: *Land Redistribution for Agricultural Development*, referred to as LRAD [MALA, 2001]. The responsibility for land reform until 2009 lay with the Ministry of Agriculture and Land Affairs, but in 2009 the Department of Rural Development and Land Reform (DRDLR) was established and this now takes administrative responsibility for the land reform process in general and LRAD in particular, while the Department of Agriculture, Forestry and Fisheries (DAFF) provides a parallel role acting mainly in an advisory capacity (Fig. 2).

In regard to the environmental implications of land reform it is worth considering the possible roles of two other government departments. Firstly, DAFF is not directly responsible for land reform *per se,* but retains an important advisory role and coordinates of land conservation work through the so-called 'LandCare' programme, inspired by the successful Australian model in 1998 [Turner and Ibsen, 2000:32]. The programme aims to build capacity and awareness around the conservation of agricultural resources. Funding is available to improve agricultural resource management, however, the national budget is small (R25 million) [DEAT, 2002:42]. Turner [2000] is critical of the programme, "...South African LandCare has done little to achieve the local environmental commitment and collaboration across social and economic sectors for which its Australian counterpart is renowned..." [Turner 2000:32].

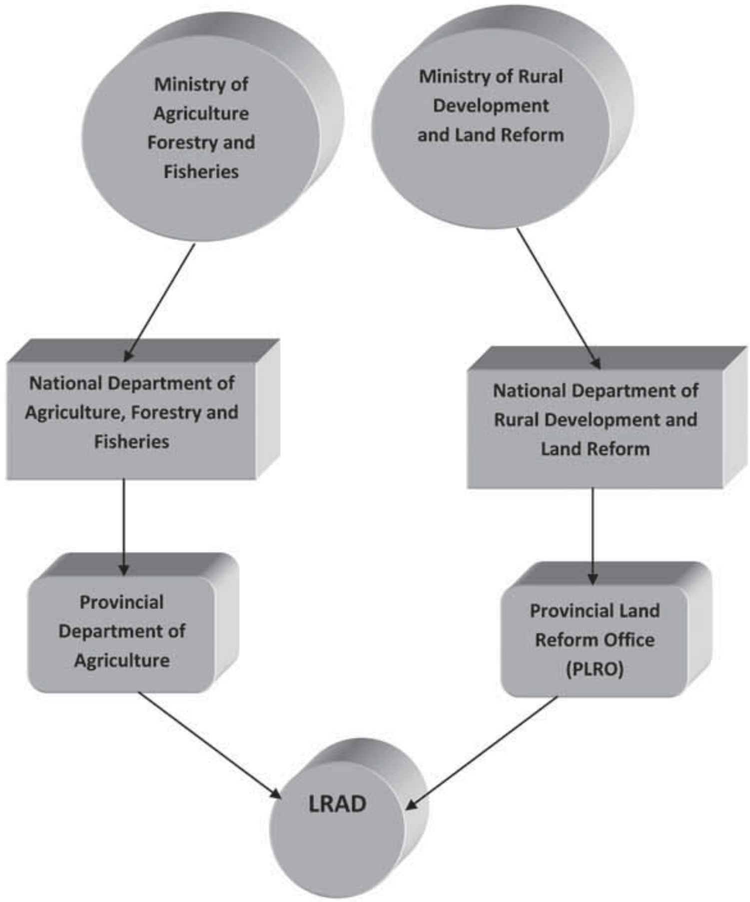

Fig. 2. Institutional framework for the implementation of land redistribution

The extent to which these conservation ideals feed into the land reform policy and practice is, in any case, very debatable [Wynberg and Sowman, 2007]. Secondly, DEAT, while one might expect a significant role in land reform, is not integrated into the programme at all – either at national or provincial level. For example, in Western Cape Province, there is no representative of Environmental Affairs on the so-called Land Reform Project Teams so that involvement appears to be absent at the LRAD project planning stage. More proactive involvement by DEAT in land reform projects only occurs when Environmental Impact Assessments (EIA) are required when a change in land use requires EIA in terms of the regulations (promulgated in terms of the Environmental Conservation Act, 1989].

POLICY AND LEGISLATIVE INSTRUMENTS RELEVANT TO LAND REFORM

The policies selected for review in this section are those considered relevant to land reform in the context of environmental sustainability.

The Constitution

The Constitution, within the Bill of Rights (Chapter 2), provides the basis for all land reform policy. The Property clause (S. 25) requires the government to take reasonable legislative action to provide citizens with access to land, secure tenure, and restitution of land rights. It also entrenches private property rights, which gives rise to the market-based land reform system. The environmental clause (S. 24) entitles every person to have the environment protected through measures which prevent "...ecological degradation" and "...secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development" (S. 24(b)). In terms of this clause, land reform administrators and participants are therefore required by the constitution to develop and implement land reform projects in a manner that will promote ecologically sustainable development and avoid ecological degradation.

White Paper on Land Policy, Department of Land Affairs, 1997

The framework policy for land reform is still the White Paper on Land Policy, 1997 [DLA, 1997]. The principles of the land reform programme stated in the White Paper, set out in Table 1 are such that planning of land reform projects must ensure "...economic viability and environmental sustainability" [DLA, 1997:12].

The White Paper on Land Policy acknowledges the existence of "...severe land degradation and soil erosion" which it attributes to landlessness, overcrowding in Bantustans, and inappropriate farming methods on commercial farms [DLA, 1997:23]. It identifies the potential of the land reform programme to result in land degradation:

One of the challenges of land reform is to relieve land pressure without extending environmental degradation over a wider area. Unless projects are properly planned and necessary measures are put in place to govern zoning, planning and the ultimate land use, the programme could result in land being used unsustainably [DLA White Paper on Land Policy, 1997:25].

The policy requires a 43feasibility study to be prepared, with the assistance of DLA planners, which includes an "...assessment of environmental consequences of the proposed undertaking" [DLA, 1997:25]. This requires the consideration of the suitability of the natural resources for the proposed farming [DLA, 1997:25].

Land Redistribution for Agricultural Development (LRAD) – Ministry of Agriculture and Land Affairs, (Version 4, 2002)

The then Minister of Agriculture and Land Affairs undertook a review of land reform policy and programmes resulting in the LRAD programme, launched in August 2001. LRAD deals with both the transfer of agricultural land to individuals or groups, and with commonage projects aimed at improving access to municipal and tribal land primarily for grazing purposes. LRAD provides technical support and grants to historically disadvantaged South African citizens, regardless of income, to access land specifically for agricultural purposes. The

Table 1. Land reform principles

Social justice	Government must deal with landlessness and to remedy the unequal distribution of land in South Africa
Poverty focus	Priority is given to the poor who need land to contribute to income and food security
Needs-based	Land reform should respond to the expressed needs of people
Government as facilitator	Government should facilitate the expression of demand and inform people of their optionas
Flexibility	Provincial and local variations require flexible application of policy within a framework of national norms.
Participation	The participation of communities and individuals as partners with government. Decisions at local level.
Gender equity	Priority should be given to women applicants
Economic and environmental sustainability	Planning of land reform projects must ensure these are economically and environmentally sustainable

Source: DLA, 1997. White Paper on South African Land Policy, Department of Land Affairs.

aim of the LRAD programme was explicitly stated as the transfer of 30% of the country's commercial agricultural land by 2014 in order to improve food sovereignty for the rural poor; decongest overcrowded former homeland areas; expand opportunities for women and young people in rural areas; and promote environmental sustainability of land and other natural resources [MALA, 2001:6]. LRAD may be considered as demand-led, meaning beneficiaries must define the type of project and must identify their own land and acquisition of land continues to be on the basis of the 'willing-buyer, willing seller' approach.

In the LRAD programme, all 'beneficiaries' must make a contribution in cash, kind or labour of a minimum of ZAR[1] 5000.

[1]Beneficiaries can access a range of grants along a sliding scale from ZAR 20 000 – R100 000 per individual, depending on the amount of their own contribution. The grant and the contribution are calculated on an individual adult basis; if people apply as a group, the total amount of the grant and own contribution are both scaled up by the number of individuals represented in the group. The programme is unclear and conflicting with regard to the requirement for environmental assessment of projects. Version 4 of 2002 states that the 'Business Plan' should include "...environmental impact assessments" but only "...if applicable to the project", without any explanation of when this would be the case.

Green Paper on Land Reform, September 2011 [DRD&LR, 2011]

The release of the Green Paper (a document issued for public comment and indicating a policy framework) on Land Reform by DRDLR in September 2011 [DRDLR, 2011] heralds a fundamentally different approach to the issue of agrarian transformation. It is implicit, although not explicitly acknowledged, that the need for a new structure lies in the failure of the LRAD programme. The vision for land reform as set out in the Green Paper is: *reasonable access to land with secure rights in order to fulfil basic needs for housing and productive livelihoods* [DRDLR, 2011]. Administratively, the most important difference between the proposed system and the existing LRAD is the adoption of a proposed Land Management Commission with extensive powers and which, working with a Land Valuer-General, will oversee the identification and purchase of land for redistribution and restitution. The message is that market principles have been an impediment to land reform and that, *de facto*, the 'willing seller, willing buyer' principle is no longer deemed central to the transaction process. It is envisaged that more properties would become State-owned and that there would be less emphasis on private ownership of agricultural land. The concept of 'land ceilings' is also alluded to, implying that there should be a maximum amount of land owned by any particular individual; this is also a new, and highly controversial, development, although there are no specific recommendations as to what such a ceiling should be. The much anticipated Green Paper has received generally highly critical reviews – from frustration that the proposed policy framework fails to give clear guidance as to how agrarian transformation can be achieved (for example, AgriSA, 2011], to outright rejection on the grounds that the proposals on land tenure violate the South African Constitution [Afriforum, 2012]. Crucially, in relation to the theme of this paper, there is no specific consideration of environmental sustainability in the vision (further discussed below).

LAND REFORM IN SOUTH AFRICA: STATUS AND CHALLENGES

The strategic objective of the land redistribution component of land reform was to ensure the transfer of 30% of all agricultural land by 2014 to the historically disadvantaged. What progress has been made and how realistic is it that the target will be met?

[1] Note, ZAR = South African Rand. At time of going to press, 1.0 US$ is approximately ZAR 8.7.

What of the environmental sustainability of the programme? Certainly there have been significant problems regarding delivery due to the enormous scale of this objective, to lack of budget, lack of capacity and skills and to constraints embedded in the actual land reform policy instruments. In this section, some of the problems experienced with the implementation of land reform are explored.

The challenge of delivery

The scale of redistribution of land envisaged in the land reform programme is enormous and way beyond the levels of delivery achieved thus far. The land reform programme has been constrained by shortfalls in budget, with potential expenditure being double or more the amount available from the national treasury as well as underspending [DLA, 1999]. Slow implementation of land redistribution projects has been a consistently alarming feature of the programme, as indicated by statistics for particular years. For example, in 2006–2007, the then Department of Land Affairs reported land transferred at 258 890 ha, which was barely 10% of the targeted figure of 2.5 million ha [Lahiff, 2008]. Indeed, by 2007 the programme was so far behind the land redistribution target that approximately 2 million ha of land a year would have to be acquired to reach the target of 30% by the end of the year 2014 and that "...this is the equivalent of an area the size of the Kruger National Park every year for the next seven years" [De Villiers 2007:7]. However, the introduction of the Proactive Land Acquisition Strategy (PLAS) and the Land and Agrarian Reform Project (LARP), "...together with a greater political emphasis on expropriation, raises the possibility of at least some increase in the rate of land transfer" [Lahiff, 2008: 2]. The most recent statistics are, accordingly, somewhat more encouraging and suggest an increasing pace of acquisition. During 2011–12, the Department actually over-performed in transferring ownership of some 392,850 ha (cf 239,990 ha in 2009) of land against an annual target of 303,612 ha [DRDLR, 2012], albeit this still falls woefully short of what would be required if the figure of 30% of total land were to be reached by 2014.

Quantity or quality?

In its early years, the land reform programme prioritised speed of delivery of land rather than sustainability and quality of land reform [DLA, 2000:36]. DLA's internal performance management systems have rewarded officials in terms of quantity, measured in hectares and households and in spending their budget. The latest report [DRDLR, 2012] hints at the transfer of 'strategically located' land and perhaps points to a greater emphasis on effective land planning as a key performance area. Davis [2011] argues that there focus has now shifted from simple land acquisition and transfer to ensuring that systems are in place to make productive use of the land, although it is difficult to see exactly what such systems are in perusing the policy instruments.

Lack of capacity

The lack of capacity within land reform offices, affects the ability to deliver both quantity and quality. Jacobs [2003] reported that understaffing throughout the ranks of DLA imposes constraints on the ability to meet the needs of land reform beneficiaries and the department itself notes that more than 11% of posts remain vacant [DRDLR, 2012]. Both implementation and effectiveness are clearly constrained by a lack of capacity and, in reviewing the programme, the department indicates that more successful land reform projects are those where the individual or group beneficiaries are adequately trained. The current programme, however, does not provide for the inclusion of environmental considerations either in the business plan or in the development of capacity for the land redistribution beneficiaries.

Accessing suitable land

A market-based model of land reform has thus far meant that land had to be obtained on a 'willing-seller, willing-buyer' basis. The high demand for land, coupled with the fact that no incentive exists for landowners to sell or subdivide their land for redistribution purposes, means that land available for land redistribution may often be of poor quality and/or high price. Landowners are also reluctant to sell land through a slow, bureaucratic process, which involves waiting for land grants to be approved before the sale transaction can be completed [Jacobs, 2003; Heibinck and Shackleton, 2010]. The problem may therefore manifest itself in terms of land degradation because the LRAD system is silent on the issue as to where land reform takes place, such as in or near the overcrowded former homeland areas. It remains to be seen if the new procedures proposed in the 2011 Green Paper will address some of these shortcomings, but the lack of any attention to land quality in the documentation remains a concern.

DISCUSSION

It is clear that South African land reform, particularly in the context of land redistribution, has thus far failed to deliver on its lofty aims. The goal of "30% by 2014" will not be met (the current figure stands at somewhat less than 10%) and has even been referred to as trying to put out a fire with a broken teacup [Moseley and McCusker, 2008]. The 'two cycles' of policy [Hall, 2007] that saw an earlier, more populist policy aimed at very poor farmers has been replaced by one that focuses more on emerging black commercial farmers, yet neither has been able to keep pace with demand. This is a policy shift that arguably '...reflects a desire on the part of the government to support the expansion of black commercial farmers ...rather than radically restructure the agriculture sector in South Africa' [Boudreaux, 2010] and misses the opportunity to improve social justice. The policy set out in the 2011 Green Paper aims to redress some of these shortcomings but it proposes to do so by placing more land in the hands of the State – a highly controversial and, as yet, untested strategy.

Although environmental sustainability in general, and land degradation in particular, are to some extent reflected in the land reform policies and instruments, it is clear that they remain secondary or minor considerations. Thurs, the White Paper on Land Policy 1997 acknowledges the existence of severe land degradation and the risk of increased land degradation as a result of the land reform programme but the LRAD policy documents do not provide sufficient detail to ensure that adequate attention to environmental planning occurs in the design stages of projects. There is insufficient guidance on the issue of environment as it relates to land reform for private sector consultants, agricultural officers or planners to ensure sustainability. Any future policy needs to be translated into simple tools that can be used by planners, consultants and agricultural officers to achieve both quantity and quality in terms of land reform projects. Regrettably, the new dispensation promised in the Green Paper is silent on such matters. The only, tangential, reference to sustainability in this policy document are those comments that refer to 'livelihood security' or 'sustainable rural production systems' but these terms are more likely used in the context of the economic, rather than environmental or ecological, context.

Poorly planned and managed land redistribution may easily lead to more intensive production, resulting in over-cultivation or overgrazing. Exceeding the carrying capacity of land (humans and livestock) therefore has the potential to increase land degradation. The viability of farming enterprises will be threatened if farmers have unrealistic expectations of the supply of natural resources and the productive potential of their land. Detailed resource assessments and land evaluations prior to project implementation, can avoid potential risks associated with pressure from overcrowding, both humans and livestock.

Review of land reform projects post-implementation clearly reveals some of the negative environmental impacts of land reform [see DLA, 2000]. These impacts need to be minimised through more thorough environmental planning if intensified land degradation is to be avoided. The effect of land degradation goes beyond the physical impacts and the issue of agricultural production. The social impacts of land degradation are increasing urbanisation, as farming becomes less productive. [Hoffman and Ashwell 2001]. As Hebinck and Shackleton [2010: p xx] note: "... resources and their use can and should not be treated as disconnected from the social actors that access and use them" and there is a distinct risk in the current and likely future implementation of the land reform programme in South Africa that such a disconnection can result in significant environmental deterioration. An environmentally unsustainable solution cannot resolve the crisis of rural poverty and inequity [see Giller *et al*., 2008, for a possible approach to addressing this problem].

Returning to the key elements of this paper, it is clear that environmental sustainability and land degradation have not yet been adequately addressed in South Africa's land reform programme. Initially, it appears that there was recognition of the potential risk of environmental deterioration but the policy in practice has fallen short of providing adequate, sufficiently detailed and user-friendly guidelines to avoid further degradation. Environmental planning is not integrated into the land reform process in a consistent and coherent manner. The potential impact of land reform on land degradation is problematic and could result in the failure of land reform projects. The impact of land reform on land use and land degradation has thus far not been monitored. It is a lesson that we need to learn fast if the land reform process, controversial and complex as it already is, is not to result in further environmental degradation and the exposure of South Africa's historically disadvantaged rural poor to even greater levels of risk and vulnerability. Land reform experience elsewhere suggests that ecological and environmental factors can be incorporated successfully into the system. In Brazil, for example, where historically agrarian reform had been associated with deforestation and environmental degradation, the government introduced a scheme in 2003 that actively encouraged citizens to adopt an ecologically sustainable attitude to land [Wittman, 2010]. Successive governments in that country have successfully integrated food production and environmental management into the land reform programme [Davis, 2011]; South Africa would surely do well to implement such a model.

CONCLUSION

Although it is important not to delay the process of land reform even further, incorporation of environmental guidelines and proper follow-up to individual land reform projects in the form of sound ecological monitoring and advice is essential if land degradation is not to be accelerated as a result. The South African environment has been termed a 'neglected dimension' in agrarian transformation [Wynberg and Sowman, 2007] and, unfortunately, newly proposed policy interventions appear unlikely to be any more sustainable than existing ones. Given the semi-arid nature of much of South Africa, the words of Geist and Lambin [2004: 828] are highly pertinent where they note that "...a detailed understanding of the complex set of proximal causes and underlying driving forces affecting dryland-cover change is required before any assessment or policy intervention". Furthermore, as Seekings and Nattrass [2004] argue, several post-1994 government policies have accentuated rather than alleviated poverty so that, without proper environmental planning, land reform is at risk of doing the same.

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URBAN SPRAWL AND THE ENVIRONMENT

ABSTRACT. Urban sprawl is among the most debated topics in the field of urbanism, environmental sciences, ecology, economics, and geography. As urban sprawl involves different subjects of study, this phenomenon is extremely fascinating on the one side, but very complex and difficult to analyze on the other side. For this reason, sprawl has and is attracting the interest of many researchers from all over the world, having the objective to define the nature, dynamics and consequences that the process of low-density urban expansion is having on the biophysical and socioeconomic environment. The aim of this review is to provide a brief picture on the nature of the relationship existing between sprawl and the environment with special attention to Europe. The growing environmental vulnerability of the European urban regions was discussed according to a bibliographic survey based on quali-quantitative studies. Evidence support the idea that environmental policy and regional planning should cope more effectively with the increasing vulnerability of 'shrinking' urban regions to natural hazards.

KEY WORDS: Urban Sprawl, Regional Geography, Land consumption, Indicators, Europe

INTRODUCTION

Compactness and dispersion were and are the two main schemes with which cities have evolved. There has always been an intellectual debate regarding the positive and negative traits of these two patterns of urbanization. But only since the beginning of the 20th century, as the world population rapidly increased and concerns regarding the preservation of the natural environment from the effects of urbanization grew, the debate on compact versus sprawl trajectories of urban development has become a matter of intense research [Bruegmann, 2005]. Urban sprawl, that is the phenomenon of low-density settlement diffusion over large peri-urban regions, is amongst the most debated topics in the fields of urbanism, environmental sciences, ecology, economics, geography, and sociology. As sprawl involves different subjects of study, the phenomenon is extremely fascinating on the one side, but very complex and difficult to analyze on the other [Davoudi 2003]. For these reasons, sprawl has and is attracting the interest of many researchers from all over the world, having the objective to define the nature, dynamics and consequences that the phenomenon of low-density urban expansion is having on the natural environment [Chin 2002, Hasse 2004, 2008, Classically, sprawl is a phenomenon associated with the rapid low-density outward expansion of United States cities, steaming back to the early part of the 20th century, fueled by the rapid growth of private car ownership and the preference for detached houses with gardens [European Environment Agency 2006]. Therefore, the first studies on the sprawl process of cities have been conducted in North America, where the phenomenon initially appeared with greatest intensity [Downs 1999]. Today, the sprawl process is amongst the major concerns in developed and developing countries of the world for its adverse environmental impact [Frenkel and Askenazi 2007]. Nevertheless, the vast majority of secondary sources regarding the urban phenomenon are still of North American origin [Johnson 2001].

