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THE ECONOMIC VALUATION OF CARBON FOOTPRINT

Larysa An. NEKRASENKO[1], Olha V. PROKOPENKO[2]

[1]*Poltava State Agrarian Academy, Ukraine*
nekrasenko.la@gmail.com

[2] *Sumy State University, Ukraine; University of Economics and Humanities, Poland*
olha.w@gmail.com

Abstract. Currently, Greenhouse Gas Emissions are the main reason of the global warming threat. Carbon sequestration by the forests plays the important role in reducing CO_2 emissions. Therefore, the environmental policy of the state to reduce greenhouse gases should first of all focus on the development of forestry. But at the same time the environmental policy depends on the tax policy of the state and is significantly different in developed countries and in countries with transition economies.

Keywords*: Air pollution, carbon tax, crop rotations, environmental taxes, reforestation, sustainable development, valuation of environmental effects.*

INTRODUCTION

Relevance and statement of the problem. Mankind has always carried the changes in the environment. But today, these changes have led to the accumulation of large amounts of gaseous pollutants in the air. Some of these substances are deposited near emission sources and some are dissipated in the air and become global. One of them is carbon dioxide. It is turned out dangerous because it is spread around the world and in large quantities leads to the greenhouse effect.

One option for reducing CO_2 indicator, which would show objective reasons for the increase in carbon dioxide concentration emissions, is the treatment of industrial and transport emissions. But, in addition, the authors should not forget about the possibility of natural forests to absorb carbon from the air. Thus, the authors have come to the idea of finding the indicator which would show objective reasons for the increase of carbon dioxide concentration in the air.

The analysis of recent research and publications. The search for effective indicators has been ongoing for a long time, and today there is a wide range of indicators more or less satisfying international and regional framework. The UN Classification includes 134 indicators of sustainable development (Indicators of Sustainable Development: Guidelines and Methodologies, 2007). But they do not universal and not reflect the complex interactions between social, political, economic, and environmental issues. Nevertheless, the present research is a notable endeavour to integrate a wide range of variables in order to make information easily accessible to the understanding of the broader public and for the decision makers (Daly, & Cobb, 1989).

One example of environmental indicators is the Ecological Footprint (EF). The largest part of EF is Carbon Footprint. Thus, the authors have made the main attempt to improve the method for calculation of the Carbon Footprint.

The purpose of this article. In this paper, the authors focus on the calculation of the Carbon Footprint and on the search of the way to reduce CO_2 emissions using the reforestation in forestry and propose introducing the concept of crop rotation for carbon uptake. The authors discuss taxes as the lever to improvements of environmental management.

1. THE CARBON FOOTPRINT

It is obvious that Ukraine intends to continue using fossil fuels. According to the Statistics Department, the fuel balance of the Ukrainian economy has changed slightly in the direction of increasing the consumption of natural gas and remained relatively stable in the period from 2008 to 2012.

The Ecological Footprint is one of the most popular and well-known environmental indicators. It is a measure of human pressure on the environment in the form of territories and water areas needed for resource extraction and waste disposal.

The calculations for this indicator show that our planet is experiencing pressure from mankind. Ecological footprint conception was created in 1990 by Mathis Wackernagel and William Rees (Wackernagel & Rees, 1996).

The overall ecological footprint of Ukraine has been calculated by Kubatko in 2009 (Kubatko, 2009). But the author did not calculate the carbon footprint, fishing grounds footprint, build-up land footprint, grazing land footprint, forest and cropland footprint. Also GDP was taken as productivity and yield.

The largest part of the Ecological Footprint is comprised by Carbon Footprint. Its share is 33 % to 65 % in different countries.

