

THE ANALYSIS OF CARBON FOOTPRINT IN CENTRAL AND EASTERN EUROPEAN COUNTRIES

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Abstract

Carbon footprint is said to be a widely accepted indicator originating from different economic activities. Due to its important role in raising awareness of global warming, scientists and policymakers often use it as a management tool for measuring environmental degradation. In the last decade, climate change became an urgent issue in many countries and region, therefore, it is important to investigate how the carbon footprint is changed in Central and Eastern European countries. This study investigates the evolution of carbon footprint considering the role of economic development, agriculture and agricultural trade between 1961 and 2013. Data are derived from the Global Footprint Network and the World Bank. The sample includes a dataset of 13 CEE countries and 53 years period. Results indicate that carbon footprint is positively correlated with economic development, agricultural production, and agricultural trade in CEE. By contrast, their carbon footprint is negatively associated with agricultural development.

Keywords: carbon footprint, economic development, agriculture, trade, Central and Eastern Europe

1. INTRODUCTION

In the upcoming years, the world population will continue to grow increasingly, thereby increasing demand for food in the world. Jorgenson and Clark (2010) suggest that population size has a large and stable positive association with anthropogenic carbon dioxide emissions.

Furthermore, the IPCC (2014) concludes that human influence on climate change is obvious and growing impacts are observed across all over the world. The increasing amount of waste is also becoming a bigger and bigger problem in the world (Corsten et al. 2013).

Moreover, agriculture faces several challenges in order to overcome food insecurity and undernourishment (FAO 2011). However, with the intensification of agricultural activities, beyond natural source consumption, it necessarily means the utilization of new lands resulting in deforestation and even more greenhouse gas (GHG) emission.

In addition, the whole agricultural processes: the production, processing, transport and storage of agricultural products, such as most of the human activities rise greenhouse gases emissions (Steenblik and Möisé 2010).

Indeed, approximately one-third of total anthropogenic GHG emissions come from agriculture and deforestation, fertilizer use or mismanaged rangelands (FAO, 2011, Gilbert, 2012). Consequences are rising temperatures, acidifying oceans, destroying coastal reef systems on a small scale, and global warming plus climate change on a large scale (Thornton, 2012).

In the context of sustainable development and with objectives attempting to quantify GHG emissions to regulate them, the carbon footprint is a widely accepted indicator considering all GHG emissions throughout agricultural products. In spite of its raising awareness, the application and evaluation of carbon footprint for Central and Eastern European (CEE) countries (Detlef 2001, Atici 2009, Jorgenson 2011) are still underrepresented in the empirical literature.

For that reason, this paper aims to evaluate the changes of ecological and the carbon footprint in Central and Eastern Europe considering the role of economic development, agriculture and agricultural trade, for a period of 1961-2013.

2. MATERIALS AND METHODS

2.1. Materials

To find consistent indicators for assessing the environmental pollution in Central and Eastern Europe is not simple (Jahn 2001). Although there is an analysis of more complex indicators, which include many aspects of environmental pollution (Jahn 1998; Scruggs 1999), these indices are often difficult to interpret. In CEE countries environmental indicators are limited and for some countries, data are missing for several years especially for the period before 1990.

This study applies the ecological footprint that measures a country's use of cropland, forests, grazing land and fishing grounds for providing resources and absorbing carbon dioxide from burning fossil fuels. The ecological footprint and carbon footprint are strongly related to each other, in many countries and at the world level.

On one hand, the carbon footprint is often used for the amount of carbon being emitted by an activity. On the other hand, the carbon footprint is also an important component of the ecological footprint since it is one competing demand for biologically productive space (Global Footprint Network, 2018).

On average, carbon footprint represents more than 50% of the total ecological footprint in the world. Furthermore, the carbon footprint is supposed to be a widely accepted indicator of GHG intensity, originating from different economic activities (Global Footprint Network, 2018).

In this research, the applied data are derived from the online database of the Global Footprint Network (2018) and World Bank (2018) World Development Indicators. The sample includes a panel dataset of 13 CEE countries and 52 years' period.

More specifically, this research explores the evaluation of carbon footprint and its components in 13 CEE countries covering Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Moldova, Poland, Romania, Slovakia, Slovenia, and Ukraine.

