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ASSESSMENT OF COSTS ON THE ADAPTATION TO CLIMATE CHANGE IN UKRAINE

The paper focuses on the main adaptation measures financed in Ukraine at the expense of state and regional budgets region-wise during 2016-2018 within the framework of environmental activities. The source of data was "Environmental passports of the regions". The paper finds that during 2016-2018 the most funded items of expenditure were the construction and repair of sewerage, clearing of riverbeds, repair of water protection structures and wastewater treatment. A significant gap in the cost of measures of an adaptive nature between the regions is established. Expenditures in the Transcarpathian region, which most suffers from floods, were the lowest: they were 46 times lower than expenditures on adaptation measures in the Dnipropetrovsk region, which actively allocated funds for clearing riverbeds and strengthening the river banks. During 2016-2018, almost USD 110 million were proved to be spent on adaptation measures in Ukraine. The main source of funds were local budgets, in particular regional environmental funds. Green bonds are determined to become a promising source of funding for adaptation measures in Ukraine. For the first time, the amount of funds required for adaptation measures in Ukraine until 2050 has been partially estimated. It is proved that the only international funds that can provide funding for adaptation measures in Ukraine in late 2020, is the Global Environmental Facility.

Keywords: *climate change, adaptation, financing of adaptation measures, Ukraine*

Over the past hundred years, the average temperature in Ukraine has risen by almost 2°C. The consequences of climate change are becoming more frequent: in May-June 2019, floods occurred in Western Ukraine. That led to numerous casualties and economic losses in the region. The previous amount of damage caused by the latest flood is estimated at UAH 2 billion. The winter of 2019-2020 was nearly

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snowless, so the yield of almost all crops in 2020 decreased by an average of 10% compared to the previous year [1].

Losses from floods in Ukraine are estimated at UAH 900 million in 1995-1998, UAH 1.5 billion in 1999-2007, and UAH 6 billion in 2008-2010. There are other natural meteorological phenomena, such as droughts (detrimental to crop and livestock production), very strong winds, tornadoes, heavy snowfalls, etc. In our country, the climatic zones have already shifted through an average of 200-300 km in the direction of the North, which significantly affects the agriculture. In 2017, droughts affected 60% of the area under early cereals, and 50% of the area under sunflower and corn, and the moisture content in the soil with a thickness of 1 m was the lowest in the last 10 years [2].

The existence of climate change is no longer in doubt, so the need for adaptation measures is growing. Available publications in Ukraine on climate change are interdisciplinary and address a wide range of issues, such as the study of the impact of climate change on forest phytocenosis, changes in the frequency of abnormal hydro meteorological phenomena, changes in convection intensity (V. Balabukh, etc.) [3], changes in extreme temperatures (V. Babychenko, etc.) [4], changes in the precipitation regime (M. Kulbida [5], T. Adamenko [6]), etc. At the same time, the issues *of financing adaptation measures in Ukraine have not been sufficiently studied.* There are some international studies in the field of economics of adaptation to climate change. Their authors are unanimous that climate change is characterized by high uncertainty. Thus, in [7], multi-criteria analysis and cost-effectiveness analysis were studied among the methods of economic analysis of adaptation to climate change. Multi-criteria analysis has become the basis for formulating the adaptive regulatory policy of the Netherlands, and cost-effectiveness analysis is appropriate for formulating measures to be applied at the regional level. The optimal combination of structural (for example, infrastructure reform) and non-structural (for example, early warning systems) adaptation measures depends on the level of losses, discount rate, investment time, etc. [7]. With global warming rate at 3℃, the additional *annual* loss of welfare in the EU alone will be EUR 175 billion (excluding mortality – EUR 54 billion), at 2℃ – EUR 83 billion (excluding mortality – EUR 18 billion), and at 1,5℃ – EUR 42 billion (excluding mortality – EUR 6 billion). That means an additional loss of welfare due to the impact of the level of warming on the modern economy compared to the current economy (August 2020) in today's climate [8].