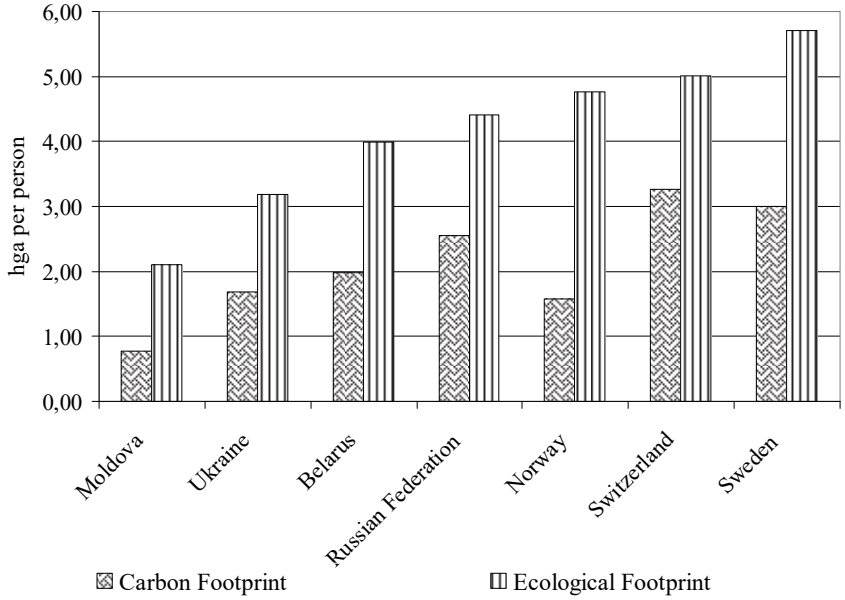

Fig. 1. Carbon component of ecological footprint (Eurostat, 2012).

Carbon Footprint is the indicator that could be used to show volumes of pollution damage which happens as a result of the use of fossil fuels to meet the needs of energy-intensive Ukrainian industry. Carbon Footprint is calculated similarly to Ecological Footprint. In the authors' previous publications (Nekrasenko, Prokopenko & Konchakovskiy, 2014), the Carbon Footprint has been calculated by the method Ecological Footprint. But this method has a lot of uncertainty and is very time-consuming. Therefore, it is not suitable for estimating the adjustment coefficient. Therefore, the authors propose considering carbon footprint in terms of environmental damage. The authors propose calculating the damage as the ratio of carbon emissions and uptake capacity of forest per year (Nekrasenko, Prokopenko, & Aranchiy, 2015).

The main natural agents to reduce the impact are coniferous forests, which absorb and accumulate carbon dioxide. To achieve ecological balance, it is necessary to increase the absorption of CO_2 through reforestation of pine forests. One reason for the decline in absorption is a decrease in forest areas that have been destroyed in the previous century. Unfortunately, more than 100 years of forest management due to a consumer approach have led to a decrease in the forest area. So far, the state of the forest industry does not meet the needs for reforestation. In order to fix the current state, forestry has to pay tax for cutting the forest area. Tax cuts can be made in case forestry plants trees that will not be cut. The areas of this forest have to compensate the cutting down of forest or destroyed forest due to other causes. This tax rate should be progressive depending on the area of cutting and high enough to motivate forestry in its decrease.

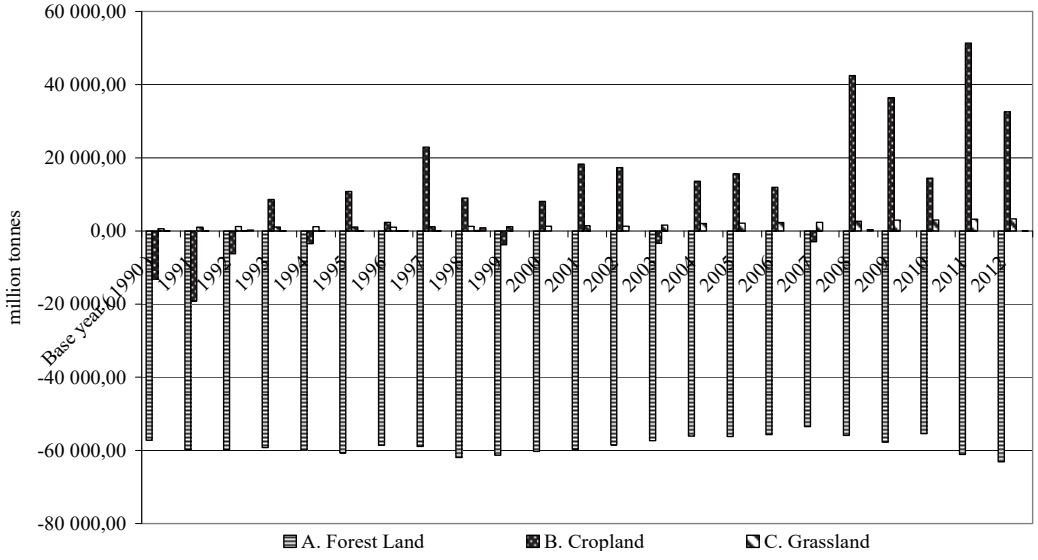

Fig. 2. Changes in carbon uptake in Ukraine (National Cadastre of anthropogenic emissions from sources and absorption of greenhouse gases absorbers in Ukraine in 1990–2012).

