# ЕКОЛОГІЯ

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## APPLICATION OF ECOLOGICAL FOOTPRINT METHODOLOGY IN CONSTRUCTIVE AND GEOGRAPHICAL RESEARCH

***Н.В. Грищенко. ВИКОРИСТАННЯ МЕТОДИКИ ЕКОЛОГІЧНОГО СЛІДУ У КОНСТРУКТИВНО-ГЕОГРАФІЧНОМУ ДОСЛІДЖЕННІ.*** *У статті визначено аспекти використання методики екологічного сліду у конструктивно-географічному дослідженні задля оцінювання навантаження на навколишнє середовище в регіонах України. Проаналізовано, яким чином методологія враховує комплексність впливів на навколишнє середовище, які просторові властивості можуть бути визначені, а також яким чином екологічний слід може бути використаний у процесі прийняття рішень.*

*Дослідження складається з трьох етапів: 1) аналіз переваг та недоліків використання методології екологічного сліду; 2) розрахунок величин екологічного сліду та біологічної ємності території регіонів у 2000-2012 рр. та визначення тенденцій; 3) аналіз корисності методології для прийняття рішень.*

*У результаті, було визначено величини екологічного сліду та біологічної ємності для жителів українських регіонів, тренди зміни цих величин та обмеження щодо використання методики.*

***Ключові слова**: екологічний слід, біологічна ємність, прийняття рішень, регіон, Україна.*

***Н.В. Грищенко. ИСПОЛЬЗОВАНИЕ МЕТОДИКИ ЭКОЛОГИЧЕСКОГО СЛЕДА В КОНСТРУКТИВНО-ГЕОГРАФИЧЕСКОМ ИССЛЕДОВАНИИ.*** *В статье определены аспекты использования методики экологического следа в конструктивно-географическом исследовании для оценивания нагрузки на окружающую среду в регионах Украины. Проанализировано, каким образом методология учитывает комплексность воздействия на окружающую среду, какие пространственные свойства могут быть определены, а также каким образом экологический след может быть использован в процессе принятия решений.*

*Исследование состоит из трех этапов: 1) анализ преимуществ и недостатков использования методологии экологического следа; 2) расчет величин экологического следа и биологической ёмкости территории регионов в 2000-2012 гг. и определение тенденций; 3) анализ полезности методологии для принятия решений.*

*В результате были определены величины экологического следа и биологической ёмкости для жителей украинских регионов, тренды изменения этих величин и ограничения по использованию методики.*

***Ключевые слова:** экологический след, биологическая ёмкость, принятие решений, регион, Украина.*

**Problem statement.** As it is known, the aim of **c**onstructive and geographical research is to develop approaches and techniques useful for solving complex environmental issues. A geographer faces a few issues while studying the impact of the Ukrainian population on the natural environment. The research should consider four important aspects, namely 1) spatial aspect; 2) complexity of environmental impacts; 3) a possibility to map the results for further analysis; and 4) usefulness for making decisions.

To select and improve appropriate research methods some preliminary work should be completed, including collecting the necessary data and choosing a mapping approach.

**Research review.** In 2015, as compared to 1997, a number of scientific publications in Science Direct [1] related to the application of ecological footprint (EF) [2] as a research methodology in environmental impact assessment has increased more than 40 times. In the work [3], the importance and usability of the method in natural resources management and environmental policy were highlighted.

However, in the scientific literature the discussion about the representatives and validity of the results obtained using EF is ongoing. It is worth mentioning the criticism by J. C. J. M. Van Den Bergh and his colleagues, from 1999 in [4] and the latest publication [5] that was an answer to the points provided by M. Wackernagel [3] and A. Galli [6] which included:

1. EF is an evolving tool used for accounting population demand for Earth's natural resources and comparing that demand with the planet's capacity to generate these resources.
2. Indeed, it makes sense to calculate the indicator for geographical zones. However, this is hardly possible considering available statistical data.
3. The advantage of the methodology is the ability to consider a complex environmental impact caused by different kinds of human activity, e.g. growing plants, producing meat, emitting carbon dioxide, etc.
4. Although EF assessment is more about historical aspects than making forecasts, it allows to identify important trends and can be used in decision-making.

