DEVELOPMENT OF KERNEL'S REGIONAL INITIATIVES BASED ON THE SPATIAL STRUCTURING OF THE AGRICULTURAL ENVIRONMENT OF UKRAINE

by

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TABLE OF CONTENTS

Chapter 1

INTRODUCTION

1.1 Kernel is a leading Ukrainian agro-industrial company founded in 1994 by Andriy Verevskyi. With its headquarters in Kyiv, it has developed into one of the biggest exporters of Ukrainian grain and one of the top producers and exporters of sunflower oil worldwide (Kernel, “Company Overview”).

Crop production, oilseed processing, grain storage, and export logistics are all part of the company's operations, which span the whole agricultural value chain. Kernel's agriculture segment grows crops such as corn, wheat, soybeans, sunflower, and rapeseed. The company's refining facilities produce refined sunflower oil in bulk and bottles. In addition, the company owns an extensive network of elevators and port terminals, which contributes to the efficient export of agricultural products (Kernel Holding S.A., Annual Report for FY2024 9-15)

Even with persistent difficulties in worldwide markets and the local operating landscape - including the ongoing effects of the war in Ukraine - Kernel displayed financial strength in fiscal year 2024.
The firm announced total earnings of $3.58 billion, representing a 4% rise from the year before. Nevertheless, its earnings before interest, taxes, depreciation, and amortization (EBITDA) fell to $381 million, indicating a 30% reduction compared to the previous year (Kernel Holding S.A., Annual Report FY2024 6). The decline in profitability was linked to pressures on worldwide commodity prices, interruptions in exports, and the challenging security conditions in Ukraine.

Sustainability stands as a fundamental priority for Kernel. The company dedicates resources to digital tools and precision farming systems which enhance agricultural efficiency and environmental sustainability. The company enhances its infrastructure while supporting local communities, which enables it to maintain stability through both crisis situations and logistical disruptions (Kernel Holding S.A., Annual Report FY2024 24–28).

Kernel maintains its position as Ukraine's largest private-sector agricultural employer and exporter, which enables it to support food security and rural development and economic expansion. Through its long-term investments in technology and sustainability and local partnerships Kernel has established itself as a leading player in both Ukraine and global agribusiness.

In response to the need for long-term sustainability and structural modernization of Ukraine’s agricultural sector, Kernel has launched a strategic initiative aimed at strengthening regional agricultural ecosystems. The initiative, known as OpenAgriClub, reflects a shift from centralized supply chain management to a more decentralized, partnership-based model. The project places a particular emphasis on supporting small and medium-sized agricultural producers, who often lack access to affordable resources, financial instruments, expert advisory services, and export infrastructure.

OpenAgriClub is envisioned as a multi-stage regional platform, beginning as a virtual ecosystem and later formalized through a public association or cooperative. The core idea is to bring together smallholder farmers (typically cultivating between 300 and 1,500 hectares), Kernel’s business operations, local authorities, donors, educational institutions, and agritech partners into a single integrated value-creation system.

At its core, the project offers farmers access to:

- agronomic and legal consulting,
- financial instruments, including preferential lending and grant-based support,
- digital planning tools and precision agriculture solutions,
- joint procurement of agro-inputs under improved terms,
- educational programs developed in partnership with agricultural universities and innovation hubs.

The platform is designed not only to improve farm-level profitability and transparency but also to contribute to broader goals such as regional employment, rural infrastructure development, environmental sustainability, and compliance with EU agricultural standards.

What distinguishes this initiative is its systemic approach: OpenAgriClub is not just a commercial service model but a strategic effort to rebuild trust, competitiveness, and innovation in Ukrainian agriculture through a regionally adapted and digitally supported partnership network.

1.2 Internal context of the OpenAgriClub

The OpenAgriClub initiative is grounded in the internal strengths of Kernel as the system's founding company. The successful scaling of this type of agri- cluster is possible due to several strategic advantages held by the company.

1. Kernel's internal resources and expertise

Kernel possesses substantial internal resources, including a team with many years of experience in IT, agricultural production, sustainable development, finance, trading, and export. The company owns a vertically integrated infrastructure that spans the full agricultural value chain — from cultivation to storage and export. This operational scale enables the development of supporting infrastructure for OpenAgriClub participants and guarantees access to established sales and logistics channels. (Kernel Holding S.A., Annual Report FY2024)

2. Experience in building partnerships

Kernel has already accumulated considerable experience in building long-term partnerships through its Open Agribusiness project, which encompasses over 5,000 farmers in Ukraine. This well-functioning model of cooperation with smallholder producers serves as a solid foundation for the OpenAgriClub. The company has built strategic alliances with input suppliers (fertilizers, seeds, crop protection products, and agricultural machinery), which not only reduces costs for farmers but also enhances the quality of their production. (Kernel, “Open Agribusiness”)

3. Digital solutions and innovation support

Kernel actively implements digitalization in agricultural processes. This includes electronic document management, smart analytics, traceability solutions, automated crop rotation planning, yield forecasting based on data analytics, and elements of artificial intelligence. These tools are the foundation of a data-driven agri-system that promotes precision farming and agricultural education within the cluster. (Kernel Holding S.A., Annual Report for FY2024)

4. Research and development capacity

Kernel operates its own R&D centers, soil laboratories, and a team of agronomists and agrochemists. These assets allow the company to provide farmers with practical, localized recommendations tailored to specific climatic zones. This research capacity is essential for demonstrating the effectiveness of sustainable farming practices, regenerative agriculture, and advanced agrotechnologies. (Kernel Holding S.A., Annual Report for FY2024)

5. Social capital and reputation

Kernel is widely recognized as a responsible market player, trusted by both domestic institutions and international partners — including donors, financial institutions, and educational organizations. This reputation is vital for securing grants, launching pilot projects, and deploying the OpenAgriClub as a national platform.

1.3 External context of the OpenAgriClub

In parallel with its internal strengths, the external environment presents compelling motivation for the implementation of OpenAgriClub, as it is characterized by structural challenges that individual smallholder farmers cannot overcome on their own.

1. Vulnerability of smallholder farmers

There are approximately 25,000 small agricultural enterprises in Ukraine that manage around 4 million hectares of land. An additional 1.5 million hectares are informally cultivated without legal registration. Most of these farmers lack access to modern technologies, best practices in agricultural production, and a transparent system for record-keeping. They often overpay for inputs, operate without proper certification, and lack access to quality legal or accounting support. OpenAgriClub offers a set of basic but critical services to fill these existing gaps. (Dodd and Welsh)

2. Limited access to finance

Smallholder farmers in Ukraine face significant barriers to accessing concessional loans, grant programs, or government assistance. This is due to both complex administrative procedures and low levels of financial literacy. The OpenAgriClub proposes a donor-supported financing model and utilizes a centralized scoring system to assess the reliability of participating farmers, making the process more accessible.

3. Lag in digitalization and technology adoption

Despite the availability of agri-tech solutions on the market, most smallholder farmers lack the resources or knowledge to implement digital tools and smart technologies. As a result, they lose potential yields or overpay for inputs. OpenAgriClub functions not only as a service platform but also as a conduit for innovation through training programs, consultations, IT platforms, and demonstration events.

