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Geospatial Analysis of Life Quality in Ukrainian Rural Areas

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***Abstract* — In this work, the authors developed an initial algorithm for assessing the quality of life in rural areas of Ukraine using the aggregation of heterogeneous geospatial information. The approach consists in a comprehensive assessment of the remoteness of the village from vital infrastructure facilities (hospitals, educational institutions, banks, libraries, shops, roads, power lines, etc.), to natural ecosystems (water bodies, forests or parks), as well as to occupied territories. The obtained results show that the largest number of villages with a depressed quality of life are located in the eastern and southern territories of the country, and with a positive quality - mainly in the west and central Ukraine. This, of course, is partly related to active hostilities, but considering that the proposed algorithm works based on the analysis of distances to various objects, it can be concluded that the war only worsened the condition of life in the villages.**

Keywords — smart village, life quality, geospatial analysis

I. INTRODUCTION

The quality of life in rural areas and its enhancement has been a topic of interest for several nations across the globe. Techniques such as geospatial analysis and GIS have been widely employed to evaluate rural development levels based on access to vital infrastructure such as schooling facilities, hospitals, roads, and utilities [1]. Studies conducted in India have leveraged variables such as amenities, income sources and social indicators to develop a ranking index for villages [2], the results of which exposed a substantial gap between many villages and national standards.

The authors of [3] used availability of healthcare, transportation, sanitation, schools, retirement homes and cultural facilities in a model to evaluate livability of rural settlements in China. Significant regional variations were observed, with western villages lagging in access to services. The authors of [4] assessed quality of life in South African villages using household survey data on water, energy, sanitation, housing, nutrition and other welfare indicators. Their results showed depressed living conditions driven by inadequate basic services and infrastructure deficits. The study [5] examines the correlation between township development and hub level by using remote sensing of nightlight imagery.

The development of rural areas and communities is an important strategic direction for Ukraine. In the conditions of war and large-scale destruction in Ukraine, the issue of restoration and development of rural areas has become acute. Many rural communities suffered significant damage to infrastructure, housing stock, and social facilities. There is a forced migration of the rural population, which leads to the depopulation of certain territories.

In Ukraine, various studies have used multi-criteria techniques to evaluate the sustainable development of rural settlements in the context of decentralization [6]. These studies have taken into account the accessibility of essentials such as healthcare, education, transport, and other facilities, the findings of which pointed towards noticeable gaps in many villages when compared to urban areas.

In such conditions, the development of information technologies and analytical systems that would allow making informed decisions regarding the priorities of restoring rural infrastructure and resettlement is extremely relevant. Geospatial analysis of data on the current state of development of villages, their location, climatic and geological conditions, etc., can play a key role in this.

Therefore, the development of algorithm for assessing the quality of life in villages based on geospatial data analysis is extremely necessary for the justified restoration and modernization of rural areas of Ukraine. It will allow taking into account various factors and features of regions, as well as effectively allocate limited resources to achieve the maximum socio-economic effect [7]-[9].

II. DATA USED

A comprehensive analysis of data from various sources allows for an objective assessment of the situation and trends in the development of rural areas. According to the results of a comprehensive analysis, the current state of development of rural areas and communities in Ukraine can be characterized by the following factors.

Many rural settlements do not have centralized water and gas supply. The problem of poor roads condition is widespread. The level of provision of social infrastructure facilities (schools, hospitals) is lower than in urban settlements. Infrastructure was destroyed as a result of hostilities and shelling. Some of the buildings of the social sphere (schools, hospitals, cultural centers) were destroyed or damaged, which made it difficult to provide services to rural residents. The forced resettlement of people from the zones of active hostilities caused an additional burden on the social infrastructure of rural communities outside the conflict zone. Damage to the electricity and water supply systems exacerbated the problem of communal services for rural residents [10]. Within this work, the most important socio-economic factors that have a direct impact on the quality of life in rural areas are selected (Table 1).

