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THE ROLE OF NATURAL RESOURCE POTENTIAL IN SHAPING TAX REVENUES OF TERRITORIAL COMMUNITIES

Abstract: This study assesses the natural resource potential (NRP) of 66 territorial communities in Zhytomyr Oblast (urban, settlement-type, and rural) and examines its association with local tax revenues. An integrated database of land cover, climate, relief, water resources, soils, vegetation, and ecological pressure was derived from open geospatial products (Sentinel-2, Sentinel-5P/TROPOMI, ERA5-Land, Dynamic World, OpenLandMap) and aggregated to community boundaries, then linked to key taxes (land fees, resource rents, single tax Group IV, environmental tax, PIT, and single tax Groups II–III) for 2021–2025 (deflated and averaged). Results reveal a near balance of forests (~47%) and agricultural land (~42%) in rural communities and a strong north–south natural gradient. Correlation patterns differ by community type, with built-up area dominating urban fiscal capacity, mixed resource channels in settlement-type communities, and stronger NRP–revenue links in rural areas.

Keywords: territorial communities, natural resource potential, land use, satellite data, tax revenues, correlation analysis

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Introduction

The natural resource potential (NRP) of a territory is one of the key conditions shaping local socio-economic development. It provides the environmental and material basis for economic activity and, indirectly, influences the fiscal capacity of communities. Yet the mere availability of resources does not automatically lead to stronger development outcomes. Much depends on the ability of local economies and institutions to transform natural assets into value added, employment, business activity, and tax revenues (Martínez, 2022; OECD/NRGI, 2020). For this reason, the assessment of NRP at the community level should not be limited to an inventory of natural assets; it also requires an empirical examination of how these assets are associated with economic and fiscal indicators.

Geoinformation technologies and open satellite data now allow natural resource potential to be assessed more regularly, comparably, and with clear spatial reference. At the local level, this is especially relevant for analysing land use and land cover, vegetation condition, soil and water resources, as well as environmental risks. Recent studies show the increasing use of Sentinel-2 imagery for land-cover and land-use mapping, particularly in the monitoring of cropland, forests, urban areas, and water resources. The spread of cloud platforms, including Google Earth Engine, has also made large-scale and reproducible processing of remote sensing data more accessible. Global high-resolution land-cover products, such as Dynamic World, ESA WorldCover, and other 10 m datasets, further expand the possibilities for comparable territorial assessments, although their thematic accuracy and classification limitations must be considered. When such geospatial evidence is combined with local fiscal statistics, it becomes possible to examine the resource–development relationship in a more territorially differentiated and methodologically coherent way.

The scientific novelty of the study consists in bringing together multi-source geospatial indicators of natural resource potential and local fiscal data at the level of territorial communities. Previous research usually considers land resources, satellite-derived land-cover data, or local tax revenues as separate analytical domains. In this paper, these components are combined within a single community-level database that includes land-cover structure, climate, relief, water resources, soil properties, vegetation indicators, environmental pressure, and tax revenue indicators. Such an approach makes it possible to examine not only the spatial differentiation of natural resource potential, but also the extent to which different types of communities are able to convert this potential into fiscal outcomes. The study is therefore distinguished by its territorial detail, the joint use of Earth observation and fiscal statistics, and the differentiation of resource–revenue relationships by community type.

The aim of this study is to identify empirical regularities in the relationship between the natural resource potential of territorial communities and indicators of their financial capacity, measured through tax revenues. The paper develops an approach that brings heterogeneous geospatial and economic data into a single analytical framework at the community level. The analysis concentrates on three interrelated issues: spatial differences in community land-use structures, leading and lagging communities according to selected environmental indicators, and correlations between NRP indicators and tax revenues as a proxy for how effectively natural potential is transformed into fiscal outcomes (Kyryziuk et al., 2021; Martínez, 2022).

Materials and methods

Study area. Zhytomyr Oblast is located in northern Right-Bank Ukraine, within the transition zone between Polissia, with its mixed-forest landscapes, and the forest-steppe. This position creates clear spatial contrasts in soils, land use, and natural conditions (Figure 1).