There are separate estimates of the cost of adaptation activities by sector. For example, the protection of coastal zones in the EU in 1998-2015 cost an average of EUR 0.88 billion per year. And it is projected that this amount will remain largely unchanged in the future (about EUR 0.85 billion per year) [9].

Unfortunately, even financing and implementation of adaptation measures will not be able to *fully* prevent human and financial losses, but will be able to reduce them [10]. And ignoring climate problems leads to significant budget losses. According to the International Bank for Reconstruction and Development, the annual

damage caused by extreme weather and climate events at the state and regional levels in Ukraine in 2000-2006 reached USD 340 million. According to Ukrainian Hydro meteorological Center (UHMC) and the Ministry of Agrarian Policy and Food of Ukraine, the annual damage from severe weather events is about USD 900 million [11]. The loss of land suitable for recreational purposes over the next 20 years in the Odessa oblast alone will lead to economic losses of USD 70 million. Rising levels of the Black and Azov Seas could lead to annual losses of USD 1 billion [12].

Existing public policies in the field of adaptation to climate change need to be comprehensive to ensure investment in adaptation measures. The costs of adaptation in Ukraine are borne not only by business but also indirectly by the state.

The **purpose** of this paper is to analyze the amount of expenditures for adaptation measures that were financed in Ukraine from the state and regional budgets during 2016-2018 in the framework of environmental activities.

For this purpose, the volumes of actual expenditures on environmental protection measures by regions in Ukraine were analyzed in detail based on information provided in the Ecological passports of the regions [13]. These passports are prepared in accordance with the Order of the Ministry of Ecology and Natural Resources of Ukraine No 150 of 31.03.2017 "On approval of the Procedure for interaction of the Ministry of Ecology and Natural Resources of Ukraine with regional, Kyiv and Sevastopol city state administrations on environmental protection". Some environmental measures are inherently adaptive. In particular, adaptation measures included such measures as clearing of riverbeds and tributaries, restoration of favorable hydrological regime of reservoirs, construction and reconstruction of sewerage, cultivation of protective forest plantations, afforestation and protection of forests, reconstruction and strengthening of dams, hydraulic and other water protection structures, strengthening the shores of reservoirs, flood protection measures, wastewater treatment, landscaping, conservation and maintenance of diversity, etc.

Ecological passports of oblasts' for 2016–2018 for most oblasts' were published on the website of the Ministry of Environmental Protection and Natural Resources of Ukraine. There are no data on Ivano-Frankivsk, Odesa, Kherson, Khmelnytsky and Chernivtsi oblasts'. For Donetsk and Transcarpathian oblasts', data are available only for 2018 and for Zhytomyr oblast for 2015-2017.

Based on the analysis, one may state that the largest expenditures on adaptation measures were made in Dnipropetrovsk, Zaporizhia, Lviv and Donetsk oblasts' (Fig. 1). As was noted, data for Donetsk oblast are available only for 2018, and the cost of adaptation measures for Donetsk oblast for one year was significantly higher than in Chernihiv, Ternopil, Rivne, Luhansk, Sumy and Transcarpathian oblasts' for three years. The difference in expenditures for adaptation measures between Dnipropetrovsk and Transcarpathian oblasts' was 46.5 times, despite the fact that Transcarpathian oblast is particularly vulnerable to floods.

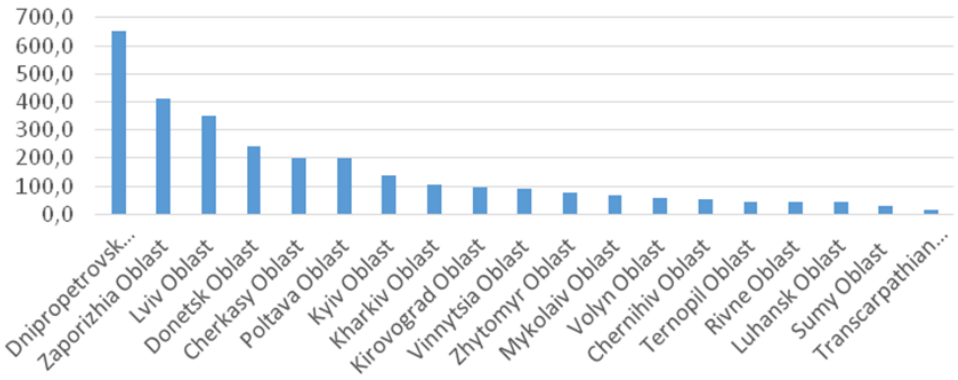

Fig. 1. Expenditures on adaptation measures by oblasts' of Ukraine in 2016–2018, *UAH million*

Source: author's own calculations based on [13].