2.2. Methods

The paper assesses the evaluation of the ecological and carbon footprint of CEE countries employing graphical analysis (diagrams, boxplot), descriptive statistics for data available in Global Footprint Network (2014) and correlation analysis for the determinants of carbon footprint.

According to the Global Footprint Network (2018), 'the ecological footprint is derived by tracking how much biologically productive area it takes to provide for all the competing demands of people. These demands include space for food growing, fibre production, timber regeneration, absorption of carbon dioxide emissions from fossil fuel burning, and accommodating built infrastructure'.

The ecological footprint uses yields of primary products (from cropland, forest, grazing land and fisheries) to calculate the area necessary to support a given activity. The ecological footprint (EF) calculated as follows (Global Footprint Network, 2018):

$$EF_c = EF_p + (EF_I - EF_e) \text{ where}$$

EF_c denotes ecological footprint of consumption

EF_p captures ecological footprint of production

$(EF_I - EF_e)$ capture net ecological footprint of trade

Both the ecological and carbon footprint is usually expressed in global hectares (globally comparable, standardized hectares with world average productivity).

Besides footprint measures, the study test the relation between economic development, agricultural development, agricultural trade and carbon footprint in the help of pairwise correlation coefficients. In the correlation matrix, economic development is represented by GDP (in current USD). Agricultural production proxied by crop and food production index. Agricultural development measured by agriculture value added per worker (constant 2010 USD). Finally, agricultural trade is captured by aggregated agricultural export in quantity.

3. RESULTS

The total ecological footprint, composed of 6 elements in particular: build-up land, carbon footprint, cropland, fishing grounds, forests and grazing lands. In the CEE countries, the carbon footprint has the highest share (30-40%) in the total ecological footprint followed by cropland, forest product and grazing land components (Figure 1).

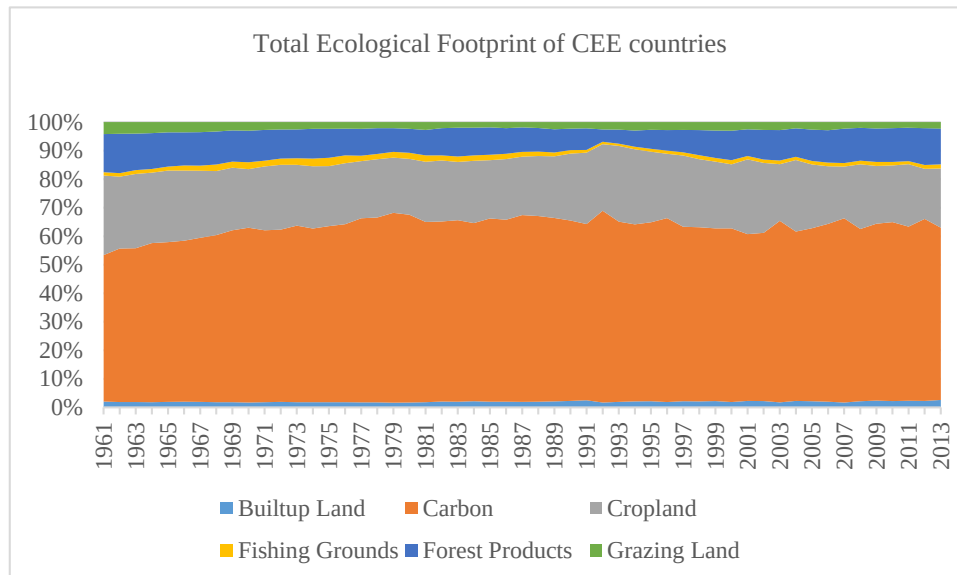


Fig. 1. Total Ecological Footprint of CEE, over time, 1961-2013, mean values in global ha

Source: Global Footprint Network (2014)

The country-level data shows that there is a huge difference among the individual CEE countries in terms of ecological footprint (Figure 2). On average, Poland, Ukraine, Romania, and the Czech Republic accounted for the highest total ecological footprint for a period of 1961-2013. The abovementioned countries were followed by Hungary and Bulgaria. The footprint of Albania, Bosnia, Moldova, Macedonia, and Croatia was the lowest.