Also the authors have studied the relation between the yield of various crops and CO_2 absorption or excretion in Ukraine. Since 1990, there has not been observed stability in carbon dioxide sequestration in cropland. Prevalence of CO_2 excretion above absorption has been noticed.

The authors hypothesized that there was some connection between the yield of various crops and the balance of absorption/excretion. The authors explored this relationship. According to the authors' research, an econometric model of the dependence of absorption/excretion by harvesting different crops was developed.

2. METHODOLOGY

To calculate the environmental damage from carbon dioxide, the authors improved Ecological Footprint method. The authors believe it is enough to know carbon dioxide emissions, forest area and carbon absorption.

Therefore, for performing Carbon Footprint calculation in Ukraine, the authors use Equation 1:

$$CF = P_{cu}/Y_{cu}, \quad (1)$$

where

CF – Carbon Footprint in Ukraine, million ha;

P_{cu} – CO_2 emissions in Ukraine or in the region, million tonnes (National Cadastre of anthropogenic emissions from sources and absorption of greenhouse gases absorbers in Ukraine in 1990–2012, 2014);

Y_{cu} – potential of carbon sequestration by forests of Ukraine, (it is calculated as the ratio of carbon uptake U_u to the forest area S_u), t/ha, Equation 2:

$$Y_{cu} = U_u/S_u, \quad (2)$$

where U_u – carbon uptake in Ukraine, million tonnes (National Cadastre of anthropogenic emissions from sources and absorption of greenhouse gases absorbers in Ukraine in 1990–2012, 2014); S_u – forest area in Ukraine, million ha (National Cadastre of anthropogenic emissions from sources and absorption of greenhouse gases absorbers in Ukraine in 1990–2012, 2014).

Carbon Footprint is a negative indicator. Opposite to it, there is a positive index – biological capacity, which determines the ability of the environment in the respective territory to heal itself (Calculation methodology for the national footprint accounts, 2010 edition). The authors believe biocapacity (BC) of absorption is equal to the forest area S in Ukraine, Equation 3:

$$BC = S, \quad (3)$$

The difference between footprint and bio capacity shows debt or sufficiency of uptake potential, Equation 4:

$$CD = BC - CF, \quad (4)$$

where *CD* – debt of uptake potential or Net Carbon Damage, million ha.

The next stage will be the calculation of price of timber manufacture from 1 ha, Equation 5:

$$I = P_t/S_f, \quad (5)$$

where

I – price of timber manufacture from 1 ha of forest, UAN/ha;

P_t – sold products, million UAN (Ukraine in Figures in 2013, 2014);

S_f – Cutting area, million ha (National Cadastre of anthropogenic emissions from sources and absorption of greenhouse gases absorbers in Ukraine in 1990–2012, 2014).

The next step will be the calculation of cost of Carbon Footprint or the debt of uptake potential, which is related to productivity of timber manufacture, Equation 6:

$$DF = I * CF, \quad (6)$$

where

DF – cost of Carbon Footprint, UAN;

I – price of timber manufacture from 1 ha of forest, UAN/ha;

CF – cost of Carbon Footprint, million ha.

Payment for deforestation or cost of carbon uptake could be calculated as a loss of productivity of carbon uptake.

First of all, productivity of absorption of 1 hectare of land is calculated:

$$Yf = U_c/S, \quad (9)$$

where

Yf – productivity of absorption of 1 hectare of land, t / ha;

U_c – uptake, million tonnes;

S – forest area of Ukraine, million ha.

The authors calculate the price of absorption as the ratio of the revenue from sale of wood to lost absorption, UAN/t:

$$C = P_t/U_{cx}, \quad (10)$$

where

C – price of carbon uptake, UAN/t;

P_t – revenue from sale of wood, million UAN;

U_{cx} – lost absorption, million t.

The cost of lost absorption is equal to the product for absorption and debt of uptake capacity, million UAH:

$$C_u = U_{cx} * C, \quad (11)$$

where

C_u – cost of absorption, UAN;

C – price of carbon uptake, UAN/t;

U_{cx} – lost absorption, million t.