In terms of expenditure items, the largest actual costs were directed to the construction and repair of sewers, clearing riverbeds, waterproofing and wastewater treatment (Fig. 2). In total, almost UAH 3 billion, or USD 109.5 million, was spent on environmental protection measures that can be considered adaptive during 2016-2018 (at the exchange rate of USD to UAH at 26.63 in 2016-2018. [14]). It should be noted that this is a regular necessary upgrade of sewage systems, but it is not known whether such regular upgrades took into account the significant increase in precipitation during very reduced intervals.

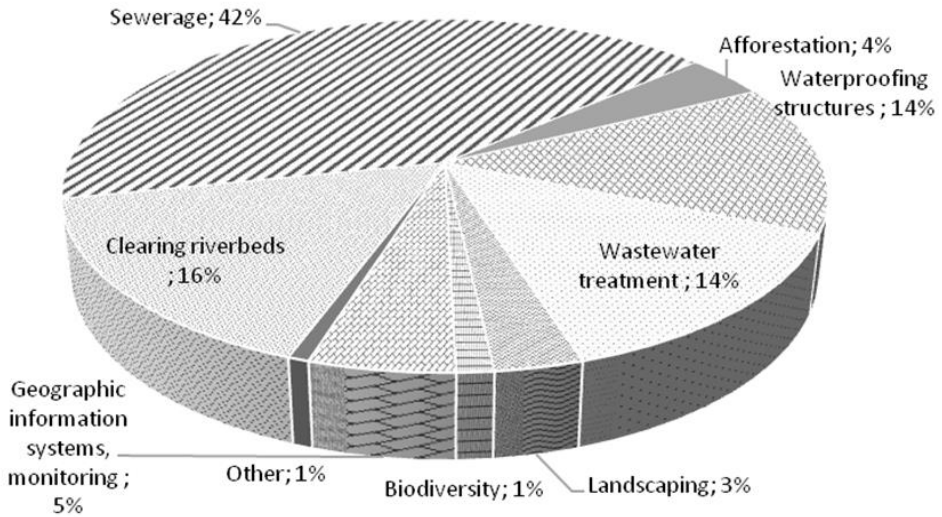

Fig. 2. Cost distribution per adaptation measure in 2016-2018, *%*

Source: author's own calculations based on [13].

Different oblasts' had different adaptation priorities taking into account the amount of resources spent that are shown in Table 1.

Table 1

List of priority costs for adaptation measures according to oblasts

Oblast	Priority
Vinnytsia	Sewerage, water protection structures, wastewater treatment
Volyn	Sewerage, wastewater treatment, water protection structures
Dnipropetrovsk	Clearing of riverbeds, water protection structures, sewerage
Donetsk	Sewerage, *landscaping, geographic information systems and monitoring*
Zhytomyr	Wastewater treatment, sewerage, water protection structures
Transcarpathian	Sewerage, water protection structures, clearing of riverbeds
Zaporizhzhia	Sewerage, wastewater treatment, water protection structures
Kyiv	Sewerage, *geographic information systems* and *monitoring*, water protection structures
Kirovograd	Wastewater treatment, sewerage, *geographic information systems* and *monitoring*
Luhansk	Sewerage, *afforestation*, water protection structures
Lviv	Sewerage, wastewater treatment, water protection structures
Mykolaiv	Sewerage, wastewater treatment, water protection structures
Poltava	Sewerage, wastewater treatment, *biodiversity*
Rivne	Sewerage, wastewater treatment, water protection structures
Sumy	Sewerage, water protection structures, clearing of riverbeds
Ternopil	Wastewater treatment, riverbed cleaning, sewerage
Kharkiv	Sewerage, wastewater treatment, riverbed clearing
Cherkasy	Sewerage, water protection structures, clearing of riverbeds
Chernihiv	Clearing of riverbeds, sewage treatment, sewerage

Source: author's own calculations.