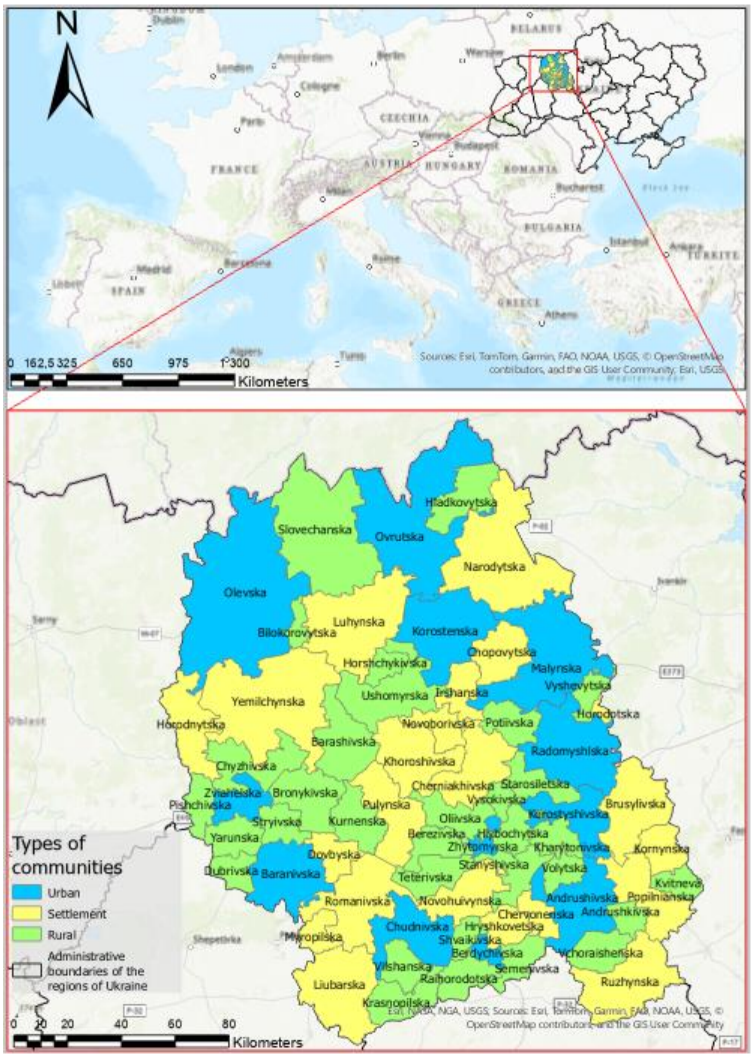

Figure 1. Study area
Source: authors’ elaboration based on administrative boundaries of territorial communities, OpenStreetMap/ESRI basemap and GIS processing

The heterogeneity of the oblast is reflected in the coexistence of more forested and less intensively developed northern areas with more agriculturally productive central and southern territories. Administratively, the oblast comprises 66 territorial communities formed after the 2020 administrative reform, including urban, settlement-type, and rural communities with markedly different demographic and economic profiles. This combination of natural and socio-economic diversity makes Zhytomyr Oblast a suitable area for analysing how variations in community-level natural resource potential are associated with differences in fiscal capacity and tax revenues.

Data sources. The empirical basis of the study combines open geospatial datasets with statistical information at the level of territorial communities. Natural resource potential was characterised through several groups of indicators, covering land use and land cover, climate, relief, water resources, soils, vegetation, and environmental pressure. This structure allows the resource base of each community to be described not as a single aggregate value, but as a multidimensional territorial profile.

- **Land cover / land use.** The global Dynamic World land-cover classifier derived from Sentinel-2 imagery (10 m resolution), providing near-real-time maps of nine land-cover classes (Hernandi et al., 2023). Using Google Earth Engine, we produced a 2021 composite and calculated the areas of major classes for each community: built-up land, cultivated land, forest land, water bodies, and other land categories (Brown et al., 2022).
- **Climate indicators.** Weather and agroclimatic parameters were obtained from the ERA5-Land reanalysis (ECMWF). We extracted mean annual air temperature (T_mean, °C), annual precipitation sum (Precip_sum, mm), the sum of active temperatures > +10°C (GDD, °C) for 1991–2020 (climate normal), and annual global horizontal irradiance (GHI, kWh/m^2) as a proxy for the territory's energy potential (Muñoz-Sabater et al., 2021).
- **Relief.** The SRTM digital elevation model (~30 m resolution) was used to compute mean elevation above sea level (DEM_mean, m) and derivatives – mean slope (Slope_mean, degrees) and predominant aspect (Aspect_mode). These indicators reflect physical constraints or advantages (e.g., erosion risks, microclimatic effects) (Farr et al., 2007).
- **Water resources.** The Normalised Difference Water Index (NDWI) and the area of open water surfaces (Area_Water, ha) were calculated using Sentinel-2 imagery (via GEE) and Dynamic World. NDWI was derived as the median value for 2021 to capture soil moisture and the presence of small water bodies.
- **Soils.** Global gridded soil-property models from OpenLandMap (OpenGeoHub) were used to obtain mean values of soil organic carbon content (SOC, %), soil acidity (pH in water), and clay fraction (%) in the topsoil (0–30 cm) at ~250 m resolution. These properties are fundamental to soil fertility and the resilience of the soil cover (Hengl et al., 2017).
- **Vegetation.** Sentinel-2 data were used to compute median NDVI (Normalised Difference Vegetation Index) and NDMI (Normalised Difference Moisture Index) for 2021 for each community. NDVI captures overall biomass and vegetation productivity, whereas NDMI reflects vegetation moisture conditions. Dynamic World was also used to estimate the areas of cropland (Area_Crops, ha) and forest/tree cover (Area_Trees, ha).
- **Environmental condition.** Tropospheric NO_2 concentration was used as an indicator of anthropogenic pressure. We relied on mean NO_2 values for 2019–2025

from Sentinel-5P/TROPOMI (~3.5×7 km). This proxy reflects air pollution associated with transport and industrial activity and is increasingly used in spatial environmental assessments (Oharenko, Neuweg 2023). Data were accessed via Google Earth Engine and aggregated to community boundaries (Veefkind et al., 2012).

Statistical data. Information on territorial communities' tax revenues were obtained from open government databases (OpenBudget, 2026). The analysis included revenue items that are directly or indirectly connected with the use of a community's natural resources: land fees, including land tax and rent payments for land plots; resource rent payments for the use of subsoil of local significance and the special use of forest resources; the single tax of Group IV, applied to agricultural producers; and the environmental tax, which reflects charges for pollutant emissions and discharges. To provide a fuller picture of local fiscal capacity, two major budget-forming revenue sources were also included: personal income tax (PIT) and the single tax paid by entrepreneurs of Groups II–III. This selection reflects the general structure of local public finance, where PIT remains central to local revenues, property-related taxation is becoming increasingly relevant, and environmental taxation still plays a comparatively limited role in local budgets (Tkachyk, Turuk, 2025; Oharenko, Neuweg, 2023)..