3. ESTIMATION

Ukraine is one of the world's leading CO_2 emissions. Therefore, the authors made the calculation of Carbon Footprint on the example of data of Ukrainian National Cadastre of Anthropogenic Emissions (see Table 1).

For calculations, the authors used annual emissions of CO_2, carbon uptake and forest squares, which were taken from national inventories of anthropogenic emissions in Ukraine in 2012 (National Cadastre of anthropogenic emissions from sources and absorption of greenhouse gases absorbers in Ukraine in 1990–2012, 2014).

Table 1. Calculation of Carbon Footprint of Ukraine (Nekrasenko, Prokopenko, & Aranchiy, 2015)

Parameters	Equation	2012
S_u, forest area in Ukraine, million ha*	National Cadastre of Anthropogenic Emissions in Ukraine	10.36
P_{cu}, CO_2 emissions in Ukraine, million tonnes	National Cadastre of Anthropogenic Emissions in Ukraine	302.7
U_u, carbon sequestration in Ukraine, million tonnes	Ukraine in Figures in 2013	−27.00
Y_{cu}, potential of carbon sequestration by forests in Ukraine, t/ha	$Y_{cu} = U_u/S_u$	−2.61
CF, Ukraine Carbon Footprint, million ha	$CF = P_{cu}/Y_{cu}$	−116.10
BC, absorption biological capacity, million ha	$BC = S$	10.36
CD, debt absorption capacity, million ha	$CD = BC - CF$	−105.74

The Ukrainian Carbon Footprint was −116.1 million ha in 2012. Absorption biological capacity in Ukraine was 10.36 million ha in 2012. Debt of absorption was −105.74 million ha. Next, the authors calculated the cost of Carbon Footprint (see Table 2).

* National Cadastre of anthropogenic emissions from sources and absorption of greenhouse gases absorbers in Ukraine in 1990–2012, 2014

Table 2. Calculation of Cost of Carbon Footprint (Nekrasenko, Prokopenko, & Aranchiy, 2015)

Parameters	Equation	2012
S_f, cutting area, million ha	National Cadastre of Anthropogenic Emissions in Ukraine	0.417
CD, debt of absorption, million ha	$CD = BC - CF$	−105.74
P_t, sold products, million UAN	Ukraine in Figures in 2013	5911.60
I, price of timber from 1 ha of forest, UAN/ha	$I = P_t/S_f$	14176.50
DF, cost of Carbon Footprint, million UAN	$DF = I*CD$	1499.09

Thus, the amount of tax should be increased to 1499.09 million UAN.

The share of each region in the total carbon footprint will be determined as part of a total volume of CO_2 emissions.

$$CD_n = CD_u \times \left(\frac{P_n}{P_u} \right) \qquad (12)$$

where CD_u – adjustment factor or Net Carbon Damage in Ukraine; CD_n – adjustment factor or Net Carbon Damage in the region.

The main natural agents to reduce the impact are coniferous forests. The authors calculated the payment for deforestation on the example of data of Ukrainian National Cadastre of Anthropogenic Emissions in 2012 (see Table 3). Thus, the amount of payment for deforestation should be 5911.60 million UAN.

Table 3. Calculation of Payment for Deforestation in Ukraine

Parameters	Sources / equations	2012
U_c, uptake, million tonnes	National Cadastre in Ukraine	−27.00
S, forest area in Ukraine, million ha [3]	National Cadastre in Ukraine	10.35584
S_f, cutting area, million ha	National Cadastre in Ukraine	0.417
Yf, productivity of absorption of 1 hectare of land, t / ha	$Yf = U_c/S$	−2.61
U_{cx}, lost absorption, million tonnes	$U_{cx} = Yf*S_f$	−1.09
P_t, revenue from sale of wood, million UAN	Statistic service	5911.60
C, price of carbon uptake, UAH / t	$C = P_t/U_{cx}$	−5437.39
C_u, the cost of lost absorption, million UAN	$C_u = U_{cx}*C$	5911.60

To investigate the factors that mainly affect the excretion and absorption of carbon by plants, the authors resorted to the correlation analysis. The analysis showed that the ability to release carbon plants was different and had both direct and indirect relationship with the studied factors (harvesting various cultures for years). The authors used a multiple regression analysis to examine the impact of all factors in order to determine which ones had the most impact.

