

DOI: <https://doi.org/10.34069/AI/2022.56.08.17>

How to Cite:

Chumachenko, O., Kustovska, O., Tymoshevskiy, V., Kolhanova, I., & Kaminetska, O. (2022). Reclamation of the war affected agricultural land in east of Ukraine. *Amazonia Investiga*, 11(56), 159-168. <https://doi.org/10.34069/AI/2022.56.08.17>

Reclamation of the war affected agricultural land in east of Ukraine

Recuperación de las tierras agrícolas afectadas por la guerra en el este de Ucrania

Received: July 26, 2022

Accepted: September 5, 2022

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Abstract

One of the most critical components of Ukrainian economic complex is its agriculture. The development within the industry is generally determined by the current economy's state which is also impacted by the agricultural indicator. The research aims to study the renewal and reclamation of agricultural lands, which has deteriorated during the military operations especially in the east of Ukraine. Satellite data set was used, which was obtained based on Moderate Resolution Imaging Spectroradiometer images and covers the whole Ukraine with a spatial resolution of 232 m. The annual information on inactive and active agricultural land was then used to calculate the frequency of fallow/active land at each pixel level and to translate the subject/action series on neglect trajectories. The factors determining reclamation are related to the suitability of the land for agriculture. Accessibility to major cities was also important because most of the renewal and reclamation occurred closer to population centers, but this influence varied East of Ukraine. These factors suggest that renewal and reclamation patterns were primarily driven by

Resumen

La agricultura es tradicionalmente un componente importante del complejo económico ucraniano. Las tendencias y perspectivas de desarrollo del sector vienen determinadas por el estado general de la economía nacional, que a su vez está muy influenciado por la dinámica de los principales indicadores agrarios. La investigación tiene como objetivo estudiar la renovación y recuperación de las tierras agrícolas, que se han deteriorado durante las operaciones militares, especialmente en el este de Ucrania. Se utilizó un conjunto de datos de satélite, obtenidos a partir de imágenes del espectrorradiómetro de imágenes de resolución moderada, que cubren toda Ucrania con una resolución espacial de 232 m. La información anual sobre las tierras agrícolas inactivas y activas se utilizó para calcular la frecuencia de las tierras en barbecho/activas en cada nivel de píxel y para trasladar las series de sujetos/acciones en trayectorias de abandono. Los factores que determinan el abandono están relacionados con la idoneidad del terreno para la agricultura. La accesibilidad a las grandes ciudades también fue importante, ya que la mayor parte de la renovación y recuperación se produjo cerca de los centros de

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factors related to land productivity, with renewal and reclamation focused on the most promising sites.

Keywords: agriculture, renovation, reclamation, land improvement, farmland.

Introduction

Agricultural development determines a country's level of food security and helps identify reserves for future prosperity. Each country chooses its own style of farming and type for growing certain crops, livestock or fisheries. The question of the appropriate type of agricultural activity in rural settlements or even some areas of urban areas depends on the type of land, geographic and climatic zones, temperature regimes, and amount of rainfall. How citizens use a country's natural wealth determines the future stability of its development. Harmful ways of using land, forests, and water basins lead to catastrophic consequences.

Generating high incomes from harvesting, raising livestock or fishing is the basis of food security. Problems in the agricultural sector can lead to malnutrition, hunger, and disease among children and adults. Another aspect, the effectiveness of agricultural activities in the country indicates the level of food supply, access to foreign markets, and availability of raw materials, and resources for other industries (Czyżewski & Matuszczak, 2018; Maertens & Vande Velde, 2017). Trends and prospects for the development of the industry are determined by the general state of the national economy, which in turn is influenced by the dynamics of the main agricultural indicators. The agricultural sector of Ukraine affects the development of the world food market, especially certain sectors, in particular grain and oil, and fat (Khan & Ashfaq, 2018; Sinha, 2019). In this context, there is inevitably a contradiction between the resource potential of agricultural production in Ukraine, the needs of the domestic market, and the dynamics of world demand for food. This is especially relevant due to the fact that the current successful development of agriculture, especially in comparison with other sectors of the Ukrainian economy, has not eliminated a number of important systemic problems.