Data preparation. All indicators were integrated into a single community-level database to ensure comparability across territorial units. Spatial datasets, including raster and vector layers, were aggregated within official community boundaries and linked to KATOTTG codes, the national classifier of administrative-territorial units and community territories. For each community, the relevant environmental indicators were recorded as mean, median, or total values, depending on the nature of the variable. Before integration, datasets from different sources were harmonised by reference period, mainly using averages for 2020–2021, while the 1991–2020 climate normal was applied to ensure climatic stability. Measurement units were also standardised. Tax revenues for 2021–2025 were deflated to 2021 prices using the official GDP deflator, after which the average annual value for each community was calculated. This procedure reduced the influence of inflation and occasional revenue shocks, producing a more stable measure of local fiscal capacity.

Methods of analysis. The study is descriptive–analytical and comprises several stages:

1. **Classification of communities by land-use structure.** Based on the shares of major land categories (arable land, forests, built-up land, etc.), communities were typologised by specialisation: forestry-oriented (forest share markedly exceeds arable land), agricultural (agricultural land dominates), and urbanised/transformed (elevated share of built-up land). Rankings were constructed for visual comparison.
2. **Comparative analysis of land-use structures.** Mean indicators for rural communities in the oblast were compared with corresponding figures for Ukraine as a whole and selected EU countries (Poland, Germany, France, Slovakia, Moldova) to identify similarities and contrasts. The comparison drew on global land-cover products (Dynamic World) and official European statistics.

3. **Analysis of extreme values in environmental indicators.** For each selected NRP indicator (climatic, soil-related, etc.), leading communities and those with the lowest values were identified. This allows the delineation of "poles" of resource endowment and potential problem areas. Results are presented as a table of the top three and bottom three communities for each indicator.
4. **Correlation analysis of "NRP–tax revenues".** Pairwise Pearson correlation coefficients were computed between natural resource potential indicators (independent variables) and tax revenues (dependent variables). Analyses were conducted separately for three groups of communities – urban, settlement-type, and rural – to identify type-specific patterns; an "all communities" analysis was also performed to assess overall tendencies. For statistically significant correlations ($p < 0.05$), scatterplots were produced to visualise the functional form of the relationships. To ensure consistent interpretation of the correlation results, the strength of associations was described according to the following indicative scale: weak association for $|r| < 0.30$, moderate association for $0.30 \leq |r| < 0.50$, moderately strong association for $0.50 \leq |r| < 0.70$, and strong association for $|r| \geq 0.70$. These thresholds were used only as interpretive guidelines and were not treated as evidence of causality.

The proposed methodology allows the analysis to follow a complete logical chain: from environmental endowment as the resource base, through the spatial forms of its use and transformation, to fiscal outcomes reflected in tax revenues. In conceptual terms, the approach corresponds to the "resource – development – efficiency – transformation" framework. Resources define territorial potential, but this potential becomes development only when it is converted into measurable socio-economic and fiscal results (OECD/NRGI, 2020; Martínez, 2022). Deviations from this pattern are especially informative. Communities with high NRP but low revenues, or conversely those with limited resource endowment but stronger fiscal performance, may indicate governance constraints, unequal access to infrastructure, weak local economic activation, or other external limitations that should be considered in regional policy design (Khodan, Burtnyak, 2025).

Results

Land-use structure and community specialisation types. The spatial analysis of land use and land cover shows considerable heterogeneity among territorial communities in Zhytomyr Oblast. The differences are especially visible in the proportions of built-up land, cultivated land, forests, water bodies, and other land categories. On this basis, all communities were grouped into three typical specialisation types: forestry-oriented, agricultural, and urbanised or transformed territories.

Table 1 presents an excerpt of leading communities by specialisation type rather than a separate analytical sample. The classification was performed for all 66 territorial communities of Zhytomyr Oblast, while the table reports only the most representative leaders within each land-cover specialisation group. Forestry-oriented communities were identified by the predominance of forest/tree cover, agricultural communities by the predominance of cultivated land, and urbanised communities by an elevated share of built-up land. The remaining communities are included in the full statistical and correlation analysis and form the background distribution against which these leading cases are interpreted.

Table 1. Ranking of territorial communities by land-cover structure (excerpt: leaders by specialisation type)

Community	Share of built-up land	Share of cultivated land	Share of forested land	Share of water	Other
Forestry-oriented specialisation*					
Horodnytsia	1%	1%	95%	0%	3%
Olevsk	1%	2%	90%	0%	6%
Slovechne	1%	6%	89%	0%	5%
Agricultural specialisation					
Andrushky	4%	82%	11%	1%	1%
Vchoraishe	3%	79%	14%	1%	3%
Ruzhyn	4%	76%	15%	2%	3%
Urbanised (transformed)					
Zhytomyr	57%	15%	22%	2%	4%
Berdychiv	30%	23%	39%	3%	6%
Zviahel	12%	40%	43%	0%	5%

Source: authors' calculations based on Dynamic World satellite-derived land-cover data

Forestry-oriented communities are concentrated mainly in the Polissia zone, in the northern part of the oblast. Their defining feature is very high forest cover: in many cases, forests occupy more than 80–90% of the territory, whereas cultivated land remains marginal, usually below 10%. Horodnytsia and Olevsk are the clearest examples: in Horodnytsia, forests cover approximately 95% of the area and cultivated land only about 1%; in Olevsk, the corresponding figures are around 90% and 2%. A different pattern is observed in the southern part of the oblast, where agricultural communities have 75–85% of their land under cultivation and relatively limited forest cover, generally about 10–15%. Andrushky and Ruzhyn demonstrate this agro-dominant profile particularly clearly, with cultivated land exceeding 76–82% and forests accounting for roughly 11–15%. Urbanised communities, especially those that include oblast-level cities such as Zhytomyr and Berdychiv, have the largest share of built-up land – in some cases up to 30–60% – while cultivated land and forests form a more mixed background. In Zhytomyr City Community, for instance, built-up land accounts for 57% of the territory, whereas cultivated land covers about 15% and forests about 22%. These differences reflect both the north–south natural and climatic gradient and the historically formed economic specialisation of the territories.