The aim of this contribution is to discuss about sprawl dynamics at various geographical scales and to comment on its relationships with environmental quality and natural resource depletion [Kahn 2000]. After having given a general overview on the phenomenon, the first paragraph illustrates the typical spatial morphological forms and other features with which the process manifests itself [Hall 1997]. Single-use zoning, low-density development, ribbon and leapfrog development, land-sealing of agricultural and natural areas, infrastructure-driven development and car-dependent communities have been described and interpreted as different forms of urban sprawl [Jaret et al. 2009].

In the subsequent paragraphs, the impact and environmental consequences of sprawl are explored both qualitatively and quantitatively. The latter analysis has revealed particularly difficult as the effects of deteriorating ecosystems and consumption of natural resource due to low-density urbanization are not easy to quantify [Craglia et al. 2004]. Nevertheless, for a better understanding of the environmental impact of sprawl, the paragraph has focused on the energy and natural resources consumption differentials between compact and diffused patterns of urbanization [Frenkel and Askenazi 2008].

In the present contribution, the analysis of sprawl and its environmental consequences was concentrated on Europe. In order to give a picture on the diffusion of urban sprawl in Europe, four categories of urban development trends have been provided. The very general picture is that Atlantic, Central, Eastern and Southern European regions present mixed patterns of growth and decline combined with sprawl, the Western region is growing with sprawl and Northern Europe is growing with containment [Hasse and Lathrop 2003]. Through data provided by the European Environment Agency, the impacts of urban sprawl in Europe have been studied and quantified where possible. Land consumption (mainly to the expense of agricultural areas), water consumption (the interferences of soil sealing on the recharge of groundwater basins, especially in the mountain ranges of Europe where the main water tanks are located), raw materials growing demand (especially for concrete) and energy consumption (mainly fossil fuels for transport) related to the sprawl process in Europe have been discussed [e.g. Haase and Nuissl 2010]. Furthermore, this study has shown the connection between sprawl, climate changes and increasing vulnerability of urban zones to extreme weather events. By extending urbanized areas over greater portions of land, probability and frequency of disasters related to extreme weather events raises.

DISCUSSING THE MORPHOLOGICAL TRAITS OF SPRAWL

According to the location where the phenomenon has been studied, researchers have arrived to different definitions of urban sprawl since the phenomenon greatly varies over the cities of the globe. It has different characteristics, dynamics, effects and consequences according to the nature of human societies that determine it. Consequently, searching for a unique definition of sprawl is made even more difficult when the differences in patterns and processes of urbanisation in various countries and regions are considered [Longhi and Musolesi 2007]. Traditionally, urban sprawl was defined as a low density, inefficient suburban development around the periphery of cities, characterised by auto-dependent development on rural land. This definition emphasises sprawl as a spatial pattern of urbanisation associated with design features that encourage car dependency. Nonetheless, other definitions of sprawl emphasise different characteristics of the phenomenon, as we can see from the following quotations:

"Urban sprawl refers to a gluttonous use of land, uninterrupted monotonous development, leapfrog discontinuous development and inefficient land use". [Peiser, 2001].

"Urban Sprawl is a pattern of urban and metropolitan growth that reflects low density, automobile-dependent, exclusionary new development on the fringe of settled areas often surrounding a deteriorating city". [Squires, 2002].

"Urban Sprawl is random unplanned growth characterized by inadequate accessibility to essential land uses such as housing, jobs, and public services like schools, hospitals, and mass transit". [Bullard et al., 2000].

It is possible to state that the term *"sprawl"* has a negative connotation in most writings; social scientists usually depict sprawl as a problem. Some do it explicitly by definition, others link it to negative consequences such as the decline of central cities or worsening public health. Neutral terms (such as *urban deconcentration, suburban expansion, counter-urbanisation*) have not caught on, in part, because these terms do not suggest any distinction between sprawl and suburbanisation in general. In other words, many scholars studying sprawl view it as *"a particular form of suburbanisation with several characteristics that differentiate it from other conceivable forms of suburbanisation"*.

From the above definitions, it is possible to notice that even if there is still no consensus on the exact meaning of sprawl, experts seem to agree on the key components of the concept. It seems clear that sprawl refers to spread out low-density development beyond the edge of a city's boundaries, where people depend on the automobile for transportation because they live far from where they work, shop, go to school, worship, or pursue leisure activities. Downs [1997] stressed six features of sprawl, some of which distinguish it from other forms of suburbanisation: (i) no limits placed on the outward suburban expansion; (ii) legal control over land-use, local services, transportation, property taxes, and fiscal policy divided among many small entities or jurisdictions, with no central agency responsible for the planning or control of these issues regionally; (iii) extensive *"leapfrog"* development; (iv) fragmented land ownership; (v) different types of land-use, spatially separated or zoned into distinct areas; and, finally, (vi) extensive strip commercial and residential development along larger suburban roads.

Downs' formulation of sprawl is valuable because it suggests the need to think of and measure sprawl in terms of multiple indicators or dimensions rather than simply in terms of low-density settlement patterns. A recent report by Ewing *et al.* [2002] provides a summary of some of the indicators that can be used to measure sprawl. In general, these reflect the characteristics outlined above and include: (i) low-density residential developments; (ii) a rigid separation of homes, services and workplaces; (iii) a network of roads marked by large blocks and poor access; and (iv) a lack of well-defined activity centers, such as 'downtowns' and town centers. Finally, Ewing *et al.* [2002] suggests that sprawl might be regarded as a *"process in which the spread of development across the landscape far outpaces population growth".*

In this sense, the definition given by Glaster [2001] is the one that best allows sprawl to be considered as a process and not merely a spatial pattern. This process is initiated by social, economic and environmental pressures that cause a fall in demand for land development in the centre of the city whilst increasing it in the peripheral areas. The city spreads over a larger surface (while the volume remains approximately constant). With this definition of sprawl, we must be very careful in distinguishing the (compact) growing process of the city with the spreading one.

ENVIRONMENTAL IMPLICATIONS OF URBAN SPRAWL

Low-density urban patterns of development have several costs and implications. Most of these concern the degradation of the natural and social environment, besides direct financial costs. In this section, a research on the impact of sprawl will help us understanding whether anti-sprawl crusaders correctly boycott low-density urbanization in favor of compact growth. Sprawl not only results in direct habitat loss [McInnes, 2010], but also has a considerable impact on ecosystems and natural resources. The essential biological and physical systems include:

- wetlands, useful for flood control and wastewater renovation;
- forests, and grasslands that allows climate regulation;
- biodiversity factors that provide to healthy, well-functioning ecosystems;
- goods such as solar energy, wind energy, aesthetics, clean air, clean water, and potential resources.

Environmental resources to help maintain the ecosystem until the goods, services, and the space required to generate them remain unchanged. The excessive pollution, ecosystem destruction, and other forms of abuse, degrade or destroy the environmental resources in the long term. The environmental impact of sprawl stretches of geographical scales local, regional and global [Barnes et al. 2002]. An unintended consequence of low-density suburban growth is greater resource consumption leading to greater environmental damage if compared with a compact development pattern. Here below is presented a comparison between the energy and natural resources consumption (which is directly related to impacts on the environment) of compact and low-density patterns of urbanisation.

Compact vs sprawl: energy consumption differentials

According to Kahn [2000] the environmental costs of increased suburbanisation are a function of how much extra resources new households and inhabitants of suburbia consume. These resources are mainly fossil fuels (related to home energy consumption and the increasing vehicle mileage) and rural-agricultural land. Newman and Kenworthy [1989] clearly evidenced the relation between low-density urban development and the energy consumption per capita.

Sprawl inevitably brings to higher demands and consumption of energy mainly in the transport sector, which fundamentally relies on non-renewable forms of energy, such as fossil fuels. In contrast, travelling distances are kept relatively small in compact cities, thus favouring other forms of transport (mainly walking and bicycling) and a reduced use of automobiles. Furthermore, as dwelling units in suburban areas are larger than the usual apartments of the compact city, home energy consumption is also scaled up by low-density patterns of urbanisation. Even if new constructions are more likely to incorporate energy-conservation technologies and materials, thus increasing their efficiency, in the overall suburbanite's household-level energy consumption is greater than the one of compact cities.

The most immediate consequence of growing rates of combustion processes of fossil fuels due to higher consumption rates of low-density urban centres is air pollution. The carbon dioxide in vehicular emissions and power stations is a major greenhouse gas that has been linked to global warming. Traffic-generated air pollution threatens human health, agricultural production, and ecological systems. This is illustrated by ground-level ozone, a major air pollutant linked to the patterns and volumes of traffic stimulated by sprawl development. Ozone impairs respiratory functions in healthy individuals and aggravates the ill health of those suffering from heart and respiratory diseases. Other health problems arising from ozone exposure include chest pains, nausea, and throat irritation. Ozone also damages foliage, interferes with the physiological operations of plants, and is responsible for important annual losses in crop production. On the other hand, long-term effects of fossil fuel combustion are at the current moment subjected to a certain degree of uncertainties. Nevertheless, according to the Intergovernmental Panel on Climate Change (IPCC) there is a general agreement amongst scientist on the rationale that human activities are significantly contributing to the rise in Green House Gas in the atmosphere, which are believed to be responsible of climate changes. If the rationale that urban sprawl leads to higher energy consumption and land-use per capita is accepted, then its role in contributing to climate changes must be considered. Consequently, one of the major objectives of planning will be to promote and develop efficient urban forms that rely always less on the consumption of fossil fuels and agricultural/forest land. If the list of countries that signed the Kyoto Protocol intend to decrease their GHG emissions by the amounts that they have promised, then sprawl needs to be controlled in the future.

Natural resource depletion

Suburbs *"are now the dominant residential, retail, and commercial centres of growth and political muscle"* and the continuation and replication of this trend *"place(s) enormous pressure on land, water, and other resources"*. Amongst the major concerns regarding the sprawl process is that it *"eats into open space"* [Kahn 2000]. Low-density suburban and exurban development not only degrades environmental resources such as water quality, air quality, and wildlife habitats, but also limits or eliminates accessibility to natural resources such as agricultural lands, timberland, minerals, and water. The U.S. Environmental Protection Agency (EPA) has created a *sprawl index* based on per capita consumption. According to these studies, a home owner whose year income is $50,000 and who lives in a central area of the city has an average lot size of 7.8 thousand square feet (less than a quarter of an acre), while the average home owner in the suburbs with the same income has an average lot size of 12.3 thousand square feet. Even if city-suburb land consumption differential varies among cities, the general trend is that suburbanites consume more land per capita.

As suburban land grows, farmland is likely to decline. The idea of sprawl conjures up images of concrete roads and parking lots replacing agricultural land. As the population of metropolitan areas grows, it is likely that land at the fringe of such areas will be converted for urban use. As forest cover and agricultural land is cleared for urban development, both the quantity and quality of water supply are threatened: as impervious land is built over larger areas, rainfall is less effectively absorbed and returned to groundwater aquifers. Instead, relatively more stormwater flows to streams and rivers and is carried downstream. Frumkin [2002] shows that, in USA, about 4% of rainfall on undeveloped grassland, compared with 15% of rainfall on suburban land, was lost as runoff. This phenomenon also applies to the snow-melt, especially early in the melting process. With less groundwater recharge, communities that depend on groundwater for their drinking water may face shortages.

Agricultural production depends on a mix of environmental services such as soil fertility, soil moisture, solar energy, and climate; inputs of human, animal, and fossil fuel energy via labour and machinery; and an array of other inputs, practices, and programs such as fertilisers, pesticides, irrigation, soil conservation, research, and agricultural support programs. Although sprawl may not threaten overall agricultural production, it does result in alterations and declines in local agricultural activities and to the loss of prime farmland. Many cities were sited, and subsequently developed, due to the rich agricultural soils of their hinterlands. The metropolitan areas grow spatially, entire zones previously dedicated to agriculture have been replaced by apartment blocks. This phenomenon is facilitated by the main characteristics of agricultural soils make them suitable for commercial and residential development. Therefore, competition for use of these lands is often intense, with conversion typically uses to those that provide more immediate economic returns. To compete with alternative uses, farmers in urbanising areas must work remaining agricultural lands more intensively, change to more profitable crops, or shift to operations that require less investment in infrastructure.

Many authors showed that since the mid-twentieth century, American farmers have been producing more crops on fewer acres; also they measured that crop production increased from the use of hybrids, fertilisers, and pesticides with a major loss of farmland [Furuseth and Pierce, 1982, Buelt 1996]. The forest resources have made significant contributions to the economic development and industrial growth of many regions. The harvesting of timber can be severely reduced in order to preserve habitat needed for endangered and threatened species, or to support economically important, non-extractive uses of forests, such as recreation or can be threatened by sprawl. In fact, with expanding residential land-use, forests become more valuable for development than for timber production. Urbanization alters landscapes and fragments prior patterns of land-use and land cover, dramatically reducing the amount of habitat, the size of remaining patches of habitat, and the degree of connection amongst the remaining patches [Barlow et al, 1998].

Sprawl not only dramatically reduces the amount of habitat's wildlife, but also degrades adjacent habitats with light and noise pollution emanating from developed areas. According to the National Wildlife Federation, *"artificial lighting may also fragment the landscape and habitat for wildlife, even if there are connecting corridors".*

Another consequence of the suburban and exurban development is closure and/or re-locate aloof since urban centre the quarries extraction of mineral resources. This can be problematic for several reasons. First, industrial minerals such as the limes, sands, and gravels used to make cement and required in large amounts for building, are commodities sensitive to transportation costs. If these must be *"transported any appreciable distance from the originating pit to the building site, then transport costs can readily come to be even higher than the original purchase price" [Legget, 1973].*

Second, shifting operations to other sites can compromise and destroy the ecological and aesthetic integrity of remaining open spaces.

In summary, resource consumption differentials in compact and diffused cities range from +31% in vehicle mileage, to +58% in lot size and to +49% in household energy consumption.

Results of this comparison indicate that urban sprawl leads to higher consumptions of fossil fuels and natural resources such as agricultural land and forest areas. This brings to higher levels of air pollution, declining farmland activities, less natural and forest land, loss of natural habitats and problems related to water supply [e.g. Attorre et al. 1998, Alphan 2003, Aguilar 2008]. Other environmental impacts related to natural resource consumption by spreading urban centres include poor water quality stemming from urban "non-point" sources of pollution; destabilisation of stream channels and flooding due to stormwater runoff from developed areas; alterations of micro-climates and local climates, including the urban heat island effect and increases in extreme summer heat hazard; loss and fragmentation of wildlife habitats; degradation of landscape aesthetics; and noise and light pollution.

In order to understand the future pressure on urbanization and, possibly, urban diffusion, data from the World Urbanization Prospects have been considered. The overall picture provided by such data suggested that in developed countries, but above all in less developed countries, the percentage of urban population is expected to grow in the following years [Kasanko et al. 2006]. This further evidences the necessity of planned growth (for less developed countries) and containment (for industrial countries) strategies in order to tackle the pressure on sprawl, especially if sustainable development is really an objective that the world is committed to achieve [Brouwer et al. 1991, Balchin 1996, Camagni et al. 1998, Burchell et al. 2005].

THE IGNORED CHALLENGE? AN OUTLOOK ON EUROPEAN URBAN TRENDS

Urban dispersion is advancing in many metropolitan areas of the world, and it is becoming a common feature also in all the cities of the European Union, regardless of their geographical, economic or administrative characteristics. The rising interest amongst European countries in mapping and exploring this particular pattern of growth is testified by the increasing number of studies and EU research projects [e.g. Couch et al. 2007] which aim at providing the debate with vivid arguments and satellite images of cities undergoing explosive changes, scattering over ever-greater areas.

By the late 1980s the first environmental concerns regarding urban sprawl began to appear throughout the European Union. By then, the control of sprawl had become a major consideration of urban policy in most European countries. According to the Brundtland Commission, *"uncontrolled development makes provision of housing, roads, water supply, sewers and public services prohibitively expensive. Cities are often built on the most productive agricultural land, and unguided growth results in the unnecessary loss of this land. The UN Agenda 21 asked all states to promote sustainable patterns of urban development and land use that should aim for compact growth".* The European Commission also stated that: *"uncontrolled growth results in increased levels of private transport, increased energy consumption, makes infrastructures and services more costly and has negative effects on the quality of the countryside and the environment. (...) It is therefore necessary to work together to find sustainable solutions for planning and managing urban growth"* [European Environment Agency 2006].

In this period, the European Commission began to work on town planning strategies that would consider as a priority mixed land-use and denser urban development in order to reduce the impact of sprawl on the natural and social environment. With this objective, the European Environmental Agency stated that *"it is clear according to the good governance criteria that the EU has specific obligations and a mandate to act and take a lead role in developing the right frameworks for intervention at all levels, and to pave the way for local action. Policies at all levels including local, national and European need to have an urban dimension to tackle urban sprawl and help to redress the market failures that drive urban sprawl. The provision of new visions for the spatial development of Europe's cities and regions is vital for the creation of a range of integrated mutually reinforcing policy responses"* [European Environment Agency 2006].

To sum up, as in North America and other parts of the world, throughout Europe urban sprawl is becoming a consolidated threat. The environmental, social and economic impacts of the phenomenon for both cities and the countryside of Europe are becoming always more evident and require immediate action, especially now that the global challenge for climate change is putting more pressure on governments. For this reason, modern town planning was developed, with the objective of controlling urban expansion.

Nevertheless, in its early stages urban planning did not manage to accomplish its objective and is still struggling today. For example, between 1922 and 1939 over 340,000 hectares of rural land in England and Wales were converted to urban uses (a 40% increase in the total urban area of the country). In the aftermath of World War II, many European countries invested heavily in planned urban expansions schemes.

Most of these schemes produced peripheral extensions of existing urban areas with very low densities.

With the strong economic rise experienced by Western Europe, demographic growth increased significantly. Urbanisation of land was the inevitable consequence of bigger population and stronger economy. Land change was extremely rapid, as well as the transformation of urban landscapes across the continent. But whilst North-West European cities reached their growing peak towards the middle of the 20th century, most conurbations of South and East Europe followed increasing growing trends until nearly the end of the century.

Changing industrial structures also influenced the process of sprawl. A number of trends can be observed in Europe: the movement of production to other regions and countries (globalisation); the decentralisation of employment to suburban locations; the development of new forms of employment, especially in the service sector; the shrinkage and closure of traditional industries. The latter had the effect of removing employment and weakening the links between inner urban residential and workplaces areas. Outward migration of workers to suburban areas was therefore encouraged. By the end of the 20th century, tackling urban sprawl was becoming a global affair. In 1992, the United Nation's Agenda 21 asked that all states promote sustainable patterns of land-use and development in order to contrast the diffusion process [European Environment Agency 2006].