These are structural imbalances in the industry, low efficiency and provision of financial

población, pero esta influencia varió al este de Ucrania. Estos factores sugieren que los patrones de renovación y recuperación fueron impulsados principalmente por factores relacionados con la productividad de la tierra, y que la renovación y la recuperación se centraron en los lugares más prometedores.

Palabras clave: agricultura, renovación, recuperación, mejora de la tierra, tierras de cultivo.

resources (especially in comparison with developed countries), Miller et al., (2018) incomplete land reform, insufficient skills of workers, and the presence of significant environmental problems. Moreover, all this occurs against the background of a high degree of involvement of the domestic agricultural sector in the global agro-food system, the corresponding increase in their interaction in the framework of increasing global competition (Weiss, 2021). Delaying the process of solving these problems can lead to the gradual degradation of production, loss of export positions, and even a threat to national food security in the long term.

The military conflict in Donbas was a turning point for many Ukrainians, and many families who had lived and lived peacefully in the East of Ukraine were forced to migrate from their settled homes. It is painful to see the number of civilian casualties, 2,000 of which have been recorded throughout the hostilities. With the outbreak of hostilities, the recruitment of a large number of soldiers to the AFU (Armed Forces of Ukraine) began. This represents approximately 250,000 persons. Most of them have gone to defend Ukraine's territorial integrity in the East; the tragic fate has befallen many. Namely, some 24,000 people were wounded and about 10,000 people died.

During the fighting, a large number of protected areas were damaged or contaminated, which were affected by fires caused by obstetric and arson to create smoke screens.

Private-rental relations, that concerns a substantial part of land relations in the country, impose a number of special features on the system of land ownership and use, especially in Eastern Ukraine. Thus, the development of approaches for assessing the state of land and developing approaches for the effective use of land that has been damaged by the hostilities in

the region is a relevant scientific and practical task.

Theoretical Framework or Literature Review

The various approaches in agricultural development research can be divided into several groups:

1. Approach devoted to the efficiency of agricultural production in general. Mosavi et al. (2020), see the efficiency of agriculture as an increase in agricultural production or income at minimum material and financial costs, but with multiple use of land, labor, material, and technical resources (Mosavi et al., 2020). The authors study such indicators as the area of agricultural land and the productivity of various types of crops, and vegetables, the results of dairy and poultry farms, and the dynamics of their profitability.
2. A comparative analysis of the effectiveness of public administration of agriculture in Ukraine and the European Union (EU) (Miller et al., 2018). Miller et al. (2018) investigated trends in financial support, sources of transfers to Ukraine and the EU, the growth rate of public services, the structure of spending on public services, and trends in customer support. The authors point out the differences in agricultural support that exist between Ukraine and the EU.
3. Presentations of quantitative analysis. For example, some foreign researchers investigated how farmers' readiness, advantages, specifics of their activity, size of farmland, remoteness from urban settlements, and the number of family members of the farmer influence the efficiency of cooperation and income growth in agriculture (Weiss, 2021).
4. Econometric models. Mosavi et al. (2020) used econometric models to study the profitability of small and medium enterprises over a long period (Mosavi et al., 2020). They analyzed accounts receivable, accounts payable, inventories, cash conversion cycle, and firm profitability, and then constructed a multivariate regression model. They presented the results of a correlation analysis between working capital and profitability of countless Spanish manufacturing firms.

A similar approach is demonstrated by Van Es & Woodard (2017) who considered the problem of the lack of technology that could ensure both

environmental safety and agricultural growth at the same time (Van Es & Woodard, 2017).

Quinton et al. (2018) believe that depressions in agriculture lead to threats to a country's economic sustainability and food security (Quinton et al., 2018).