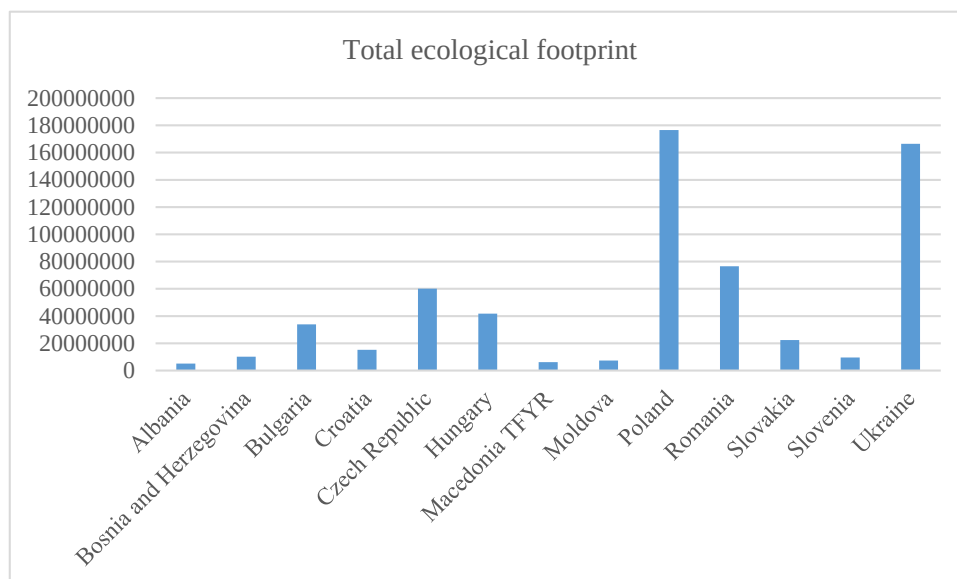


Fig. 2. Total Ecological Footprint of CEE countries, 1961-2013, mean values in global ha

Source: Global Footprint Network (2014)

Analysing the components of total ecological footprint, the carbon footprint has a higher share in the total footprint in all CEE countries analysed followed by other elements such as cropland and forest products (Figure 3).

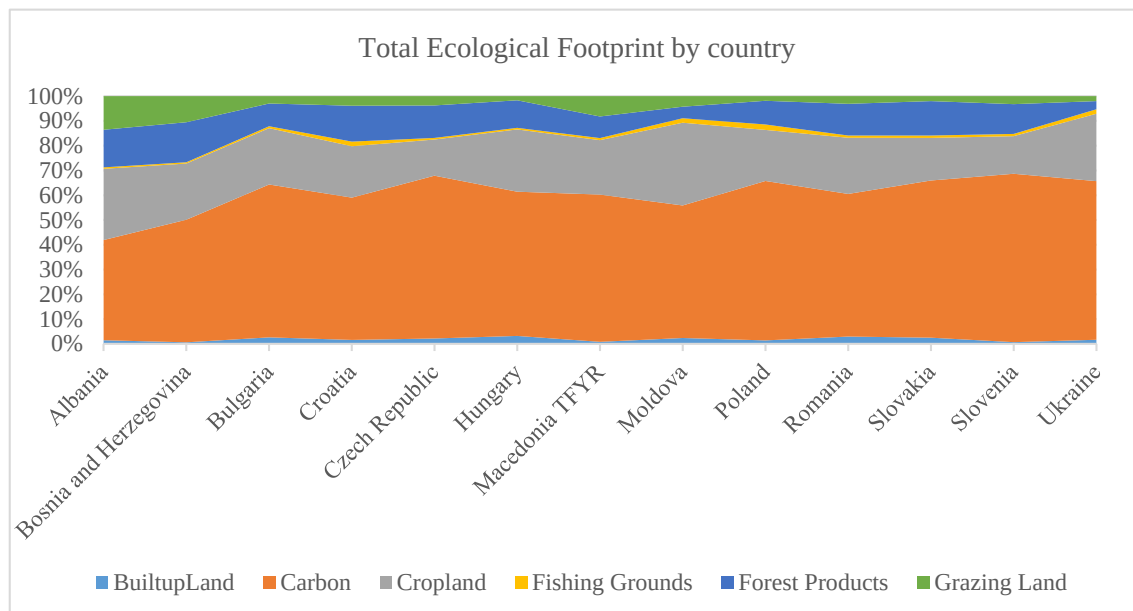


Fig. 3. Total Ecological Footprint by CEE countries and by components, 1961-2013, share in percent
Source: Global Footprint Network (2014)

Regarding the carbon footprint, Figure 4 demonstrates a diverse picture among the Central Eastern European countries. Albania had the smallest footprint with approximately 2 million gha while Poland (113,5 million gha) was in the first place. Albania together with Moldova, Macedonia and Bosnia and Herzegovina had the lowest carbon footprint during the period analysed.