Funding for environmental measures that are also adaptive, in 2016-2018 was provided by two funds: the State Fund for Environmental Protection and regional funds for the protection of the natural environment. It was at the expense of regional funds that the vast majority of environmental and adaptation measures were implemented. Money came to the oblast environmental protection funds partly from the environmental tax, and partly from penalties for damage caused by economic activities, as well as from targeted voluntary contributions of citizens and organizations [15]. According to the Law, "money of local… and State funds of environmental protection may be used only for financial support of environmental measures, including protection against harmful effects of water from rural settlements and agricultural lands, resource-saving measures... in compliance with… environmental safety standards ... ". Given the COVID-19 caused crisis that began in 2020, the suspension of business activities and reduced tax revenues to local budgets may negatively affect the financing of adaptation measures in 2021 and beyond. However, in 2020, legislation allowed the issue of green bonds - a type of securities issued by municipalities. These securities can be used to finance, in particular, adaptation measures [16]. During 2020-2021, Ukraine continues to develop the secondary legislation, in other words, the issuer's procedure for implementing a project, as well as

a system of tax preferences (such as exemption of investors from a number of taxes, compensation to issuers of interest rate differences when issuing bonds and exemption from taxation not only for external issuers but also for domestic ones). Relevant changes to the Tax Code are expected in 2021.

Taking into account Ukraine's limited financial capabilities, the economic recession deepened by the 2020 COVID-19 crisis, and hostilities in the country, financial assistance from international financial institutions is needed for more comprehensive adaptation measures. Seeking such assistance requires the understanding of the amount of funding that should be attracted. The costs of adaptation measures in Ukraine are extremely difficult to estimate, as these estimations have not been made before. Table 2 provides information on some adaptation measures and their costs. However, the necessary amounts need to be estimated, as this will help justify funding needs. Currently, the available data on the required amount of funding for adaptation measures in Ukraine are quite incomplete and purely fragmentary.

Table 2

Necessary costs for some adaptation measures in Ukraine by 2050

Sector	Adaptation measures	Expenditure			Source of information
		2018–2022	2030	2050	
Agriculture	Update of irrigation systems	$ 2 million	$ 3 billion		[18]
	Update of operating drainage systems		$ 694 million		[18]
	Update of non-functioning drainage systems		$ 2.5 billion		[18]
	Resource-saving agriculture (environmental agriculture)	$ 0.6 billion[2]	$ 1.8 billion[3]	$ 3.4 billion[4]	[19]
	Renovation of rural roads		$ 30.5 billion	$ 68 billion	Own estimates based on [20]
Water sector	Strengthening the shoreline of the Black and Azov Seas (construction of protective infrastructure)	$ 170–250 million			[12]
Energy	Update of the gas transmission system[5]		$ 2.19 billion		[21]
	Update of main lines of electricity transmission system [6]	$ 2.358 billion			[22]

Source: author's own calculations.

[2] If applied based on 3 million hectares.
[3] If applied based on 9 million hectares.
[4] If applied based on 17 million hectares.
[5] Regular gas transmission system update required for 2018-2027, regardless of climate change.
[6] Regular transmission system update required for 2018-2022, regardless of climate change.

To adapt agriculture to climate change and increase the productivity of agricultural production, there are three main areas of activity: research, rural roads and irrigation [17]. In Ukraine, it is necessary to expand and update the network of existing roads, as the quality of roads indirectly affects the production of crops. The availability of roads is one of the many prerequisites for reducing malnutrition in developing countries and nutrient deficiencies in the diets of less developed countries [17]. In Ukraine, there are 123 thousand km of rural roads, in other words, those that connect rural areas and cities. About 94% of roads are in poor condition and in need of renovation. According to the Target Economic Programme for the Development of Public Roads for 2018-2022, the renewal of 1 km of the road costs UAH 15 million (USD 556,000). For further calculation, we will assume that all rural roads will need to be upgraded over time due to wear and tear. About 20,000 km of roads can be repaired in four years. It will take 25 years and USD 68 billion to upgrade 123,000 km of roads.