Thus, in various scientific conclusions, they pointed to the need to turn "traditional agriculture towards agroecology," which can prevent not only food shortages or economic crisis, but also ensure environmental sustainability (Menne, 2017). This approach changes the understanding of the goals of agriculture. The term agroecology means that agriculture should not only be for the consumption of financial transfers or the use of its products by other industries but also should not be harmful to the environment. This is the mainstream in recent research abroad.

The purpose of the study is to examine the renewal and reclamation of agricultural land, the condition of which has deteriorated during the hostilities in East Ukraine.

Methodology

Maps of recultivation

Satellite dataset 10, was obtained from MODIS. This satellite is used for covers and pictures that are obtained from Ukraine with a resolution of 230 m. The "MODIS Normalized Difference Vegetation Index (NDVI)" time series was classified into active agricultural lands (i.e., with active vegetation layer) for each year from 2010 to 2021 with a 90% accuracy, estimated from independent verification data. Annual inactive and active farmland information was then used to calculate the frequency of fallow/active land at each pixel level and to translate the subject/active series into neglect and reclamation trajectories (Abdulfatah et al., 2017). Data collected from the following mods: MCD12Q2 Version 6 (Gray et al., 2019). (From where you collected satellite data); MCD12Q2 Version 6.1 (Gray et al., 2020). Visual analysis of this dataset showed sites with no evidence of management over 12 years (consistently fallow (Abdulfatah et al., 2017). Some of this land was used during the Soviet era, such as for cattle grazing. However, the conversion of meadows along rivers to cropland is highly unlikely, and so we excluded these areas from our analysis. The final data set consisted of 462420 hectares of agricultural land.

The available land use/land cover dataset covers a period of 12 years. We took the period of 2017-

2021 for analysis, since at that time reclamation became the dominant process of land change in Ukraine. In order to clarify the effect of reclamation, an analysis of images over several previous years is necessary (Abdulfatah et al., 2017). Given that any of the crop rotation systems in Ukraine provide for a fallow period of more than 5 years, we defined these plots as “neglected” during 2010-2016. Three binary datasets were created, one for each reclamation definition, which were subsequently used as

dependent variables in our models.

Explanatory variables

The highly emphasized level shows that there is reliable arithmetical data in Ukraine, especially at the district level. There are 490 districts in Ukraine. In this paper, we analyzed the Eastern region of Ukraine, where the hostilities are taking place. Eastern Ukraine belongs to the steppe zone (Figure 1, III).

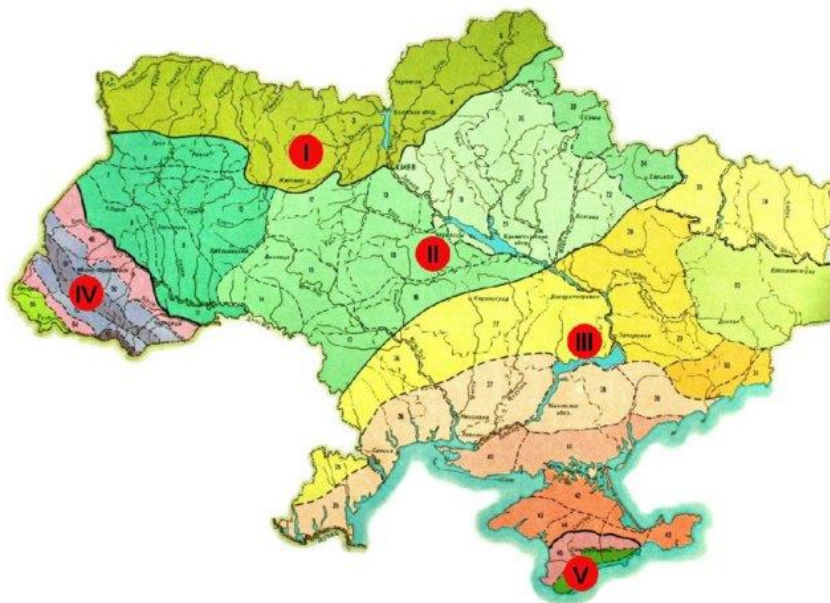


Figure 1. Ukraine Geographical Regions (The continuous line highlights the limitations in zone) (Obtained form: *National atlas of Ukraine*, by L. Rudenko, 2007). I—"Mixed Coniferous zone with forests with broad leaves", II—"the forest step zone", III—"steppe zone", IV—the "Ukrainian Carpathians", V—"Crimean Mountains"

To relate district-level statistics to other datasets, we used Euro-geographics (EuroGeographics, 2022a) district boundaries, which were manually verified and, if necessary, enhanced through the Ukrainian boundaries that are present and viewed from the Ukraine map (State Service of Ukraine for geodesy, cartography and cadastre (n.d.)).