4. Institutional weakness and resistance to change

Many farmers remain skeptical of change and lack strategic thinking. Their planning horizon is often limited to a single growing season. This mindset prevents deeper integration into cluster structures or cooperative models. The OpenAgriClub helps overcome this barrier by fostering a culture of collaboration, demonstrating tangible benefits, and shifting farmers' perspectives toward long-term sustainability.

5. Impact of war and the need for consolidation

The ongoing full-scale war in Ukraine has dramatically increased the need for support systems, the reintegration of veterans, the reallocation of land resources, and the strengthening of domestic supply chains. Many horizontal networks between farming communities have been disrupted. In this context, the OpenAgriClub can serve as a platform for consolidating small producers, reinforcing Kernel's role as a systemic actor, and contributing to the long-term recovery and sustainable development of Ukraine's agricultural regions.

1.4 Stakeholder interest alignment within the OpenAgriClub System

One of the critical foundations for the long-term success and sustainability of the OpenAgriClub initiative lies in the balanced alignment of interests among all key stakeholders — namely Kernel (the system's founder), smallholder farmers (the primary beneficiaries), and the state (as a regulatory and strategic actor). Ensuring that each party benefits from participation is essential for maintaining mutual engagement, transparency, and systemic resilience.

Kernel's Strategic Interests

For Kernel, the OpenAgriClub initiative represents not only a corporate social responsibility effort but also a pragmatic business strategy with measurable advantages:

1. Securing supply volumes and optimizing processing infrastructure

By integrating smallholder farmers into the ecosystem, Kernel strengthens the reliability and scale of raw material procurement — particularly grain and oilseeds — which supports the efficient operation of its trading activities and oil processing plants.

2. Enhancing AI-driven forecasting models

The initiative allows Kernel to gather extensive agricultural data from cluster participants. This data is used to train and refine internal AI models for yield forecasting and production planning, contributing to improved decision-making.

3. Scaling and commercializing innovations

The platform enables Kernel to pilot its proprietary digital and agronomic innovations — including precision agriculture tools, sustainability programs, and carbon tracking technologies — in real-world conditions and, upon success, scale them further across the sector.

4. Improving brand reputation and public perception

Active participation in creating an inclusive, innovation-driven agri-ecosystem helps position Kernel as a responsible leader in Ukrainian agribusiness, fostering trust among communities, farmers, and institutional stakeholders.

5. Promoting transparency and fair competition

A transparent and standardized model of cooperation with smallholder farmers promotes equity in access to services and markets, which strengthens Kernel's regional procurement operations and enhances systemic resilience.

Benefits for Smallholder Farmers

Small and medium-sized farms (typically between 300 and 1,500 hectares) stand to gain substantial support through their participation in the OpenAgriClub:

1. Access to agronomic and laboratory services

Farmers can benefit from free or discounted agronomic consultations, soil testing, and precision agriculture diagnostics — all of which are typically financially inaccessible to small-scale producers.

2. Improved knowledge and training

Through workshops, demonstration field days, and advisory sessions, farmers enhance their agronomic and financial literacy, enabling them to adopt modern, sustainable practices more confidently.

3. Adoption of digital tools and regenerative practices

The initiative facilitates the implementation of advanced agricultural technologies (e.g., NDVI monitoring, digital crop planning) and regenerative methods (e.g., crop rotation, cover crops, soil biologization), improving yields and sustainability.

4. Legal and accounting support

Farmers receive assistance in registering land titles, accessing legal counsel, and utilizing centralized accounting services, helping to formalize and stabilize their operations.

5. Access to financing and grants

Through partnerships with donors and financial institutions, participants can apply for concessional financing or grants to support land purchases, input procurement, and on-farm infrastructure investments.

6. Lower input costs through group procurement

By participating in joint procurement of seeds, fertilizers, and crop protection products, farmers benefit from wholesale pricing, reducing overheads significantly.

7. New sources of income

Farmers can increase their revenues by selling certified, high-quality products at premium prices (e.g., ISCC-certified goods), participating in carbon credit markets (via CO_2 reduction certificates), and accessing logistics services at discounted rates.

State-Level Benefits

The Ukrainian government also benefits strategically from the implementation of OpenAgriClub, particularly in terms of rural development and policy alignment with EU agricultural standards:

1. Food security enhancement

Supporting the inclusion of smallholder farms in a formalized ecosystem helps stabilize domestic food production, especially in times of conflict or climate stress.

2. Promotion of value-added production

Encouraging sustainable, certified, and locally processed agri-products increases their market value and competitiveness, strengthening Ukraine's agri-export potential.

3. Support for rural entrepreneurship

OpenAgriClub assumes some of the state's responsibilities for supporting small farmers by providing advisory, legal, financial, and educational services through a centralized platform.

4. Regional development and decentralization

Legalizing land use, increasing tax revenues, attracting investments, and creating jobs in rural areas all contribute to stronger and more resilient communities across Ukraine.

1.5 International agri-cluster models: strategic parallels for OpenAgriClub

Comparing OpenAgriClub to established agri-cluster frameworks elsewhere can illuminate pathways for its development in Ukraine. Although local conditions—such as fragmented infrastructure and ongoing conflict—pose distinct obstacles, insights from successful international examples can guide the design of regional networks, innovation governance, and stakeholder collaboration.

1. Food Valley (Netherlands)

In the Wageningen region of the Netherlands, Food Valley has emerged as a preeminent agri-food innovation ecosystem. Centered on Wageningen University & Research (WUR), the cluster binds together private enterprises, government agencies, and research institutes via shared infrastructure, joint data platforms, and coordinated export initiatives. Public-sector funding underpins specialized incubators, demonstration fields, and digitized extension services, while WUR's academic output directly informs commercial product development. This close integration—in which research priorities align with industry needs—facilitates rapid prototyping of precision-agriculture tools and accelerates the global competitiveness of Dutch agri-tech firms (Food Valley, Wageningen UR).

2. Silicon Valley AgTech Cluster (California, USA)

Originating in 2014, the Silicon Valley AgTech Cluster is not confined to a single campus; instead, it operates as a distributed network of more than one hundred stakeholders, including agri-tech startups, multinational technology companies, research laboratories, and venture capital investors. Its organizational model centers on partnership platforms—rather than co-location—where cross-sector actors collaborate on automation, machine learning, and IoT solutions for agriculture. Initiatives range from smart irrigation systems and autonomous harvesting prototypes to real-time soil-moisture monitoring using sensor arrays. Crucially, this cluster provides early-stage funding mechanisms and testbeds—such as the Innovation Center at UC Davis—enabling emerging ventures to validate concepts under real-world conditions ("Silicon Valley Innovation Center," SVIC).

3. Texas A&M AgriLife Research Cluster (USA)

Since 2009, Texas A&M AgriLife Research has coordinated one of North America's most expansive state-backed agri-innovation ecosystems. Encompassing over five hundred participants—spanning university departments, experiment stations, agribusiness firms, and extension services—the cluster concentrates on applied research in areas such as sustainable farming, climate-resilient crops, water-use efficiency, and rural economic development. Its distinguishing feature is the systematic coupling of scientific studies with farmer outreach, delivered through field trials, on-farm demonstrations, and educational workshops. The infrastructure spans multiple campuses (College Station, Corpus Christi, Amarillo) and specialized laboratories, facilitating region-specific innovations that ultimately inform state and federal policy ("Texas A&M AgriLife Research" 2023)

1.6 Purpose and Significance of the Study

The aim of this study is to contribute to the development of Kernel's regional initiatives — particularly the OpenAgriClub platform — by creating a spatially informed clustering of Ukraine’s agricultural landscape. Rather than treating segmentation as a purely statistical exercise, this work positions clustering as a foundational tool for supporting regional differentiation, strategic planning, and the localization of OpenAgriClub services. The clustering process enables Kernel to move from a one-size-fits-all approach toward a regionally tailored framework that reflects the diverse climatic, logistical, infrastructural, and socio-economic conditions across Ukrainian oblasts.