It is necessary to constantly finance the regular renewal of the gas transmission network and the electricity transmission network. Climate change only to a limited extent directly affects the condition of these networks, but obsolete energy equipment is significantly prone to decline.

As can be seen from the Table, by 2050, it is necessary to spend USD 82.4 billion, or USD 2.5 billion on average per year on adaptation purposes, which is 6.4% of the State Budget expenditures. Some of the adaptation measures are relatively inexpensive. One of these inexpensive measures is landscaping. Table 1 above shows that landscaping has so far become a priority measure only in Donetsk oblast. Landscaping reduces the temperature of air and pavement in cities, and prevents moisture loss. This is important for Ukrainian cities, because during a few recent decades the average annual temperature of Ukrainian cities has increased by 1.2℃ compared to the climatic norm of 1961-1990 [23]. We analyzed the norms of landscaping of Ukrainian cities (Table 3). Thus, the 2001 Master Plan of Kyiv provided that the area of green public areas in the city would increase from 5289.4 hectares in 2001 to 7608.0 hectares by end of 2020, and their per capita provision would increase from 20.3 sq.m per person (in 2001) to 28.7 sq.m per person (in 2020) [24]. In 2016, the number of green areas in Kyiv was 16.5 sq.m per person. In Odessa, the territory of green areas is 5.4 thousand hectares, being the square of green areas for public use equal to 1044 hectares.

Table 3

Green areas availability in selected Ukrainian cities

City	**Standard,** *sq.m / person*	**Actual**, *sq.m / person*	**Share in total city square,** *%*
Uzhhorod	10	3	30
Kyiv	20	16.5	82.5
Lviv	17	11.2	65.9
Odesa	14.4	7.4	51.4
Average			57.45

Source: author's own calculations based on [25].

Overall share of green areas in all cities is only 17% of total urban area. In fact, there are 10 sq.m of public green areas per one urban resident as compared to the standard of 12 sq.m. (State Construction Standards 360-92**) And the World Health Organization has even 50 sq.m. per one urban resident as a necessary public health standard.

Let us calculate the necessary costs for landscaping of Ukrainian cities. We assume that Ukraine's urban population is 29.371 million people. The population provided with green areas will be 16.874 million people (29.371 million people X 57.45%). In addition, 12.497 million people (29.371 - 16.874) should be provided with green space. Based on data from Italy, Great Britain, and Iran, it can be stated that the cost of creating a city park is on average EUR 1.5 per person [26]. Therefore, an additional EUR 18 million (12.497 million people X EUR 1.5 per person) is needed to provide urban green space in Ukraine.

As mentioned above, the data presented in Table 2 are fragmentary and do not reflect the full need for adaptive finance, but give an idea of the "order of magnitude". Data on many topics, such as the necessary costs for improving the early warning system, preventing the spread of pests and pathogens in forests, maintaining and conserving biodiversity, restoring and growing forests, and many others - are still missing. A research on climate change and vulnerable sectors is needed to better assess the necessary adaptation finances. At the oblast level, it would be appropriate to prepare regional climate change adaptation strategies that would reveal the necessary priority areas for adaptation by sectors and activities in each specific oblast. In addition, to ensure funding for adaptation measures, the latter should be included in regional development plans.

Business plays an extremely important role in adaptation and climate mitigation: in agriculture, the world's leading companies already use such a financial instrument of adaptation as insurance, although there are similar examples from banking institutions operating in the Ukrainian domestic market. Agricultural production is a high-risk business as it is, and climate change exacerbates these risks even more. The insurance program "MeteoZakhyst" on the domestic market was launched by the manufacturer of plant protection and seed material Syngenta. In the future, the number of similar programs in different sectors is expected to expand.

