Issues of the territory assimilative potential and anthropogenic impact comparison

I. Belik & N. Starodubets
Department of Energy and Production Systems Economics,
Ural Federal University, Russia

Abstract

The paper aims to evaluate, using different methods, the ecological capacity of the territory and maximum anthropogenic impact that it can withstand as the result of economic activity. Timeliness of the study is determined by the need of Russia transition to the model of sustainable development. In this context, the paper examines the approaches to the estimation of the territory's maximum capacity in relation to anthropogenic impact, methods of quantitative assessments of the environmental capacity of the territory in units and in fuel equivalents (energy approach), and its correlation with the actual anthropogenic impact and energy consumption.
Keywords: assimilative potential, anthropogenic impact, greenhouse gases emissions, fuel consumption, energy efficiency.

1 Introduction

Over the past decades, the environment has experienced an unprecedented human impact. The growing impact, especially in the old-developed regions, where development traditionally was based on exploitation of the available natural assets, is causing the further accumulation of production/consumption waste and, consequently, accelerated degradation of environment and its resource components. Any increase of the current input of pollutants to environment which for decades is under negative impact will lead to the loss of sustainability and decrease of the ecosystems' assimilation capacity. At that, economic system suffers losses as well, due to both ecosystems' productivity decrease, depletion of mineral/raw material base, and growth of expenses for nature-protective measures aimed at maintaining the environment normal status.

WIT Transactions on Ecology and The Environment, Vol 190, © 2014 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/EQ140151

In other words, nowadays, the biosphere assimilation ability performs as a factor of the environment quality and territorial social/economic development preserving. In this connection researches intended to study interconnections between anthropogenic impact and the territory assimilation ability, as well as influence of this impact consequences for economic activities and population living standard acquire special significance. Within the framework of this direction the research with the objective to assess anthropogenic impact influence on the territory assimilation capacity has been conducted. To do this, comparison of territory assimilation potential with anthropogenic impact has been carried out with the use of an energetic approach through revealing threats to the assimilation capacity, as well as assessing the level and consequences of this impact.

2 Literature review

As early as in 1975 Forester pointed to the fact that "natural decay function, i.e. the amount of pollutant that environment is able to absorb without increasing the cumulating stock of damaging pollution, should be stylized in a more sophisticated way" [1]. But, in spite of the role of the territory assimilation potential as one of the most prominent ecosystem services offered by the environment, issues connected with its definition and assessment stay weakly investigated in literature on environmental economics. Nevertheless, there are some significant papers devoted to this subject-matter. Thus, Pearce and Turner define this assimilation property as the capacity of the environment "to receive a determined level of residues, to degrade them and to convert them in non-damaging and even beneficial products" [2]. Hueting thinks, that this capacity to destroy residues or to insert them in natural cycles of matter not only guarantees the protection of the ecosystem itself, it also provides society with a valuable environmental function: the sink function. Without this waste assimilative capacity of ecosystems, much greater flows of anthropogenic pollutants would affect social welfare negatively. In many cases, there exist no technological substitutes yet for this crucial ecosystem service. Hence the need to preserve this environmental function from being reduced to nil by overwhelming flows of pollutants. What's more, the degradation of the waste-assimilative capacity of an ecosystem often implies an overall reduction of the other services it provides, such as environmental amenities or biodiversity pools [3].

Leandri defines assimilative capacity as a natural resistance towards anthropogenic pollution that ecosystems display. This property allows them to keep functioning normally as long as the polluting waste they receive does not exceed a specific threshold [4].

Thus, assimilative capacity can be defined as a territory capacity to withstand some technogenic load for a long time without alteration of its structural and functional properties. At the same time it should be mentioned that this capacity is a critically important ecosystem service which require assessment and comparison with the existing anthropogenic impact.

3 Comparison of assimilative capacity and anthropogenic impact

The list of the main threats to assimilative potential (AP) from various types of human impact has been presented as a threat matrix (table 1).