This approach is especially important given the complex and uneven development of Ukraine’s agro-industrial environment. In the context of climate instability, fragmented infrastructure, and the disruptive impact of war, small and mid-sized agricultural producers face highly region-specific challenges. At the same time, Kernel is shifting toward a decentralized and partnership-based model that relies on trust-building, inclusive innovation, and localized interventions. Spatial clustering helps identify where specific needs, constraints, and opportunities concentrate — thereby allowing for the design of relevant agronomic support, financing mechanisms, and infrastructure investments.

The practical value of this segmentation lies in its dual applicability:
For Kernel: it ensures more efficient resource allocation, better service targeting, and scalable deployment of innovations aligned with local agricultural potential;
For Ukraine: it strengthens the capacity for inclusive, resilient, and sustainable development by directing support to regions with the greatest strategic relevance and need.

Ultimately, the study transforms heterogeneous regional data into an actionable map that supports Kernel’s long-term vision for regional growth and systemic cooperation in Ukrainian agriculture.

Chapter 2

DATA DESCRIPTION

2.1 Climate Data Collection and Processing

To account for regional agroclimatic differences that directly affect agricultural productivity and risks, this analysis integrates three key climate indicators at the oblast level: mean maximum summer temperature, mean minimum winter temperature, and total annual precipitation. These variables were chosen to reflect long-term environmental conditions that shape crop choices, planting calendars, and the need for climate adaptation measures in different parts of Ukraine.

The data were obtained from the ERA5 Reanalysis dataset published by the Copernicus Climate Data Store (CDS) and developed by the European Centre for Medium-Range Weather Forecasts (ECMWF) (Copernicus Climate Data Store). ERA5 provides consistent, high-resolution climate data that combine historical observations with atmospheric modeling, making it particularly suitable for regional comparisons over time.

For this project, weather data were extracted for a 10-year period (2015–2024) to ensure statistical robustness and indicate general climate in the required territories. The selected variables included:

- 2-meter temperature in degrees Kelvin used to derive summer and winter averages;
- Total hourly precipitation expressed in meters.

Since ERA5 outputs data in gridded format rather than administrative units, it was necessary to perform spatial aggregation. Using the R programming language and GADM level-1 shapefiles for Ukraine, each grid cell was assigned to its respective oblast. This enabled the computation of oblast-level climate averages.

Time aggregation was conducted as follows:

- For maximum summer temperature, the daily maximum temperatures for June through August were averaged across all 10 years;
- For minimum winter temperature, the daily lows for December through February were averaged over the same period;
- For annual precipitation, hourly values were summed for each year and then averaged across the decade.

Prior to integration into the clustering model, temperature values were converted from Kelvin to Celsius. Precipitation was converted from meters to millimeters. The resulting dataset contains standardized climate profiles for each oblast, enabling consistent comparison and spatial differentiation. These variables were instrumental in distinguishing agro-climatic zones—for example, identifying the hotter, drier southern regions versus the cooler, wetter western oblasts—and ensuring that subsequent recommendations for Kernel's OpenAgriClub initiative are environmentally grounded and regionally appropriate.

2.2 Agro-soil Zoning of Ukraine

Soil characteristics are a fundamental factor in determining regional agricultural potential, as they directly affect crop selection, nutrient requirements, and yields. To account for this variation across Ukraine, the analysis included a categorical variable representing the dominant agrosoil zone of each region.

The classification was based on publicly available data from the national agrosoil zoning of Ukraine, developed by the Institute of Soil Science and Agrochemistry in collaboration with the Ministry of Agrarian Policy and Food of Ukraine (GeoMap.Land).

The zoning system divides the country into seven distinct agrosoil regions, each with specific physical, chemical, and fertility profiles that influence land use suitability and input requirements.

Seven agro-soil zones used in the analysis:

- Polissya – sod-podzolic acidic soils with low fertility; requires significant soil improvement and fertilization.
- Transition zone – intermediate between Polissya and Forest-steppe; moderate fertility.
- Forest-steppe – dominated by rich black earth soil; highly fertile and suitable for various crop rotations.
- Carpathians – mountainous terrain with shallow and erosion-prone soils; limited intensive farming.
- Steppe – deep black earths with high humus content; suitable for large-scale production of grain and oilseed crops.
- Southern steppe – drier, with increased risk of salinization and limited natural moisture.
- Dry Steppe – arid conditions, low rainfall and higher susceptibility to climatic stresses.

Each region was assigned a zone based on its predominant agro-soil type. The assignment was done manually using an interactive map provided on GeoMap.Land, cross-referenced to the administrative boundaries of the regions. Although this variable is qualitative in nature, it adds a critical dimension to the analysis, highlighting regional differences in soil fertility, resource dependence and crop adaptation needs. For Kernel, such differentiation is important for developing regionally specific agronomic recommendations within the OpenAgriClub framework, such as fertilizer packages in Polissya versus moisture conservation practices in Dry Steppe zone.

The resulting classification allows Kernel to identify clusters where soil conditions may require more intensive agronomic support compared to those that are naturally productive and better suited to scaling up advanced agricultural technologies.

2.3 Logistics Data

Logistics is a key operational factor for Kernel, as the company’s business model is heavily dependent on grain exports through a network of port terminals, particularly in Odessa. Transportation costs can significantly impact farmers’ profitability and determine the attractiveness of regional collaboration for Kernel’s supply chain. To account for these differences, the analysis includes a variable reflecting the average logistics tariff per ton of wheat (chosen as a basis for comparison) transported from each region to Kernel’s export terminal.

The data was obtained from the publicly available logistics platform Tripoli Land, which provides regularly updated estimates of regional grain transportation tariffs in Ukraine (Tripoli Land). These figures reflect average costs based on trucking routes, road conditions, and distances to key export hubs.

The dataset contains transportation tariffs in UAH per ton for each region, which are typically updated seasonally. The values used in this project were manually extracted from the interactive interface of the platform map. The rates were recorded for shipment to Kernel’s main port in Chornomorsk, as it serves as the company’s central export point.

Each region was assigned a single logistics cost value, reflecting the average rate set for that region. No conversions beyond the unit standardization (UAH/ton) were applied. The result is a quantitative indicator of transport load that directly influences Kernel’s economic calculations when assessing the potential for partnerships in different locations.

This variable is particularly relevant in clusters located further from port infrastructure or with undeveloped access to roads and railways. In contrast, regions with low logistics costs are priority areas for scaling OpenAgriClub due to their higher export margin potential and lower entry cost for Kernel.