In a broader European comparison, the average land-use structure of rural communities in Zhytomyr Oblast is closer to the Central European pattern than to the national Ukrainian profile. According to the estimates, forests occupy about 47% of the area of the oblast's rural communities, while cultivated land accounts for approximately 42%. This creates an almost balanced forest–agricultural configuration. Ukraine as a whole has a more distinctly agricultural land-use profile, with arable land covering around 55% of the territory and forests about 31%. Poland, by contrast, demonstrates a nearly balanced structure, with forests accounting for approximately 44% and agricultural land for about 41%, which makes its profile quite close to that of rural Zhytomyr Oblast. Germany shows a similar ratio, close to 40% for both categories. Slovakia is more forest-oriented, with forests covering about 57% of rural territory, whereas Moldova represents the opposite pattern: only about 19% forest cover alongside 63% agricultural landscapes (Figure 2).

Figure 2. Natural-resource specialisation of communities in Zhytomyr Oblast
Source: authors' elaboration based on Dynamic World land-cover data and authors' classification of territorial communities

The average share of built-up land in rural areas of Zhytomyr Oblast is approximately 4%, which is almost twice lower than in Poland, Germany, or France, where this indicator reaches about 8–11%. Such a proportion suggests a relatively low level of infrastructural transformation. It may indicate remaining space for future spatial development, but also points to a possible weakness: low settlement density, limited economic activity, and, in some communities, demographic decline (Table 2).

Table 2. Land-cover structure of rural territories: comparison of Zhytomyr Oblast and selected European countries

Territory	Agricultural land (%)	Forests (%)	Built-up land (%)	Other land (%)
Ukraine (national average)	55	31	6	8
Rural communities of Zhytomyr Oblast	42	47	4	7
Settlement-type communities of Zhytomyr Oblast	36	53	4	7
Urban communities of Zhytomyr Oblast	30	51	11	8
Poland	41	44	8	7
Germany	40	40	11	9
France	35	41	8	16
Slovakia	26	57	6	11
Moldova	63	19	8	10

Source: author's calculations based on Dynamic World datasets

Consequently, rural communities of Zhytomyr Oblast can be characterised as being in a state of "transitional land-use transformation". They combine a relatively high degree of ecological stability (substantial forest cover) with a strong agricultural base, which brings them closer to Central European landscape configurations. The observed similarity suggests that it is appropriate to implement in the region practices of sustainable forest management and climate-oriented (climate-smart) agriculture that are widely applied in the EU. At the same time, the lower density of built-up land signals the need to stimulate infrastructure development and processing industries in order to avoid a trajectory of a depressed agro-forestry region.

Differentiation of natural–climatic indicators across communities. To examine the natural resource potential of communities in greater detail, we analysed a set of quantitative indicators describing agroclimatic conditions, soil fertility, vegetation productivity, and environmental status at the community level. Table 3 presents leading and lagging communities for selected indicators (three highest and three lowest values). These extremes reflect the "poles" of resource endowment within the oblast.

The recorded indicators point to a clear geographical separation of natural conditions within Zhytomyr Oblast. The agroclimatic block, represented by growing degree days (GDD) and precipitation, shows a distinct north–south gradient. Southern communities, including Kvitneve, Popilnia, and Kornyn, have the warmest conditions, with GDD values of about 1270°C, but at the same time receive the lowest annual precipitation, approximately 550–560 mm. This combination increases drought risk and makes moisture-conserving agricultural practices particularly relevant; in some areas, irrigation may also be needed to stabilise crop production. Northern Polissia communities, such as

Horodnytsia and Olevsk, follow a different pattern. They receive considerably more precipitation, around 780 mm per year, but have cooler thermal conditions, with GDD close to 1110°C. Historically, such a combination has favoured forestry rather than intensive arable farming.

Soil indicators are also distributed unevenly across the oblast. The highest soil organic carbon content, above 8%, is observed in northern forest communities such as Horodnytsia and Olevsk, where peat-influenced and forest soils are widespread and humus accumulation is relatively high. In the agriculturally developed southern communities, including Brusyliv and Vysokivka, SOC values are almost twice lower, at around 4%. This may indicate a gradual depletion of organic matter under long-term intensive ploughing. Soil acidity reveals another important limitation. In Polissia, soils are strongly acidic, with pH values around 5.4 in Horodnytsia, and therefore often require liming to improve productivity. Southern chernozem and grey forest soils are closer to neutral, with pH values of 6.4–6.6 in Andrushky and Ruzhyn, which gives these communities a clear agronomic advantage.