The raster format's variables were highlighted with their separate resolution that is visible on the maps. The variables that were biophysically related to the terrain's slope and elevation were received from the 4th version of the SRTM or the Shuttle Radar Topography Mission (Maertens & Vande Velde, 2017). The model consisted of two variables that allowed for the reflection of patterns of climate which helped in the testing of average daily temperatures that were found to be above 5 degrees. These were obtained at a 1 km resection calculated from the global climate data. (Are et al., 2018). The ratio of annual

precipitation to evapotranspiration helped in identifying the global rigidity index through the process of soil data being obtained from 1 km resolution which represented the topsoil pH under 30cm of layer (Borelli et al., 2019, Carter et al., 2017).

Multiple variables for accessibility were used to assess and determine the regional and local markets along with expenses of facilities and costs of transportation. The lack of official information about networks of roads and boundaries of settlements lead the researchers to extract data from multiple web resources such as Euro geographics (EuroGeographics, 2022b). The Euclidean distance was then calculated between each avocation and its nearest settlement. The largest city had a population of over 50,000 and had paved roads. The distance calculated from the forest makes to the closes edge was attained through GlobCORINE

landscape map (Catacutan et al., 2018). Therefore, this value was then used as an indication of the marginality of ecology pertained to the locale of agriculture and its relative accessibility. Furthermore, the value is also a reflection of used land history as the forests were converted to agricultural areas recently which changed the landscape.

To be used as a reflection of demographical conditions, the rural population's average density was used as well as the changes in population between 2010 and 2016. This excluded larger cities with over 50,000 population. The ratio of dependency along with the portion of the employed and registered population where the individual was over 65 years of age or under 15 was then included in the assessment of the availability of labor (Smaliychuk et al., 2016). The effect of management of agriculture was assessed on district level data and states which were collected from 2001 to 2006 in yields of grain. Other indicators were the usage of fertilizers, and mechanization levels such as the number of harvesters and tractors (Smaliychuk et al., 2016).

The statistics about Ukrainian agriculture are rather lacking when it comes to farms and the only official data is held by registered agricultural entities which comprises societies, operations, joint stock companies, and farms. The number of farms and the area cultivated have seen no change as they only occupy 15% of the study area (Smaliychuk et al., 2016). Several covariates were inserted into the stream to reduce the model's complexity and enhance its readability. The act of determining the final variables requires multicollinearity and statistical analysis. The variables were estimated using a Pearson correlation value and if any greater than 0.5 were retained then the verifiable showed that there was a higher level of correlation with the dependent value. These descriptive statistics allow for influencing the variables and provide a wide array of information which can also be found in Table 2 as per the analysis.

Regression Setup and Design of Sampling

The process involved the evaluation of different models as per the reclamation definition (Table 1). Furthermore, the model estimation of Ukraine was kept separate from the models of Eastern Ukraine. Therefore, six models of regression were estimated along with a further 3 for separate ecological areas. Three models of Ukraine were also used and observations were made only regarding the agricultural land that was unused

between the time of 2010 and 2016 (Abdulfatah et al. (2017)). The reclamation that took place from 2017 to 2021 was considered regarding the observations that we used as code 1 and the farmland that was not used between 2017 and 2021 was code 0.

To lessen the impact of autocorrelation, the observations were made using 500m of spacing thus resulting in a 16% reduction in the accuracy of the dataset. These steps ultimately lessened the observation number to 169387. Then finally the sampled observations were put in the ecological areas and global models were selected in correlation to the reclamation of ecological areas.