2.4 Smallholder Land Index

In order to estimate the spatial distribution of small and mid-sized agricultural producers across Ukraine, a custom indicator - referred to as the Smallholder Land Index - was developed. This variable captures the relative importance of small farms (operating less than 1000 hectares) in the land structure of each oblast, and is particularly relevant for targeting OpenAgriClub services, which are aimed at independent producers.

The index was calculated as:

$Index_{ha}$ = Area of agricultural land operated by farms under 10 ha ÷ Total land area of the oblast

Although OpenAgriClub is designed to work with farms in the 300–1,500 ha range, data in this range are not systematically published.

Therefore, the <1000 ha category was used as a proxy indicator, assuming that regions with a high share of micro-farms are likely to have a higher overall presence of small and mid-sized independent producers.

This index enables Kernel to identify regions where the OpenAgriClub model - based on cooperation, shared input procurement, and advisory services - would be more scalable due to a stronger presence of the target demographic.

2.5 Kernel Infrastructure Proximity Index

To reflect the influence of Kernel's processing infrastructure on regional readiness for OpenAgriClub implementation, a custom variable - referred to as the Kernel Infrastructure Proximity Index - was created. This index quantifies how easily each oblast can access Kernel's existing processing assets, which is a key factor in determining the logistical feasibility of regional expansion.

Rather than using absolute processing capacity per region, the variable was constructed based on spatial proximity zones. Using Kernel's publicly available infrastructure map (Kernel Holding S.A., Annual Report FY2024 7), the locations of plants were mapped across Ukraine, and a 100 km buffer radius was drawn around each.

For every oblast, it was verified whether any part of its territory falls within the proximity zone of a Kernel facility. The oblasts were then grouped into infrastructure zones, manually ordered from east to west, and assigned an ordinal index (e.g., 1–5), reflecting both logistical alignment and regional directionality. This transformation allowed the creation of a spatially meaningful ordinal variable, not based on distance per se, but on operational grouping.

By encoding proximity in this way, the variable reflects Kernel's physical footprint and logistical influence, which are essential for supply chain planning and farmer coordination within OpenAgriClub.

2.6 Limitations

Given the ongoing full-scale war and the temporary loss of governmental control over certain Ukrainian territories, it was not possible to obtain comprehensive, up-to-date, and verifiable data for all oblasts. Consequently, several regions — including Donetsk, Luhansk, Crimea, parts of Zaporizhzhia, and areas within Kherson — were excluded from the current analysis. This limitation stems from restricted access to consistent climate, infrastructural, and agricultural data rather than a lack of relevance. Although the exclusion of these territories somewhat reduces the geographic scope of the study, it preserves the analytical robustness and reliability of the clustering model. As conditions stabilize and authoritative data from national or international sources becomes accessible, these regions can be incorporated into future iterations of the analysis to ensure full territorial representation.

Chapter 3

METHODOLOGY

To adapt the OpenAgriClub initiative to the diverse conditions across Ukraine's regions, this project applies a spatial clustering approach that combines both agro-environmental characteristics and geographic proximity. Clustering was selected as a suitable technique to segment oblasts into groups with similar farming conditions, infrastructure access, and climate profiles, while also maintaining spatial contiguity — an essential factor for real-world implementation by Kernel (Chavent et al. 1799 - 1822). The analysis was conducted using the ClustGeo algorithm, which enables hierarchical clustering with spatial constraints (Chavent et al.1799 - 1822). This approach integrates two types of dissimilarities:

D_0, which reflects differences in standardized agro-logistical and environmental variables, such as climate (average summer and winter temperatures, annual precipitation), soil zones, logistics tariffs, smallholder prevalence, and proximity to Kernel processing plants; D_1, which measures geographic distance between oblasts, computed based on the coordinates of oblast centroids.

To construct these matrices, regional data were joined with shapefiles representing Ukraine's administrative boundaries at level 1 (GADM). Numeric variables were scaled using the scale() function to ensure comparability across indicators. The dissimilarity matrices were then computed using dist() for both D_0 and D_1. Geographic distances were calculated from spatial centroids obtained through the st_centroid() and st_coordinates() functions from the **sf** package (Chavent et al. 1799 - 1822).

The ClustGeo algorithm allows users to introduce a weighting parameter, α (alpha), to control the trade-off between feature similarity and spatial compactness. A range of alpha values from 0 to 1 was tested using the choicealpha() function to identify an appropriate balance for Kernel's use case (Chavent et al. 1799 - 1822). Additionally, several values of *k* (the number of clusters) were evaluated using the silhouette method, which quantifies how well each oblast fits within its assigned cluster (Rousseeuw 53-65).

Once the appropriate α and *k* values were determined, hierarchical clustering was performed using Ward's method, which minimizes within-cluster variance and tends to produce compact and interpretable clusters (Ward 236–244). The resulting segmentation provided a spatially coherent and analytically meaningful division of Ukrainian regions that served as the basis for tailored regional recommendations.

Chapter 4

CLUSTERING RESULTS

Overview of clustering output

To segment Ukraine into operational regions for the OpenAgriClub initiative, a spatial clustering approach was applied using the ClustGeo algorithm. This method allows for the integration of both agro-logistical indicators and geographic proximity into a unified segmentation model. After testing various configurations, the clustering solution with seven clusters (k = 7) and a spatial constraint weight of α = 0.3 was selected as optimal. This choice was based on both statistical evaluation and practical interpretability.

4.1 Optimal number of clusters (k)

To identify the most appropriate number of clusters, the average silhouette score was calculated for values of k from 5 to 10. The silhouette method measures how well each region fits within its assigned cluster. The results (Figure 4.1) indicate that k = 7 produces the most coherent segmentation (score ≈ 0.329), followed closely by k = 6.

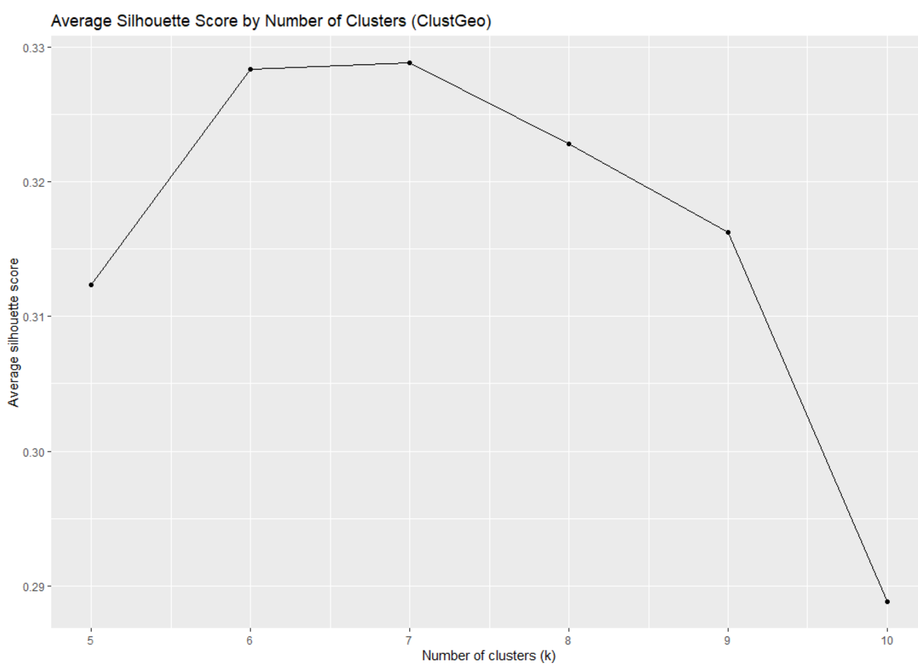

Figure 4.1. Average silhouette scores by number of clusters (ClustGeo)

4.2 Spatial weight selection (α)

To determine the balance between data similarity and geographic proximity, the choicealpha() function was applied. The resulting quality curves (Figure 4.2) demonstrate that $\alpha = 0.3$ maintains high intra-cluster homogeneity ($Q\_D0 \approx 0.86$) while also ensuring strong geographic compactness ($Q\_D1 > 0.9$). This value was therefore selected as the optimal spatial weighting.