Table 3. Highest and lowest values of key natural resource potential indicators across communities in Zhytomyr Oblast

Indicator	Top 3 communities (value)	Lowest values in communities (value)
SOC, % (soil organic carbon)	Horodnytsia (8.39); Olevsk (8.24); Slovechne (8.11)	Brusyliv (3.86); Potiivka (3.87); Vysokivka (4.05)
Soil pH	Andrushky (6.63); Brusyliv (6.44); Ruzhyn (6.44)	Horodnytsia (5.41); Slovechne (5.49); Dovbysh (5.49)
NDVI (median)	Horodnytsia (0.782); Olevsk (0.744); Luhyny (0.725)	Chervonenske (0.463); Vchoraishe (0.485); Volytsia (0.509)
GDD (°C), heat availability	Kvitneve (1278); Kornyn (1273); Popilnia (1267)	Horodnytsia (1110); Bilokorovychi (1115); Olevsk (1116)
Precipitation, mm	Horodnytsia (788); Zviahel (765); Pishchiv (765)	Kvitneve (557); Ruzhyn (559); Andrushky (560)
NO_2, μmol/m^2 (air pollution)	Zhytomyr (2.69); Hlybochytsia (2.34); Stanyshivka (2.32)	Narodychi (1.78); Hladkovychi (1.81); Ovruch (1.82)

Source: authors' calculations based on Sentinel-5P, Dynamic World, OpenLandMap data

Vegetation indicators, particularly NDVI, reflect the general bioproductivity of local ecosystems. The highest NDVI values, approximately 0.75–0.78, are recorded in forest-rich communities with limited anthropogenic pressure, primarily Horodnytsia and Olevsk. The lowest values, around 0.46–0.50, are typical of intensively cultivated communities such as Chervonenske and Vchoraishe, where a large share of biomass is removed each year with the harvest. NDVI is closely associated with forest cover and soil organic carbon: more forested territories tend to maintain denser natural vegetation and accumulate more organic matter in the soil. This underlines the ecosystem value of Polissia forests as reservoirs of carbon and biodiversity.

Environmental conditions differ sharply between communities. For NO_2 air pollution, the highest values are recorded in communities located near major transport nodes and industrial centres – Zhytomyr, Hlybochytsia, and Stanyshivka, which form the urban and suburban belt of the oblast centre. Their NO_2 concentrations exceed the oblast background level by roughly 1.3–1.5 times, reflecting the influence of transport flows, including the international Kyiv–Chop corridor, as well as industrial activity. The lowest values are found in remote northern communities, particularly Narodychi, Hladkovychi, and Ovruch. These are largely peripheral and sparsely populated territories, with extensive areas withdrawn from intensive economic use, including the Chornobyl Exclusion Zone and wetland complexes, and with minimal industrial emissions. The pattern confirms that ecological pressure in rural Zhytomyr Oblast is spatially localised: it concentrates near urban agglomerations and major highways, while most peripheral communities still retain a considerable environmental reserve of resilience.

Summarising this part of the analysis, the natural resource potential of communities in Zhytomyr Oblast is highly uneven and creates different initial conditions for development. Southern communities have more favourable agroclimatic parameters – warmer conditions and soils closer to neutral reaction – which, in principle, should support higher agricultural productivity and stronger related revenues. Northern communities, by contrast, possess significant forest resources and ecosystem services, but their opportunities for intensive crop production are limited by excess moisture and acidic soils. These contrasts suggest that economic models and fiscal capacity may differ substantially between Polissia and the forest-steppe part of the oblast. The following correlation analysis examines whether more favourable natural conditions are actually converted into higher tax revenues, or whether other limiting factors play a stronger role.

Relationship between natural resource potential and tax revenues. To assess how natural resource potential is reflected in local fiscal outcomes, we analysed correlations between NRP indicators and tax revenues of territorial communities (Table 4). Because community types differ substantially in their economic structure, the calculations were carried out separately for urban, settlement-type, and rural communities. This distinction is important: the same natural resource characteristic may have different fiscal meaning depending on whether the community is urbanised, agriculturally oriented, or resource-based. The selected design therefore makes it possible to trace type-specific patterns in the relationship between environmental endowments and local budget revenues.

Urban communities. In communities with urban centres, natural resource potential plays a largely secondary role compared with the urbanisation factor: the most pronounced – and statistically meaningful – associations in tax revenues are shown by indicators linked to the scale of built-up land. In particular, the area/share of built-up territory is strongly correlated with personal income tax (PIT; $r \approx 0.75$) and the single tax (Groups II–III) ($r \approx 0.68$), reflecting the concentration of jobs, business activity, and wage incomes within urban agglomerations. In addition, built-up land shows a positive association with the environmental tax ($r \approx 0.57$) and the single tax (Group IV) ($r \approx 0.56$), which may point to an indirect "support effect" whereby urban infrastructure and investment in peri-urban zones enhance the functioning of adjacent agricultural activities. By contrast, natural indicators (forest cover, NDVI, agroclimatic parameters) generally do not provide a noticeable contribution to the urban tax base, confirming the predominance of an industrial–service economy and labour-market mechanisms over resource endowments as drivers of fiscal capacity.

The variables used in the correlation matrix include: Area_Built_ha – built-up area; Area_Crops_ha – cropland area; Area_Trees_ha – forest/tree cover area; Area_Water_ha – water area; DEM_mean – mean elevation; GDD – growing degree days; NDVI_median – median NDVI; NO2_mean – mean tropospheric NO_2; Precip_sum – annual precipitation sum; SOC – soil organic carbon; pH – soil pH. Tax indicators include: T_eco – environmental tax; T_IV – single tax Group IV; T_II_III – single tax Groups II–III; T_PDFO – personal income tax; T_Land – land fee; T_Nadra – subsoil rent; T_Forest – forest-related rent payments.