EF can be used for the acquisition of key competences for sustainable development [7]: system thinking, thinking about the future, learning about the key values and responsibility, understanding a

personal role in achieving sustainable development. The author has analyzed the application of the EF methodology in the Environmental management course at Kharkiv National University (see more in [8]).

Thus, the appropriateness of the methodology and its practical value is considered justified.

**The aim of this work is** to identify the vital aspects of using the ecological footprint methodology in constructive and geographical research to solve the practical problem of environmental impact assessment in Ukrainian regions.

**The scope and methodology of research.**

***The first stage*** of the current research includes some background study that was conducted to determine whether the ecological footprint (EF) methodology was useful for environmental impact assessment at the regional level in Ukraine.

The author has analyzed human and environmental risk assessment, material flow analysis, substance flow analysis, physical input-output table, ecological network analysis, and life cycle assessment methodologies popular worldwide. The comparison of the aforementioned methodologies was made by E. Loiseau, et al. in [9]. Environmental impact assessment, ecological expertise, and territorial complex system of nature conservation have also been analyzed, as they are widely used in Ukraine.

The analysis included the following criteria:

- Possibility to assess the environmental impact of a given population and its average representative on a particular territory.
- Accounting for sustainable development indicators.
- Application of the methodology on different spatial levels.
- Consideration of complex environmental impacts.

Another important aspect that was kept in mind was a possibility to use the results for educational purposes and for sharing information about the sustainable development.

***The second stage*** of research has actually been completed earlier (see works [10] and [11] for further reference): it included calculation of EF, biocapacity (BC), and ecological balance in Ukrainian regions in 2000-2012. The data for the later period of time is incomparable with the previous data because it excludes data from the temporarily occupied territory of the Autonomous Republic of the Crimea and Sevastopol city and the zone of the antiterrorist operation in Donetsk and Luhansk regions, as stated on the website of the State Statistics Service of Ukraine [12].

***The third stage*** of research was the analysis of a spatial aspect of anthropogenic impact on the natural environment in Ukrainian regions, determining the trends in changes of EF and BC, and considering the usefulness of the methodology for decision-making. The illustrations were created using MapInfo Professional 10.5.2.

***Data for the analysis.*** To obtain and analyze regional EF and BC, the data provided by the State Statistics Service of Ukraine [12] and the State Agency of Land Resources of Ukraine (now – the State Service of Ukraine for Geodesy, Cartography and Cadastre) [13] were used.

***Vital aspects of using EF in constructive and geographical research.*** As the result of a thorough analysis and literature study, EF methodology was chosen to assess the environmental impact of Ukrainian population on the regional level.

The EF considers a complex environmental impact caused by an individual's consumption of goods and services. Moreover, the EF and BC were representative and could be used to determine if the particular population consumes the natural resources and ecosystem services sustainably by calculating the Earth fullness indicator (more information about the indicator can be found here [14]). It is a ratio between the total EF of a given population and the total biocapacity of the territory where they reside in a given year.

EF is applicable on different spatial levels, e.g. it is possible to calculate the indicator for a national level, as well as for the regional level, and compare them. Such a research was conducted on national and regional levels in Ukraine in 2014 [11]. It was found out that the EF in 11 regions was higher than Ukrainian EF. Moreover, in 6 regions, mainly in Eastern Ukraine, the indicator exceeded the average value in 1, 5 – 3, 5 times.

According to the analysis, the advantages of using EF methodology are the following:

1. It can be used for local, regional, national, and global level research. The results will be comparable.
2. The results are useful for policy makers to assess the sustainability of consumption of the population (see also [15]).
3. The method is analytically sound.
4. The results are easily calculated if there is enough data (see also [16]).
5. The indicator is intelligible to the public.

Another important aspect is that the results can be used in education and for sharing information about sustainable development.

In terms of constructive and geographical research, the ecological footprint allows to account for a complex impact on the natural environment and points to the limitedness of natural resources available for the population of a given region. If the amount of available natural resources and services is

exceeded, the difference is imported from other territories, so the population becomes a recipient of natural resources and ecosystem services produced elsewhere.