Population trends

The total population of the 25 states of the European Union in 2005 was just over 455 million, with an average population density of 117 inhabitants per km^2 (much higher in compare with the average of the United States: 32 inhabitants per km^2). Due to the ageing and low fertility rates of the Europeans, it is predicted that population will increase moderately and will depend mainly on inward migration form countries outside the continent. Within Europe, consistent migration from East to West and from rural to urban areas still seems to be the general trend. It has been predicted that between 2005 and 2025 the population of Europe living in urban areas will rise from 73% to 78% [United Nations 2007]. This means that urban areas will have to provide accommodation for 28 million additional inhabitants over the next 20 years. The pressure for urbanisation will be considerable. Besides the increasing housing demand determined by urban migration, new and changing economic functions are requiring cities to release more peripheral land for commercial and industrial development. Moreover, this process is further reinforced by the competition for capital attraction amongst cities. The European Environment Agency [2006] concluded by stating that *"over the past 20 years low density suburban development in the periphery of Europe's cities has become the norm, and the expansion of urban areas in many eastern and western European countries has increased by over three times the growth of population".* Figure 1 documents the parallel and progressive increase in built-up area, road network and population in selected

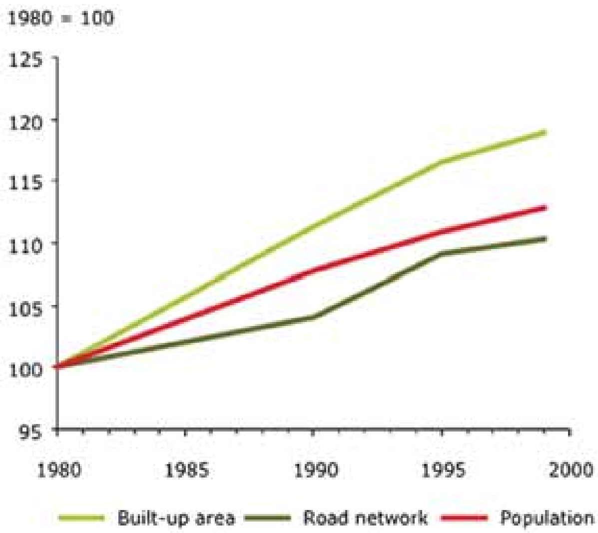

Fig. 1. Built-up area, road network and population

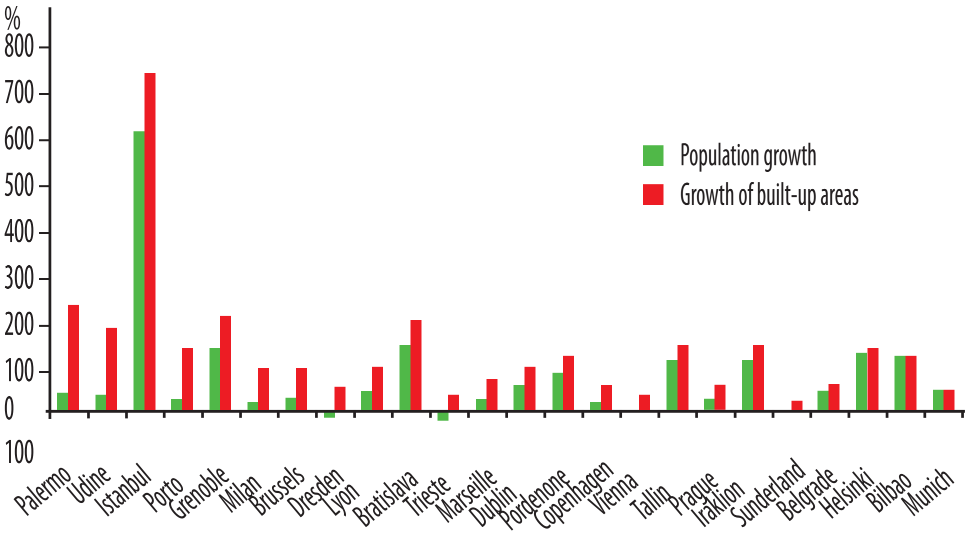

Fig. 2. Population growth and growth of built up areas (mid-1950s to late 1990s), selected European cities

EU countries. Figure 2 compares, in selected European cities, the growth of population with the increase of built-up areas, showing similar trends in some cities only: in general, built-up areas grew at a higher pace than population.

QUANTIFYING THE ENVIRONMENTAL IMPACT OF URBAN SPRAWL IN EUROPE

In this section, the environmental impacts associated to the sprawl process in the European context will be discussed. As already said before, urban development involves substantial consumption of natural resources. Above all, the rapid consumption of scarce land resources due to the expansion of cities well beyond their boundaries is of greatest concern. Figure 3 illustrates how the phenomenon is taking place in Europe. Sprawl and the development of urban land is dramatically transforming the properties of soil, reducing its capacity to perform its essential functions. These impacts are evident in the extent of soil compaction leading to impairment of soil

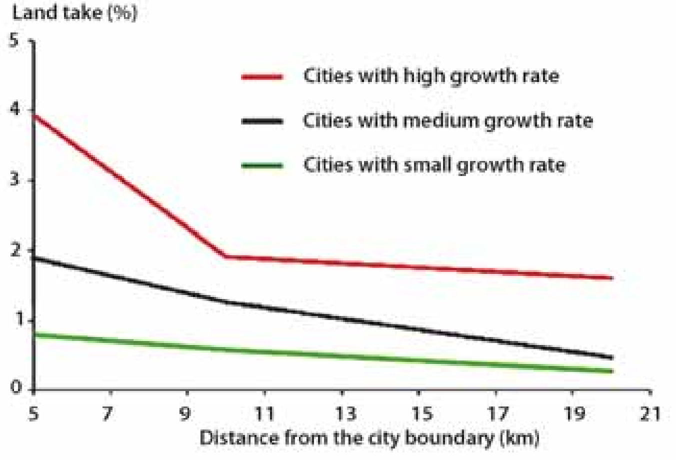

Fig. 3. Growth of built-up areas outside urban centers (1990–2000)

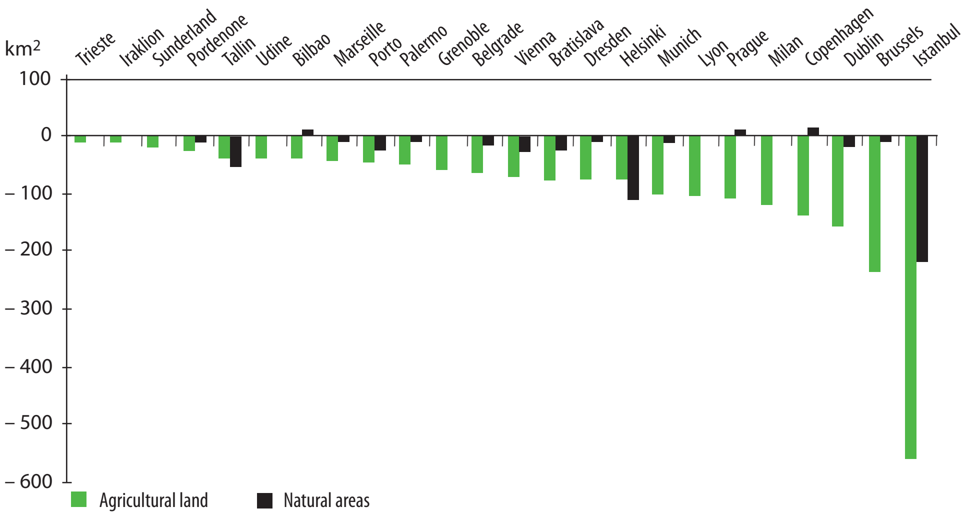

Fig. 4. Sprawl impacts on agricultural land and natural areas, selected European cities

functions; loss of water permeability (soil sealing) which dramatically decreases; loss of soil biodiversity, and reductions of the capacity for the soil to act as a carbon sink. In addition, rainwater that falls on sealed areas is heavily polluted by tire abrasion, dust and high concentrations of heavy metals, is later washed into rivers with consequences on the hydrological system. In Germany, for example, it is estimated that 52% of the soil in built-up areas is sealed (the equivalent of 15 m^2 per second over a decade).

The growth of European cities in recent years has primarily occurred on former agricultural land (Figure 4). Typically, urban development and agriculture are competing for the same land, as agricultural lands adjacent to existing urban areas are also ideal for urban expansion. The motivations of farmers in this process are clear as they can secure financial benefits for the sale of farmland for new housing or other urban developments. In Poland, for example, between 2004 and 2006 the price of agricultural land increased on average by 40%. Around the main cities and new highway developments, increases in price are often much higher.

Soils need to be conserved. It is a non-renewable resource and the loss of agricultural land has major impacts on biodiversity with

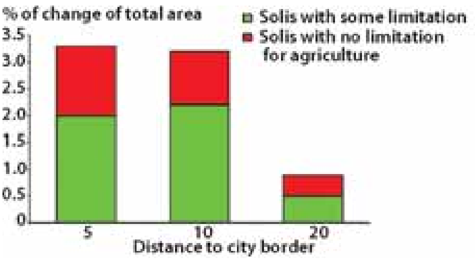

Fig. 5. Loss of agricultural land outside urban areas

the loss of valuable biotopes for many animals, and particularly birds. Sprawling cities also threaten to consume the best agricultural lands, displacing agricultural activity to both less productive areas (requiring higher inputs of water and fertilizers) and more remote upland locations (with increased risk of soil erosion). In addition, the quality of the agricultural land that is not urbanized but in the vicinity of sprawling cities has also been reduced. All these characteristic impacts of sprawl are well illustrated in the Mediterranean coastal areas. Throughout the region 3% of farmland was urbanized in the 1990s, and 60% of this land was of good agriculture quality (Figures 3–5).

Water consumption

Land-use changes are also altering water/land-surface characteristics which, in turn, are modifying surface and groundwater interactions (discharge/recharge points), to the point that a majority of the small watersheds affected by sprawl are showing hydrological impairment. If the capacity of certain territories to maintain the ecological and human benefits from ground water diminishes, this could lead to conflicts due to competition for the resource. These conditions generally generate strong migratory flows of people looking for places offering a better quality of life [Craglia et al. 2004]. Areas in the southern part of Europe, where desertification processes are at work, are particularly sensitive to such a situation. Reducing groundwater recharge might in addition negatively impact on the hydrological dynamics of wetlands that surround sprawled cities.

The impacts of urban diffusion in the mountain ranges of Europe is of particular concern, as these are universally recognized as both the 'water tanks of Europe' and sensitive ecosystems. Currently, they are under severe threat from urban impacts. New transport infrastructures facilitate commuting to the many urban agglomerations with populations over 250,000 inhabitants that lie close to the mountain regions, encouraging urbanization in the mountain zones. Increased transit and tourist traffic, particularly day tourism from the big cities, also adds to the exploitation of the mountain areas as a natural resource for 'urban consumption' by the lowland populations. More balance is needed in the urban-mountain relationship if the unique ecosystems of these regions are to be conserved.

Raw material consumption

Urban sprawl has also produced higher demands for raw materials typically produced in remote locations and requiring transportation. The consumption of concrete in Spain, for example, has increased by 120% since 1996, reaching a level of 51.5 million tons in 2005. This increased demand reflects major expansion of construction activity in Spain, mainly along the coast and around major cities, where sprawl has become endemic. Associated environmental conflicts include the expansion of quarries adjacent to nature reserves and the over-extraction of gravel from river beds. Transport related energy consumption in cities depends on a variety of factors including the nature of the rail and road networks, the extent of the development of mass transportation systems, and the modal split between public and private transport. Evidence shows that there is a significant increase in travel related energy consumption in cities as densities fall [Newman and Kenworthy, 1999].

Essentially, the sprawling city is dominated by a relatively energy inefficient car use, as the car is frequently the only practical alternative to more energy efficient, but typically inadequate increasingly expensive public transportation systems. Increased transport-related energy consumption is in turn leading to an increase in the emission of CO_2 to the atmosphere. The relationship between population densities and CO_2 emissions is apparent as emissions increase progressively with falling urban densities (Figure 6).

Although there are several factors that may explain differentials in CO_2 emissions between cities, including the level of industrial activity and local climatic conditions, the predominance of car borne transportation in sprawling cities is clearly

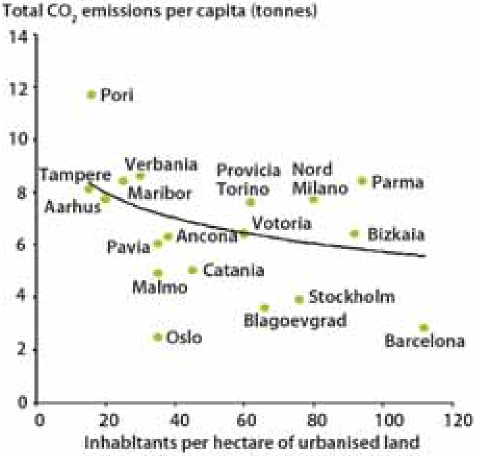

Fig. 6. Population density and CO_2 emissions, selected European cities

a major factor in the growth of urban green house gas emissions. Urban sprawl therefore poses significant threats to the EU Kyoto commitments to reduce greenhouse gas emissions by 2020. Sprawl also increases the length of trips required to collect municipal waste for processing at increasingly distant waste treatment plants and this is expected to continue as household waste grows 3–4% annually. The material cycle is becoming geographically decoupled with increasing transport demands, impacting on transport related energy consumption and pollution emissions.

Climate changes

Sprawl related growth of urban transport and greenhouse gas emissions have major implications for global warming and climate change, with the expectation of increasingly severe weather events in the coming years and increased incidences of river and coastal flooding. The risks from the continuous development of these areas in the context of a changing climate is evident in the recent major floods in Europe that have affected large urban populations. The floods in central Europe occurred in august 2002 caused 112 casualties and over 400,000 people were evacuated from their homes. These expected transformations pose major challenges for urban planning that are clearly focused on the growth of urban sprawl along the coastal fringes throughout Europe, as well as development of sprawling extensions across greenfield sites in the river valleys and lowlands of Europe.

The flooding of the coastal regions of Europe due to rising sea levels and climate change is particularly worrying considering the concentration of urban populations along the coasts and the importance of these areas for tourism. The countries of Europe most vulnerable to coastal flooding include the Netherlands and Belgium, where more than 85% of the coast is under 5m elevation. Other countries at risk include Germany and Romania where 50% of the coastline is below 5m, Poland (30%) and Denmark (22%), as well as France, the United Kingdom and Estonia where lowlands cover 10–15% of the country. Overall, 9% of all European coastal zones lie below 5m elevation. Even with conservative estimates of predictions for sea level rise, a substantial part of the population of Europe living in the coastal regions are highly vulnerable to sea level rise and flooding. It is clear that this is not a specific issue generated by sprawl, however, the management of these risks and planning for adaptation will be made more complicated if sprawl is not controlled. By extending urban areas over greater portions of lands, the probability and frequency of disasters related to extreme weather events will grow in the future.

Impact on society and urban quality

Changes in lifestyle associated with sprawl contribute to increases the demand of natural resources. People are living increasingly in individual households, which tend to be less efficient, requiring more resources per capita than larger households. For instance, a two-person household uses 300 liters of water per day, two single households use 210 liters each. A two-person household will use 20% less energy than two single person households. The number of households grew by 11% between 1990 and 2000, a trend that increases land-use and acts as a driver for expansion of urban areas. The general trend is for greater consumption of resources per capita with an associated growth in environmental impact. This adds pressure to the fact that about 60% of large European cities are already over-exploiting their groundwater resources and water availability.

Moreover, market oriented land-use allocations driving urban expansion and the transformation of economic activity often result in the abandonment of former industrial areas. As a result, there are many derelict or underused former industrial zones throughout Europe that have moved to peripheral areas or less developed countries. For example, in Spain about 50% of sites contaminated from past industrial activities are located in urban areas (1999), and in Austria it is estimated that abandoned industrial sites cover about 2% of all urban areas (2004). Generally, the efficiency savings of more compact city development as compared with market driven suburbanization can be as high as 20–45% in land resources, 15–25% in the construction of local roads and 7–15% savings in the provision of water and sewage facilities.

Finally, urban sprawl produces many adverse environmental impacts that have direct effects on the quality of life and human health in cities, such as poor air quality (worsened by the increased use of cars in sprawled areas) and high noise levels that often exceed the established safety limits. In the period 1996–2002 significant proportions of the urban population were exposed to air pollutant concentrations exceeding the EU limit values (25–50% of the urban population for different pollutants). It is estimated that approximately 20 million Europeans suffer from respiratory problems linked to air pollution.

CONCLUSION

What is urban sprawl and how does it adapt to the different territorial contexts in which it is taking place? These are the principal questions that have been tackled with the analysis of a vast body of literature mostly originating from North America. Formal and informal definitions of the phenomenon have been investigated. The former have illustrated various different features of sprawl, but at the same time they have evidenced the lack of a global and unique definition of the urban process being discussed [Tsai 2005]. This goes in the direction of the initial hypothesis of this research, that is the necessity of studying sprawl with comparative analysis, as the phenomenon presents different features and consequences according to the territorial context being considered [Newman and Thornely 1996].

Informal definitions have been also discussed, as these result useful in giving a solid comprehension on the concept of exurban development. The sand-castle metaphor has been illustrated in order to stress the main feature of sprawling spatial patterns of urbanisation: the "volume" of the city remains approximately constant, but it is spread over a larger surface. Therefore, the concept of sprawl has been associated to the process of transformation of the density gradient line of urban and residential activities, which will result always less steep as the phenomenon takes place. To emphasise the importance of the process of transformation rather than the final urban configuration of sprawling cities, the necessity of treating the phenomenon as a verb more than a noun, and to differentiate it forms the process of urban growth has been underlined [Couch et al. 2007]. In the early 1980s, the European Commission officially manifested its concerns for the diffusion of the sprawl process within the continent, as this is negatively contributing to the achievement of a sustainable development imposed by the United Nations. Pressure on modern town planning for reaching this objective has not produced positive effects, with urban uncontrolled expansion still being the norm in many European countries since the aftermath of World War II. But as concerns regarding low-density urban diffusion grow, the need for an accurate analysis of the phenomenon in the European context is becoming increasingly urgent for the formulation of efficient territorial policies [Prud'homme and Lee 1999]. In the second half of the 20th century, Europe, and especially southern Europe, experienced a period of rapid population growth and urbanisation. In these last years, the former has significantly slowed down and stabilised while the latter is still increasing. All this indicates that the sprawl process is at work in the region since several years. Furthermore, the EEA report entitled "Urban sprawl in Europe" [2006] also evidences this trend, stating that 6 out of 10 of the European cities with the highest sprawl rates are located in the Northern Mediterranean region, and more in general, in economically disadvantaged regions [Richardson and Chang-Hee 2004].

Besides the general impact of sprawl, coastalisation along the European shores, taken as a paradigmatic example of (sometimes uncontrolled) urban diffusion, brings to a loss of farming and natural land (which is amongst the richest and most productive of the region), the destruction of highly valuable natural habitats, the degradation and pollution of the shores and sea, the reduction of small scale fishing and the increasing vulnerability of the area to extreme weather and natural events. With regards to this last point (the increasing vulnerability towards extreme weather and natural events) this study dedicates further attention [Turok and Mykhnenko 2007]. Research shows that the growing pressure on the environment due to human-induced demand factors (urbanisation and natural resources consumption), is increasing the disaster potential of cities and megacities [Scott 2001]. Cities are expanding over more and more area [Schneider and Woodcock 2008], thus increasing their exposure to natural disasters (such as earthquakes and floods). This situation is raising concerns as extreme weather events are likely to increase both in frequency and intensity due to climate changes [APFM, 2012].

The growing vulnerability of urban centres is testified by the increasing damages related to natural hazards [Salvati 2010]. A survey on natural disasters shows that the region is more vulnerable to extreme seasons, short-duration hazards (such as floods and earthquakes) and slow long-term changes, including sea-level rise and *coastal squeeze*. These evidence support the idea that environmental policy and regional planning should cope more effectively with the increasing vulnerability of large urban regions to natural hazards. ■

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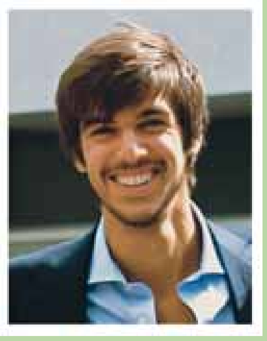

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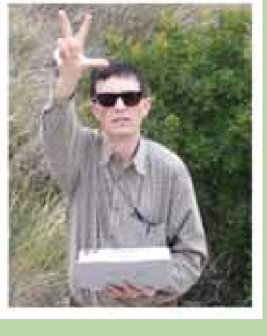

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ECO-GEOGRAPHICAL APPROACH TO INVESTIGATION OF STABILITY OF CULTURAL LANDSCAPE

ABSTRACT. Today in Russia, much attention is given to research and practical identification of the cultural landscape (CL) stability parameters that define its dependency on the character of the territorial land use. As a rule, these are projects of territorial and landscape planning (LP) aimed at assessment of stability of the CL depending on the conditions of the social and natural environment, on the level of changes of its components, and on the direct relation with the nature and the type of natural resources management. This approach defines most fully conditions and the level of impact on the landscape.

The paper discusses the main types of natural resource management of the CL. Residential areas are the most complex and multifunctional types of natural resource management. They are of the greatest interest to the research as an object of "co-creation of man and nature" [Sochava, 1978]. This is determined by an important role of residential areas with their infrastructure as a landscape reshaping element that influences the functioning and structure of the CL. Cities, suburbs and towns, as human environment, require a special attention in order to achieve an environmentally friendly and sustainable landscape.