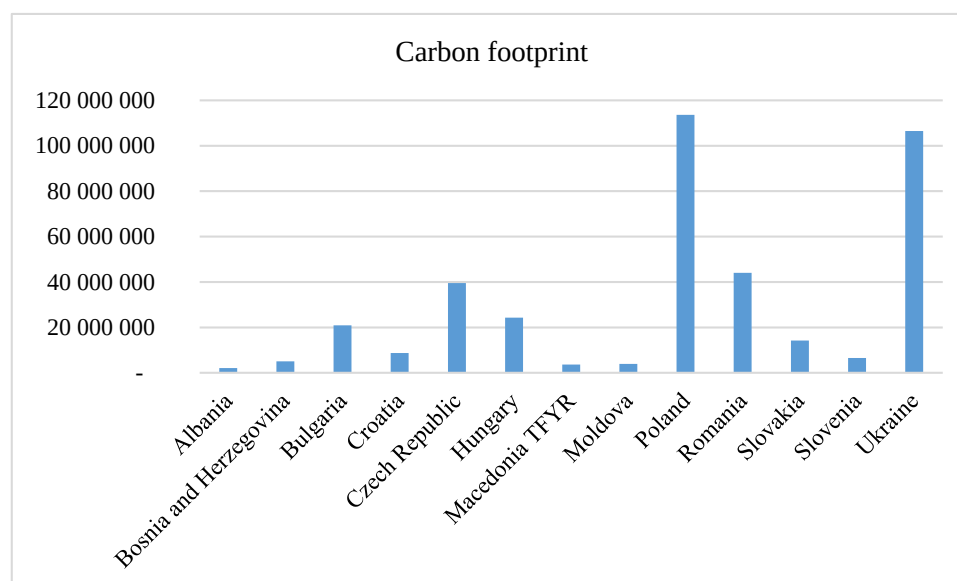
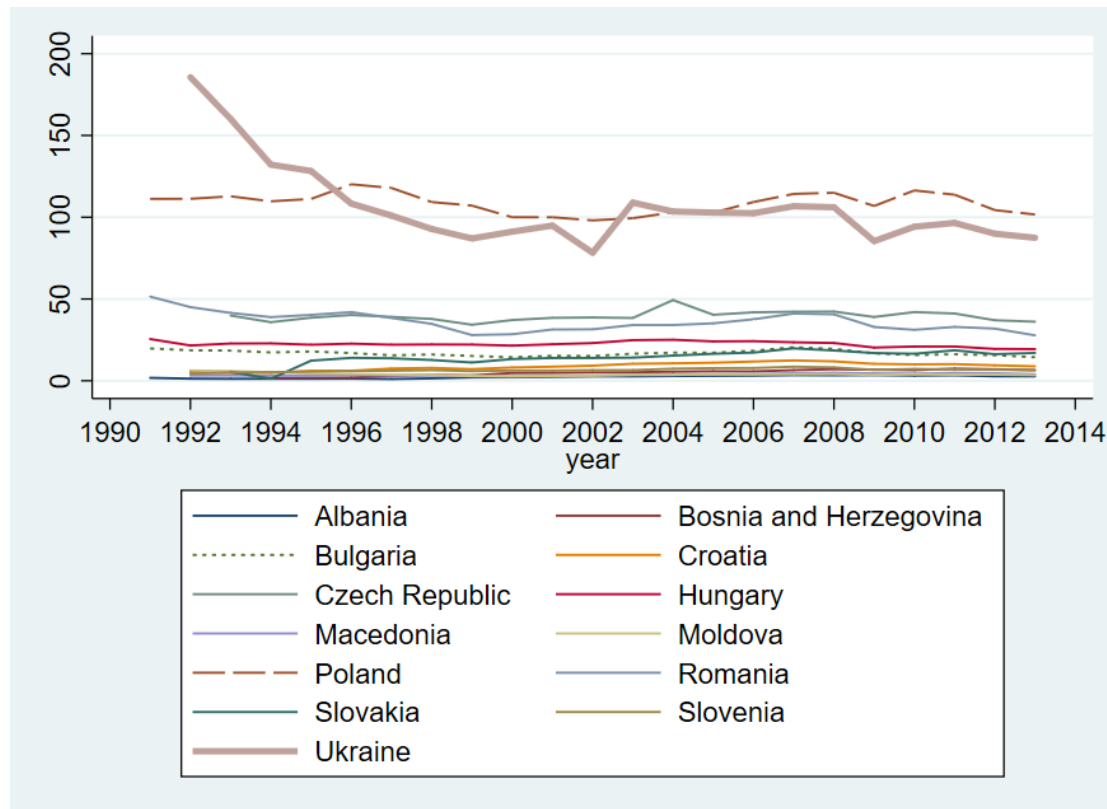