**Results.** ***The features of EF calculation: spatial aspect and consideration of complex impacts.*** The methodological features of EF and BC calculation on the regional level are provided in detail in [11] and some general aspects of this research are described in [17]. Traditionally, EF indicator is calculated as a territory necessary to support a given population, it is based on the local productivity of ecosystems, as stated by D.P. van Vuuren and E.M.W. Smeets in [15]. The vital aspects worth mentioning here include the following.

First, the current system of statistical data collection lacks indicators to calculate EF of livestock products precisely.

Second, the regions that do not produce a particular kind of agricultural products are considered recipients of ecosystem services of other regions, wherein the average Ukrainian productivity in a given year is used for calculation (also mentioned in [11]). This approach was also used by A. Galli in [6].

Third, the bioproductivity of the sea is not taken into account because of lack of data, so only inner waters are considered in the EF of fishery products consumption.

Fourth, the value of BC is determined by geographical zoning in the first place. Because of the latter, the area, located in the zone of mixed and deciduous forests, has a greater potential to absorb carbon dioxide emissions. Regions of the steppe zone specialize in providing ecosystem services for the plant products cultivation, which is reflected in the structure of the biocapacity in each region.

It is also important to mention that real structure and assimilation potential of ecosystems is impossible to present using the available statistical data. The author has also kept in mind that EF presents the relative equivalent of the area that is needed to support the human population on a given territory.

***Mapping the results of the research and using them for decision-making.***

In Ukraine, anthropogenic pressure increases as well as worldwide, where EF has not exceeded BC per capita until 1970 [1], which causes environmental degradation, despite the fact that the country's population has been steadily decreasing since 1991 [12].

According to the Global Footprint Network, the population of Ukraine from 1991 to 2012 demonstrated unstable consumption in almost every year during the study, e.g. EF exceeded BC of the territory [18].

The resulting values of the EF and BC at the regional level during the period from 2000 to 2012 have been analyzed in terms of how they can be useful for monitoring the effects of environmental policy. A similar analysis, but for a global scale, was made by V. Niccolucci, et al in [19].

As a result, several trends have been obtained (See Fig. 1):