In the concept of LP, much attention is given to assessment of the natural components of the CL. As a rule, assessment of soil, climate (atmosphere), water, and landscape sensitivity and significance is conducted [Drozdov, 2006]. The selection of assessment criteria varies depending on the natural resource management type. Obtained results are compared with parameters that are indicative for or specific to naturally occurring landscape. The crisis of environmental components makes LP the vitally necessary management instrument. The goals of landscape planning are broadly formulated – landscape planning should cover the entire territory of the country, should consider both natural and socio-economic factors, and should develop measures to prevent and control impacts on the landscape.

KEY WORDS: cultural landscape, stability of cultural landscape, landscape planning, landscape stability criteria, environmental management, sustainable development

INTRODUCTION

The concept of LP is connected with the concept of CL and specifically emphasizes sustainable development of these systems.

In summary, this concept (LP) means such a development (change), which allows the present generation to meet their needs without threatening the existence of such landscapes for future generations. This development is based on sustainable use of CLs to the extent that will not damage their possible long-term use. This concept includes economic, social, environmental, and cultural aspects. The complex structure of "culture-nature" relationships in the CL is very diverse. It is expressed in material objects created by man through human activities (environmental management) specified by natural features. Culture is included in the natural landscape. It leaves there the objects of cultural heritage. Heritage preservation and restoration represents a special area of activities of modern society. Intensive economic activities are increasingly threatening objects of natural and cultural heritage and may lead to their loss and disappearance.

In order to determine the ability of the CL to its restoration and self-preservation and its resilience under human (external) impact, it is necessary to assess the stability of the CL components and adapt them to local conditions. It should be understood that, because of diversity of culture and nature, there are no accepted methods for integrated assessment of the CL. This is especially true for the "cultural" components which are dynamic objects.

In this context, the study of geographical aspects of the CL stability is very relevant and timely. The aim of our study is to identify a comprehensive and environmentally sound method of assessing the stability of Russian cultural landscapes. The goal of the study involves the following objectives:

- To analyze approaches to the CL stability assessment;
- To review the stability criteria of natural components of the CL;
- To analyze the categories of the CL stability;
- To conduct assessment of the stability of natural components of the CL;
- To examine the concept of ecological foundation for sustainable development of the CL.

THE NATURE-CENTRIC AND CULTURE-CENTRIC APPROACHES TO THE STUDY OF THE STRUCTURE AND STABILITY OF THE CL

Let us consider the structure of the CL, i.e., the quantity and "quality" of its components that are essential to a comprehensive research approach. This structure is associated with a distinct vertical and horizontal orientation. The vertical orientation is expressed primarily in the "layering" of the landscape, where two main layers – cultural and natural – can be identified (Fig. 1).

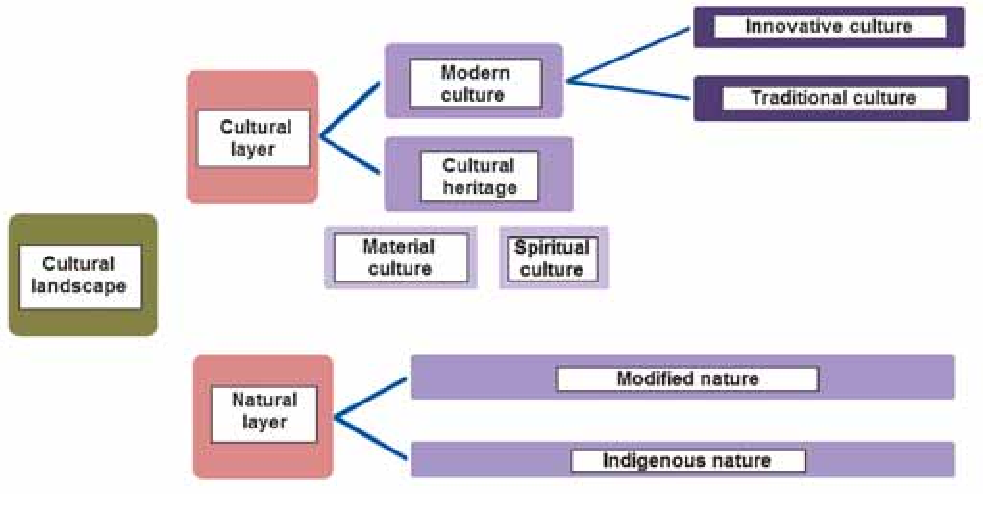


Fig. 1. The main components of the cultural landscape. The vertical structure [Vedenin, 1997]

The cultural layer is of particular interest to our research. This layer reflects the entire body of the processes and results of human activity aimed at creation of the system of values. The cultural layer, during the period of its accumulation, is becoming increasingly important in the landscape and eventually becomes a dominant factor of its further development. The saturation of the cultural layer with accumulated and new events and cultural objects defines its spatial character. The natural layer of the CL may be viewed as a complex of natural components from the stand point of its preservation and relation to technical and natural-technical systems [Vedenin, 1997].

The CL, as a research object, has a complex structure (Fig. 2). Thus, V.N. Kalutskov [2008] defines two different research approaches in respect to the CL, i.e., nature-centric and culture-centric. Each approach has its own features. For example, the nature-centric approach examines thoroughly natural components of the CL, while cultural components are scaled down and viewed as the cultural environment. In the nature-centric approach, the structure of the CL looks as follows: geological material, topography, climate, water, soil, vegetation, wildlife, and cultural environment [Solntsev, 2001].

In the culture-centric approach, when the priority is given to the cultural component of the landscape, the structure of the CL is explained in detail. This structure consists of such components as the natural environment, human society, economy, residential areas, language, and spiritual culture [Kalutskov, 2008].

Human society, having created and developed its CL, endues it with such qualities that make it both typical and unique and that allow its development, adaptation, and improvement. It also forms its spatial organization as well as architectural and sacral objects. Any CL has its own community that is inseparably, as a part of the whole, connected with it and views its landscape territory as its own. The residential aspect, through the system of settlement, promotes formation of the spatial infrastructure of CLs and may be viewed as the way of spatial structure/self-organization of a society. A world view of its own is formed through language. Local native geographical terminology, i.e., toponymic system, reflects natural and cultural features of the CL.

The nature and complexity of the links between the natural and cultural layers depend greatly on the level of development of the cultural component of the landscape. Peoples' culture, with its traditional ways and methods of production activities and traditional customs is best and seamlessly linked with the natural landscapes. The influence of the nature on the innovation

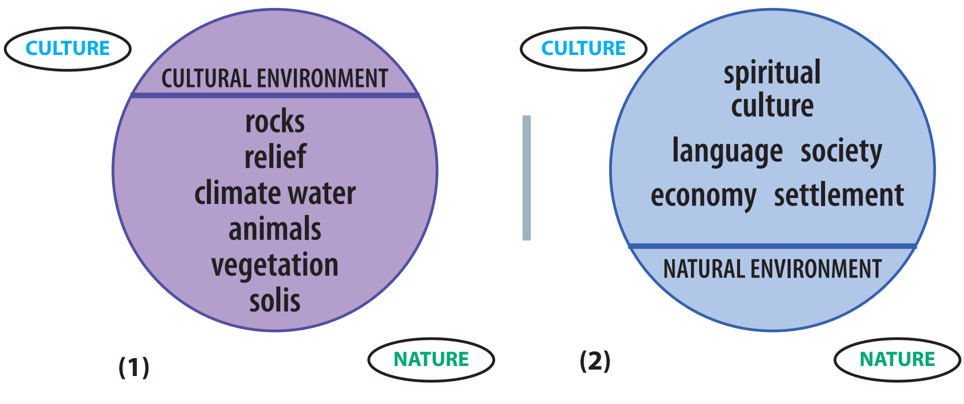


Fig. 2. The components of the cultural landscape in nature-centric (1) and culture-centric (2) approaches [Kalutskov, 2008]

culture and on the production of higher cultural values (science, professional art) is much weaker. The reason for it, first of all, is that, contrary to the traditional culture that leans towards weakly urbanized landscapes, the innovation culture associated with activities of professional specialized institutions often adopts international standards and modern technologies. Activities of artists who work in the area of innovative culture are often take place in urban landscapes where the nature has already been greatly modified, where a human is surrounded by structures from artificial materials, and where, instead of the natural environment, there are geometricized residential areas, artificial water bodies, orderly designed and specially created green areas, etc. Therefore, the development of the landscape cultural layer is also occurring with a relatively high degree of independence from the natural factors. At that, under the influence of different innovative and specific cultures and often on the same natural base, there form different elements of culture and, therefore, different CLs.

Under the influence of specific characteristics of the nature, the degree of its transformation and the level of development of society, regional and national features, a territorial cultural-natural system is formed. This system is defined by many mutually complementing cultural and natural communities, by pronounced vertical morphological structure, by existence of close links between different layers, and by territorial and genetic unity. The territorial cultural-natural systems differ depending on relations between heritage and contemporary culture and the level of development of traditional and innovative elements and cultural and natural layers of landscape.

The most noticeable differences are between urban and rural cultural-natural systems. They are associated, first of all, with the dominance of primarily innovative culture in cities. In the rural culture and in its associated territorial systems, the presence of traditional values is higher compared to cities. Significant differences in these two types of systems are also manifested in the level of expression of their links with the natural components. It is weak in cities, but it is the leading factor in rural systems. Urban cultural-natural systems are characterized primarily by a high density of built-up areas, noticeable dominancy of hard surfaces on the earth surface (asphalt, pavement), developed network of artificial elements in the landscape, almost complete absence of undisturbed natural systems, and by the high saturation of urban space with artistic and cultural-intellectual processes (that have, primarily, innovative character).

The rural system represents a collection of small built-up sites inside agricultural areas (fields, meadows, hay lands) and different natural elements (forests, river valleys, lakes, etc.). Here, the traditional culture dominates and innovative processes are manifested less compared with cities. At the same time, in the most part of the systems, the elements of urban and rural cultures are blending and, therefore, their specific properties are manifested not so clearly, which is reflected not only in the character of processes that take place here, but also in the morphology of the landscape.

The CL is composed of a set of territorial cultural-natural systems comprising an interconnected system that provide for development, regeneration, and preservation of objects and phenomena of both the innovative and traditional cultures. This predefines the original diversity of the CL, the basis of its hierarchical structure, and a specific interdependency of its internal elements.

Stability is the ability of a system to maintain its parameters under impact or to return to its original state after disturbance of its structure. The CL has its own limits of stability that have not yet been well studied. Now it is possible to state the following: stability is not a static state of a system, but fluctuations around some medial state. The wider the natural span of the landscape states, the lower the probability of an irreversible transformation after disturbance impacts [Golovanov, et al. 2006; Sochava, 1978; Isachenko, 1974, 1980].

STABILITY CRITERIA OF THE CL NATURAL COMPONENTS

Under the nature-centric approach to research on stability of the CL, it is necessary to discuss the natural basis of the landscape and regard as a system that consists of natural components.

The main stabilizing natural element is the biota, as the easily adapting and the most rapidly regenerating landscape element. Intense biological cycles and biological productivity are the main prerequisites of the landscape stability. The vegetation cover maintains gravitational balance of the landscape and prevents its denudation. The biota plays the leading role in the landscape self-regulation process.

The lithosphere is the most stable element of the landscape. However, if it is disturbed, it is not capable to regenerate. Its stability is an important prerequisite of the landscape stability. Three categories of stability can be identified in terms of impacts on geological-morphological basis of the landscape; these impacts are the results of abrupt disturbances of the surface at different types of construction, mining of mineral deposits, movement of track equipment in permafrost conditions, of violations of erosion- and filtration-preventive measures in agricultural and forestry sectors, and of other types of impacts [Vorontsov, et al., 1989]:

- relatively stable (in the absence of massive deformations of the morphological-lithogenic basis and with possibility of a complete regeneration of the landscape after disturbances);
- fragile (geological-geomorphological basis has substantial deformations as a result of active erosion, cryogenic-eolian, and other exogenic processes, with possibility of a partial natural or artificial regeneration of the landscape after disturbances);
- unstable (large and massive deformations of the morphological basis with intense formation of landslides and gullies, thermokarst, thermoerosion, mudslides, etc., that lead to irreversible changes or to the degradation of the landscape).

For the first two types, there is a possibility of preservation or regeneration of the landscape through its recultivation and landscape planning activities. Landscapes with significantly modified morpho-lithogenic basis have little chance of resembling the original ones, however, there are ways of creation of artificial landscapes (for example, technoparks) with intensive recultivation.

In the process of development, any landscape undergoes impacts and its stability is limited. The threshold of stability, expressed through resistance of the landscape and of its parameters and properties, as well as the critical parameters of impacts are defined in each particular case.

Thus, it is possible to formulate the general criteria of landscape stability [Isachenko, 1974, 1980]. First of all, it is a high level of organization and intense performance and balance of its functions, including biological productivity and ability to regeneration of the vegetation cover. These properties are defined by the optimal ratios of heat and moisture and are manifested by the level of development of the soil cover and, eventually, by soil fertility. The natural stability is one of the prerequisites for sustainable natural resource management [Sochava, 1978].

Resistance of landscape depends on the internal heterogeneity of its elements. For example, a diverse composition of meadow herbs makes the meadow more stable under different weather conditions compared with the artificial hay land with lesser species diversity (as well as in the case of lawns, for example). A well-defined micro-topography and variations in water-physical properties of soils also increase stability of both the soil and the vegetation covers: during dry periods of the year, the biomass productivity is higher in low parts; during wet periods it is better at micro-elevations.

Landscape stability grows with the increase in its ranking in the landscape classification system. In this sense, the least stable is the facies, i.e., the smallest unit. It is characterized by homogenous conditions of its location, environment, and biocoenosis. Facies have strongest response to both changes in external natural conditions and human activity. They are radically altered through natural resource use. Larger units of landscapes are less susceptible to change. In general, in defining static stability, there are the following determining relations between properties of natural elements and resistance to anthropogenic pressure [Kazakov, 2008]:

- gravitational, or denudational, potential of the area (relative elevations and differentiation) – the greater it is, the lesser is resistance to denudation, erosion, mechanical loads, and even to toxicants;

- surface slopes – the steeper they are, the lesser is the stability, however, at the slopes of lesser than 1°, stability may decrease due to possible water logging and low self-purification of landscapes from pollutants;

- mechanical composition of soils – is usually associated with natural territorial systems (landscapes) composed of light loams and fine sands, however, the maximum may shift somewhat depending on types of impacts (under the impact of acid precipitation, the graph of natural territorial system stability is sharply asymmetric; at the soil depth of 1.2 m, the natural territorial system stability falls with decreasing depth;

- hydrotopes (moisture content) – in meso moisture condition resistance is high; in dry and wet habitats it is decreased;

- climatic characteristics – high-resistant landscape enjoys the optimal ratio of heat and moisture (hydrothermal coefficient and humidity factor are close to one); the low-resistant corresponds to areas with distinct limiting thermal and moisture factors and large amplitudes of their fluctuations; temperate winds of 2.5–4 m/sec also promote increase in landscape stability;

- soils – the greater the thickness of humus horizon, the humus content, and the base-saturation and capacity of the soil absorbing complex, the greater the natural territorial systems stability;

- biota – the greater the capacity and intensity of biogeochemical cycle and the density of the projective cover of the surface, the higher the natural territorial system stability.

The landscapes are resistant if they are:

- characterized by increased diversity and overlapping (doubling) of structures;

- located in the centers of their zonal and regional typology;

- trans-accumulative (more stable than trans-alluvial);

- larger in scale and matter;

- higher in hierarchal ranks.

THE CHARACTER OF NATURAL RESOURCE MANAGEMENT AS A CATEGORY OF THE CL STABILITY

After isolation of the main criteria of the natural landscape components, it is now necessary to identify categories of the CL stability. The connection between the natural and cultural elements is rather complex and the best correspondence is manifested through the character of the territorial natural resource management. The character reflects the natural structure of the CL and also the social-economic specifics of the territorial use.

The natural stability is one of the prerequisites of sustainable natural resource management. It is based on unaltered characteristics of the natural components. With increasing economic activity, the natural stability of the natural landscape decreases and there appears a new acquired stability of, now, the CL A new criterion is formed from given natural factors under the impact of the type of land use in the process of landscape evolution. The sense of the acquired stability is in the adaptive variability of the landscape structure and functions that undergo human impact.

Considering the main natural resource management function of the landscape, it is possible to suggest the typology of the CL in terms of their functional-economic classification [Basalikas, 1977; Fedotov and Dvurechenskyi, 1977; Runova, et al., 1993]. There are the following main functions of the isolated parts of the territory: agricultural, forestry, recreational, industrial-urbanistic, and reservational [Basalikas, 1977]. The further division occurs within the types that include distinct, in terms of functions, subtypes.

The following types of natural resource management can be isolated: forestry-industrial, forestry-agricultural, agricultural, agro-recreational-forestry-industrial, industrial, transportation, urban, traditional, reservational, and environmental disasters [Runova, et al., 1993].

From the works of classic landscape science, the correspondence of these classifications of the types of natural resource management to the classification of the CL in terms of its content, becomes apparent – agricultural, forest, water, industrial, residential; in terms of genesis – technogenic, shifting-agricultural, arable, pyrogenic, pastoral-digressive [Milkov, 1973].

It is known that any territory is used in many ways, and its landscapes can be multifunctional. During isolation of types and subtypes of territorial use, researchers identify the main (background) landscape use that makes the main impact on the nature, Thus, in the agricultural, such impact is represented by soil management; in the forestry – by industrial logging. Significant changes of the natural landscape are associated with the industrial and urban types of natural resource management. These types contain all the most significantly altered landscapes and they, at the same time, reveal the main structure of the socio-economic subsystem – of the main carrier of stationary and mobile sources of the natural environment pollutants.

Thus, the industrial and urban types may be considered the most unstable natural-anthropogenic formations due to the intense economic activity and a relatively "young age" of these formations – all this promotes weakening of the internal links and prevents gradual restoration and regeneration of the natural stability of the industrial and urban territories. In order to optimize conditions of landscape rehabilitation, it is necessary to apply modern methods of reclamation and to use principles of sustainable territorial and landscape planning.

The agricultural and forestry-industrial types of territorial use differ qualitatively from the industrial and urban, whose identification principles are close to economic-geographic. They are characterized by the type of direct natural resource management – resource use, i.e., use of the nature as the means of the production of products of natural origin [Runova, 1985]. In this case, the nature stability is organically linked with its use and requires the support for sustainable economic activity.

These types of the territorial use encompass the largest ranges of native landscapes transformations. They create the main natural and anthropogenic-natural background for natural resource management.

The traditional natural resource management should be isolated into a special type that predetermines sustainable use of resources with the minimal impact on the natural environment. Such traditional types include reindeer husbandry, fishing, farming, stock-breeding, and economic activity of private households that provide for the greatest stability of all CL components.

The other types of natural resource management are associated with the extensive character of the use of resource, thus, influencing the native landscapes to the smallest extent. Such types are the reservational and recreational types that maintain the function of landscape preservation. However, the number of such islands of natural environment is so small that they can not, without external support, provide stability and preservation of the entire CL saturated with industrial and residential areas.

Considering the information presented above, it is possible to conclude that the CL stability is strictly linked with the character of natural resource management. This allows us to suggest three types of stability that depend on the territorial use type:

- stable, including extensive type – traditional, recreational, and nature reservational;
- moderately stable vast territories under forest-economic and agricultural use;
- fragile urban and industrial zones with significant differentiation and changes of the structure of the native landscapes.

ASSESSMENT OF STABILITY OF THE NATURAL ELEMENTS IN THE CL

The CL can be defined as a single system that consists of components whose number and characteristics are not always determined to the fullest extent. It is especially true for the "cultural" elements, for which it is not always possible to assess stability and to define significance in the common system. For some non-material elements, it is quite difficult as well. Therefore, in the identification of the landscape stability criteria, it is feasible to identify the main criteria of the assessment for the natural elements. They should satisfy the following requirements [Drozdov, 2006]:

- be directed towards achieving the main goals of the territorial use in conditions of equal priorities of maintenance of the ecological balance and sustainable socio-economic development;
- reflect to the fullest extent the current conditions of the natural environment of both natural and altered by economic activity ecosystems;
- give an idea about possible changes in the state of isolated natural elements in achieving the main goals of the territorial use and under the allowable level of such use.

Landscape planning may serve as the main methodological instrument in identifiaction of criteria of the landscape stability. It provides integrated assessment of the CL, its state, significance, and possible changes. The method is based on the assessment of natural elements, for which a set of criteria is developed; the criteria reflect the nature of the CL.