Table 4. Correlation matrix between natural resource potential indicators and tax revenues across different types of territorial communities in Zhytomyr Oblast

Variables / Tax indicators	Area Built ha	Area Crops ha	Area Trees ha	Area Water ha	DEM mean	GDD	NDVI median	NO2 mean	Precip sum	SOC	pH
All communities (n = 66), Zhytomyr Oblast											
T_eco	0.567	-0.098	0.021	0.089	0.304	0.098	-0.202	0.161	-0.108	-0.167	0.223
T_IV	0.568	-0.090	-0.026	-0.005	0.252	0.095	-0.127	0.190	-0.074	-0.110	0.137
T_II_III	0.518	-0.110	-0.042	-0.020	0.219	0.083	-0.106	0.178	-0.063	-0.090	0.111
T_PDFO	0.583	-0.087	-0.056	-0.009	0.269	0.063	-0.124	0.183	-0.046	-0.133	0.139
T_Land	0.673	0.005	0.052	0.097	0.355	0.124	-0.179	0.239	-0.102	-0.157	0.190
T_Nadra	0.230	-0.085	0.908	0.006	0.110	0.414	-0.308	0.277	-0.454	-0.120	0.151
T_Forest	-0.032	-0.167	0.117	0.168	0.250	0.005	-0.105	-0.043	0.026	-0.108	0.062
Urban communities (n = 12), Zhytomyr Oblast											
T_eco	0.802	-0.445	-0.218	-0.075	0.160	-0.101	0.083	0.324	0.162	-0.058	-
T_IV	0.746	-0.499	-0.293	-0.309	0.104	-0.210	0.185	0.471	0.289	-0.081	-
T_II_III	0.739	-0.468	-0.284	-0.296	0.078	-0.168	0.177	0.454	0.245	-0.063	-
T_PDFO	0.744	-0.516	-0.339	-0.354	0.125	-0.259	0.201	0.492	0.347	-0.108	-
T_Land	0.847	-0.461	-0.240	-0.256	0.269	-0.297	0.259	0.410	0.396	-0.091	-
T_Nadra	0.004	-0.093	0.962	0.188	-0.300	0.322	-0.210	-0.106	-0.380	-0.226	-
T_Forest	0.271	-0.214	0.754	0.288	0.098	0.152	-0.124	-0.355	-0.128	-0.102	0.122
Settlement-type communities (19), Zhytomyr Oblast											
T_eco	0.338	0.227	-0.159	0.385	0.093	-0.346	0.226	-0.380	0.398	-0.031	-
T_IV	0.762	0.641	0.239	0.291	-0.118	-0.148	0.429	-0.360	0.092	0.346	-
T_II_III	0.706	0.552	0.389	0.069	-0.073	0.016	0.163	-0.195	-0.061	0.384	-
T_PDFO	0.624	0.473	-0.050	0.173	0.038	-0.386	0.316	-0.365	0.290	-0.086	-
T_Land	0.465	0.456	0.011	0.466	0.213	-0.073	-0.042	0.135	0.059	0.083	-
T_Nadra	-0.195	-0.260	0.869	-0.272	-0.206	0.266	-0.174	0.130	-0.290	0.278	-
T_Forest	-0.239	-0.236	-0.085	0.139	0.362	-0.174	-0.009	-0.204	0.289	0.008	-
Rural communities (35, Zhytomyr Oblast											
T_eco	0.229	-0.057	0.199	0.287	0.187	0.188	-0.525	0.200	-0.298	-0.466	0.499
T_IV	0.892	0.090	0.217	0.297	-0.402	0.407	-0.167	-0.261	-0.367	-0.038	0.034
T_II_III	0.641	-0.096	0.316	0.595	-0.290	0.455	-0.259	-0.089	-0.420	-0.070	0.042
T_PDFO	0.748	0.154	0.195	0.375	-0.098	0.133	-0.187	-0.104	-0.201	-0.172	0.176
T_Land	0.565	0.084	0.284	0.200	-0.171	0.162	-0.104	-0.120	-0.258	-0.109	0.063
T_Nadra	-0.064	-0.369	0.774	-0.120	0.050	0.632	-0.171	0.574	-0.608	-0.102	0.019
T_Forest	0.030	-0.209	0.178	0.152	0.163	0.107	-0.196	0.202	-0.240	-0.302	0.230

Source: authors' calculations based on Sentinel-5P, Dynamic World, OpenLandMap data

Settlement-type communities. Communities centred on settlement-type localities show the most mixed model of converting natural potential into fiscal capacity. Several resource channels operate here at the same time. The agricultural channel is clearly visible, although its strength differs across indicators. The area of cultivated land has a moderately strong positive association with revenues from the single tax of Group IV (r ≈ 0.64), while NDVI, used here as an indicator of vegetation productivity, shows a moderate positive association with the same tax (r ≈ 0.43). These results support the interpretation of an agricultural revenue channel, but they do not suggest equally strong relationships for all agricultural or vegetation-related indicators. At the same time, settlement-type communities demonstrate a very strong linkage between the forest/resource component and rent revenues: forest cover correlates with resource rent payments at r ≈ 0.87. This points to the fiscal importance of forestry and, in some cases, extractive activities. NO_2, by contrast, does not show a stable positive relationship with revenues, which is consistent with the relatively weak industrialisation of most settlement-type communities and the limited role of the environmental tax in their budget structure. Their fiscal resilience is therefore based mainly on diversification between agricultural and resource-based sectors; if one of these channels weakens, the budgetary capacity of such communities may become more vulnerable.