Table 1: Threat matrix of assimilative potential.

Threats to AP from anthropogenic impact	Problem situation (influence upon the AP)	Influence degree*
Alienation of territories as a result of human economic activities	Replacement of natural ecosystems with technogenic systems that do not possess the natural self-restoration functions	++
Deforestation	Alteration of structural and functional properties of forest ecosystems, reducing of biodiversity	+
Catch of fish and other seafood	Alteration of structural and functional properties of aquatic ecosystems, reducing of biodiversity	+
Increase of volume of pollutants delivered to the environment	Exceeding of pollutants input over the territory assimilative capacity	++
Growth of carbon dioxide emission volume	Breaking of climate balance caused by the biota inability to assimilate and bind waste	++

* + : moderate influence on assimilative capacity
++ : strong influence on assimilative capacity

This matrix contains description of threats, consequences of their action, and degree of influence upon the assimilative potential.

From the authors' point of view, depletion of the region's assimilative potential occurs as a result of the revealed threats action; at that, the above said potential calculated value can stay relatively stable for a long period of time. Therefore, it is important to compare the existing assimilation potential with the changing anthropogenic impact in order to present information on the territory assimilative potential status. This approach is based on the condition of not exceeding of the natural systems self-restoration potential with the total anthropogenic impact.

It should be mentioned that a number of the revealed threats to the assimilative potential (alienation of territories as a result of economic activities, deforestation, catch of fish and other sea organisms, and greenhouse gases emission) is covered by the "ecological footprint" parameter.

3.1 Comparison of assimilative capacity and anthropogenic impact

The human ecological footprint reflects anthropogenic pressure on the Earth's live resources and, according to the international methodology [5], takes into account production of such resources as crops, caught fish, timber, grass used as forage, etc. According to the approach popular within the sustainable

development concept, the ecological footprint should be commensurate with the (country, region, etc.) territory and should not exceed its limits.

On the basis of the WWF method the authors have carried out an assessment of the ecological footprint for Sverdlovsk Oblast for 2006–2011 (table 2).

Table 2: Sverdlovsk oblast ecological footprint.

Indicator	2006	2007	2008	2009	2010	2011
Pasture area, thousand km^2	3.65	3.65	3.64	3.64	3.63	3.57
Forest area, thousand km^2	30.20	30.43	30.73	36.28	37.22	45.00
Arable land area, thousand km^2	20.36	20.34	20.35	20.33	20.30	20.04
Build-up area, thousand km^2	10.95	10.97	10.98	11.02	11.15	11.66
Disturbed land area, thousand km^2	0.14	0.15	0.15	0.15	0.19	0.19
Forest area necessary for CO_2 absorption, thousand km^2	615.6	666.2	657.0	615.5	609.9	606.3
TOTAL ecological footprint, thousand km^2	680.9	731.7	722.9	686.9	682.3	686.8

The ecological footprint of other countries was taken from published data [5] and is shown in table 3.

Table 3: Ecological footprint and territories of Sverdlovsk Oblast, Russia, and several other countries, 2011

Territory	Ecological footprint, thousand km^2	Territory area, thousand km^2	Ecological footprint/territory area ratio
Sverdlovsk Oblast	686.8	194.8	3.5
Russia	6 259.55	17 098.00	0.4
Germany	4 182.87	357.02	11.7
United Kingdom	2 989.26	244.8	12.2
China	29 537.76	9 599.00	3.1

Results of comparison of the ecological footprint with area of territories of Sverdlovsk Oblast, Russia and a number of countries (2011) show that the Sverdlovsk Oblast ecological footprint more than 3 times exceeds the area of administratively related territories. This indicator is higher than the average value for Russia and China and this ratio is considerably higher than for the Earth as a whole. This is evidence that Sverdlovsk Oblast, like other countries,

faces the anthropogenic impact exceeding over territory's ability for self-restoration.