In order to provide a comprehensive approach to the landscape state, A.V. Drozdov (2006) isolates the main element for the assessment, i.e., the biotope that reflects all natural landscape elements and defines its two criteria – sensitivity and significance.

The sensitivity criterion means the ability of a given natural element to change its properties and dynamic characteristics under the impact of human economic activity. In a general case, an object's sensitivity is:

- ability to react to change;
- strength of reaction; in this context, it is the thresholds of sensitivity – low, high, etc.;
- tolerance threshold; in this case, it is the range of a factor impact where an object is preserved (an organism survives, a state of something does not change, etc.).

Sensitivity of biotopes, depending on the true state of the environment of the biocoenosis, should be defined considering possible consequences of impacts that may include fires, harvest, herd grazing, summer grazing and free-range animal husbandry, aerosols inputs, etc. The biotopes' assessment, in terms of sensitivity, is conducted based on the species composition of vegetation communities, their dynamic state, disintegration, and structural parameters. For forests, the latter includes structure, crown density, height, presence or absence of thick under-storey and undergrowth, character of grass cover, presence of rare species, forms of plants dissemination, presence of constraints, etc.

Highly sensitive systems may include biotopes where:

- part of species composition of the biocoenosis may be lost irreversibly due to large breaks between the area of distribution;
- specific life forms of the inhabitants may disappear for a long time due to the absence of conditions of secondary dissemination or to the elimination of the dissemination promoters;
- quality and of fodder grasses stocks attract herd animals and it increases the danger of overgrazing.

Moderately sensitive systems may include biotopes where:

- composition and structure of biocoenosis regenerate due to migrants or to the supply of seed material (germs) from the outside;
- soil is preserved or changes following the age-regeneration succession of biocoenosis.

Low sensitive systems include biotopes where conditions for emergence and expansion of fires are not favorable and consequences of other impacts (stock grazing, agricultural activities, etc.) are insignificant. Sensitivity of soils is usually defined in terms of potential ability of water and wind erosion under the impact of different types of anthropogenic pressure [Isachenko, 1980]. The main soil sensitivity criterion is the degree of impact of the natural modern exogenic soil-destructive processes. The level of soil sensitivity is within, as a rule, three qualitative grades and is associated with the following cases or conditions:

- high sensitivity level – exogenic processes may completely disturb the natural soil structure or to completely destroy it;
- moderate soil sensitivity – partial changes of soil structure or of its elements are possible;
- low soil sensitivity – under anthropogenic impact, soils maintain their natural structure and functions, and soil fertility and other properties are preserved.

Soil sensitivity for territories affected by anthropogenic pollution should be assessed by using well-established methods [Glazovskaya, 1981].

Sensitivity of territories to changes in hydrological situation should be defined based on the assessment of runoff properties. Sensitivity of areas on the slopes of watersheds and sensitivity of alluvial-valley systems should be assessed individually.

Atmospheric sensitivity to pollution should be assessed using natural ability of air for self-purification from hazardous pollutants. The following criteria may be used in the assessment:

- annual amplitude of air temperature;
- mean annual wind speed;
- annual frequency of zero-wind;
- annual sum of atmospheric precipitation;
- number of days per year with the relative air humidity of 80% or greater;

- qualitative characteristics of conditions of formation of air temperature inversions in the surface atmospheric layer.

The assessment of landscape sensitivity under technical and recreational use is based on specifics of its reaction to changes in the morphological-lithogenic foundation (intensity and reversibility) in response to anthropogenic impacts. The following grades of landscape sensitivity can be suggested:

- stable, i.e., safe and favorable surfaces where activity of exogenic processes is insignificant; they are suitable for intense use;

- relatively stable, where the intensity of exogenic processes is not significant; they are suitable for extensive use under conditions of preservation of soil and ground cover;

- unstable, i.e., dangerous surfaces whose use may lead to landscape degradation and irreversible processes;

- extremely unstable, i.e., very dangerous surfaces whose use is not feasible; in this case, economic activity and even human lives are threatened by possibility of emergency disastrous situations.

Significance is the second criterion in the landscape assessment and for developing recommendations for further use. It defines the priority goals and objects for LP. In terms of significance, biotopes can be divided into three groups:

- highly significant – biotopes where original (potential) and existing conditions of the environment are almost identical (locations of rare endemic and relict species of flora and fauna; rare biotopes; biotopes that are relatively wide spread but only in specific conditions);

- moderately significant – biotopes where existing conditions (or those that can be restored) of the environment are close to the potential;

- insignificant – the current state is not the same as the original.

The criteria for the landscape significance assessment may be:

- diversity and uniqueness that are expressed through the quantity of different landscape types or their morphological parts that exist within a specific area;

- contrast that is defined by a combination of diverse landscapes and the level of topography differentiation;

- esthetic attractiveness that allows identifying landscapes with a unique appearance and the best distinctiveness;

- uniqueness that accounts for the distribution of rare and relict landscapes and of nature monuments of educational and scientific values;

- recreational and commercial potential (berries and mushroom picking, etc.); it also considers comfort that define types of recreation and its specialization.

As it can be seen, the methodology of LP has developed rather distinct recommendations for assessment of sensitivity and significance of the natural landscape elements, which cannot be said in respect to the CL that requires specific and individual approach in each case.

As we have already mentioned above, two approaches are possible in assessment of stability of the CL: the nature-centric and the culture-centric. First of all, let us review the nature-centric approach because the CL is developing within the limits of a specific natural territorial system.

We evaluated this approach using an example of such category of the CL as a country estate. Thus, the works of T.E. Isachenko (2004) give a detailed analysis of changes of the natural components, landscape structure, and fragmentation of the territory during existence and abandonment of estates. Through analysis of country estates, the author arrives at a conclusion that maximal changes are associated with undulating plains in contrast to flattened tops of gently sloping hills and of steep slopes of kame hills (Fig. 3–5).

We used this approach for the analysis of the estates of Central Russia. We found similar trends in changes of the landscape structure during the establishment of the park estate complexes [Toporina, 2011]. Thus, in the estate of Almazovo (see Fig. 8), the dominant natural landmark is a flat surface of moraine-glacial plains with a characteristic nano-relief, i.e., alternation of elevations and depressions (± 0.5–0.8 m) of indistinct shape that are only noticeable through the presence or absence of hygrophilous vegetation. The main site is an undulating plain composed of loams. Its special feature is the absence of creek and river valleys. The natural vegetation cover consists of mixed-herb-small-reed or mixed-herb-bracken pine and spruce forests.

The estate was owned by manufacturers Demidovs who created a uniquely designed park in Almazovo, i.e., a jewel – a "pearl" – of the Moscow countryside. Despite of being only partially intact, the estate, even now, is a picturesque place. The most impressive is the park established around an artificial water system.

During the estate construction (the 1860s), the transformation affected all components of the landscape:

– topography and hydrological network – in the 1860s–1870s, depressions (ponds and channels) were dug and elevations (hills and islands) were created (Fig. 6–8). The artificial hydrological network had decorative and functional meaning. The main 700 m-long channel was laid in a

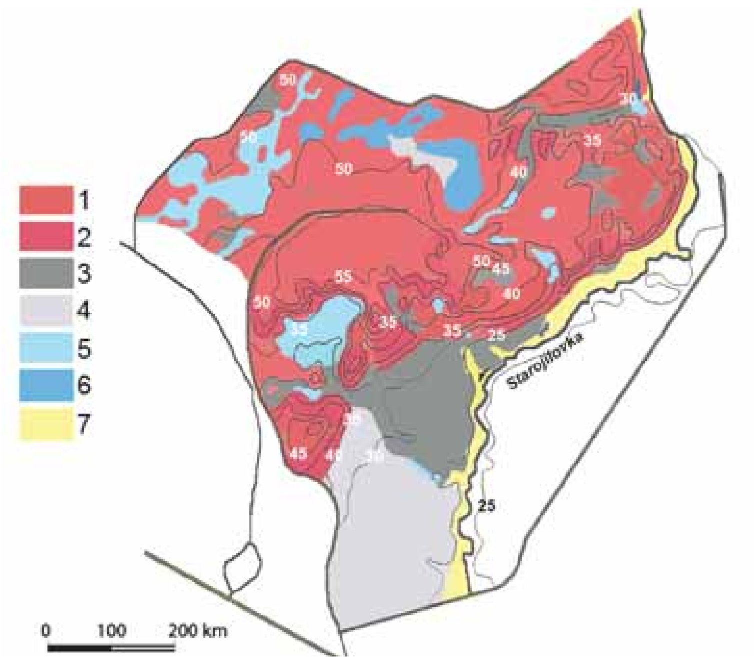


Fig. 3. Reconstruction of the landscape structure of the Shuvalov park prior to the establishment of the estate

Locations: 1. flattened tops and gently sloping kame hills; 2. steep slopes of kame hills; 3. undulating plains on sands and light sands covered with eutrophic peat of low thickness; 4. undulating plains on sands and light sands covered with mesotrophic peat of low thickness; 5. eutrophic peatlands and wetlands on slopes (with peat of different thickness); 6. mesotrophic peatlands; 7. floodplain with low-land peat of different thickness

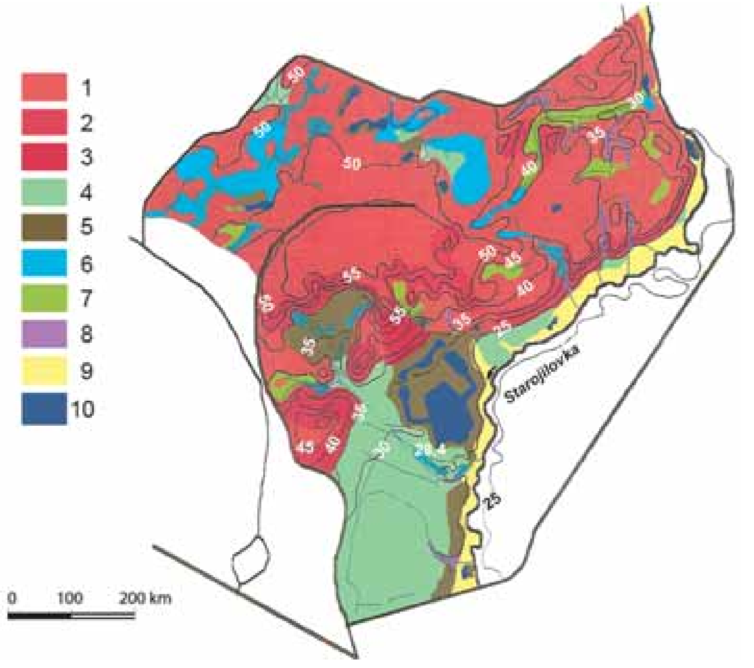


Fig. 4. Reconstruction of the landscape structure of the Shuvalov park, second half of the XIXth century

Locations: 1. flattened tops of gentle slopes of kame hills; 2. steep slopes of kame hills; 3. steep slopes of kame hills artificially terraced; 4. undulating terraced plains on sands and stoneless light sands; 5. artificially drained with mineralized peat of low thickness; 6. flattened surfaces with added soils; 7. drained mesotrophic and eutrophic peatlands; 8. artificially drained inter-kame depressions with mineralized peat of low thickness; 9. artificially deepened depressions with water flow regime (including creek valleys); artificial water bodies; 10. drained peat floodplain

straight line from west to east. It started from Small Pond near the three-tiered Mount Zion and ended in the Big Pond with an island in the middle. Approximately in its central part, the channel was divided into two arms. One arm surrounds a small round island with a wooden manor, galleries, and bridges that hang over the channels and connect the main house with wings on the "mainland."

– natural vegetation cover was, by 1813, infused with park elements: a birch grove – between the island with the manor and the pond near the Mount Zion; a linden grove to the east of the Big Pond; an oak grove and a pine grove along the main alley (parallel to the channel) and to the east of the Bannyi Pond; spruce boskets and a labyrinth to the east of the round island.

In the birch grove, between the island with the manor, the estate theater was constructed. Later, a new magnificent house and a stone church were built at the estate.

Till this time, the general design of the estate has been preserved: two ponds and depressions of the formal channels, islands, and creeping hills. Vegetation of the park has also been partially preserved: linden (*Tilia cordata*) along the banks of the Big pond and oaks (*Quercus robur L.*). Formal (regular) spruce boskets, birch grove, and the labyrinth disappeared. The largest part of the territory is covered with birch-spruce and birch-pine mixed- herb-small-reed forests on low-podzolic glay soils.

Thus, after reviewing the estate complex history and the analysis of the current trends, we can conclude that, without a proper

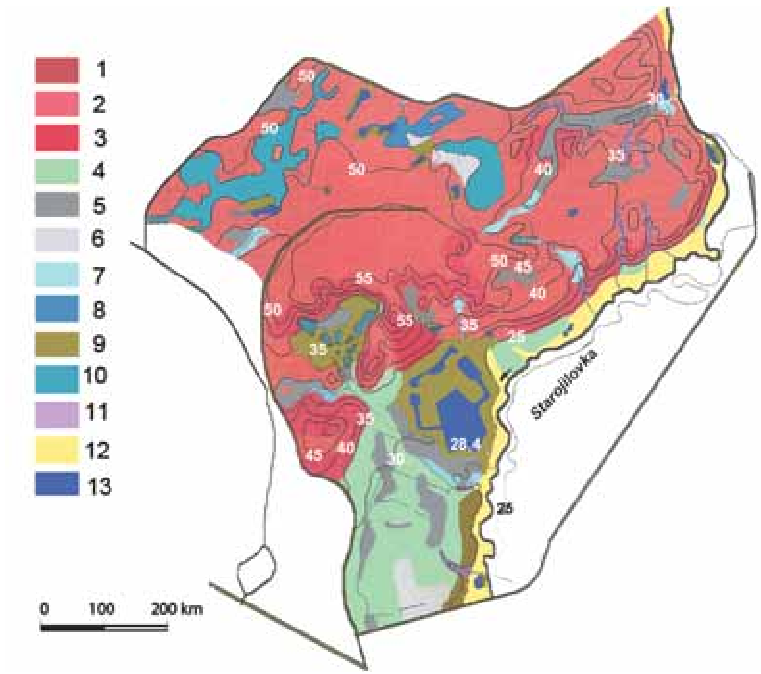


Fig. 5. Landscape structure of the Shuvalov park, 2002

Locations: 1. flattened tops and gentle slopes of kame hills; 2. steep slopes of kame hills, well drained; 3. steep slopes of kame hills artificially terraced; 4. undulating terraced plains on sands and stoneless light sands, artificially drained with mineralized peat of low thickness; 5. undulating plains on sands and light sands, covered with eutrophic peat of low thickness; 6. undulating plains on sands and light sands, covered with mesotrophic peat of low thickness; 7. eutrophic peatlands and wetlands on slopes (peat of different thickness); 8. mesotrophic peatlands; 9. flattened surfaces with added soils; 10. drained mesotrophic and eutrophic peatlands; 11. artificially deepened depressions with water flow regime (including creek valleys); artificial water bodies; 12. drained peat floodplain; 13. artificial water bodies

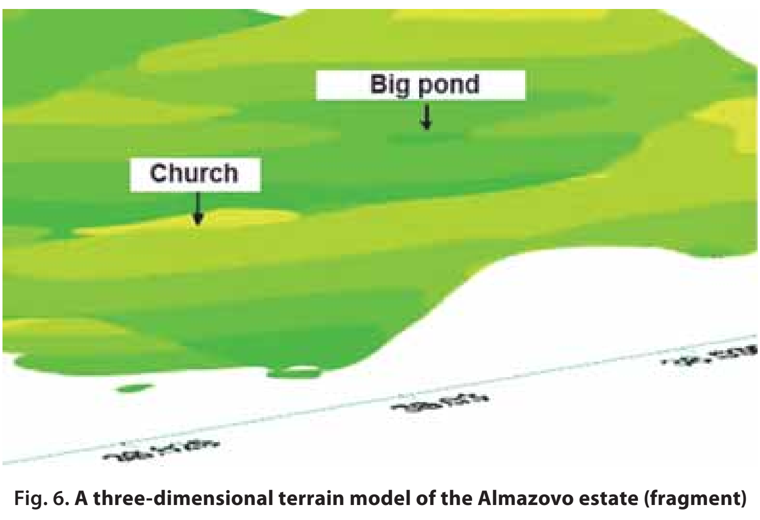


Fig. 6. A three-dimensional terrain model of the Almazovo estate (fragment)

human maintenance, the CL of estates is gradually returning to the initial landscape structure. This process is accompanied by the loss of the landscape architecture features and it follows the laws of natural succession.

Fig. 7. The vegetation cover of the Almazovo estate (circa 1813)

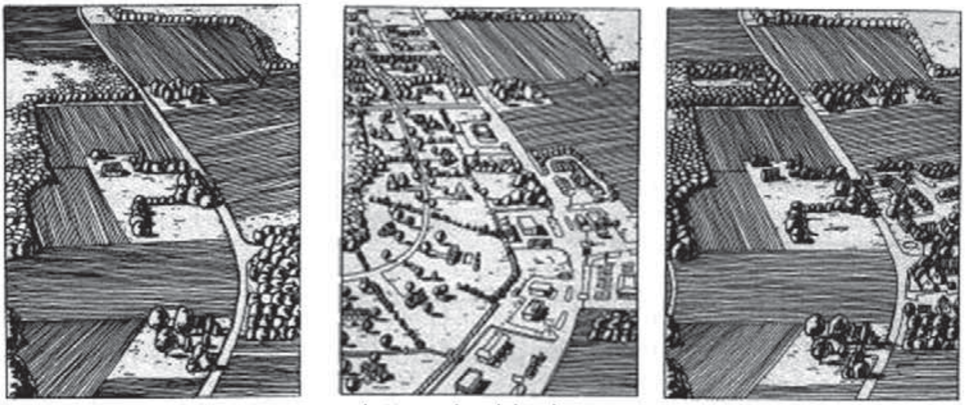
1a – spruce-broad leafed forest; 1b – birch-spruce (pine) forest; 1c – pine (spruce)-birch forest; 2a – spruce (pine)-birch forests blueberry-reed grass-mixed herb forest; 2b – spruce (pine)-birch forest; 3 – grass -mixed herb meadow; 4a – grass-reed birch grove; 5 – planted birch grove; 6 – planted linden grove; 7 – oak grove; 8 – pine grove; 9 – spruce bosket

Fig. 8. **Vegetation of the Almazovo estate (2009)**

1a – spruce-broad leafed forest; b – birch-spruce (pine) forest; 1c – pine (spruce)-birch (with evidence of heavy logging) forest; 2a – spruce (pine)-birch blueberry-reed grass-mixed-herb forest; 2b – spruce (pine)-birch (with traces of heavy logging) forest; 3 – herb-grass meadow; 4a – birch mixed-herb-grass-reed forest; 4b – birch mixed-herb-grass-reed forest (with traces of heavy logging)

THE CONCEPT OF THE ENVIRONMENTAL FOUNDATION FOR SUSTAINABLE FUNCTIONING OF THE CL

Up till the last century, landscape changes were of extensive character and, likely, complemented it and did not destroy it. However, beginning in the middle of the XXth century, there began to appear industrial and urbanized territories characterized by a strong depletion and deterioration of the natural components. However, with development of science and technology, society learned to restore and maintain landscapes [Ignatieva, 2011].



a. Present state b. Unregulated development (forecast) c. Regulated development (forecast)

Fig. 9. Possible scenarios for the development (Program "Dealing with Change in the Connecticut River Valley")

One of the first cases of recultivation of disturbed landscape took place in 1860s in France, where at the site an old quarry, a park with an artificial pond and man-made topography was created (Le Parc des Buttes Chaumont) [Sokolskaya, et al., 2007]. In Russia, one of the largest landscape parks was established at the site of former manganese quarries near Vladikavkaz only in the 1960s [Ozhegov, 1993].

Soon, there emerged a method of preservation and maintenance of the natural landscape, i.e. designing planned activities that provide for the minimal changes in the landscape environment during new activities.

Targeted preservation of the natural landscape is an extremely complex and multifaceted task. In the last century, landscape projects were initiated in the USA, Germany, The Netherlands, Russia, and a number of other countries. In the USA in the state of Massachusetts, the Center for Rural Massachusetts created a program entitled "Dealing with Change in the Connecticut River Valley" (1988) [Robert et al., 1988]. In order to promote its program, the Center demonstrates, with the help of simple figures, how specific intact landscapes look (Fig. 9a), how they might look in a number of years after traditional spontaneous development (Fig. 9b), and how they might look as a result of targeted management pursuing the same goals as in spontaneous management (Fig. 9c). This clearly shows the work of landscape planners.