Rural communities. In rural, more remote, and often mono-functional agro-forestry communities, the role of the natural base is expressed most clearly. Yet this role is not direct. It is mediated by infrastructure, investment, and the broader economic activation of the territory. The strongest correlation in the whole set of estimates is observed between built-up land and revenues from the single tax of Group IV (r ≈ 0.89). For rural communities, built-up area should therefore be read not simply as urbanisation, but as a proxy for the concentration of economic activity and the presence of supporting infrastructure – logistics, services, storage, and processing capacities – that can strengthen agricultural performance and, consequently, tax payments. A positive association is also found between heat availability, measured by GDD, and resource rent payments (r ≈ 0.63), which may reflect the spatial overlap between warmer southern territories and the location of extractive activities. At the same time, ecosystem indicators such as NDVI and SOC are negatively correlated with the environmental tax (r ≈ −0.53 and r ≈ −0.47, respectively). This suggests that more nature-oriented communities with lower technogenic pressure receive fewer revenues from pollution-related payments. For rural territories, then, the decisive issue is not only whether a resource exists, but whether the community has the capacity to convert it into income through infrastructure, investment, and the structure of the local economy.

The consolidated results of the correlation analysis are consistent with the broader "resource – development – efficiency – transformation" concept. In urban communities, natural-resource factors appear mostly indirectly and acquire fiscal relevance only where infrastructure, labour markets, and human capital are already sufficiently developed. Cities, in this sense, convert resource endowments through an urbanised economy – industry, services, construction, and related activities. Settlement-type communities follow a more multifactor model: agricultural, forestry, and resource-extractive channels operate simultaneously, although none of them provides an unconditional advantage. Financial stability in these communities is achieved mainly through diversification. Rural communities remain more dependent on their natural base and on the conditions under which this base is economically used. Productive land or mineral resources may create opportunities for higher revenues, but limited investment, weak local processing, and insufficient technological capacity often constrain the full realisation of this potential. Natural resource potential therefore acts as a system-forming foundation of fiscal capacity, while the future development trajectory of each community depends on how effectively this potential is translated into income through investment, infrastructure, processing, and sustainable resource-use practices. This interpretation should remain cautious: correlation analysis identifies statistical associations, not causal relationships.

The observed associations should be read as possible resource–revenue mechanisms rather than as direct causal effects. Several channels may stand behind them. Agricultural land and vegetation productivity can affect local fiscal capacity through the activity of agricultural producers and the single tax of Group IV. Forest cover and subsoil resources are more likely to be connected with rent payments and resource-based economic activities. Built-up land, in turn, works as a broad proxy for infrastructure, settlement density, business activity, labour markets, and processing capacity. Environmental tax revenues should also be interpreted carefully: they usually reflect the spatial concentration of industrial and transport-related pollution, not the overall quality of the natural environment. These mechanisms require further verification through regression models that include population, investment, distance to markets, business structure, administrative capacity, and war-related disruptions as control variables.

Discussion

The results bring several issues of sustainable community development into sharper view, especially where local development is closely tied to natural resources. The pronounced differentiation of communities by natural resource potential forms distinct models of economic behaviour and fiscal capacity. Forest-dominated Polissia communities possess considerable ecological capital – forests, peatlands, and related ecosystem functions – but face a persistent problem: how to transform this capital into stable local revenues without degrading it. Their budgets depend substantially on rent payments and revenues connected with resource extraction, including timber and mineral deposits, as well as on intergovernmental transfers. Opportunities for deeper value-added processing of raw materials, eco-tourism, and other nature-based activities remain only partly used in many of these communities.

Agricultural communities in the south show a relatively stronger conversion of natural potential into income, mainly through farming-related activities. Their revenue base is more stable, but not risk-free. Dependence on agricultural production increases sensitivity to weather-related shocks – droughts, spring frosts, excessive rainfall or floods – as well as to fluctuations in global commodity prices. In this situation, diversification of the local economy becomes especially important. Processing industries, green energy, logistics, and other activities connected with local value chains could increase value added within the community and, as a result, broaden the tax base. Peri-urban communities occupy a somewhat different position. They often benefit from the combination of environmental advantages, proximity to markets, jobs, and urban infrastructure. Their main challenge is to maintain a balance: preserve environmental quality while still creating conditions for investment and spatial development.

Indicators such as NDVI and SOC may show negative associations with certain tax revenues in the cleanest and most ecosystem-rich communities. This result is not paradoxical. It reflects what may be described as an “ecological trap”: territories with better ecosystem conditions often have a weaker industrial base, lower concentration of business activity, and, consequently, a narrower tax base linked to conventional economic development. The practical task is therefore to identify development models that are compatible with nature conservation rather than opposed to it. Eco-tourism, organic agriculture, recreation, and service-based activities could generate additional revenues without undermining natural capital. For remote and ecologically valuable communities, targeted support appears justified, especially when it is directed toward infrastructure, local economic diversification, and projects that allow ecosystem assets to acquire real fiscal significance.

The comparison with European countries underscores that Zhytomyr Oblast – by its land-use structure – is closer to more balanced land-use models (typical for Poland or Germany), and thus has the capacity to develop both agricultural and forestry sectors without creating critical ecological pressure. By contrast, the high national average share of arable land in Ukraine (around 55%) points to an overreliance on agricultural land use in many regions and to heightened risks of soil degradation. In this sense, the experience of Zhytomyr Oblast is illustrative: the region has maintained substantial forest cover and biodiversity, which increasingly constitutes an economically meaningful asset, especially in the context of climate change and rising demand for ecosystem services. The key task is to establish mechanisms for the long-term conversion of natural capital into fiscal resilience – inter alia, through higher value-added processing, recreational clusters, and approaches such as payments for ecosystem services (e.g., carbon projects/credits linked to CO_2 sequestration by forests).