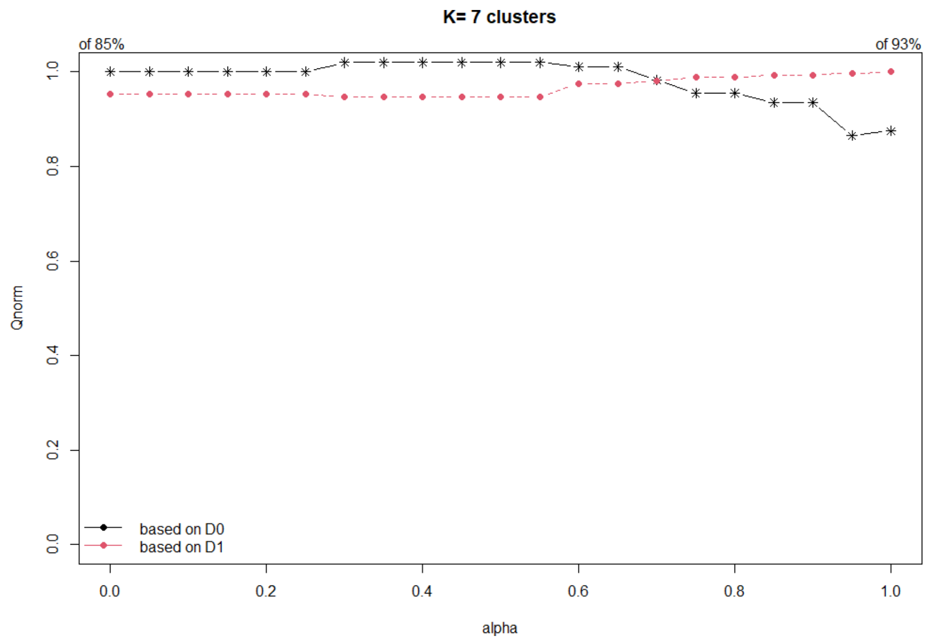

Figure 4.2. ClustGeo Q values for varying alpha (k = 7)

4.3 Map of final cluster assignment

The resulting seven clusters are displayed in Figure 4.3. Each cluster comprises oblasts with similar climate, infrastructure access, logistics cost, and farm structure. The spatial continuity of the clusters also supports real-world regional implementation by Kernel.

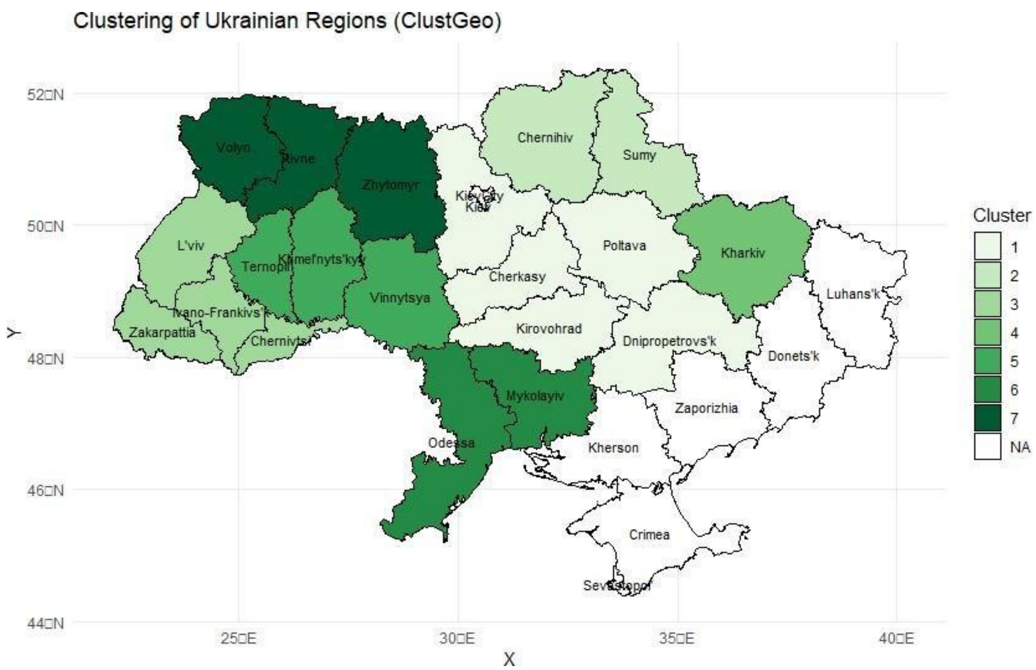

Figure 4.3. Clustering of Ukrainian regions (k = 7, α = 0.3)

4.4 Cluster profiles

The table below presents the average values of key variables across the seven clusters.

Summary of Key Variables by Cluster

cluster	avg_s_t	avg_w_t	avg_precip	avg_soil	avg_log	avg_small_farms	avg_plant_prox
1	27.70	-3.16	533.36	3.6	1600.00	13.46	4.20
2	26.27	-4.31	607.55	1.0	1800.00	6.84	4.25
3	25.26	-2.99	724.03	3.5	1950.00	3.43	0.00
4	28.06	-4.18	547.16	5.0	2100.00	7.78	5.00
5	26.27	-2.85	566.49	3.0	1683.33	11.43	1.00
6	28.89	-1.73	460.29	6.0	1100.00	13.07	2.50
7	25.99	-2.59	615.69	1.0	1833.33	4.43	0.67