3.2 An approach with the "carbon footprint" parameter application

As calculations have demonstrated, for Sverdlovsk Oblast the forest area necessary for absorption of the greenhouse gases input into the environment (about 90%) is the most part of the ecological footprint. In this connection the authors mention that the ecological footprint "carbon" component can be used for characterizing of alteration (decrease) of the territory assimilative potential resource due to the growth of threats caused by anthropogenic impact (including carbon factor). When proving this conclusion it should be noted that the greenhouse gases emissions (comprising other even more dangerous gases beside CO_2) give complete enough characteristic of the load to be affected on the environment as they reflect combined impact of all spheres of human activities including economic activities.

This point of view is supported by the direct dependence between the fossil fuel consumption volume and general level of the given territory social/economic development. There is a good reason to propose the use of a parameter which represents an absolute value of greenhouse gases absorbed by biota for assessment of the territory assimilative potential reserve.

According to data on specific absorption capacity of various territories cited in the national report [6], as well as to data on various sources of greenhouse gases (GHG) absorption in Sverdlovsk Oblast, total annual GG absorption on the Oblast territory is 19.454 million tons $CO_{2\ eqv.}$/ year (table 4).

Table 4: Sverdlovsk Oblast territory potential in terms of greenhouse gases (GHG) absorption.

Category of GHG absorption sources	Area, million hectare (RF/ Sverdlovsk Oblast)	GHG absorption in the RF, million tons of $CO_{2\ eqv.}$/ year	Specific absorption of GHG, tons of $CO_{2\ eqv}$/ hectare	GHG absorption in Sverdlovsk Oblast, million tons of $CO_{2\ eqv.}$/ year
1. Timberland				
1.1. Coniferous forest	372/7.2	565	1.5	10.8
1.2. Deciduous forest	378.5/5.6	509	1.34	7.504
2. Area of permanent plantations	1.02/0.01	4.6	4,5	0.05
3. Pasture	80.1/0.4	224	2.8	1.1
Total		1 303		19.454

Greenhouse gases emission volumes have been determined by the regional strategy data [7]; their dynamics from 2007 to 2011 is presented in table 5.

Table 5: Greenhouse gases anthropogenic emissions.

Year	2007	2008	2009	2010	2011
CO_2 emissions, thousand tons $CO_{2\ eqv/year}$	94572	93251	87439	86520	85946

Table 6 shows comparison of greenhouse gases emission and the territory absorption capacity for Sverdlovsk Oblast and a number of other countries. A territory capacity to absorb greenhouse gases calculated for other countries have been determined according to the above described approach. The data on areas of various category lands and about GHG emissions were obtained from the source [8–10].

Comparison of the greenhouse gases input volumes with the assimilative potential according to carbon footprint (the territory ability to absorb greenhouse gases) was performed with the use of indicator that was a relative value of GHG emissions to an absolute value of the greenhouse gases volume absorbed by biota. This indicator values for Sverdlovsk Oblast and several other countries for 2011 are summarized in table 6.

Table 6: Greenhouse gases emission and absorption capacity of territories of Sverdlovsk Oblast, Russia, and several other countries, 2011.

Territory	GHG emission, thousand tons $CO_{2\ eqv./}$year	Absorption capacity of a territory, thousand tons $CO_{2\ eqv./}$year	GHG emissions ratio to the territory absorption capacity
Sverdlovsk Oblast	85 946	19 454	4.4
Russia	1 608 000	1 303 000	1.2
Germany	723 000	30 343	23.8
United Kingdom	448 000	36 600	12.2
China	7 430 000	1 452 114	5.1

The outcomes received for Sverdlovsk Oblast are evidence that the greenhouse gases emission considerably (more than four times) exceed the territory biota absorption capacity.

The proposed indicator is informative enough and can be applied for more just setting of country-special quotas for GHG emissions with taking into account relative indicators instead of absolute ones. The relative indicators take into account the fuel and energy balance structure, factors of different kinds of fuel emission, and absorption capacity of the given territory.