One of the main areas of a planner's activity is the maintenance and preservation of CL properties and functions. For sustainable functioning of the CL as an ecosystem, a concept of the ecological framework (EF) has been introduced. The EF is a minimal, in terms of area, formation that is able to provide suitable conditions for humans and to preserve the nature in isolated reserves [Kolbovsky, 2008].

The EF is a complex of natural (wild) and cultural ecosystems located around the centers and axes of economic activities and created on the basis of large reserves connected by ecological corridors. The EF secures ecological stability (relative homeostasis) of the space that they encompass at appropriate scales (region, farm, territory of rural administrative area, municipality). The EF addresses the following goals [Kolbovsky, 2008]:

- regeneration of main components of the natural environment that provide a necessary balance in interregional flows of matter and energy;
- maintenance of the balance between the strength of anthropogenic impact and the

level of biochemical activity and physical stability of the natural environment including the existence of conditions for sufficiently high rates of pollution, their biological processing, and stabilization of impact of transportation, engineering, and recreational loads on the landscape;

- maintenance of the biological mass balance in intact or lightly disturbed areas that are affected by economic activity in main landscapes of the region;
- provision of maximal possible, in given conditions, diversity and complexity of environmental systems in the region.

In reality, the EF is formed among given structural lines and ranges, i.e. a city with its suburbs and industrial areas, large transportation centers and arterials, agricultural areas and forests, river network, sources and range of pollution, interregional transit flows of pollution, etc. The main blocks (components) of such foundation are forests of different size, river network, wetlands (that represent hydrographic centers), reserves and national parks, and different natural monuments.

As it was mentioned above, the main unstable territories are the industrial-urbanized areas. In order to improve conditions of settlement areas, the principles of creation of the urban EF have been developed. The urban EF is an environment territorial system designed for enhancement of the environmental situation of urbanized areas through [Yang, et al. 2004]:

- isolation of the most hazardous centers of technogenic impact;
- protection of historical elements of the CL;
- restoration of valuable components of natural ecosystems;
- enhancement of comfort level in residential environment.

The urban EF should consist of different elements of the CL (parks, gardens, boulevards, street trees) and elements of the remaining nature (suburb forests, parks, valley forest-meadow areas). The EF includes blocks of different size (large inter-arterial wedges and spots of vegetation of residential gardens and of different functional purposes – green, recreational, sanitary-protective, and engineering-protective). Finally, and the most importantly, the EF is characterized by integrity – all components and blocks should be spatially connected in a single live network of centers (areal blocks of the EF) and corridors (linear blocks of the EF). From the positions of zoning law, the EF achieves urban nature-protective and recreational goals, forming special legal zones: recreational, specially protected natural territories, protected historical and cultural monuments, and their landscape space. Development of the EF assumes regeneration of its natural elements and the formation of new green spaces that restore continuity of the urban natural landscape structure; preservation, identification, and visual realization and accentuation of historically characteristic landscape views, garden-park complexes, and urban scenic views [Gobster, et al., 2007].

Restoration of spatial continuity of the natural and semi-natural elements of the urban EF is achieved through the creation of a well-developed system of green connectors that unite isolated territories and the natural complexes. It assumes:

- formation of a system of specially protected suburb territories by identification of the most valuable, typical, and unique ecosystems and landscapes (or their elements) of both the natural and the cultural origin;
- preservation of existing and restoration of lost landscapes of valleys of large and small rivers as environmental corridors;
- identification and preservation, in each sector, of the urban rosette of free arterial wedges and territories-connectors that include existing and reserve areas of the

EF and that provide interconnection of its main areas and between them and suburb landscapes;

- restoration and design of new large urban parks (as spatial intercity areas of the EF) instead of old and lost, especially in the new housing development areas;

- formation, in the contact zones of the EF and in the urbanized territories of buffer zones, of low-density and heavily green areas that are able to decrease pressure on the natural complex;

- development of a system of inter-block greening and of greening of pedestrian zones, streets, industrial zones, and engineering network;

- preservation and creation of new green areas of common use (boulevards, gardens) and areas of special purposes (protective belts along railways, engineering-technical zones, and networks);

- recultivation and rehabilitation of wastelands, industrial areas, storehouse and public utilities zones, protected zones of different purposes, developed depositing sites, watersheds, slurry reservoirs, ash disposal areas, and tailing dumps;

- establishment of environmental corridors along major roadways and railways.

The urban EF is, at the same time, a recreational foundation. In urban conditions, these two concepts practically blend together because it is difficult to rely here on the creation of protected elements of the EF that are closed for the public and for the recreational use (it may only be possible within botanical gardens, protected private areas, or areas with regulated schedule of operation). Therefore, the formation of the EF assumes a simultaneous creation of recreational areas. Park is seen as the main urban recreational type. In the urban environment, large parks (exceeding 5 ha) are especially important since they maintain complex layered structure of the biota (ground layer, several shrub layers, low-trees layer, groundfloor, and layer of developed species different in height). Specifically such parks exhibit the maximal biodiversity and are able to regulate and form microclimate. Parks may be artificially created or created on the basis of natural vegetation.

Parks and urban cultivated green areas are, of course, the main remnants of the nature at any urbanized territory with a set of environmental niches [Alvey, 2006]. Their species diversity depends on the age and the storey-structure of plantings, frequency of mowing, soil and fertilizing regime, intensity of trampling, and existence of water bodies. These factors, in turn, determine the number of nesting sites and shelters for birds that nest in hollows of trunks or in branches of trees. Parks are the refuges for disappearing local species and for archaeophytes and neophytes; besides, they are the islands for lichens in urban conditions. In parks, there are also edge communities and communities of grazing areas; locally, there are thickets of shrubs similar to natural [Goroshyna and Ignatyeva, 2000]

Urban parks are a vivid example of the island environment under significant anthropogenic impact (disturbance by people, dogs, automobile pollutants, chlorides, dust, pesticides, mechanical disturbances, altered microclimatic parameters). As any island, a park, depending on its size and configuration, consists of an internal center and an edge. The edge zone carries an especially strong anthropogenic load. The smaller the park, the greater a relative area of the edge zone where the influence of the surrounding environment of the urban territory is spread through the entire island and the central zone disappears; after that, its functional zoning is obsolete.

Today, urban and other planners have a sufficient number of ways to maintain environmental situation in residential areas by forming the EF that includes blocks different in size, i.e., inter wedges, green belts and urban nature-protective and recreational zones.

CONCLUSION

1. The CL is less stable compared with its original natural landscape. Stability of the natural landscape is defined by its intrinsic diversity. As a rule, the following potentially more stable geoecosystems can be isolated: with increased diversity and overlapping (doubling) components of structure; in the centers of their zonal and regional typicality; trans-accumulative are more stable than trans-alluvial; larger in area and matter; and of higher hierarchal ranks. The main methodological instrument of assessment of landscape stability is LP that defines stability criteria of the natural landscape components. The main element of assessment is the biotope. It reflects all natural components of the landscape. Its two criteria, i.e., sensitivity and significance, are identified. The sensitivity criterion assumes an ability of a given natural complex to change its properties and dynamic characteristic under the impact of human economic activity. The second criterion is significance that helps to identify priority goals and objects for LP.

2. Identification of the stability categories of the CL is associated with a number of difficulties. The methodology of LP has developed rather clear recommendations for assessment of sensitivity and significance of the natural landscape, which cannot be stated in respect to the CL that requires a specific and individual approach in each particular case. In contemporary scientific research, only basic and general assessment criteria of natural components are used for the identification of the CL stability criteria.

3. The link between the natural and cultural components is rather complex and the maximal correspondence is manifested through the character of territorial natural resource management. It reflects the natural structure of the CL and it also considers the socio-economic features of the territorial use. The natural stability is one of the prerequisites for sustainable resource use. With the increase in human economic activity, the natural stability of the natural landscape decreases and there emerges new acquired stability, but in this case, already of the CL. The essence of the acquired stability is in the adaptive variability of structures and functions of the landscape under anthropogenic impact.

4. Stability of the CL is closely associated with the character of natural resource management. This allows identifying three groups of stability that depend on the types of territorial use: stable (they include extensive types – traditional, recreational, nature protective), moderately stable (vast territories of forest management and agricultural purposes), and unstable (urbanized and industrial zones with strong differentiation and changes in the structure of the native landscapes).

5. For the sustainable functioning of the CL as an ecosystem, a concept of the EF has been introduced; the EF is the minimal, in area, formation that is able to provide for suitable environmental conditions for humans, to preserve the nature at least in the form of isolated reserves, to identify the most hazardous centers of technogenic impact, to preserve historical elements of the CL, to restore valuable fragments of natural ecosystems, and to enhance comfort of the residential area. The urban EF consists of different elements of the CL (parks, gardens, boulevards, and street plantings) and of fragments of the remaining nature (suburb forest, parks, and valley forest-meadow spaces).

6. The EF achieves the nature protective and recreational goals of urban territories, forming special legal zones: recreational, specially protected natural areas, and protected historical and cultural monuments together with space around them.

7. Development of EFs assumes restoration of the natural urban elements, formation of new green spaces (a system of inter-block green areas and greening of pedestrian zones, streets, industrial areas, storehouse and public utilities zones, protected zones of different purposes, developed

depositing sites, watersheds, slurry reservoirs, ash disposal areas, and tailing dumps) that restore continuity of the urban natural-landscape structure; preservation, identification, visual realization, and accentuation of characteristic historical landscape views, park-garden complexes, and urban scenic views.

Thus, we can reach a conclusion on the incomplete and insufficient level of development of criteria for assessment of stability of the CL in modern science. This results from great diversity of both the CLs themselves and their natural conditions of formation, as well as of the types of natural resource management. All discussed research approaches on CL stability were developed with the obvious domination of the nature-centric approach that is based on assessment of the natural component of the landscape. This is explained by the difficulty of identification of the structure of the CL, its components, and assessment of their stability. Today, the methodology of the EF for urbanized areas may be considered the best developed methodology of the CL stability assessment. Modern methods of assessment and formation of the EFs in cities promote preservation of properties and functions of the CL. ■

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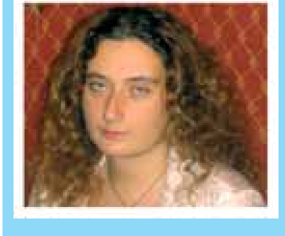

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BALANCED FERTILIZATION FOR SUSTAINABLE DEVELOPMENT OF AGRICULTURE IN THE SAVANNAS OF SOUTH AMERICA: TOWARDS A GEOGRAPHICAL APPROACH

ABSTRACT. South American countries still possess considerable land reserves for agricultural development. Huge areas of virgin lands and natural pastures have been converted to agricultural crops and suffer increasing pressure. Growing demand for food in the world and attractiveness for capital investment drive this colonization further deep into the regions that cannot be converted to commercial agriculture without serious negative environmental consequences. Agricultural development in these areas neither can be considered economically sustainable, as high production costs sometimes surpass revenues from the harvest. Most of the recently colonized regions in South America are those under savanna landscapes, where low nutrient availability in the soil restricts agricultural use. Understanding the problem of sustainability of agricultural development in savannas is impossible without geographical analysis. Spatial approach at different scales enables precise vision of weak points of recently established agricultural systems and helps to draw solutions to diminish their instability. The objective of this paper was to develop, with GIS tools, a geographically based analysis that could identify the spatial variation and magnitude of soil potassium, potassium uptake, potassium fertilization, and potassium balance in order to improve the efficiency of mineral fertilizers use.

KEY WORDS: Sustainable development of agriculture, mineral fertilizers, savannas, cerrado, South America, Brazil

INTRODUCTION

South America, perhaps, is one of the last agricultural frontiers of the humanity. Since its conquest by Spain, Portugal and other European powers, agricultural development on this continent is going along with colonization of virgin lands. After the colonial period, the late 19th – early 20th centuries were marked by colonization of the Argentinean Pampa and the southern states of Brazil. The last large-scale colonization campaign started in the 1980s, with colonization of the Center-West region in Brazil. Later on, it also affected the fringe of the Amazon region and the inner parts of the North-East region of this country [Naumov, 2005]. From Brazil, colonization has spread to the neighboring areas of Paraguay and Bolivia. In Colombia and Venezuela, the agricultural frontier also started moving towards the peripheral regions [Naumov, 2010]. These areas, together with some Argentinean provinces, became the ground for the recent soybean production boom in Latin America [International Potash Institute, 2011].

Analysis of the land use data shows that many South American countries still own considerable land reserves for colonization (Table 1). In most cases, these reserves can be found in the regions of tropical savannas. In the authors' estimates, savanna landscapes occupy approximately 25%, 33%, 50%, and 25% of the total land area in Brazil, Venezuela and Colombia, Bolivia, and Paraguay, respectively. Besides, there are areas outside the Tropics, like Argentinean North, with physical-geographical characteristics similar to the savannas.

Until the middle of the 20th century, tropical savannas in South America were almost not used for commercial agriculture. Nevertheless these regions were drawn to the attention of a German origin geographer Leo Waibel (1888–1951), who visited Brazil in the 1940s and predicted, that savannas would become the potential breadbasket of the humanity [Etges, 2000]. Nowadays, about 170 million ha in Brazil are considered suitable for agricultural colonization, and 65 million ha from this huge area correspond to virgin lands in the savannas (for comparison: in the rain forests of the Amazon, only 10 million ha were considered suitable). Another 90 million ha in Brazil that may be converted into fields from natural pastures are also located primarily in savannas [USDA, 2003].

Brazil, no doubt, is the leading country in South America in terms of the potential area for colonization of savannas, and by the size of the already colonized area in these regions. Tropical savannas, locally known as *cerrado*, occupy approximately 204 million ha, mostly in the Center-West region of Brazil and, partly, in the South-East, North-East and the Amazon regions of this country. During the last three decades of the 20th century, some 20 million ha in the Brazilian *cerrado* were colonized for commercial crops planting [Manzatto et al., 2002].

The *cerrado* regions are characterized by hot climate, with the annual average temperatures of over 20°C and the average monthly temperatures of 18–28°C. The annual precipitation varies between 1200–1800 mm,

Table 1. Land Use in Selected Countries of South America, 2003

Country	Land Area (LA)	Agricultural Area (AA)		Arable Land		Permanent Crops		Permanent Pasture	
	1000 ha	1000 ha	% of LA	1000 ha	% of AA	1000 ha	% of AA	1000 ha	% of AA
Argentina	273 669	128 747	47.0	27 900	21.7	1000	0.8	99 847	77.6
Bolivia	108 438	37 087	34.2	3050	8.2	206	0.6	33 831	91.2
Brazil	845 942	263 600	31.2	59 000	22.4	7600	2.9	197 000	74.7
Colombia	103 870	45 911	44.2	2293	5.0	1557	3.4	42 061	91.6
Guyana	19 685	1740	8.8	480	27.6	30	1.7	1230	70.7
Paraguay	39 730	24 836	62.5	3040	12.2	96	0.4	21 700	87.4
Suriname	15 600	89	0.6	58	65.2	10	11.2	21	23.6
Venezuela	91 205	21 640	23.7	2600	12.0	800	3.7	18 240	84.3
South America	1 753 237	584 285	33.3	107 105	18.3	13 645	2.3	463 535	79.3

Source: [Faostat, 2005].

with strongly pronounced wet (October–March in the Southern hemisphere) and dry seasons. Abundant heat and moisture permit planting without irrigation of maize, soybean, sorghum, sunflower, cotton, and harvesting commercial crops twice a year from the same field.

The soil properties, which predominate in the *cerrado*[1], such as high acidity (pH 4–5), low cation-exchange capacity (CEC), low base saturation, and high levels of Al^{3+}, limit their agricultural use. Only after liming and application of mineral fertilizers, these soils become suitable for continuous planting of grains, oilseeds, and other crops. No-till practices on these soils became popular for preventing soil erosion, maintaining stable temperature and moisture regime in the upper soil horizons, and improving low organic matter contents. According to the Brazilian Federation of Direct Planting into the Straw, the area under no-till systems in Brazil in 2005/2006 agricultural year equaled 25.5 million ha; 38% of this area corresponded to the *cerrado* regions [Andrade et al., 2010]

Along with agricultural colonization of the Brazilian *cerrado*, the consumption of mineral fertilizers in this country has been increasing. Potassium is one of the macronutrients highly demanded by crops such as soybean, maize, and sugarcane. For example, for each 1 t of yield of soybeans, 20 kg of K_2O are extracted from the soil. Assuming that the average soybean yield in Brazil approaches 3 t ha^{-1}, this is just enough to maintain the "zero" balance of potassium in the soil; farmers need to apply 100 kg ha^{-1} of KCl, the most widespread potassium fertilizer, containing 60% of K_2O. In 2010/2011 agricultural year, Brazilian farmers harvested 69 million t of soybeans from 24 million ha [Companhia Nacional de Abastecimento, 2011]. For this, they have used 25% of the nearly 7 million t of potassium fertilizers, imported in 2010 to Brazil, making this country the 3rd in the world after USA and China by the volume of their imports [Potash Statistics, 2011].

[1] *Ferralsols* by the FAO soil classification, or *latossolos* by the Brazilian soil classification [Sistema brasileiro de classificação de solos, 1999].

OBJECTS AND METHODS OF RESEARCH

In 2001, after establishing of a formal agreement between the International Potash Institute (IPI) and the Brazilian Corporation for Agricultural Research (EMBRAPA), a joint research project "Fertilize Brazil", aiming to develop and disseminate balanced fertilization practices for Brazilian agriculture, was initiated. In 2004, at the first stage of the project implementation, potassium balance in agricultural systems was estimated at the level of 26 states and for more than 4000 *municipios* (counties) of Brazil.

During 2006-2007, data from 3000 soil profiles, collected by the EMBRAPA National Soils Research Center, were used for mapping potassium contents in the soil. Spatial interpretation of these data proved to be technically difficult, because of complicated linking of the data to the soil types, landscape contours, and the network of administrative units [Prado et al, 2008]. Soil profiles, described by EMBRAPA, are unequally distributed by Brazilian territory. They are very sparse in regions, where the *cerrado* landscapes predominate. However, as soil profiles data comparison showed, soils of the Brazilian *cerrado* and similar savanna landscapes are not uniform and vary in physical and chemical properties. For example, potassium availability in the upper layers of the soil may differ from 15 to 150 mg kg^{-1} [Naumov and Prado, 2008].

The potassium export calculation was done with the crop yield data on agricultural production (for harvestable parts of the crop) from the municipal statistical database of the Brazilian Institute for Geography and Statistics (IBGE). The estimates were based on such indicators as the annual volume of production (t) of 19 main commercial crops: soybean, maize, sugar cane, coffee, cocoa, oranges, beans, etc., including planted eucalyptus, and the average uptake of the nutrient with 1 t of their yields. The estimates of the potassium input in the soil were less precise. The only data source available was statistics on the volume of potassium fertilizers sales by state (t), provided by the National Association of Mineral Fertilizers Dissemination [ANDA, 2004].

From many points of view, those Brazilian agricultural regions that were formed after clearing of the *cerrado* natural vegetation, deserve special attention for evaluation of sustainability of agricultural systems regarding balanced fertilization. Initially, the *cerrado* regions with more fertile soils were colonized, but now agricultural frontier has shifted towards marginal areas with poorer soils. Data on these soils are scarce; farmers, who moved there are mostly from the southern states of Brazil and they often neglect local natural conditions. Until recently, there was a lack of scientific knowledge about how to adopt agricultural practices in these areas. From the technical point of view, extrapolation of the EMBRAPA data on soil profiles to all areas under the *cerrado* vegetation for purposes of further evaluation of potassium balance in the soil and for the development of recommendations for farmers could result in significant discrepancies.

On the next stage of the project implementation, we decided to carry out a more detailed research and to create a GIS-based spatial description of potassium balance in agricultural systems in one of the main grain and oilseed producing regions of the Brazilian *cerrado* – South West of the Goias state (Fig. 1). Large-scale commercial agriculture began to develop in this state in the late 1970s, and nowadays, Goias is one of the main maize and soybean producing regions (8.1 million Mt, or 15% of the total national annual harvest of maize grain in Brazil in 2010, and 7.5 million Mt, or 11% of soybeans). Cotton and sugarcane planting is also spreading in this region, and cattle ranching and poultry industry are developing fast in association with forage production [Projecções do agronegócio, 2010].