Fig. 4. Carbon Footprint by CEE countries, 1961-2013, mean values in global ha
Source: Global Footprint Network (2014)

Observing the evolution of carbon footprint for CEE countries over time, Ukraine managed to reduce its footprint the most significant way. By contrast, Ukraine and Poland still have the highest footprint compared to the other 11 CEE countries (Figure 5). Poland produced constant footprint around 100 million gha annually with only a moderate standard deviation between 1990 and 2013.



Note: Because of the lack of data for certain CEE countries for a period of 1961-1990, the graph was drawn from 1991.

Fig. 5. Evaluation of Carbon Footprint of CEE, over time, in million global ha

Source: Global Footprint Network (2014)

Figure 5 shows all the data points of the carbon footprint for CEE countries: minimum, maximum values, medians, Q1 and Q3, yearly for a given country and period (boxplot). Regarding the boxplot graphs of the carbon footprint for CEE (Figure 5), Ukraine, Poland and Romania produced the highest plots during the analyzed period. They had relatively high interquartile range (IQT) and rage (difference of its maximum and minimum values). Ukraine exhibits both lower and upper limits outside values revealing outliers for certain years. It should be noticed that the median values for Poland were higher than for Ukraine. The detailed descriptive statistics can be found in Appendix.

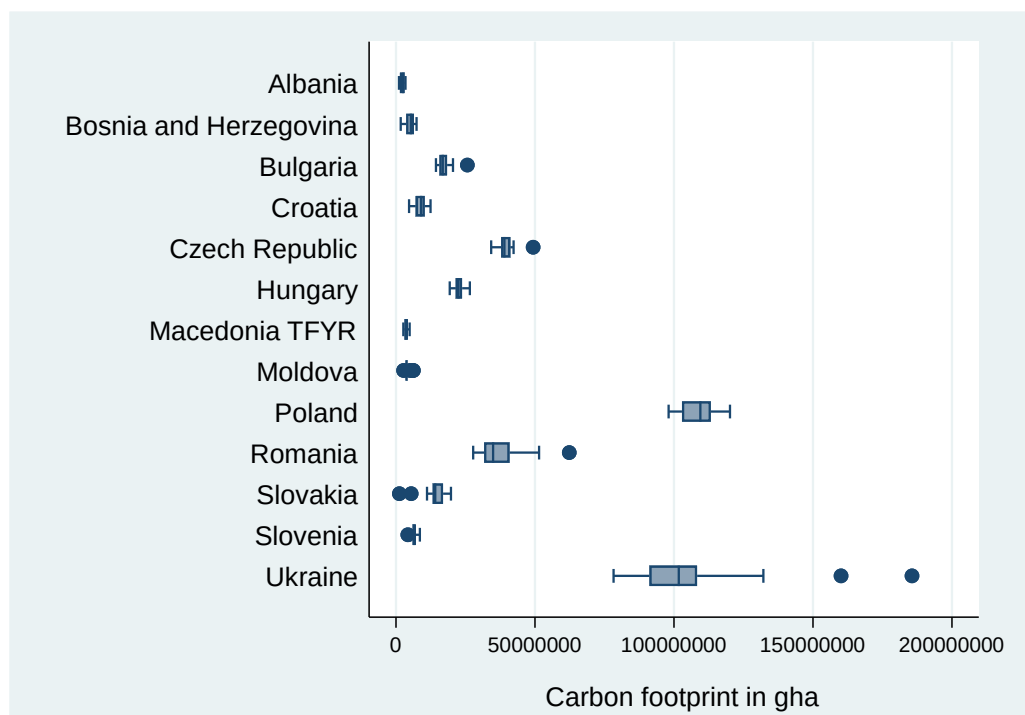


Fig. 6. Boxplot of Carbon Footprint for CEE countries, 1990-2013

Source: Global Footprint Network (2014)