Also the proposed indicator can be used at the regional level for estimation of the environmental threats degree and for determining of priorities in industrial policy and social/economic development of the region.

These recommendations are based on the results of analysis of threats to assimilative potential (AP) of the territory (table 1) which has shown that the most threats from the point of view of scale and intensity of effects are associated with greenhouse gases emission. Also the recommendations are based on conclusions taken from the Russian practice: this threat influence on assimilative potential are not taken into account (or are ignored) and the greenhouse gases emission indicator is not involved into formation of the region development strategic priorities.

It is important to note that the use of this indicator in the system of strategic decisions taking has one more advantage: it enables to control the GG emissions structure. At present the emissions structure in Russia is characterized by the most specific weight of power industry in the total emission; the same situation is in Sverdlovsk Oblast, too. According to the Guiding principles of national inventory of greenhouse gases by the Intergovernmental panel on climate change (2006), the "power industry" sector includes GG emissions occurring due to combustion of fossil kinds of fuel in all branches of economy.

In this connection the authors consider it more reasonable to turn to studying of the influence of such a treat as fuel/energetic resources (FER) consumption (in tons of reference fuel) on the territory assimilative potential. Besides, this parameter is being actively used in strategic development documents of many countries.

The proposal looks obvious and this is confirmed by the common opinion concerning a quantity of energy consumed on a certain territory as one of the measures of human impact on the environment. The reasons of this: first, fuel and energy complex is one of the main sources of environment pollution; second, each unit of the produced energy participates in production of commodities and services by other branches of economy, that are sources of anthropogenic impact upon the environment, too (along the production life cycle, starting from manufacturing through consumption and finishing with utilization).

The above said gives grounds to accept the "quantity of fuel/energetic resources consumed on the territory" indicator for assessment of anthropogenic impact upon the environment, while such an aggregate parameter as maximal permissible energy load (MPEL) can be considered as an equivalent of the territory assimilative potential. In this case the territory AP is a parameter equivalent to the certain amount of combusted FER which can be tolerated by the environment/economy system without any harm to their main properties.

In this case interconnection between actual (current) power consumption for the needs of economy (E_{actual}) and the calculated value of MPEL in fuel equivalents will express the state of the environment/economic system which can be expressed as follows: $E_{actual} \leq$ MPEL and their relation will be able to function as a kind of comparison standard.

To determine MPEL it is necessary to have information on the territory ability to absorb greenhouse gases. In compliance with carried out calculations, the total

annual GHG absorption by the Sverdlovsk Oblast territory with the current land categories structure is 19.454 million tons $CO_{2\ eqv.}$/ year. At that, it should be noted that during the discussed period specific GHG emissions changed insignificantly and at average were 2.3 ton of $CO_{2\ eqv.}$ per 1 ton of reference fuel. This indicator is directly connected with the territory fuel/energetic balance structure. As GHG emissions are directly dependent on the type of combusted fossil fuel and it is confirmed by the "emission factor" indicator. In this sense, the most "climatically dangerous" kind of fuel is coal followed by black oil, crude oil, and natural gas. In the case of the renewable energy (solar, wind, water, etc.) use tend to zero.

Hence, to determine MPEL of Sverdlovsk Oblast, with the stable structure of GHG emissions, it is proposed to use the specific GHG emissions indicator equal to 2.3 ton of $CO_{2\ eqv.}$ per 1 ton of reference fuel. Then, for the Sverdlovsk Oblast it will be:

$$\text{MPEL} = \frac{19{,}454 \text{ mln. tons } CO_{2\ eqv.} \text{ / year}}{2.3 \text{ ton of } CO_{2\ eqv.} \text{ per 1 ton of ref. fuel}} = 8.46 \text{ mln. tons of ref. fuel /year}$$

When applying the above approach, the "ratio of fossil fuel consumption to maximal permissible energy load" indicator was calculated for Sverdlovsk Oblast and a number of other countries for 2011. (table 7). Data on combustion of fossil fuel types and on greenhouse gases emissions were taken from [9].