TABLE I. GEOSPATIAL DATA USED FOR LIFE QUALITY ESTIMATION

Data	Layers	Source
Villages	Villages	The Humanitarian Data Exchange (as of 17.07.2021)
Cities	City, Town	
Elevators	Elevators	Elevators in Ukraine (as of 23.02.2022)
Water	Water	Land Cover classification
Roads	Major roads, Secondary roads, Rural roads	Open Street Map
Education	School, college, university	
Hotels	Hotel, guesthouse, shelter	
Medicine	Hospital, clinic, pharmacy	
Shops	Supermarket, mall, clothes, market place	
Bank	Bank	
Church	Church	
Library	Library	
Kindergarten	Kindergarten	
Powerline	Powerline	
Parks	Forest, Local Park, National Park, Regional Park	Land Cover classification, Open Street Map
Occupation territory	Occupation territory	Front line in Ukraine (as of 26.08.2023)

III. METHODOLOGY

To determine the quality of life in the villages, 16 indicators were used, which are listed in Table 1. For each village, the shortest distances for each of the indicators were calculated. An example of the obtained distances is shown in Fig. 1 on the example of cities (cities are shown in blue, and the corresponding shortest distances for each of the villages are in yellow).

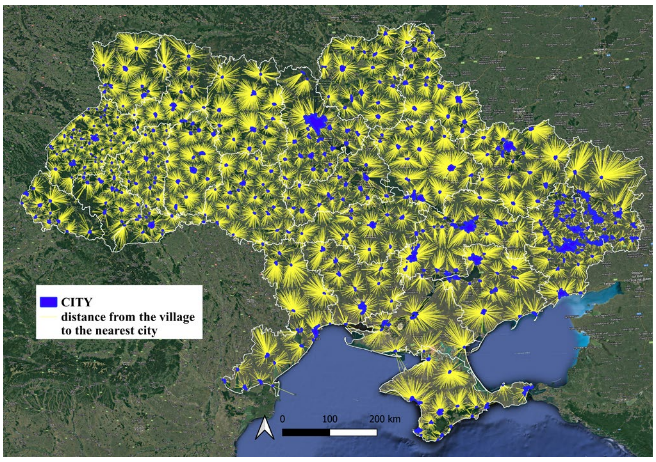

Fig. 1. Distance from the village to the nearest city (in a straight line).

For each village, according to each of the selected indicators, the villages are divided into three classes according to their location: 0 - positive location, 1 - moderate location, 2 - depressed location.

We define this class as follows. For each indicator *i*, we calculate the value of $up\_val = mean_{Indicator_i} + 3 * std_{Indicator_i}$ and consider only those distances that fall into the interval [*0, up_val*] according to the rule of 3-Sigma [11]. We divide this interval into three equal parts and life quality gradation for village *j* and for prediction *i* as follows:

$$Gradation_i^j = \begin{cases} 0, \ dist^j_{prediction_i} \in [0; up\_val/3] \\ 1, \ dist^j_{prediction_i} \in (up\_val/3; 2*up\_val/3). \\ 2, \ dist^j_{prediction_i} \geq 2*up\_val/3 \end{cases} \quad (1)$$

The Fig. 2 shows, on the example of the distribution of distances from villages to cities, how to determine the life quality indicator for each predictor. Only for the "occupied lands" predictor, the values 0 and 2 are swapped.

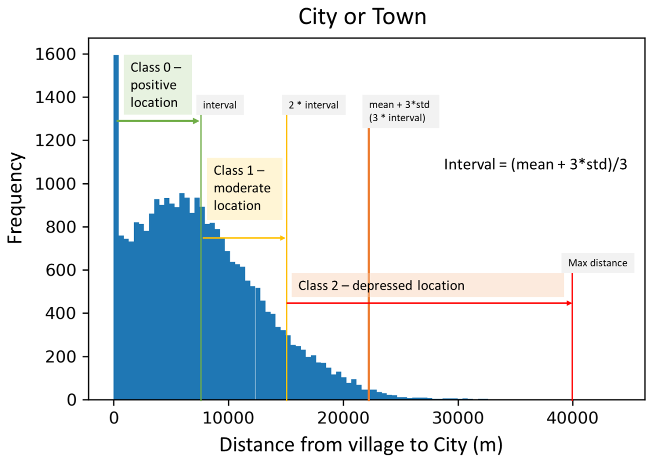

Fig. 2. Algorithm for determining the quality of life in a village using the example of distance from cities.