Table 4.1. Summary of key variables by cluster

4.5 Cluster dendogram

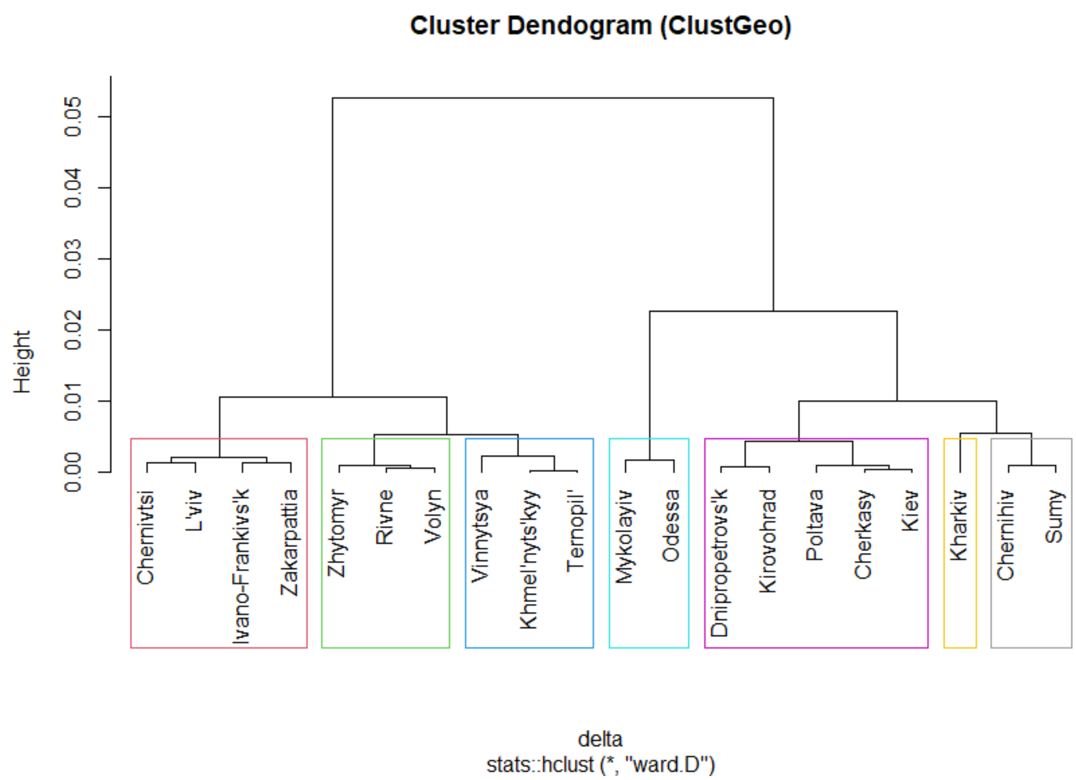

Figure 4.5. Dendrogram of Ukrainian oblasts clustered using the Ward.D method with spatial weight α = 0.3 (ClustGeo).

This dendrogram illustrates how regions merge based on combined agro-climatic indicators, transportation costs, farm structure, and proximity to processing facilities. Each branch point marks the stage at which the most similar groups of oblasts join together, revealing the hierarchical relationships and differences that inform tailored OpenAgriClub strategies for each cluster.

4.6 The resulting segmentation provides Kernel with a regionally differentiated view of Ukraine's agricultural landscape. The analysis is based on critical indicators specific to OpenAgriClub, such as climatic conditions, logistical accessibility, farm structure, and proximity to processing infrastructure. Thanks to this clustering, Kernel is able to develop targeted strategies that take into account the actual field conditions, farmers' needs, and infrastructure constraints of each region. This allows us to optimize resources, reduce risks, and increase the efficiency of implementing OpenAgriClub services, ensuring that each cluster receives exactly the solutions that will lead to sustainable development and increased profitability for local producers.

Chapter 5

RECOMMENDATIONS

The following recommendations are based on the results of the spatial clustering analysis conducted using the ClustGeo algorithm. By grouping Ukraine's oblasts into seven distinct clusters according to agro-climatic conditions, logistics costs, soil zones, farm structure, and proximity to Kernel's infrastructure, the analysis provides a practical foundation for region-specific strategies.

Rather than applying a one-size-fits-all model, this section outlines a tailored implementation plan for OpenAgriClub across different regional profiles. Each cluster demonstrates unique strengths and constraints, requiring differentiated levels of investment, service delivery, and partnership models. The recommendations are further informed by best practices from international agri-clusters and aligned with Kernel's strategic priorities, such as supply chain reliability, sustainability, digital transformation, and inclusive growth of independent producers.

This targeted approach ensures that OpenAgriClub is scalable, cost-efficient, and responsive to both environmental realities and socio-economic contexts in each region.

The strategic vision of Kernel's OpenAgriClub initiative includes a comprehensive package of support services and innovations designed to empower small and mid-sized farmers across Ukraine. These core business processes are envisioned as universal elements to be introduced in every cluster, regardless of regional differences. They include the deployment of innovative agritech and digital solutions, provision of agronomic consulting and precision farming services, and support with legal and accounting operations.

Additionally, Kernel aims to facilitate input provision, access to financing, and certification of agricultural products. A crucial part of the model is also the creation of long-term partnerships — both with agribusiness enterprises and educational institutions — to ensure the training of new technical specialists and promote sustainable resource use. These priorities serve as the guiding framework for the region-specific recommendations presented below.

5.1 Cluster 1 – central agronomic core

Regions: Kyiv, Cherkasy, Poltava, Kirovohrad, Dnipropetrovsk

Cluster 1 can be considered the agronomic backbone of Ukraine. The results of the spatial clustering analysis reveal that this region combines favorable environmental conditions, moderate logistics costs, and a particularly high concentration of smallholder farmers—Kernel's primary target group for OpenAgriClub. With average maximum summer temperatures of 27.7°C and relatively mild winter lows (–3.16°C), the climate in this area supports the cultivation of a wide range of crops. Average annual precipitation of 533 mm allows for rain-fed farming without substantial dependence on irrigation, thus reducing infrastructural costs for both farmers and service providers.

An important factor is also the availability of Kernel's processing facilities within Cluster 1: the plants in Poltava and Kirovohrad consistently accept both cereal and oilseed crops in significant volumes. According to the State Statistics Service of Ukraine, the total volume of production of cereal and leguminous crops in weight after cleaning and drying for the five regions of Cluster 1 in 2024 amounted to 172,722.7 thousand centners (equivalent to 17,272,270 tons) (State Statistics Service of Ukraine). This figure demonstrates that the region has a sufficiently strong raw material base, and for Kernel there are no obstacles to securing raw materials.

From a logistical standpoint, the average transport tariff of 1600 UAH per ton to Kernel's terminals is competitive, especially in light of the region's proximity to the company's elevators, processing plants, and trading nodes. This spatial and infrastructural alignment makes supply chain integration more efficient and cost-effective. Furthermore, the smallholder index in this cluster—13.46%—is the highest among all seven groups, indicating strong demand potential for decentralized agronomic services, digital tools, and coordinated input procurement.

Given these attributes, Cluster 1 represents an optimal starting point for the full deployment of OpenAgriClub. The concentration of small and mid-sized producers makes it possible to achieve economies of scale early in the rollout process. Shared logistics, centralized advisory services, and bundled input procurement can be launched with relatively low fixed costs per participant, enhancing both affordability for farmers and operational efficiency for Kernel.

Beyond the immediate operational benefits, this region also offers strategic value for business model testing and iterative innovation. For example, pilot programs focused on subscription-based service models, differentiated pricing tiers, or bundled offers (agronomic advice + digital diagnostics + legal support) can be launched here with a high probability of uptake. Feedback from these early adopters can then be used to refine offerings before expansion to more heterogeneous or underserved areas.

Additionally, the region's central location and access to national transportation infrastructure make it an ideal coordination base for OpenAgriClub's training programs, demonstration farms, and agri-innovation events. The visibility and accessibility of Cluster 1 can help attract donor engagement, academic partnerships, and ecosystem collaborators. With the right institutional support, this area could evolve into a Ukrainian analogue of Food Valley in the Netherlands—an innovation anchor zone where public–private synergies drive regional rural development.