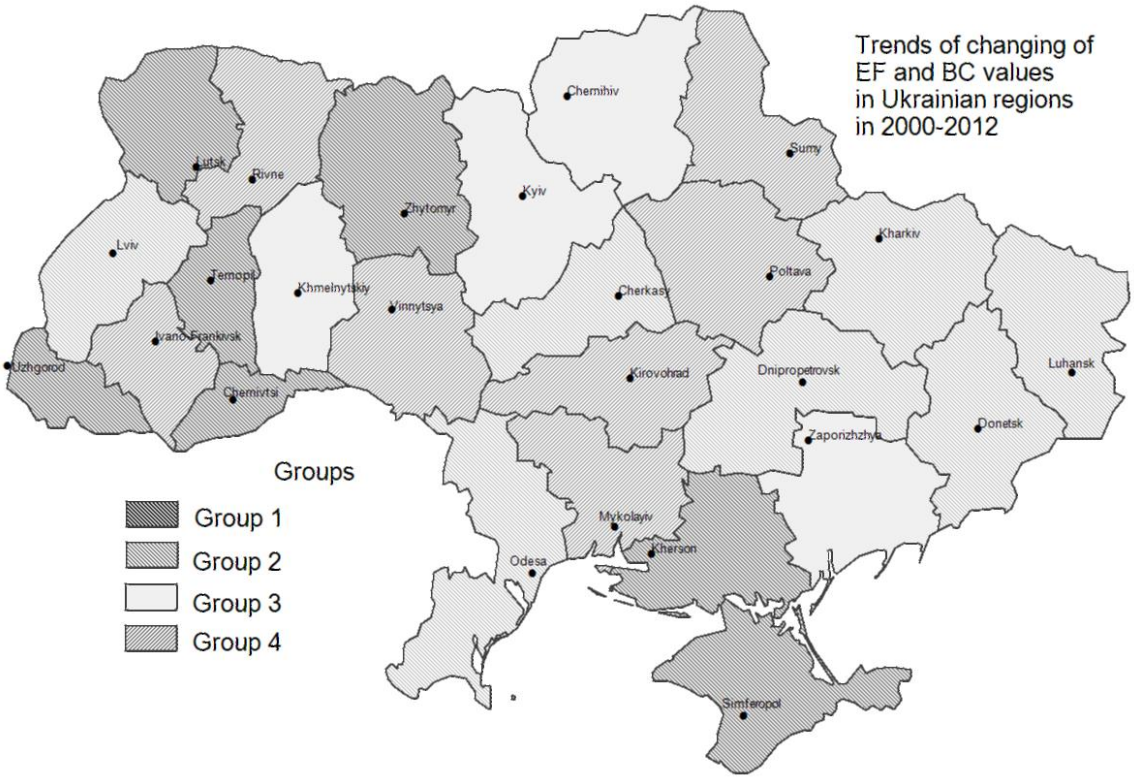
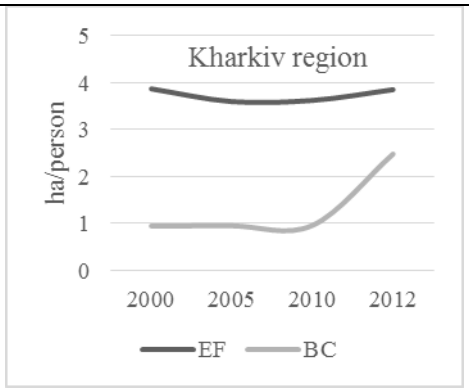
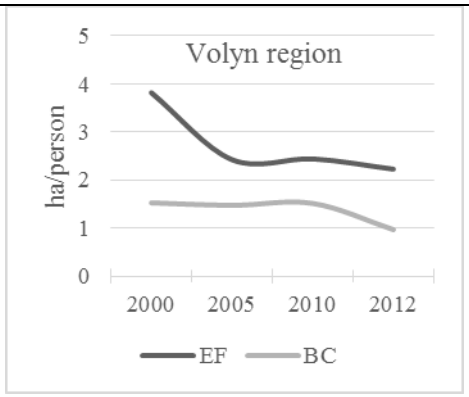
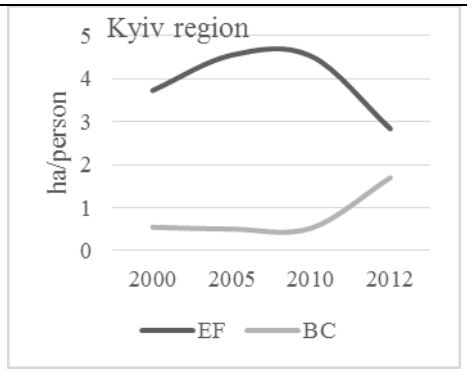
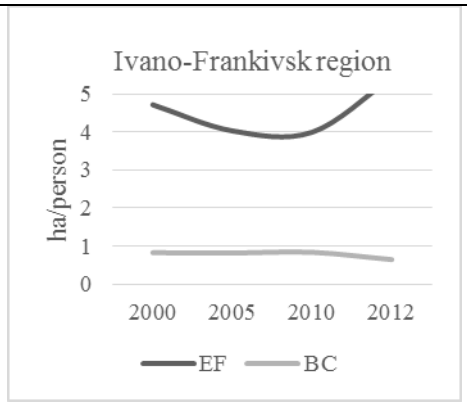



Fig. 1. Trends of ecological footprint (EF) and biocapacity (BC) change in the regions of Ukraine in 2000-2012

Legend:

| Group | Characteristics | Example |
|---|---|---|
| 1 | Both the values of the EF and BC show a tendency to increase |  |
| 2 | Both the values of the EF and BC show a downward trend |  |
| 3 | The values of the EF and BC demonstrate different trends, the EF decreases |  |
| 4 | The values of the EF and BC demonstrate different trends, the EF increases |  |

1. The values of the EF and BC have changed unidirectionally in 14 regions of Ukraine (both values increased in 7 regions).