Regression Trees Boost

BRTs or boosted regression trees are often made use of within a framework of regression allowing for a nonparametric method (Chausson et al., 2020). This method can view the relationships which are complex and not linear between predicting and relevant variables (Cohen-Shacham et al., 2019). The general thought behind the boosting processes is the combination of various weak models into an entity that will enhance performance (Are et al., 2018). BRTs involve decision trees that highlight the different variances of the values by dividing the space in a fashion reminiscent of binary numbers. The minimization of enhancement allows for the functional loss in the decision trees by adding new decision trees and the existing trees remain unmodified. This allows the values to be estimated. The loss observed is the highest in the first tree while the other trees that come next focus on the previous model to fit themselves thereby resulting in an enhancement of the prediction variables. (Are et al., 2018).

Boosted trees are not used to rebuild data rather they create links between the missing information and the predictors that are used in relationships and interactions (Corwin & Scudiero, 2019). Making sure the BRT works perfectly, requires various parameters that are used in calibration. They include tree complexity, package fraction, a large number of trees as well as the learning rate. The determination of the batch fraction comes from the samples that fit each model (Are et al., 2018). A fraction of 0.5 was made use of in the division to get observations for 10000 models as well as the test and training samples. The test also led to the testing of other parameters such as the cross-evaluation to assess the parameter settings as well as different measures. The interaction level, therefore, was chosen at a rate of 0.01 followed

by a level of 4. The Para terms are then used to evaluate the number of trees required for the best prediction in the dismo package (Diop et al., 2018).

Results and Discussion

The overall areas for the study are differentiated based on the concept of renovation provided in Table 1 as well as the 170,000 ha from the exclusive definition of cultivation that has been going on for the last 5 years. The 445100 ha for the last 6 years of cultivation is the intermediate definition while the comprehensive one is 987800 ha. The place of the farmland that was abandoned also majorly varies as they are between different ecological zones. The rates of reclamation were found to be the highest in the steep zone which was around 52%.

The linearity analysis of the variables that explain the phenomenon highlights that a major relation of 0.5 Pearson is present. The Drought Index along with the population, change, the yield of grain, and other variables acted as the final values that predict the results of the study. The reclamation methods and their drivers highlighted the variables of accessibility that allowed for the overall annual amount of above 5-degree temperatures which contributes to the performance of the model. The management of agriculture is another set of explanatory variables. The most explanatory power in the models goes towards availability and temperature. Other variables such as the mechanization level, employment, as well as slope have major impacts on the steppe only. Dependency ratios along with topsoil pH and organic and mineral fertilizer application did not see a major contribution to the overall variable and thus these variables had fewer significances and varied less than they were expected to. In the steppe model as well as the global model the overall distance contribution from the edge sees a decline from inclusive reclamation. The decline is from 23% to 16% however the temperature's influence and impact increased from 9.7% to 10.3%. Other variables that factor influence involve unemployment rate, slope, and the nearest town is all seen to be stable in all the different definitions of reclamation. The AUC and accuracy of prediction in the global models show an increase to 0.83 from 0.76 and 0.96 from 0.86 respectively for exceptional reclamation. The performance increase is observed in the steep model and they were far less emphasized than the global ones. But these models also showed the highest amount of positive prediction as visible in Table 4. All the models are similar such that

their distance to the edge effect lies on the reclamation of probability. The treatment probability saw a sharp rise as the distance from the edge function increased however it came to a halt at the 5km mark which is also the 10km mark in the steppe model. The distance to the edge effect was the most profound in the steep model and then the global model followed by forest-steppe and mixed forest respectively.