In 2005–2006, potassium availability in soil was estimated from the data of soil

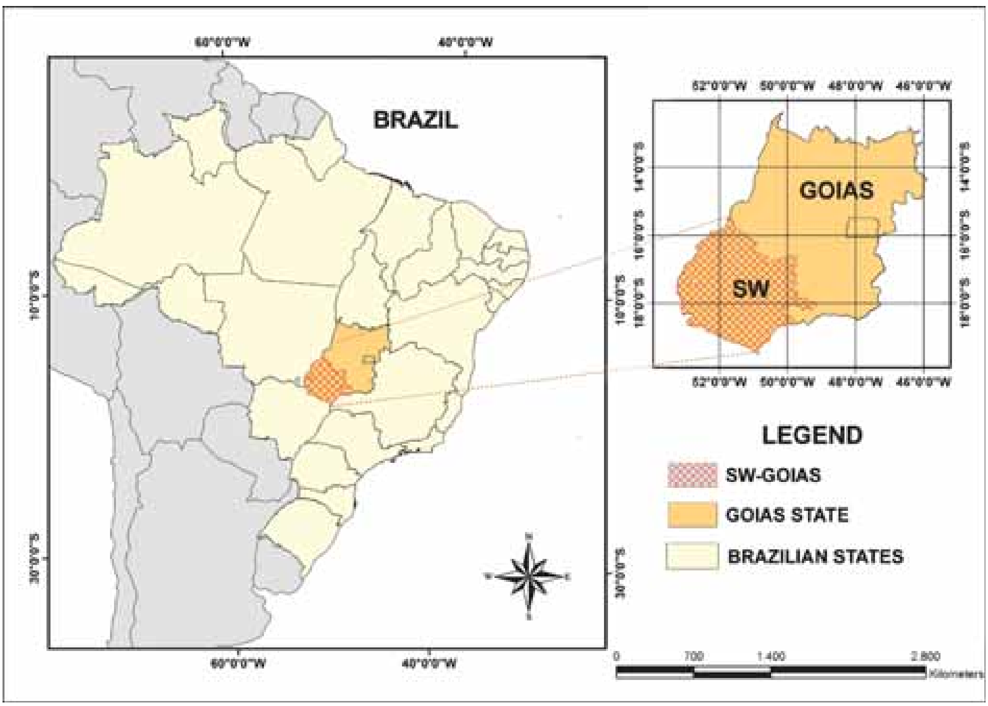

Fig. 1. Research polygon in the South West of the Goias state, Brazil

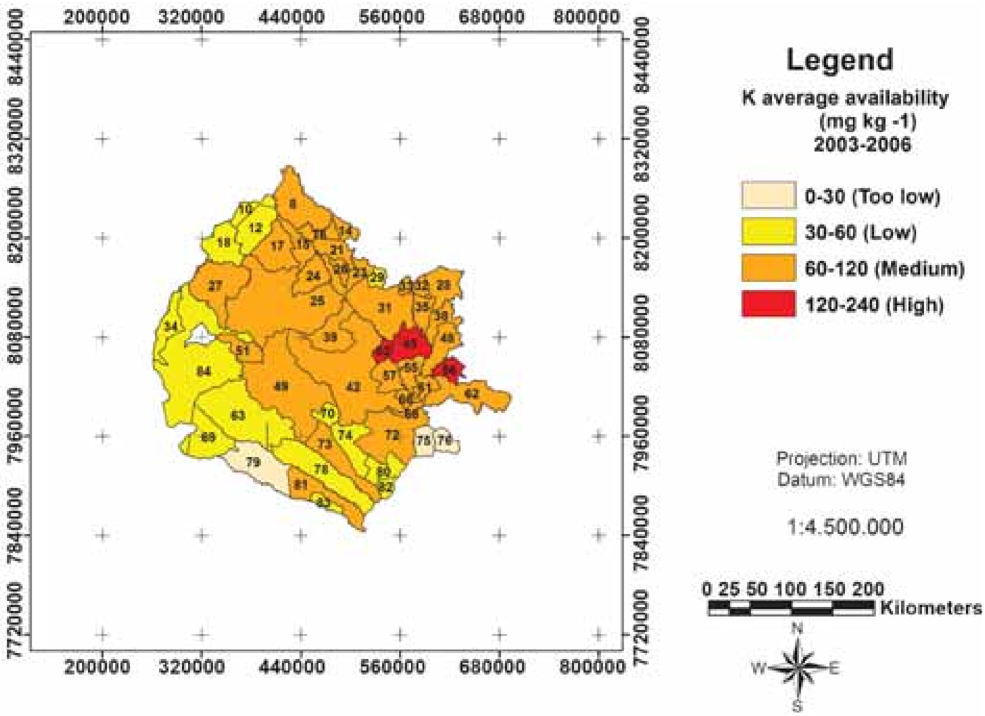

Fig. 2. Potassium availability in the soil in the South West of the Goias state (numerical scale as on the original map, same for the fig. 3 and fig. 4)

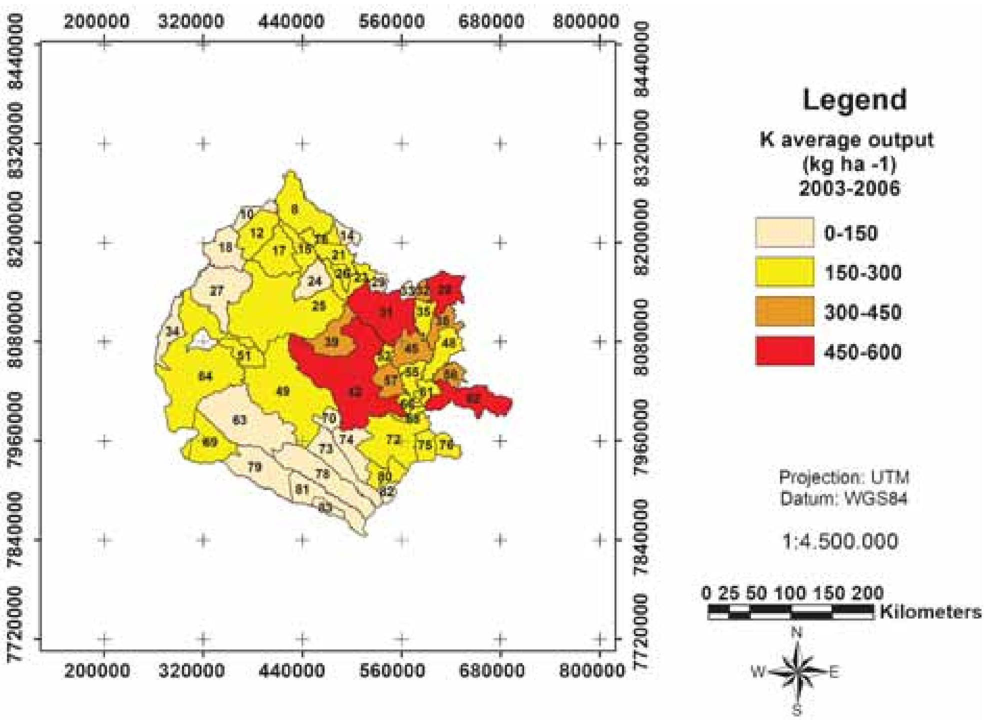

Fig. 3. Potassium uptake from soil with crop yields in the South West of the Goias state

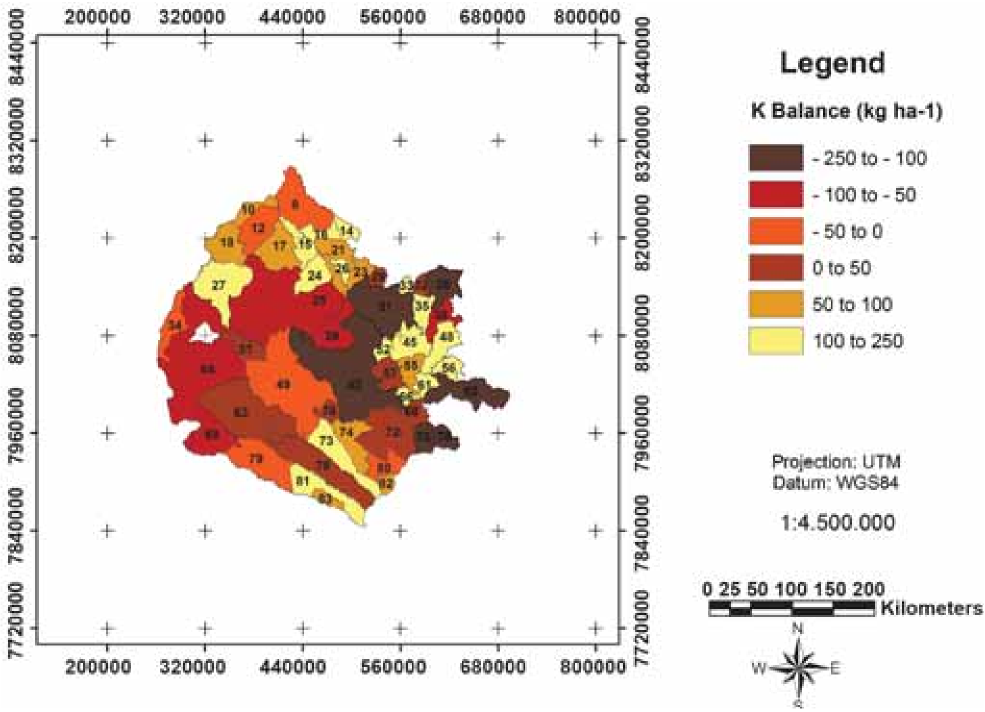

Fig. 4. Potassium balance in the soil in the South West of the Goias state

sampling at the *fazendas* (large farms) of the members of the COMIGO agricultural cooperative. Geo-referenced data on mineral fertilizers consumption were obtained from farmers during a poll in 2005 (about 500 have responded), from surveys of selected farms, and from the COMIGO agronomy database. The relationship of potassium uptake with yields of commercial crops was calculated from agricultural statistics data for 61 *municipios*. These data formed two GIS layers on a municipal level shown in Figures 2 and 3. Overlay of potassium availability, input, and output layers was used to estimate potassium balance in the agricultural region studied (Fig. 4).

Then, we focused on a more detailed territorial analysis of soil properties and agricultural land use in 6 *municipios* of the South West of Goias. For the land use evaluation, satellite images Landsat TM-5 for different periods of the agricultural cycle of 2007 were used. Using software Spring 4.3.3, enabling segmentation of images, and the semi-automatic classifier *Bhattacharrya Distance*, 10 classes of land use, depending on predominant crop, were determined (Fig. 5). Map on soil texture classes were created on the basis of a1:250,000 scale soil map, produced for the RADAMBRASIL project in 1981 (Fig. 6).

By merging consistently data on soil texture, predominant crop, and average potassium uptake with crop yield and average doses of potassium fertilizers applied for each crop for replenishment of the nutrient use[1], we have estimated the potential crop potassium demand levels on agricultural systems. Each soil texture class and land use type by crop was assigned a conventional "weight" regarding potassium demand, e.g. soybean planted under no-till on clayey soils – 1, loam soils – 2, same on sandy soils – 4; sugarcane on clayey soils – 11, loam soils – 12, sandy soils – 13. Results of mapping of these estimates are displayed on the map in Fig. 7.

[2] E.g., for sugarcane 130, for soybean 68, for maize 41 kg K_2O ha^{-1} $year^{-1}$.

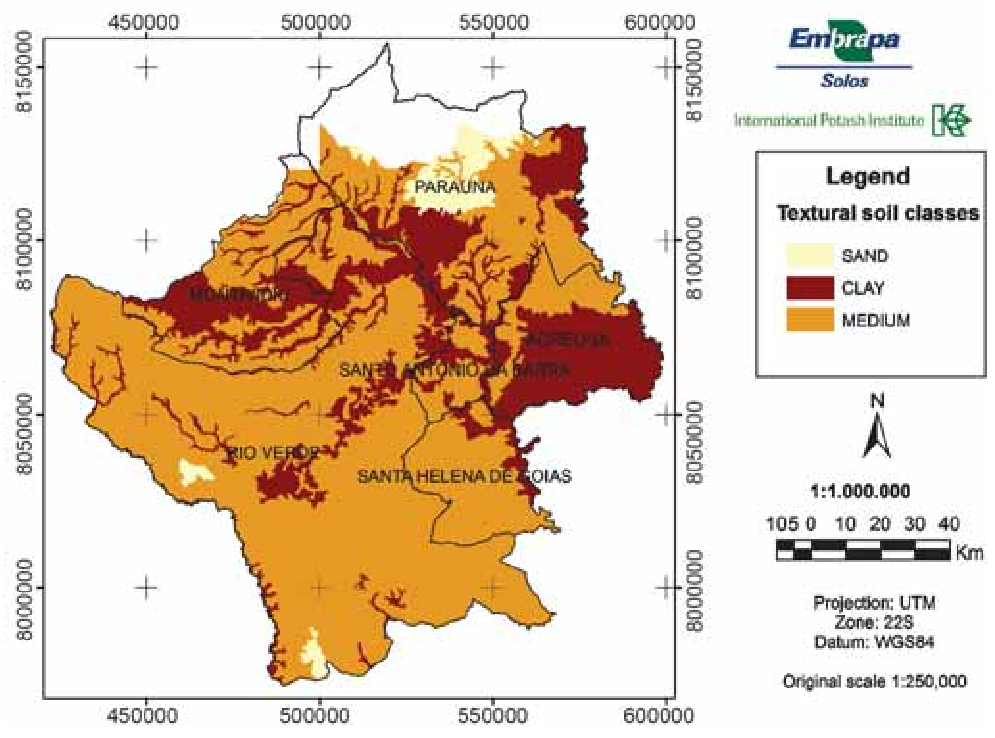

Fig. 5. Predominant land use by crop in 6 *municipios* of the South West of the Goias state

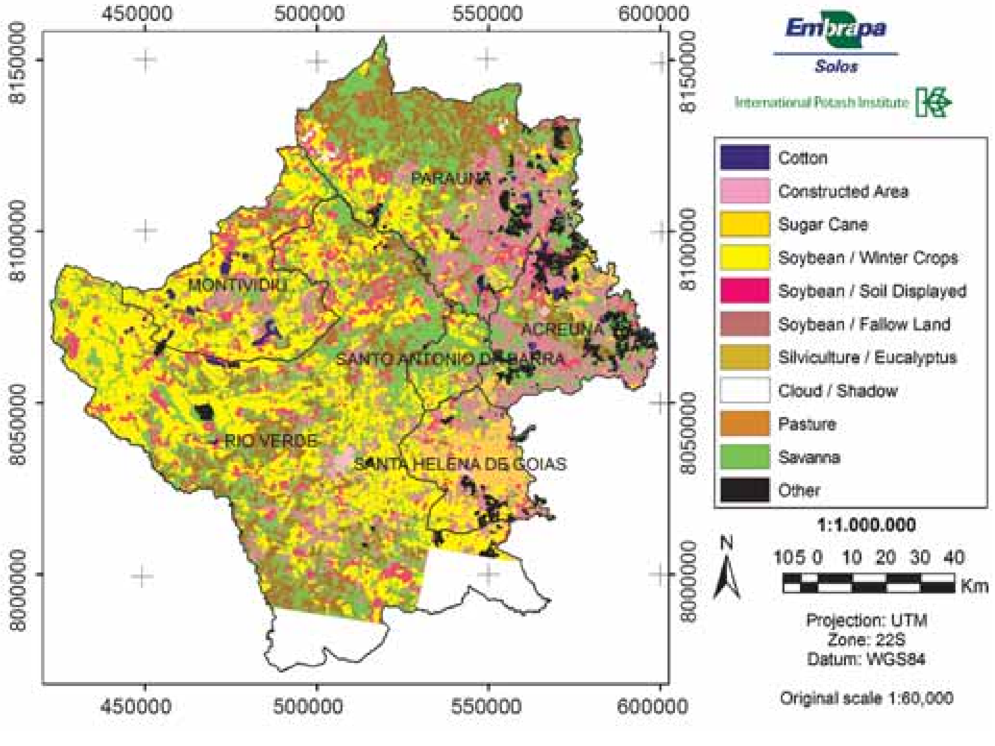

Fig. 6. Soil texture classes in 6 *municipios* of the South West of the Goias state

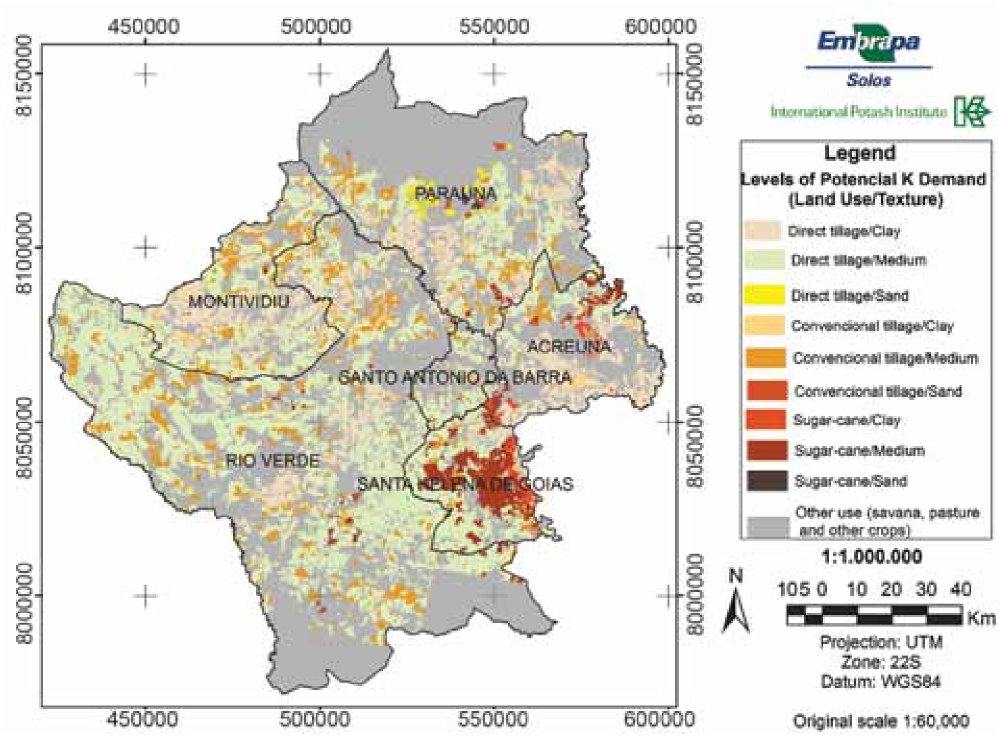

Fig. 7. Estimated potential levels of potassium demand on agricultural systems in 6 *municipios* of the South West of the Goias state

RESULTS AND DISCUSSION

Mapping of potassium uptake with yields on a macro (or national) level clearly showed "hot spots" of agricultural development, where mineral fertilizers consumption is concentrated and doses of their application should be high in order to maintain balance of nutrients in the soil. These are: agricultural regions in the *cerrado* of the states of Mato Grosso, Mato Grosso do Sul, Goias, and the western part of the Bahia state (mostly soybeans and maize planting areas); the interior of the São Paulo state (sugarcane and oranges plantations areas); the littoral of the north-eastern states and the Rio de Janeiro state (sugarcane and tropical fruits plantations areas); Petrolina-Juazeiro tropical fruits growing region on the São Francisco river, etc. [Oliveira et al. 2005].

The estimates of potassium balance in agricultural systems on a medium (or regional) level for 61 *municipios* of the studied region (Fig. 4) show that some areas of the South West of Goias suffer from deficiency of this nutrient to sustain high yields, while for other areas it is obvious that there is excessive use of potassium fertilizers. In other words, agriculture in both cases is not sustainable environmentally or economically. Farmers, applying incorrect (insufficient or excessive) doses of fertilizer, minimize profits. For example, the poll showed that most of the COMIGO associates were applying same doses of fertilizer at the same time (pre-plant), despite differences in soil (texture, depth, acidity) and rainfall regime. On average for the studied area, expenses for fertilizers (total N, P, K and micronutrients) represent 1/3 of the total production cost of soybeans and maize. But those who did not take in consideration local geographical conditions at their farms, often were spending twice as much.