2. The values of the EF and BC have changed in different directions: in 7 regions of Ukraine increased the value of EC, in 4 – they both reduced.

In terms of sustainable development, a desirable outcome is when EF decreases, while BC per capita increases. This is true only for 4 regions of Ukraine: Kyiv, Khmelnitsky, Chernihiv, and Zaporizhzhya regions.

In the regions where EF value decreases, the EF of fishery products consumption and the EF of livestock decreases significantly. However, carbon EF is rising and it makes up the largest share in total EF of a Ukrainian citizen.

BC grows mainly due to the increase of arable area in most regions of Ukraine, resulting in the increase of agricultural land proportion in BC structure.

The worst is the situation when BC reduces while the EF increases. This situation is typical for 7 regions: Ivano-Frankivsk, Rivne, Vinnytsya, Kirovohrad, Poltava, Mykolayiv, and Sumy regions.

The increased carbon EF is a cause of concern because Ukraine adopted objective not to exceed 60% of the 1990-year-level greenhouse gas emissions in 2030 during the 2015 United Nations Climate Change Conference in Paris in December 2015 [20].

For the decision-making in the field of regional environmental policy, it is advisable to select a group of regions where EF value is higher than the average one. Obviously, in these regions it is necessary to take action to reduce the anthropogenic pressure on the territories that produce ecosystem services.

In an earlier study [11], the grouping of the regions of Ukraine in terms of value and dynamics of EF in the period of 2000-2012 was made. As a result, two groups of regions with increased EF (13 regions) were selected and only 4 regions demonstrated a decrease of anthropogenic pressure. Additionally, EF was considered as a useful tool for environmental impact assessment, encouraging business to use environmentally safe technologies and educating responsible attitude towards the use of natural resources and ecosystem services.

**Conclusions and discussion.**

The ecological footprint methodology was useful in the current constructive and geographical research. It is one of the widely used techniques with indisputable advantages described below.

First, the results are representative and easily mapped for further analysis so that both researchers and public could understand spatial aspects of environmental impact in Ukraine. It is possible to obtain data considering the specific nature of the local population consumption patterns and the capacity of the territory to generate and regenerate natural resources and ecosystem services to procure that level of consumption.

Second, the anthropogenic pressure is evaluated at different geographical levels. It includes the combination of separate kinds of environmental impacts resulted from the consumption of natural resources and ecosystem services. The EF methodology allows considering different impacts resulted from land use, usage of water resources, and pollution.

Third, indicators of EF and BC demonstrate the limitation of natural resources and limited capacity of ecosystems to produce the required services and assimilate pollution. Calculation of ecological balance, Earth fullness, and similar indicators allows policy makers to set goals towards sustainable consumption and nature conservation.

Fourth, EF can be used during the educational process, so students will gain vital competencies, such as system thinking, critical thinking, and awareness of the role of everyone in achieving sustainable development goals.

In Ukraine, the EF methodology is not popular, although there is a potential for its application in decision-making, particularly at the regional level. The calculations can be done in local hectares that will reflect local characteristics in a clearer manner.

As a result of this research, the trends of changes in the EF and BC in the Ukrainian regions were obtained. They point to unstable consumption of the population in most regions. The nature of data values change can help the authorities and NGO representatives monitor the effectiveness of environmental policy, including the reduction of carbon EF, which is topical in terms of the commitments to reduce emissions of greenhouse gasses by 2030, undertaken by Ukraine under Paris Agreement.

The method for calculating of EF and BC at the regional level requires some improvements. It should be noted that there is a lack of regional statistics in Ukraine to compare EF and BC with the administrative units of other countries.

To sum up, the author identifies three limitations for using the EF methodology in constructive and geographical research:

1. Using the average indicators for calculation.
2. Implementing the methodology on administrative units, while background, lifestyle, pressure on the environment, and consumption patterns of residents within the region are differentiated by natural conditions and, therefore, reflected in the social behavior of people.
3. The calculation for the "average resident" without taking into account the complex structure of society, differences in lifestyle, consumption and environmental impact of people of different social classes and more.

However, understanding of these limitations gives the perspective for further development of the

EF assessment methodology that is important for Ukrainian society in the period of change.

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