Other variables about accessibility had significantly less power of explanation such as distance to population centers. The nearest major towns and cities variables had little to no impact on the reclamation in the models. Furthermore, the high probability observed of reclamation within the distance to identified areas within Ukrainian agricultural land shows that the paved roads and settlements are crucially important in the steppe models. The daily temperature increases above 5 degrees also impacted reclamation in these models. The abandoned agricultural areas and their reclamation can serve as a viable opportunity to expand the farm area to enhance the ecosystem (Frątczak et al., 2019). The problem however remains that the determinants of relation such as spatial patterns are not understood by any. The overall evaluation showcases that reclamation and renewal is a major trend in Ukrainian rural areas due to the absurd prices of products and agricultural foods in the last decade. The high prices have led to a major investment in agriculture in Ukraine.

Eastern Ukraine had seen a large amount of reclamation of up to 50% of all agricultural land. The reclamation patterns in this study mainly showcase the factors and reasons that contribute to product-based agriculture. The reclamation probability highlights that the projections showcase the high potential for further expansion in Eastern Ukraine in agriculture. The red zone areas of reclamation are land that is free for use and due to the ideal conditions, it is becoming less and less available (Daryanto et al., 2018). The agricultural areas that are abandoned are being reclaimed at a high speed as it leads to a major increase in the production of agriculture. This research can act as a starting point to understanding their tradeoffs within the environment.

The unused agricultural land and its plots have led to the attraction of foreign and domestic interest in agriculture. The holdings of agriculture emerged in the early 2000s when there was a reform after the post-Soviet control of Ukraine. The agricultural lands and the sectors allowed for the possibility to distribute and

divide these plots of land to farm owners and leased them to generate profit from the production of agriculture due to the reduction in costs of raw materials. Other aspects included access to loans as well as tax and farming incentives that the government implemented to encourage the cultivation and reclamation of agricultural lands (Gunawardana et al., 2018). The assessment highlights that Ukraine's eastern regions do not have enough quality for abandoned agricultural and reclamation and land areas can be found elsewhere.

During the evaluation of the reclaimed, area it is vital to note that the reclamation hotspots and the spatial structure varied greatly. The analysis highlighted large urban centers in the steppe area where reclamation spots were found. These hotspots can be explained by four different factors. The first is the growing demand and need for agricultural products which require an urban population for storage and transportation (Dorondel & Serban, 2022). The second is the presence of necessary people and personnel for the maintenance of agricultural holdings along with land (Gatto et al., 2019).

The regression models showcase the patterns of spatial differentiation where reclamation is assessed by the agroecological conditions as well as their accessibility of them. The distance and temperature to the closest jungle places have a considerable impact on the reclamation probably as they happen more often in places where temperatures are high. The overall suitability of a given area is emphasized by the ground available for agriculture, as well as the forest distance to the nearest place of settlement which is also connected to higher reclamation possibility (Frątczak et al., 2019). The same can be said for cities that are near the steppe zone. The steppe has recorded high temperatures that are connected with the change in the climate. This leads to moisture in the soil and the requirement for more water for the crops (Alarcón & Arias, 2019). A suggestion can be made that the balance of water in the steppe is necessary for the reclamation of the area. The results showcase that remote areas are much more feasible for raw material purchase and selling agricultural products. There are far better opportunities and chances to make a profit and a return on investment for decision-makers. Therefore, it leads to reason that such policies about agriculture need to be targeted towards areas that have positive conditions for sustaining agriculture. These policies can thus promote the sustainability of the environment through afforestation and other farmland cultivation.

The results match up with the factors that were evaluated for the abandonment of agriculture in the Soviet Union and eastern Europe. These agroecological conditions, even though are marginal, yet they are very unfavorable for the key determinants that highlight similar neglect patterns (van Asseldonk et al., 2018). The results highlighted that the best lands out of the available ones were those that were reclaimed earlier. However, the level of neglect among the land divided by regions and countries was also a critical factor along with the agroecological conditions that are often overlooked by the more institutional and macroeconomic effects. These include land reforms, reorganization of lands as well as economic state and support. Other miscellaneous variables include farmer skills and farming structure (Blazquez et al., 2018).