The authors created a regression model:

$$Yx = 0.57x1 - 1.04x2 - 33.93x3 + 38.71x4 + 32.88x5 + 3.05x6 + 12.77x7 + 6.59x8 - 1.11x9 - 143485$$

Table 4. Correlation Analysis Results

Land Use, Land-Use Change and Forestry, Cropland	***Y***	**−143485**
Grain and leguminous crops	*x*1	0.5728949
Sugar beet (factory)	*x*2	−1.03598
Oil crops	*x*3	−33.92927
Sunflower	*x*4	38.710469
Rape	*x*5	32.884556
Potatoes	*x*6	3.0536347
Vegetables	*x*7	12.769011
Feed root crops	*x*8	6.5923682
Maize for silage, green feed	*x*9	−1.112174

According to the results of the correlation analysis (see Table 4), the authors found that the greatest positive impact on the change in the excretion of CO_2 was exerted by sunflower, rape and vegetables. The strongest feedback (i.e., an increase in absorption and a decrease in excretion) was shown by oil crops, sugar beet and maize for silage. Moreover, over the period, there was a sharp decline in the production of fodder and silage crops as well as sugar beets. Obviously, this was due to the fall of livestock cattle.

Therefore, the authors propose introducing a tax on crop rotation. It will promote change priorities in the selection of crops and reducing carbon emissions. The tax rate should be based on exceeding the permissible area of high-carbon crops.

CONCLUSION

Conclusions and directions of further scientific research are as follows. The problem of environmental pollution could be solved by:

- The reduction of greenhouse gases and other pollutants.

- Reforestation and the formation of an evergreen forest.
- Recovery of crop production, which would promote the absorption of carbon dioxide. In other words, the authors propose introducing a crop rotation for carbon uptake.
- Implementation of an improved environmental tax, which consists of a carbon tax, tax for crop rotation, payments for deforestation by forestry enterprises.
- Implementation of effective mechanisms of redistribution of environmental taxes to compensate for damage caused by pollution of carbon dioxide. It is necessary to provide compensation of fees from the citizens.

To determine the damage caused by carbon pollution, it is suggested to calculate Carbon Footprint, which will depend on two main components – the damage and the ability to quickly restore the ecological balance.

The problems of environmental management can be solved by a balanced and scientifically-based approach to the development of forestry, introducing tax on crop rotation for promote changing priorities in the selection of crops, and reducing carbon emissions.

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AUTHORS' SHORT BIOGRAPHY

Larysa An. Nekrasenko is an Associate Professor at the Department of Finance and Credit, Poltava State Agrarian Academy. She received the Ph. D. degree in 2004.

The author's major fields of study are ecological and economic security of Ukraine, economics of sustainable development, environmental taxes, carbon footprint. The current job is an Associate Professor of the Department of Finance and Credit of Poltava State Agrarian Academy, Ukraine.

The main previous articles are: Nekrasenko, L., Prokopenko, O., Konchakovskiy, Y. (2014). Carbon footprint of Ukraine, its dynamics and prediction. *International Journal "Sustainable Development"*, 19, 64–69.

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Author's contact data: orcid.org/0000-0002-2867-6139.

Olga Prokopenko, Doctor of Economics, Professor, Dean of the Faculty of Economics and Management, Head of the Department of Economic Theory, Sumy State University (Ukraine); Professor at the University of Economics and Humanities (Poland). According to the Webometrix ranking, the Faculty of Economics and Management is the best Business School in Ukraine. She has a Doctor of Science degree in Environmental Economics and Natural Environmental Protection. She is a Full Professor at the Department of Economic Theory. She is also a Professor and Head of International Scientific and Didactic Institute at the University of Economics and Humanities (Bielsko-Biala, Poland), where she has been awarded Gold Medal and Certificate of Distinguished Performance. She carries out scientific research on motivation of the innovative activities, economics of sustainable development, customers' behaviour. Her scientific research in the field of motivation of ecologization of the innovative activities was supported with the Grant of Ukrainian President and Grant of Ukrainian Cabinet of Ministers. The list of scientific research activities was carried out by request of Ukrainian and Kazakh companies. She is a founder and member of International Association of Sustainable Development in Bulgaria. She underwent training at the universities of Poland, Bulgaria and China, worked as a Visiting Professor at the universities of Poland, Belorussia, Bulgaria and China. Around 15 years, she was combining scientific work and business activity in the sphere of trade and transport logistics. She is an Editor-in-Chief of the international scientific journal "Economic Processes Management".