Pairwise correlation coefficients of the carbon footprint for CEE countries reveal that economic growth represented by country's per capita GDP (in current USD), highly and significantly correlated ($r=0.6172$) with the carbon footprint. The significant correlation coefficient (at 5 %) suggests that agricultural production variables (crop and food production index) along with agricultural exports are positively and significantly related to carbon footprint (Table 1). By contrast, results indicate that agricultural development (agriculture value added per worker) enhance the reduction of the carbon footprint in line with the finding of Balogh and Jámor (2018). Of agricultural variables, agricultural export resulted in the highest correlation with the country's carbon footprint (0.32).

	Carbon Footprint	GDP per capita	Agriculture value added per worker	Crop production index	Food production index	Agricultural export in Quantity
Carbon Footprint	1.0000					
GDP per capita	0.6172*	1.0000				
Agriculture value added per worker	-0.2218*	-0.0688	1.0000			
Crop production index	0.2300*	0.0448	-0.0919	1.0000		
Food production index	0.1086*	-0.0086	-0.0272	0.8753*	1.0000	
Agricultural export in Quantity	0.3200*	0.2070*	-0.0863	0.2947*	0.2684*	1.0000

Note: * significance at 5 %

Table 1. Pairwise Correlation Coefficients between Components of Carbon Footprint

Source: Compiled from Global Footprint Network (2014).

4. DISCUSSION

The paper analysed the ecological and the carbon footprint in Central and Eastern Europe considering the role of economic development, agriculture and agricultural trade, between 1961 and 2013.

In sum, the carbon footprint has a higher share (30-40%) in the total ecological footprint followed by cropland, forest product and grazing land components in the CEE countries in line with global data.

Analysis of the ecological footprint shows that there is a huge difference among the Central Eastern European countries. In details, Poland, Ukraine, Romania, and the Czech Republic accounted for the highest total ecological footprint followed by Hungary and Bulgaria.

Considering the carbon footprint, Albania had the smallest footprint with approximately 2 million gha while Poland with 113,5 million gha had the highest value. All in all, Albania, Moldova, Macedonia and Bosnia and Herzegovina accounted for the lowest carbon footprint during the period analysed.

Regarding the evolution of carbon footprint over time, Ukraine was able to decrease its footprint most significantly. By contrast, Ukraine together with Poland has the highest footprint compared to the other 11 CEE countries. The boxplot diagrams presented the widest plots for Ukraine, Poland and Romania during the analyzed period. It indicates that these countries displayed relatively high IQT. Furthermore, the median values for Poland were higher than for Ukraine.

Pairwise correlation coefficients of carbon footprint revealed that economic growth highly and significantly correlated with the carbon footprint. Moreover, agricultural production and exports are positively related to the carbon footprint. By contrast, results show that the progress of agricultural development reduced the level of carbon footprint in the CEE country group.

5. CONCLUSIONS

In the last decades, Ukraine and Poland faced significant problems of environmental pollution (they had higher ecological and carbon footprint) in Central Eastern European countries. However, Ukraine significantly was able to decrease its footprint, other CEE countries were able only to maintain its previous footprint level. Ukraine together with Poland has the highest footprint compared to the other 11 CEE countries. In conclusion, these countries have to take measures in order to reduce the effect of agricultural activities on environmental degradation and to slow down environmental pollution.

The result suggests that agricultural production and trade is a significant contributor to environmental pollution in CEE countries. However, economic progress and agricultural development with innovative techniques might control the increasing ecological effects of food production and consumption.

We can mention several factors behind the relatively constant level of carbon emission in most of the CEE countries. While the connection between economic growth and environmental pollution has discontinued in highly industrialized Western European countries, by contrast, the strong interrelationship between agriculture and pollution is still held in Central Eastern Europe. Greater efforts have to be taken in order to reduce emission and pollution, especially countries out of European Union (e.g Ukraine) in order to meet the criteria of United Nation Sustainable Development Goals in the future.