A more detailed study and a small-scale approach for evaluation of potassium demand, based on soil texture and land use analysis, resulted in conclusion of even sharper geographical contrasts in potassium (and, presumably, in other nutrients) demand on micro (landscape contours, fields) level. Soil properties, such as CEC and their physical characteristics, influencing enleaching of nutrients, are very important for the estimate of right doses of mineral fertilizers to be applied. As a side – but important result of this research, we would also like to mention precise data on the predominant crops and agricultural practices by territory. As the land use classification showed, the predominant land use class for 6 *municipios* of the South West of Goias was soybean, planted in no-till systems (for the *municipio* of Montividiu – 54%, for Rio Verde – 45% of the total area). The satellite images data interpretation pointed to expansion of sugarcane in the *municipio* of Santa Helena de Goias where this crop already covers 1/3 of total area. High magnitude of no-tillage practices among the local farmers was also taken in consideration, because of a lower demand for mineral fertilizer, than in conventional practices.

CONSLUSIONS

A spatial approach for determining nutrient balance in agricultural systems enables a precise vision of weak points of agricultural systems regarding the efficiency of mineral fertilizer use, and helps to draw solutions for decreasing their instability.

Recently colonized regions of Brazil seek adaptation of farmers' practices of fertilization to local soils. Extensive growth of agriculture may not be sustainable environmentally (because of pollution of ground and surface waters with chemicals) or economically (because farmers spend more, than needed, for fertilizers). Thus, knowledge of local geographical conditions becomes essential, allowing reduction of production costs, as it helps to increase efficiency of fertilizers use and approach more sustainable models of agricultural production.

Geographic information systems are increasingly widely used in modern agriculture in order to adopt on-farm operations (tillage, planting, etc.) to the micro-geographical properties of the fields (so-called precision agriculture). The authors consider the GIS-technologies be potentially also useful for scientifically based solution of such practical targets as monitoring of nutrients in soil and soil fertility in general, evaluation and forecast of efficiency of fertilizers use, definition of rational doses, and optimal terms and methods of their application on the fields.

Geo-referenced recommendations for farmers, aimed at minimization of production costs, become an important tool for increase efficiency of fertilizers use. The authors are planning to produce even more detailed maps and complete layers of GIS with climatic and phonological data. This will allow synchronization of fertilization data, the life cycle of crops, and rainfall regime, and will help to reduce enleaching of nutrients from fertilizers. The authors expect that extrapolation of different kinds of physical-geographical, social, and economic data on landscape-type maps and, then, on the detailed map of the fields based on LANDSAT images will allow obtaining precise data on potassium availability at the depth of the agricultural horizon and on balance of this nutrient in agricultural systems of the Brazilian *cerrado*.

The results of this research have already attracted the attention of farmers and decision makers in Brazil. Currently, GIS is in the process of being placed on the web for the public use. The authors are planning to reproduce the similar methods of research for the other agricultural area of the Brazilian *cerrado* – the West of the Bahia state. This approach may be also applied for the purposes of sustainable development of agriculture in other savanna regions of South America.

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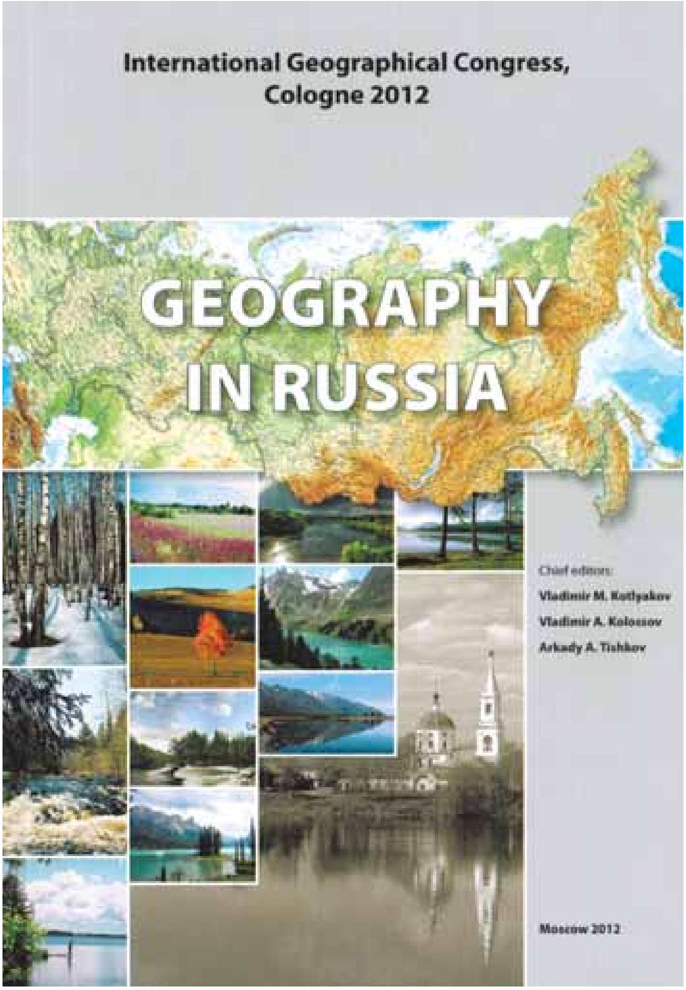
DOWN TO EARTH AND ITS CURRENT PROBLEMS (on the Results of the International Geographical Congress in Cologne, Germany, 25–30 August, 2012)

The 32nd International Geographical Congress (IGC)[1] sponsored by the *International Geographical Union* (*IGU*) took place Aug. 25–30, in Cologne, Germany. **Geographers from 80 world's countries attended with 2,400 delegates registering at the beginning of the Congress** – the record number in the last one-quarter of the century. The number of the participants could have been even bigger; however, submitted abstracts were first anonymously screened by a double-blind review of a special international academic committee. The competition depended on the themes of the abstracts and the "popular appeal" of the individual sessions of the program already approved by this committee. The selection was conducted regardless of the authors' standing: some abstracts of the IGU Vice-Presidents and of other known geographers were rejected.

Naturally, the delegation from the host country appeared to be the largest at the

The City of Cologne – venue of the IGC 2012

[1] The first International Geographical Congress was held in 1871 in Antwerp. In its present form, the IGU was founded in 1922 in Brussels. The governing body is the Executive Committee consisting of President, eight Vice-Presidents, General Secretary, Treasurer; it is elected by the General Assembly consisting of the heads of the national geographical societies and associations. The IGU structure also includes permanent commissions and research groups. Every four years, the IGU sponsors its Congresses. The Bulletin of IGU is published. The Soviet Union became a member in 1956. Coordination between Soviet geographical organizations and the IGU was achieved by the National Committee of the Soviet Geographers that has been transformed in 1992 into the Russian National Committee of the IGU (currently, Academician V.M. Kotlyakov is Chair and M.D. Ananicheva is Academic Secretary).



The overview of Russian geography

Congress; it included about 1,000 members. The Russian delegation, along with the Japanese, Austrian, Chinese, and French, was one of the largest and included 100 members. The grant of the Russian Geographical Society (RGS) to the National Committee of the Russian Geographers helped to support participation of Russian geographers in the Congress (Academician V.M. Kotlyakov, Head). The delegation primarily included representatives of academic geography (Institute of Geography of RAS – 12 people, Institute of Geography of SB RAS – 5 people, Pacific Institute of Geography FEB RAS – 5, etc.), as well as a group of scientists from the Geography Faculty of Moscow State University, headed by Academician N.S. Kasimov (over 30 people). The RGS grant also supported 15 young scientists from Moscow, St. Petersburg, and Irkutsk. The National Committee of the Russian Geographers and the Institute of Geography of RAS had published (for the Congress) a brochure, "Geography in Russia"[2], a catalog of the Exhibition on the Russian geographical literature, and a booklet on the upcoming IGU Regional Conference in 2015 in Moscow. The Russian delegation held a reception where it presented uniquely designed souvenirs to the guests.

[2] Geography in Russia. Eds.: Vladimir M. Kotlyakov, Vladimir A. Kolosov, Arkady A. Tishkov. Moscow, 2012. 104 p.

The presence of the participants from Asian, African, and Latin American countries was especially important as these regions, as a rule, are not well represented at the IGU events. A special meeting of 60 participants from 12 African countries, headed by Professor Chris Mutambirwa from the University of Zimbabwe, was organized. Its purpose was to discuss prospects of a more significant participation of these countries in the IGU activities and geography development issues in Africa.

The Congress took place at the University of Cologne, i.e., one of the oldest and largest universities in Germany. "Down-to-Earth" call became the motto of the Congress, which can be interpreted as "Let's get closer to the Earth" or "It is time to deal with the Earth's problems". At the formal opening ceremony of the Congress that took place in a new spacious and comfortable area of the Cologne Philharmonic Hall, Rector of the University, Professor Axel Freimuth, expressed his gratitude for a chance to conduct such an event in Cologne. Frauke Kraas and Dietrich Soyez, co-Chairs of the Organizing Committee, emphasized the importance of the main Congress's topics: interrelation between transition to sustainable development, globalization, urbanization, climate change, preservation of biodiversity, and "green economy". An impressive presentation by Anne Glover (Great Britain), European Commission chief scientific adviser, caused an emotional response of the audience: she encouraged geographers to "yell" about the results of their research, i.e. to more actively bring the information to the attention of political leaders and the general public.

The Congress program was extremely diverse and innovative in its form. Thus, for the first time ever, it included sessions organized by the IGU commissions and thematic meetings initiated by different groups of scientists. There were about 400 of scientific sessions only. Daily, there were "scheduled" lectures (key lectures) by leading scientists and practitioners on the current and generally important issues, which sparked great interest ("Society and Environment", "Urbanization and Demographic Change", "Global Change and Globalization", and "Risks and Conflicts"). The largest auditorium of the University with capacity for 1,000 people often could not accommodate all wishing to attend. Latecomers had to comply with the strict German rules of fire safety that do not allow standing in a lecture and regretfully went to other events.

Many introductory presentations and public lectures discussed the emergence of a new era – the Anthropocene. On a rigorous evidence-founded basis and using graphs and models, it was shown that human activity on the planet in the last century represented a powerful geological force causing *irreversible changes in the geosphere*, which can serve as an important argument to isolate, following the Pleistocene and Holocene, this new period.

The commissions (in the IGU, there are 40 in total) met in auditoriums specially designated to ease navigation in this "Congress Babylon". Several sessions were devoted to the problems of the use of economic mechanisms in the natural protection, sustainable resource management, and environmental issues of urbanization. The discussions also covered the concept of ecosystem services and approaches of "green economy" in the form declared at the World Summit "Rio+20".

Virtually all IGU commissions, groups, and projects had their organizational meetings ("business meetings") where reports of the chairpersons were presented, leadership elections were held, and commissions received new or replaced their members. Russian scientists kept their appointments in some IGU commissions: Geoinformatics (Professor V.S. Tikunov), Political Geography (Professor V.A. Kolosov), Evolution of the Environment (Professor A. Velichko), Biogeography and Biodiversity (Professor A.A. Tishkov), Karst (E.V. Trofimova), Health Geography (Professor S.M. Malkhazova), Cold Regions Environment (T.K. Vlasova), Stability of

Members of the Russian delegation in front of the Cologne University building

Water Resources (Professor N.I. Alekseevskyi), Hazards and Risks (Corresponding Member of RAS S.A. Dobrolyubov).

Overall, the Russian participants, including young geographers, whose attendance was supported by the RGS grant, presented more than 70 papers and posters. In this respect, we can mention the delegations from the Geography Faculty of Moscow State University, headed by Academician N.S. Kasimov, whose members made presentation at the meetings of over 10 commissions (Professors N.I. Alekseevskyi, S.M. Malkhazova, A.I. Alekseev, and others), the Pacific Institute of Geography FEB RAS (Academician P.Ya. Baklanov, Professor S.M. Govorushko, and others), the Institute of Geography of SB RAS (Professor L.M. Korytnyi and others), the Institute of Geography of RAS (Professors V.A. Kolosov, A.A. Tishkov, T.K. Vlasova, Ye.V. Trofimova, M.D. Ananicheva, E.A. Belonovskaya, A.A. Medvedev, and others). However, the Russian geographers practically did not participate in the work of commissions on historical geography, geographical education, tourism geography, applied geography, landscape science, urbanization and transportation geography, history of geographical cogitation and some other disciplines.

Some Congress activities were targeted to geographers-practitioners and experts in the field of geoinformatics. Just before the start of the Congress, a special session on the problems of the development of geography in Europe was held. Thus, it is difficult to establish the exact number of the Congress participants.

One of the special sessions was devoted to the ambitious project of the IGU, initiated, albeit in a somewhat different form, by a former IGU President Adalberto Vallega. The project aims at establishing the International Year of Global Understanding by the UN General Assembly. In order to be implemented, this project has to be supported by UNESCO. One of its objectives is to improve the international position and the social role of geography. It should include research and programs to improve geographic education and dissemination of geographical knowledge in a globalizing world. The main idea is to promote awareness of each person that their daily activities impact the environment on a global scale. The International Year of Global Understanding is also aimed at facilitating the integration of natural and social sciences, at providing scientific and social support for priority directions of UN and UNESCO, and on using positive results of the previous UN Years with the goals of achieving sustainable development. A booklet on this subject, including in Russian, was distributed among the participants. The project was presented by its coordinator Professor Benno Werlen (University of Jena), by a former President of the IGU Professor Bruno Messerli (Switzerland), and by Professor John Pickles (University of North Carolina, USA).

The other two special sessions hosted presentations of two IGU projects, "Geographical Magazines of the World" and "Sustainable Development of Cities" (the research advisor for both – Professor Ton Dietz from the Netherlands). The first project has been completed in general and its results include the creation of an online global database and a search engine on international and national geographic magazines available at the IGU site (www.igu-online.org). The second project, implemented jointly by Dutch and Chinese experts, on contrary, is just beginning. Its mission is to create a website on sustainable urban development, recognized by the international scientific community and practitioners of municipal government, and then to create an IGU-sponsored center for sustainable cities certification.

Special attention of the IGU Organizing and Executive Committees was directed toward youth. The Congress held the traditional International Olympiad for high school students on geography; as usual, it was well attended: 128 participants from 32 countries participated. The Olympiad program consisted of a written part, a multimedia test, and a field part. In addition, participants made poster presentations on the theme "Water Resources and Water Use Problems". The group of winners, who took the first twenty places by the total score, was dominated by students from Eastern and Central Europe, and the main prize was won by a contestant from Singapore. The winners were celebrated by high officials and all the participants at the opening ceremony of the Congress. The Russian participants were also not without rewards. The Russian team won two medals: "silver" by Maria Samoletova from St. Petersburg and "bronze" by Yegor Shustov from Slyudyanka (Irkutsk region). But most importantly, at the Olympiad, there was an atmosphere of friendship and prestige of geographical knowledge.

The Youth Forum was an important part of the program and its poster session of papers presented by young scientists was, admittedly, extremely successful. Usually, poster presentations remain on the periphery of the major events, but this time, the presentations were well attended and were often complemented with discussions in a relaxed atmosphere often resulting in the establishment of possible scientific cooperation. The Youth Forum also included interactive classes, "Science Project Management", "Thesis Work Optimization", "Publications in English: Where, When, and How", "Academic Text Art", "Collegiate Career Steps", "European Grants", "International Career Prospects for Bachelor-Students", etc.

The success of the youth programs was secured by special youth grants from the IGU and the organizers of the Congress. The program of the Congress, for the first time ever, included a special session for teachers of high school geography including discussions of issues of connecting academic research with training courses supported by federal and state ministries of education. The Organizing Committee has developed and implemented a program "IGC School – IGC in School», where a number of famous geographers gave public lectures at

At the Russian exposition of geographical literature

lycees and gymnasiums in North Rhine-Westphalia.

As usual, at the Congress, there was an exhibition of geographical literature, multimedia products, maps and atlases, which involved several major international publishers, as well as geographical societies of some countries. Russian exposition was one of the most representational. After the work of the exhibition, its materials were transferred to the University of Leibniz (Leipzig), where there is a large collection of the Russian-language scientific literature.

Concurrently with the Commissions' sessions, there were meetings of the IGU higher body – the General Assembly. The General Assembly elected President of the IGU. For the first time ever, this position is held by a representative from Russia – Professor **V.A. Kolosov**, Laboratory of Geopolitical Studies of the Institute of Geography of RAS. Previously, he served as the IGU Senior Vice-President. **This is a great success of the national academic geography and recognition of Russian geography.**

In different years, the positions of the IGU Vice Presidents were held by Academician I.P. Gerasimov, Academician V.M. Kotlyakov, and Corresponding Member of RAS N.F. Glazovskyi. This time, the presidential elections were uncontested. The precedent was set in 1996, when V.M. Kotlyakov (as the IGU Vice-President from 1988 to 1996) withdrew his candidacy in favor, in his opinion, of a more successful candidacy of a Swiss scientist – Bruno Messerli (the IGU President from 1996 to 2000).

V.P. Singh (India), **Dietrich Soyez** (Germany), **Joos Droogleever Fortuijn** (The Netherlands), and **Jarkko Saarinen** (Finland) were elected as new members of the Executive Committee and as Vice-Presidents of the IGU.

At the final meeting, it was confirmed that in the coming four years, there will be three IGU regional conferences: in Kyoto (Japan,

V.A. Kolosov – the newly elected President of the International Geographical Union

2013), in Krakow (Poland, 2014), and in Moscow (Russia, 2015); the cycle will be completed by the IGU 33rd Congress in Beijing. On the occasion of the upcoming regional conference in Moscow, the Russian delegation hosted a reception, to which the IGU President Ronald Abler (2008–2012) and other members of the IGU Executive Committee, leading geographers of the world, leaders of the national delegations, co-Chairs of the Congress Organizational Committee Frauke Kraas and Dietrich Soyez, and Counselor of the Consulate General of the Russian Federation in Bonn V.A. Pyatin were invited.

It is impossible to cover all interesting events and activities that took place during the Congress. The days in Cologne were filled not only with meetings and presentations, but also with friendly dialogue and wonderful evenings in this amazing city.

Arkady A. Tishkov,
Vladimir A. Kolosov

THE THIRD ANNUAL SCIENTIFIC ASSEMBLY OF THE ASSOCIATION OF RUSSIAN SOCIAL GEOGRAPHERS (ARGO)

On 29–30 September, 2012, in St. Petersburg, at St. Petersburg State University, a regular session of the Annual Scientific Assembly of the Association of Russian Social Geographers (ARGO) was held.

Launched in May 2010, ARGO now bands three quarters of the professional community working in the field of socio-economic geography and is represented by 28 regional offices that together cover almost all Russia's space from Kaliningrad to Vladivostok.

During the Annual ARGO Assembly held in St. Petersburg (the previous two were held in Rostov-on-Don and Kaliningrad), the international conference, "The Evolution of the Socio-Geographical Cogitation" took place, which was attended by leading Russian social geographers (including 35 Doctors of Geographical Sciences), as well as by colleagues from Belarus, the Netherlands, Lithuania, Serbia, and Ukraine. The focus of the conference were such issues as the balance of continuity and modernization in social geography, the transformation and deformation of the Russian space, as well as the prevailing variety of names of our science. Presentations of S.S. Artobolevskyi, V.L. Baburin, P.Ya. Baklanov, Yu.N. Gladkov, N.V. Kaledin, K.V. Mezentsev, A.N. Pilyasov, V.N. Streletskyi, A.I. Treyvish, G.M. Fedorov, and numerous subsequent discussions in the format of "round table" aroused lively scientific debate.

A special discussion, "Ethnogenesis as a Factor of Regional Development," was devoted to the 100th anniversary of the birth of an outstanding Russian historian, geographer, and ethnologist L.N. Gumilev. His scientific heritage and the potential of its application to understanding the post-Soviet Russia's ethnogeographical realities were the subject of presentations by A.D. Badov, D. Burneyka, N.I. Bykov, T.I. Gerasimenko, A.G. Druzhinin, V.N. Streletskyi, A.I. Chistobaev, N.A. Schitova, V.A. Shuper, etc.

At the Assembly, there was a presentation of new scientific and educational developments and publications, including the first edition of the annual "Social and Economic Geography. Bulletin of the Association of Russian Social Geographers (ARGO)" as well as the collective scientific ARGO-sponsored publication "Space of Modern Russia: Opportunities and Constraints of Development (Reflections by Social Geographers)"[1].

An important component of the Assembly was a joint meeting of the Coordination and Advisory Councils of the ARGO, where specific objectives and priorities for the future of the Association were actively discussed and identified.

Alexander G. Druzhinin

[1] Space of Modern Russia: Opportunities and Constraints of Development (Reflections by Social Geographers). Eds.: A.G. Druzhinin, V.A. Kolosov, and V.E. Shuvalov. M.: Vuzovskaya Kniga. 2012. – 336 p.

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