In conclusion, Cluster 1 provides Kernel with the most favorable combination of climatic conditions, infrastructure readiness, and farmer density. It offers a low-risk, high-return environment for launching the OpenAgriClub initiative and serves as the most suitable model for replication across other Ukrainian regions. Its successful implementation will not only generate immediate business and social value but will also establish the institutional and operational blueprint for the long-term transformation of Ukraine’s agri-sector.

5.2 Cluster 2 – Northeastern transition zone

Cluster 2 comprises two northern oblasts of Ukraine: Chernihiv and Sumy. These regions share defining agro-climatic and structural features that necessitate a more adaptive and cautious approach to the rollout of OpenAgriClub. The clustering analysis reveals that Cluster 2 is the coldest among all identified zones, with an average winter temperature of –4.31°C. While this factor does not preclude agricultural production, it does shorten the growing season and requires more specialized crop selection and management techniques.

In terms of precipitation, the cluster receives around 607 mm annually—adequate for non-irrigated farming, though subject to significant interannual variability. One of the most important indicators for Kernel, however, is the cluster's relatively low index of smallholders (6.84%), suggesting that the density of the company’s core target group—independent farms operating under 1,000 hectares—is notably lower here than in other regions.

An important factor for Cluster 2 is its overwhelming focus on corn production. According to the State Statistics Service of Ukraine, the total volume of production (gross collection) of corn for the two regions of Cluster 2 in 2024 amounted to 57 410.9 thousand centners (State Statistics Service of Ukraine). As a result, all agronomic and advisory services should be tailored primarily toward maize cultivation and post-harvest handling. In particular, emphasis must be placed on proper drying techniques, moisture-management protocols, and storage solutions to preserve kernel quality. Consultation on corn-specific input packages (variety selection, fertilizer regimes, pest control) and investments in mobile or on-farm grain dryers will be critical to maximizing yields and minimizing losses.

Additionally, both oblasts are somewhat removed from Kernel’s core infrastructure assets, increasing logistics costs and reducing coordination efficiency. The average logistics tariff stands at 1800 UAH per ton, which is above the national average and adds strain to the operating margins of both farmers and Kernel itself.

From an economic perspective, these factors signal that a full-scale deployment of OpenAgriClub services in this cluster would carry elevated financial risk, with a lower likelihood of short-term return on investment. However, this does not mean the cluster should be excluded from the strategy altogether. Rather, it calls for a phased, low-cost, and flexible implementation model. The objective should be to build trust, collect data, and stimulate gradual adoption through lightweight and mobile service formats. This includes seasonal input distribution, mobile agronomic consulting units, and digital crop planning tools with localized recommendations.

In parallel, Kernel should consider forming partnerships with local cooperatives, municipal authorities, and regional development programs to co-fund infrastructure upgrades and training initiatives. The American example of the Texas AgriLife Research Cluster offers valuable inspiration here. Like northern Ukraine, many regions of Texas deal with climatic constraints and logistical challenges. Yet, through a system of extension offices and university-led training programs, the cluster has managed to integrate even remote agricultural communities into broader innovation frameworks. Kernel could pilot a similar approach in Sumy and Chernihiv—focusing on knowledge transfer, early-stage engagement, and decentralized demonstration plots that reduce the need for hard infrastructure investment.

In terms of economic rationale, limiting initial capital expenditure and tying further investment to performance metrics (e.g., farmer adoption rates, input repayment, or pilot yield results) ensures that the initiative remains scalable and financially sustainable.

In conclusion, while Cluster 2 presents logistical and demographic challenges, it also offers long-term strategic value as a testing ground for flexible, low-touch OpenAgriClub formats. By starting small and scaling based on evidence, Kernel can establish a presence in these oblasts without overextending its resources—while positioning itself as a partner in the broader development of northeastern Ukraine's agricultural sector.

5.3 Cluster 3 – western mountain and rain-fed zone

Cluster 3 comprises four western oblasts of Ukraine: Lviv, Zakarpattia, Ivano-Frankivsk, and Chernivtsi. This cluster is distinguished by its mountainous relief, elevated precipitation levels, and minimal integration with Kernel's existing supply network. According to the clustering results (Chapter 4), it is the wettest cluster in Ukraine, with an average annual precipitation of 724 mm. Such rainfall supports rain-fed agriculture but also heightens soil erosion risks and disease pressure, especially in the upland areas of Zakarpattia and Ivano-Frankivsk.

Average summer and winter temperatures in Cluster 3 are 25.26 °C and –2.99 °C, respectively, indicating a temperate climate; however, steep slopes and fragmented land parcels significantly limit large-scale mechanization. Consistent with this, the Smallholder Land Index is lowest here (3.43 %), reflecting a highly fragmented land-ownership structure and very few medium-sized independent farms—the primary target group for OpenAgriClub. Moreover, logistics tariffs peak in this cluster at 1 950 UAH/ton, driven by poor road conditions, winding mountain routes, and long distances to Kernel's southern export terminals.

Despite these climatic and topographical limitations, soybeans are grown significantly in Cluster 3. According to the State Statistics Service of Ukraine, the total soybean production in these four oblasts in 2024 amounted to 10,228.5 thousand centners (State Statistics Service of Ukraine). This level of soybean production, which is high for a mountainous region, indicates the need to focus Kernel's field trials and outreach activities on this crop. In particular, attention should be paid to the selection of cold-resistant or early maturing varieties adapted to mountainous conditions, optimization of nutrition regimes to reduce nutrient leaching during heavy rains, and the use of genetically resistant seeds to counteract moisture. In other words, although mass transportation of grain is unprofitable here, “experience in growing soybeans” may become a key competency that OpenAgriClub will transfer to local producers.

Given these structural constraints, a standard OpenAgriClub rollout—focused on bulk grain or oilseed aggregation—would not be economically viable. Instead, Kernel’s strategy in Cluster 3 should pivot toward services and value chains that do not rely on large-volume transport. Specifically, the emphasis ought to shift from export-oriented grain sourcing to localized value creation in areas such as seed multiplication, specialty crop certification, and knowledge transfer.

One useful analogue is the agri-cluster model in the southern province of Limburg (Netherlands). Despite challenging topography, Dutch clusters maintain competitiveness by forging close collaboration among research institutes, regional authorities, and private enterprises. In Cluster 3, Kernel can play a similar convening role: partnering with local universities (e.g., Ivan Franko National University of Lviv), NGOs active in Carpathian rural development, and EU-funded programs to deliver targeted training, advisory services, and shared equipment resources for smallholders.

Operationally, OpenAgriClub’s presence in Cluster 3 would take the form of a “Knowledge Node” rather than a logistics hub. In practice, Kernel could host demonstration plots on peri-urban land in Ivano-Frankivsk or Lviv, where digital tools and regenerative practices are showcased. Periodic “field days” and agritech workshops—organized in collaboration with local academic partners—would expose farmers to contour plowing, cover-cropping, and small-scale seed processing techniques.

In conclusion, the strategic value of Cluster 3 for Kernel lies in its potential as a decentralized innovation and education zone where soybean expertise can be shared with local producers. While the immediate economic benefits may be modest, the region allows Kernel to establish itself as a leader in inclusive, sustainable rural development - a crucial competitive advantage as Ukraine moves toward EU integration.