The next step is to combine the obtained gradations according to various predictors into one common indicator, which would reflect the general picture of life in each village separately. As such an indicator, in this work, it is proposed to choose the sum of the obtained gradations for each of the predictors. If the value 0 corresponds to the fact that the village *j* is not at a great distance from the objects, and the value 2 - that it is at a great distance, then we need to minimize the total value of the gradations of all predictors *i*.

$$Life\_level^j = \sum_{i=1}^{N} Gradation_i^j \quad (2)$$

We will assume that those villages that scored up to 3 for all predictors in total have a positive location, from 3 to 10 - moderate, more than 10 – depressed:

$$Life\_quality^j = \begin{cases} positive, \ Life\_level^j \in [0;3] \\ moderate, \ Life\_level^j \in (3;10). \\ depressed, \ Life\_level^j \geq 10 \end{cases} \quad (3)$$

IV. RESULTS

According to the proposed methodology, intervals for each of the predictors are determined for three classes: 0 - positive location, 1 - average location, 2 - depressed location (Table 2). Note that the data are obtained on the basis of open data sets and may contain inaccuracies regarding the availability and relevance of updated information. Therefore, in this work, the proof of concept of the given methodology is carried out. The Fig. 3 shows the geospatial distribution of three gradations by 16 predictors. Such predictors as roads, elevators, and parks hardly have a significant impact on the overall result.

The boundaries of the settlements were downloaded from the open platform for data exchange The Humanitarian Data Exchange (HDX) [12], information about water bodies and forests - from land cover classification maps obtained by specialists of SRI NANU-SSAU and NTUU KPI [13], [14], information about elevators - from an open source [15] (no access during wartime), a native language query of the Overpass Turbo database [16] was used to obtain the power line network data, and other geoinformation products from the Open Street Map [17].