Under the Paris Agreement, there are two main financial institutions - the Global Environment Facility (GEF) and the Green Climate Fund. Ukraine receives funding from the Global Environment Facility, which finances projects, in particular in the field of climate change. The GEF consists of implementing agencies such as the United Nations Development Programme, the United Nations Environment Program and the World Bank, as well as seven implementing organizations (the Food and Agriculture Organization of the United Nations, the United Nations Industrial Development Organization, European Bank for Reconstruction and Development and others) [27]. One of the units of this fund is the Special Climate Change Fund, which provides funding for climate projects to developing countries and economies in transition. A total of USD 14.7 million is to be provided to Ukraine under the auspices of the GEF for the needs of climate projects, of which USD 11.3 million have already

been spent. Unfortunately, Ukraine does not have access to the Green Climate Fund, as its beneficiaries are only developing countries.

In addition to funds from international financial institutions and funds, another source of funding for adaptation activities is public-private partnership (PPP), which is a long-term agreement between a private party and the state to provide a service where the private party bears significant risk and management responsibility and the reward is related to the results. These models of partnerships are still being developed and implemented in the form of pilot projects (for example, in Iceland, Sweden, Norway, Jamaica, etc.). In Ukraine, the draft State Budget of Ukraine for 2021 (as at September 2020) provides for expenditures on measures to strengthen institutional capacity for the preparation of public-private partnership projects in the amount of UAH 6.1 million.

Thus, adaptation to climate change requires significant financial resources - on average about 6.4% of the State Budget annually. In Ukraine, funds for measures that can be considered adaptive are allocated within the framework of environmental protection financing. Based on the calculations, one may state that during 2016-2018, the main priority areas for financing adaptation measures at the level of oblast were the renovation and expansion of sewerage systems, renovation of water protection structures, and wastewater treatment. At the same time, local administrations should increase funding for landscaping, afforestation, drinking water supply, as well as be prepared to increase spending on the elimination of windbreaks and other natural disasters. In the future, the need for adaptive financing will only increase, so it is necessary to understand the amount of financial resources needed so that they can be attracted from various sources - from state and local budgets, as well as from international financial institutions. Alternative fundraising tools need to be developed to fund adaptation measures, but this needs to be further explored.

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ОЦІНКА ВИТРАТ НА ЗАХОДИ З АДАПТАЦІЇ ДО ЗМІНИ КЛІМАТУ В УКРАЇНІ

У статті розглянуто основні адаптаційні заходи, профінансовані в Україні за рахунок державного та регіонального бюджетів у розрізі областей протягом 2016–2018 рр. у рамках природоохоронної діяльності. До таких заходів відносяться розчистка

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русел, приток річок; відновлення сприятливого гідрологічного режиму водойм; будівництво та реконструкція каналізації; лісорозведення; реконструкція та підтримання дамб, гідротехнічних та інших водних захисних споруд, укріплення берегів водойм, заходи захисту від підтоплення; озеленення та інші. Джерелом даних слугували "Екологічні паспорти регіонів". Встановлено, що протягом 2016–2018 рр. найбільш фінансованими статтями витрат стали будівництво та ремонт каналізації, розчистка русел річок, ремонт гідрозахисних споруд та очищення стічних вод. Визначено, що наявний значний розрив в обсягах витрат на заходи, що мають адаптаційний характер, між областями. Найменшими стали видатки Закарпатської області, яка найбільше страждає від повеней: вони у 46 разів менші, ніж видатки на адаптаційні заходи у Дніпропетровській області, яка активно виділяла кошти на розчистку русел річок та укріплення берегів водойм. Обґрунтовано, що протягом 2016–2018 рр. на заходи, що мають адаптаційний характер, в Україні було витрачено майже 110 млн дол. США. Основним джерелом коштів стали місцеві бюджети, зокрема обласні фонди охорони навколишнього природного середовища. Вперше частково оцінено обсяги коштів, необхідних для адаптаційних заходів в Україні до 2050 р. Визначено, що станом на кінець 2020 р. єдиним міжнародним фондом, що може надавати фінансування на адаптаційні заходи в Україні, є Глобальний екологічний фонд.

Ключові слова: *зміна клімату, адаптація, фінансування адаптаційних заходів, Україна*