Methodologically, the approach used in this study is replicable and can be extended to other regions. The integration of heterogeneous geospatial data made it possible to describe natural resources at the local level in a comparable form (Brown et al., 2022; Gorelick et al., 2017; Hengl et al., 2017; Muñoz-Sabater et al., 2021; Veefkind et al., 2012). Its limitations, however, should be kept in view. The analysis is based on correlations, and therefore identifies statistical associations rather than causal effects. Local tax revenues are shaped not only by natural resource potential, but also by population size, business activity, infrastructure, the quality of land registration, administrative capacity, local fiscal policy, investment flows, and war-related disruptions. Satellite-derived and gridded global products may also contain classification or estimation uncertainties, especially for heterogeneous land-cover classes, soil indicators, and small spatial objects. Averaging tax revenues for 2021–2025 reduces the influence of inflation and short-term fluctuations, but it may also smooth annual shocks and local fiscal anomalies. Further research should therefore combine Earth observation indicators with econometric models that include socio-economic, institutional, demographic, and infrastructure controls.

Overall, this study opens an avenue for broader comparisons: do similar regularities emerge in other regions of Ukraine with different natural zones? Does the “resource–efficiency” concept hold at the national scale once infrastructural and institutional differences are taken into account? The initial evidence for Zhytomyr’s communities suggests that the relationship between resource endowment and fiscal capacity does exist, yet it is strongly mediated by economic structure and development conditions. This is a critical message for regional policy: “having resources” is not sufficient – what is needed is infrastructure, investment, and a strategy for responsible resource use.

Conclusions

This paper provides a comprehensive analysis of the natural resource potential of territorial communities in Zhytomyr Oblast and evaluates its relationship with local-budget tax revenues. To the best of the authors’ knowledge, this is one of the first attempts to integrate Earth observation data with tax-revenue statistics at this level of territorial detail for the territorial communities of Zhytomyr Oblast. This made it possible to quantify and compare the “environmental” and “fiscal” profiles of communities within a single analytical framework. The main conclusions are as follows:

- **Spatial differentiation of NRP.** Communities in the region differ markedly in their environmental characteristics. Northern (Polissia) communities are more strongly forested, experience a more humid climate, and are characterised by more acidic and, on average, less fertile soils; southern (forest-steppe) communities are more intensively cultivated, warmer, and have soils closer to neutral pH. This creates different development potentials: forestry tends to dominate in the north, while more intensive crop production is typical of the south.
- **Land-use structure.** The “average” community in Zhytomyr Oblast is relatively balanced between forest and agricultural land (approximately 45% versus 45%), which distinguishes the region from the national Ukrainian land-use profile and brings it closer to Central European patterns. Three community types were identified: forest-dominated (forests >80% of area), agricultural (arable land >75%), and urbanised (built-up land >30%). Each type requires differentiated approaches to land and resource governance.
- **Fiscal efficiency of resource use.** The relationship between environmental characteristics and tax revenues varies by community type. In urban communities, budget formation is driven primarily by parameters linked to an urbanised economy, while the role of natural resources is largely indirect. In settlement-type communities, several channels are simultaneously important (agricultural, forestry, and resource-extractive), resulting in a more balanced model of revenue generation. In rural communities, dependence on the natural base and on the conditions of its economic development is expressed more strongly.
- **Key correlations.** The strongest associations are observed between indicators of built-up land (as a proxy for the concentration of economic activity) and tax revenues, highlighting the importance of infrastructure even for predominantly rural

territories. Substantive relationships are also found between indicators of agricultural land use and agriculture-related taxes, as well as between forest/resource indicators and rent payments. Negative associations between ecological indicators (e.g., NDVI) and certain revenue items may reflect a structural trade-off between ecosystem condition and the current industrial base.

– **Practical implications.** To strengthen fiscal capacity, it is advisable to account explicitly for communities' natural-resource profiles. Northern forest communities should prioritise development paths that monetise ecosystem services and processing (higher value-added wood products, recreation). Southern agricultural communities should diversify through processing, irrigation and/or climate-risk adaptation, and the development of local value chains. Peri-urban communities should maintain ecological balance while leveraging environmental amenities that enhance territorial attractiveness. National and regional policy instruments should be differentiated, given the substantial variation in communities' resource endowments and constraints.

As a result, natural resource potential should be treated as a strategic asset of territorial communities. While it does not automatically determine development trajectories, it sets the boundary conditions within which different scenarios unfold. Rational governance of this potential – through spatial planning, environmental investment, infrastructure development, and transparent mechanisms for managing and distributing resource rents – is a prerequisite for communities' fiscal resilience and an essential component of a balanced regional development policy. The case of Zhytomyr Oblast illustrates both advantages and challenges along this pathway and may offer useful insights for other regions seeking to reconcile the preservation of natural heritage with economic growth.

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Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The study is based on publicly available geospatial, environmental, and statistical datasets cited in the manuscript. The processed community-level dataset generated and analysed during the current study is available from the corresponding author upon reasonable request.

Use of Generative AI and AI-Assisted Technologies

Generative AI and AI-assisted technologies were used only for language refinement during the preparation of this manuscript. The authors reviewed and edited the content and take full responsibility for the final version of the article.

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