By unitizing the global models that aim to highlight reclamation, the steppe zone has the vastest expansion of cropland along with better soils that take precedence over the neglected parts. Even though there are frequent droughts within the last few years, the models suggest that the infrastructure is improved and the steppe zone has vital constraints that are used to farming the region, therefore, enhancing the investment opportunities there. A large scale of forestation has already taken place in Northern Ukrainian areas thus it would be costly to reclaim those areas (Eriksen et al., 2021). Haymaking and cattle grazing are two ways in which reclaiming takes place while there are other viable options as well that surpass the effectiveness of traditional agriculture (Lin, 2022).

Finally, military conflict in eastern Ukraine has affected where reclamation (van Asseldonk et al., 2018) occurs and is likely to significantly reduce foreign investment in eastern Ukrainian agriculture (Cristan et al., 2019).

State financial support is an important element in the long term. It ensures intensive innovative development of the agricultural region (Denisova et al., 2021). One of the essential elements of financial support is the modernization and improvement of the state of the material and technical base (Smalychuk et al., 2016). The combination of these factors (i.e., financial support and modernization of the material and technical base) is a necessary condition for the reclamation of lands devastated as a result of military operations. The study of agricultural reclamation patterns and drivers is based on spatial and temporal factors and a nonparametric regression model, which is a powerful means of explaining the most influential factors and

predicting reclamation patterns. The study of the process of land reclamation in Ukraine was carried out in the past, during 2006-2016 (Smaliychuk et al., 2016). A key factor in reclamation is the suitability of land for planting crops. This is determined by abiotic indicators - soil types and temperature regime. In addition, the presence of a large settlement nearby agricultural land is of great importance, although this factor was not as important as the first one. Thus, the most effective reclamation takes place in promising areas with fertile soils, but near large urban agglomerations.

There are however uncertain sources that need to be highlighted. The first of which is the result of an error during the sensing of data. Climate fluctuations are a contributing factor that leads to the dry year pixelation that is prominent when the cropless has not seen a large-scale harvest. This can lead to unmanaged and barren land. Furthermore, the difficulty in separating the unmanaged lands from the managed ones lead to the exclusion of dependent lands from the study area because they had become permanent grasslands situated alongside rivers. However, their omission means that the rates of reclamation cannot be overestimated. Secondly, eastern Ukraine's agricultural system follows a specific time which leads to the misclassification of the dataset provided by the satellites due to the range of testing that took place over 6 years ago. These definitions showcase that field reclamation and reliability of the analysis lie within the space of agricultural holdings and large private farms. Lastly, various observations were made except for the steppe model. This leads to the conclusion that the data for the entirety of Ukraine is not available.

Conclusions

Land renewal and reclamation is a necessary measure, starting with the return of land to optimal qualities for further use in public production. Through the restoration of areas over a period of time it is possible to return the area to sustainable development and peaceful life for the population.

The key factors determining reclamation are related to the suitability of the land for agriculture (e.g., soil quality, temperature). Accessibility to major cities was also important because much of the renewal and reclamation occurred closer to population centers, but this influence varied east of Ukraine. Variables related to agricultural management (fertilizer application, mechanization) and demography

were insignificant in explaining renewal and reclamation in the study. These factors suggest that renewal and reclamation patterns were primarily driven by factors related to land productivity, with renewal and reclamation focused on the most promising sites.

Although the study did not assess the environmental costs of renovation and reclamation, it was shown that they have become the dominant land-use trend in the region since 2017 and that renovation and reclamation were primarily associated with agricultural entities targeting unused land with the greatest agricultural suitability and therefore potential profitability. These results provide a starting point for assessing where renewal and reclamation might occur and, therefore, what the production possibilities and socioeconomic and environmental consequences of renewal might be. Predicting where future renewal may occur in eastern Ukraine suggests that this area will be the focus because unused farmland there is still more prevalent than in the most fertile steppe zone. The resulting models also have implications for the release of unused productive capacity, highlighting major constraints on renewal and reclamation, mainly affordability that can be addressed through infrastructure investment. Given the significant area of currently unused agricultural land in Eastern Europe and the former Soviet Union, our results provide important information about the neglected process of land change and an assessment of the socioeconomic and environmental consequences of renovation.

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