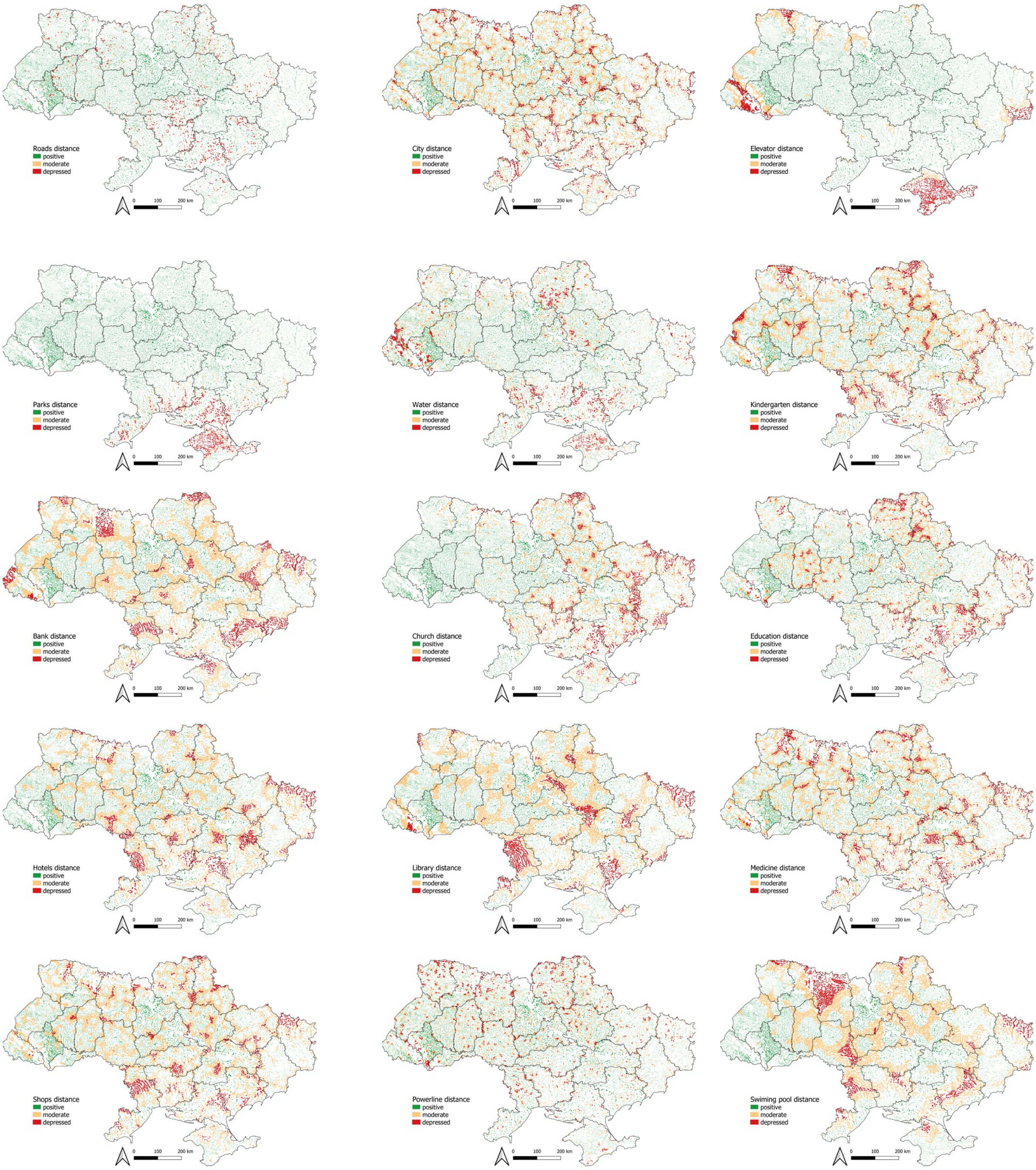

Fig. 3. Gradations of the life quality in the village are defined for each class.

TABLE II. DEFINED INTERVALS OF THE LIFE QUALITY IN THE VILLAGE FOR EACH PREDICTOR

Predictors	Intervals for gradations of the life quality (in m)		
Roads	0 - [0 - 700],	1 - (700 - 1000),	2 - [1000 - 10000]
City	0 - [0 - 7900],	1 - (7900 - 16000),	2 - [16000 - 44000]
Elevators	0 - [0 - 28600],	1 - (28600 - 57000),	2 - [57000 - 205000]
Parks	0 - [0 - 2200],	1 - (2200 - 4000),	2 - [4000 - 34000]
Water	0 - [0 - 2600],	1 - (2600 - 5000),	2 - [5000 - 28000]
Kindergarten	0 - [0 - 10600],	1 - (10600 - 21000),	2 - [21000 - 54000]
Bank	0 - [0 - 23900],	1 - (23900 - 48000),	2 - [48000 - 97000]
Church	0 - [0 - 8200],	1 - (8200 - 16000),	2 - [16000 - 55000]
Education	0 - [0 - 5400],	1 - (5400 - 11000),	2 - [11000 - 36000]
Hotels	0 - [0 - 14900],	1 - (14900 - 30000),	2 - [30000 - 93000]
Library	0 - [0 - 23700],	1 - (23700 - 47000),	2 - [47000 - 124000]
Medicine	0 - [0 - 9800],	1 - (9800 - 20000),	2 - [20000 - 46000]
Shops	0 - [0 - 12000],	1 - (12000 - 24000),	2 - [24000 - 74000]
Powerline	0 - [0 - 2700],	1 - (2700 - 5000),	2 - [5000 - 23000]
Swim. pool	0 - [0 - 30300],	1 - (30300 - 61000),	2 - [61000 - 142000]
Occupation	2 - [0 - 340400],	1 - (340400 - 681000),	0 - [681000 - 811000]

Based on the calculated gradations of the predictors, the $Life_{quality}$ level was determined and the level of quality of life for each of the villages of Ukraine was determined (Fig. 4).

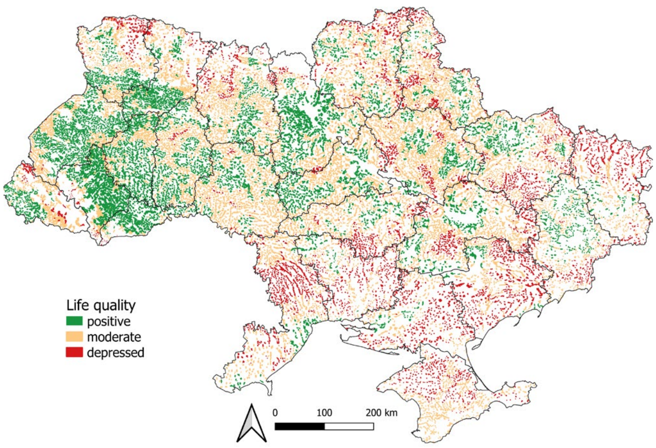

Fig. 4. Gradations of the life quality in the villages.