Table 7: Fossil fuel consumption and MPEL of territories of Sverdlovsk Oblast, Russia and several other countries in 2011.

Territory	GHG emission, thousand tons $CO_{2\ eqv.}$/year	Fuel consumption, thousand tons of ref. fuel	GHG specific emission, ton $CO_{2\ eqv.}$/ton of ref. fuel	MPEL, thousand tons of ref. fuel	Fuel consumption to MPEL ratio
Sverdlovsk Oblast	85 946	37 400	2.30	8 460	4.4
Russia	1 608 000	719 000	2.24	582 623	1.2
Germany	723 000	311 000	2.32	13 052	23.8
United Kingdom	448 000	189 000	2.37	15 441	12.2
China	7 430 000	2 607 000	2.85	509 511	5.1

Thus, the quantity of combusted FER that can be withstood by the environment/economy system for a long time without any harm to its main properties considerably exceeds actual consumption of fossil fuel on the considered territories. The indicator numerical value coincides with the value of the indicator defined as ratio of greenhouse gases emission to the territory absorption capacity.

4 Conclusion

The proposed indicator of comparison of fuel consumption with MPEL, in the authors' opinion, can function as a warning and signal about any treats to assimilative potential. Consequently, bodies that take managerial solutions are to response to any situation change with either development of some compensatory (or other) measures or to change the development objectives. As preventive measures of strategic character the following are proposed:

1. Organization of measures aimed to raise the territory capacity to absorb greenhouse gases. Such categories of land as permanent plantations and pasture possess highest specific absorption ability, hence, it is necessary to increase this category land area to raise MPEL.
2. Change of the fuel and energy balance structure with the renewable energy sources and natural gas share increase. These changes of the territory fuel and energy balance structure will enable to make it more environmentally-friendly as chemical impact of the combusted FER on the environment will decrease, as well as greenhouse gases emissions per the used FER unit; as a result the oblast territory MPEL will increase.
3. Decrease of fossil fuel consumption growth rate; that is development and implementation of the regional energy-saving strategy with optimization of the fuel and energy balance structure. Implementation of the energy-saving strategy itself without the fuel and energy balance structure alterations may not decrease treats to assimilative potential in terms of FER consumption but it can slow down this threat growth rate.

References

[1] Forster, B., Optimal Pollution Control with a Nonconstant Exponential Rate of Decay. *Journal of Environmental Economics and Management*, **2, 1-6,** 1975.
[2] Pearce, D.W., Turner, R.K., *Economics of natural resources and the environment*, Johns Hopkins University Press: Baltimore, 1990.
[3] Hueting, R., *New Scarcity and Economic Growth*, North Holland Publishing Company: Amsterdam, New-York, Oxford, 1980.
[4] Leandri, M, The shadow price of assimilative capacity in optimal flow pollution control. *Ecological economics,* **68 (2009),** 2009.
[5] Living planet report [in Russian]; World Wildlife Fund Online. http://wwf.ru/resources/publ/book/584
[6] National report on the cadastre of anthropogenic emissions and absorption of greenhouse gases, 1990-2008 [in Russian]; FGBU "IGKE Rosgidrometa I RAN" Online. http://downloads.igce.ru/part1.pdf
[7] Anufriyev, V.P., Galenovich, A.O., Kuligin, A.P., Starodubets, N.V., *Regional strategy of low-carbon development with Sverdlovsk Oblast as an example: a monograph [in Russian],*UrFU: Ekaterinburg, 2012.
[8] OECD, http://stats.oecd.org/

[9] Enerdata, http://yearbook.enerdata.net/#CO2-emissions-data-from-fuel-combustion.html
[10] National Bureau of Statistics of China, http://www.stats.gov.cn