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APPENDIX

Country	stat	Built-up Land	Carbon	Cropland	Fishing Grounds	Forest Products	Grazing Land
Albania	sum	3924044	109000000	77800000	1569752	41000000	36700000
	mean	74039	2063730	1468137	29618	773166	691593
	sd	34368	813228	453684	28230	416597	100061
	min	23606	761765	639841	416	73666	539288
	max	162923	3431714	2314431	97133	1335747	967927
Bosnia and Herzegovina	sum	1422923	111000000	50600000	1134934	36200000	23400000
	mean	64678	5023273	2298701	51588	1643283	1065206
	sd	9678	1753045	548045	31435	955648	248947
	min	48313	1715132	1289127	7855	17991	819978
	max	79494	7390625	3105670	107594	2684994	1859478
Bulgaria	sum	47700000	1110000000	410000000	14100000	164000000	53800000
	mean	899249	20900000	7736033	266925	3098326	1014694
	sd	183647	6030113	2120252	242565	821949	485882
	min	521150	8828748	3725822	0	1568995	571486
	max	1312726	31000000	11700000	1331871	4044532	3453089
Croatia	sum	5310278	192000000	69500000	6263487	48300000	12900000
	mean	241376	8722650	3158755	284704	2197663	585451
	sd	29647	2352069	448153	93678	615939	130283
	min	187133	4707882	2389276	148445	812485	323704
	max	302355	12400000	3994419	437437	3003219	792260
Czech Republic	sum	27200000	830000000	184000000	7607635	166000000	47100000
	mean	1296921	39500000	8771732	362268	7906809	2242705
	sd	106467	3156853	1406233	33299	1481596	712633
	min	1095703	34300000	5316047	321255	5693899	1087172
	max	1531369	49300000	11400000	439012	10700000	3273916
Hungary	sum	70900000	1290000000	557000000	13600000	246000000	37100000
	mean	1338402	24300000	10500000	256601	4642342	700603
	sd	281094	4416130	2311762	58565	968918	452126
	min	778862	14600000	4289925	152606	2601022	0
	max	1847242	32700000	15000000	397120	6505077	1688429
Macedonia	sum	1127886	80800000	29800000	1159219	11900000	11100000
	mean	51268	3671989	1354680	52692	539788	505449

	sd	5054	699004	148802	7236	157096	81457
	min	38247	2635026	961131	31707	0	337953
	max	59051	4902261	1614059	65740	734562	677299
Moldova	sum	3856779	86700000	54100000	2958069	7572994	6900861
	mean	175308	3942106	2460603	134458	344227	313676
	sd	37000	882460	703085	68501	165669	76224
	min	88407	2734558	1073731	22642	30505	185189
	max	253768	6269359	4234311	239509	856248	451535
Poland	sum	130000000	6020000000	1930000000	209000000	895000000	172000000
	mean	2454088	114000000	36400000	3944153	16900000	3246725
	sd	495823	21100000	4663030	2165932	6223065	1222468
	min	1402899	68600000	25900000	1484392	9606910	1256509
	max	3172136	152000000	45400000	9161227	30800000	5659748
Romania	sum	120000000	2330000000	920000000	37200000	518000000	126000000
	mean	2261804	44000000	17400000	701360	9772404	2382979
	sd	492462	14800000	3704787	330700	2366715	625641
	min	1291704	18400000	11400000	212526	5917703	1257512
	max	3332077	69800000	25300000	1581288	14700000	4106990
Slovakia	sum	11900000	299000000	81000000	4440299	65600000	9287231
	mean	567059	14200000	3856559	211443	3122293	442249
	sd	69241	4309781	967265	33402	806081	102444
	min	415107	1212013	1630265	172724	1971067	256779
	max	670596	19800000	5266796	282947	4846916	642288
Slovenia	sum	1493240	144000000	32100000	1879803	25400000	6822662
	mean	67875	6534590	1461297	85446	1156425	310121
	sd	7057	1023515	133233	10002	319043	77633
	min	52836	4255571	1144927	59739	359092	177793
	max	77237	8588901	1651207	99376	1637221	410106
Ukraine	sum	61200000	2340000000	997000000	65500000	122000000	73200000
	mean	2779864	107000000	45300000	2976678	5529087	3325469
	sd	554661	25300000	13600000	675992	2539923	1893522
	min	1758425	78300000	27100000	1838609	0	527376
	max	3903174	186000000	80800000	4256626	8285541	5438959