As can be seen from the Table 3, the proposed approach demonstrates that the largest number of villages (more than half) with a depressed state of life (based on the selected predictors) are located in Khersonska, Zaporizka, Mykolaivska, Odeska, and Luhanska regions. And in the regions of Ivano-Frankivska, Chernivetska, Lvivska, Ternopilska, Rivnenska, and Kyivska, more than half of the villages received a level of positive quality of life.

TABLE III. THE PERCENTAGE OF THE NUMBER OF VILLAGES OF EACH LEVEL OF QUALITY OF LIFE

Oblast name	positive (%)	moderate (%)	depressed (%)	Total villages
Khersonska	7,4	26,6	66,0	658
Zaporizka	7,4	28,5	64,1	917
Mykolaivska	7,3	31,9	60,8	885
Odeska	7,6	32,7	59,8	1124
Luhanska	8,6	35,1	56,3	780
AR Crimea	0,0	53,2	46,8	947
Kharkivska	23,7	40,3	36,0	1673
Chernihivska	23,8	44,8	31,5	1465
Kirovohradska	14,3	54,3	31,4	991
Dnipropetrovska	18,3	52,4	29,3	1435
Sumska	17,0	55,3	27,8	1455
Donetska	35,7	39,1	25,2	1115
Zhytomyrska	23,6	57,0	19,3	1613
Poltavska	20,3	60,8	18,9	1805
Volynska	39,6	43,2	17,3	1054
Zakarpatska	45,5	40,7	13,8	578
Rivnenska	53,5	36,3	10,2	999
Cherkaska	39,1	54,4	6,6	824
Vinnytska	27,5	66,4	6,2	1457
Kyivska	55,5	38,5	6,0	1126
Khmelnytska	48,9	47,7	3,4	1414
Ivano-Frankivska	81,0	16,6	2,4	765
Chernivetska	77,4	20,4	2,3	398
Lvivska	65,3	33,8	0,9	1850
Ternopilska	67,6	31,6	0,8	1023

V. CONCLUSION AND FUTURE WORK

This study demonstrates a novel methodology for evaluating quality of life in rural settlements of Ukraine using geospatial analysis. The algorithm developed aggregates data on remoteness of villages from vital facilities like hospitals, schools, roads, utilities etc. to quantify accessibility levels. The results reveal considerable regional disparities, with depressed conditions being most pronounced in eastern and southern oblasts.

The gradation approach classifies villages into positive, moderate and depressed categories based on the cumulative score. This provides a relative ranking and enables identification of priority areas for development interventions. The methodology can serve as a decision support tool for efficient allocation of resources and investments for restoration and growth of rural communities. Several key conclusions can be drawn from the analysis:

- access to vital infrastructure is a major determinant of rural quality of life in Ukraine, with remoteness correlating to deprived conditions. This highlights the need to improve provision of basic services in peripheral villages.

- disparities between western and eastern regions are pronounced, underlining Eastern vulnerability. Targeted support is essential for restoration and growth in these communities.

- the methodology developed provides a granular, settlement-level spatial perspective. This allows localized identification of marginalized villages to aid precise resource allocation.

- the proximity-based algorithm can serve as an objective, data-driven tool for rural development planning by policymakers.

While a range of indicators are utilized, the algorithm can be further enhanced by incorporating additional data layers like agricultural activities, nightlight analyzes, demographic attributes, localized conflict impacts, and environmental factors. Future work can also involve validation through primary surveys and ground truthing. The methodology itself needs improvement - taking into account the weighting factors for various predictors, as well as calculating the distances not directly, but along the roads to the corresponding objects, can significantly improve the obtained results.

With appropriate refinements and regular updates, the geospatial analysis technique developed here can support data-driven and equitable rural development planning by policy makers and practitioners in Ukraine. It highlights the utility of GIS tools for evidence-based assessment, mapping and monitoring of rural marginalization.

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