5.4 Cluster 4 – eastern conflict zone (Kharkiv Oblast)

Kharkiv Oblast, the sole region within Cluster 4, possesses strong agricultural potential based on its climate and soil characteristics. Average summer temperatures of 28.06 °C and winter lows around –4.18 °C support a lengthy growing season, while annual precipitation of 547 mm is sufficient for intensive grain and oilseed production. The Smallholder Land Index of 7.78 % indicates a mix of large agricultural enterprises and many smaller farms. However, ongoing military activity, recent occupation of parts of the territory, and extensive mine contamination have severely disrupted normal farming operations. Transport routes are damaged, bridges have been destroyed, and large vehicles risk encountering unexploded ordnance, driving logistics costs up to 2 100 UAH/ton and making conventional export pathways untenable (Ministry for Communities and Territories Development of Ukraine).

Currently, Kharkiv's highest priority must be ensuring safety and clearing farmland of explosive remnants. Only once demining is sufficiently advanced can agricultural production begin to resume. In this context, Kernel—drawing on its resources and network—could assist relevant agencies by supplying portable mine detectors, arranging training sessions for local demining teams, and providing the specialized equipment required to neutralize minefields (Ministry for Communities and Territories Development of Ukraine). The effectiveness and readiness of these sappers will dictate when tractors, combines, and even humanitarian aid convoys can safely operate in the region. At the same time, it is essential to restore at least one key roadway connecting district centers so that farm machinery can move freely. Even if farmers manage to harvest small quantities of wheat or sunflower, without reliable access roads they cannot transport it to storage facilities. Kernel could address this gap by providing mobile grain-storage containers stationed along cleared sections of the route. These containers would protect harvested crops from spoilage in the open air and simplify logistics once conditions stabilize.

Special attention should also be given to ensuring basic seed and input supplies. Over the most recent season, many Kharkiv farmers could not obtain certified wheat and sunflower seed, leading them to plant unverified or contraband seed with much lower yields. Kernel could organize the delivery of certified grain and oilseed varieties, as well as mineral fertilizers and crop-protection products, accompanied by clear usage guidelines. Even if yields remain limited due to remaining mine contamination, such support will help maintain production relationships and instill confidence that the company intends to assist over the longer term.

Because safe field visits remain extremely limited, it is advisable to establish remote advisory services. Kernel agronomists could offer regular video calls, telephone consultations, or messaging-based advice, explaining how to select plots with the lowest mine risk, how to prepare soil after heavy rainfall, and how to estimate appropriate seed and fertilizer quantities. While such guidance cannot fully replace in-person fieldwork, it can reduce the likelihood of costly planting mistakes and help salvage some potential harvest.

Furthermore, it would be prudent to begin developing a post-conflict cooperation plan. Kernel could draft a standard agreement for the anticipated peaceful period, outlining terms for seed supply, equipment rental, and long-term partnership formats. By collecting farmers' contact details and understanding their needs now, the company will lay a foundation of trust: once security returns, Kernel can rapidly launch a fully operational OpenAgriClub program, since growers will already be familiar with contractual terms and prepared to recommence collaboration.

In summary, Kernel's immediate mission in Kharkiv Oblast is not to introduce sophisticated innovation hubs, but to provide essential support under wartime conditions. Efforts focused on demining, reopening critical roads, supplying mobile grain storage, and delivering basic seed and inputs will create the necessary groundwork for an eventual revival of agriculture. Crucially, this assistance will sustain farmers' trust—an invaluable asset that will underpin the region's successful recovery when peace is restored. (Ministry for Communities and Territories Development of Ukraine. RDNA4: Fourth Rapid Damage and Needs Assessment, 2024.)

5.5 Cluster 5 – adaptive agro-industrial zone

Cluster 5 includes Ternopil, Khmelnytskyi, and Vinnytsia oblasts—regions that collectively form a resilient, moderately intensive agricultural zone with significant potential for scalable innovation. This cluster has balanced agro-climatic conditions: moderate summer temperatures (maximum average 26.27 °C), relatively mild winters (minimum average -2.85 °C), and sufficient annual precipitation (566 mm) to support diverse crop rotations without excessive plant stress. Only Vinnytsia region has experienced more frequent periods of drought and hot weather in recent years (Copernicus Climate Data Store). Logistics costs remain at an average level (1,683 UAH/t), indicating acceptable access to export infrastructure such as roads or railways. At the same time, the index of small farms is high (11.43%), which indicates a significant presence of independent producers, a key target audience for Kernel's OpenAgriClub.

An important asset for Kernel is the processing plant in Khmelnytsky region, which provides a reliable buyer for the grain and oilseeds grown here. Thanks to the localized aggregation and proximity of the plant, farmers can count on faster processing cycles and less losses during transportation. Given the predominantly fertile black soil of Ternopil and Khmelnytskyi regions, the yield potential for grains and oilseeds is high. Therefore, agronomic advice should focus on maximizing yields per hectare: optimal seeding rates, precise nutrition management, and improved pest and disease monitoring. In particular, desiccation (chemical drying of plants in the field) to manage late-season ripening should be included in the main recommendations. Advising small farms on the choice of desiccant and the timing of its application (e.g., 10-14 days before harvest) will help stabilize harvesting time, reduce losses in wet autumn climates, and improve overall quality.

From an economic point of view, the high density of small and medium-sized producers increases the likelihood of network effects: the more participants join, the lower the cost of services per user, such as centralized soil analysis, rental of desiccation equipment, and bulk purchases of plant protection products. This increases the accessibility of services for farmers and profitability for Kernel. In addition, moderate logistics costs allow products from this region to be shipped to both domestic processors and export terminals without significant additional costs, which adds flexibility to Kernel's procurement strategy.

The Texas A&M AgriLife Research agri-cluster, where scalable agronomic innovations are integrated with education and field support, can serve as an inspiration. Kernel can work with regional research centers, such as Vinnytsia National Agrarian University and Khmelnytsky Agrarian University, to create demonstration crops on farms. There, regenerative methods, precision farming and desiccation tools can be tested in real-life conditions in the region. Field Days and training sessions can demonstrate the best practices for growing grains and oilseeds, as well as the proper use of desiccants. Collecting yield and quality data from these demonstrations will help Kernel to continuously improve its recommendations and provide local producers with customized solutions.

In terms of policy and external support, Cluster 5 is a fertile ground for donor rural development programs, particularly those focusing on climate-smart agriculture and food security. The Kernel's role could be to provide digitalization, logistics coordination, and market access, while local institutions and development agencies would provide grants, microcredits, and training opportunities. For example, subsidized access to shared desiccation equipment could be organized through co-financing programs, incentivizing farmers to adopt the technology without large upfront investments.

Cluster 5 thus offers the perfect combination of agronomic readiness, logistical accessibility, and small farm density. With a plant in Khmelnytskyi region, fertile soils in the regions, Kernel should consider this region as a “living laboratory” for testing the “farmers as a service” strategy. The emphasis on high-yielding cultivation methods — including proper desiccation — and incentives for farmers to increase their acreage will not only increase the profitability of thousands of small farms, but also prove the effectiveness of the OpenAgriClub model for further scaling in more complex or less developed clusters.

5.6 Cluster 6 – southern export corridor

Cluster 6 consists of Odesa and Mykolaiv oblasts - two key logistical regions in southern Ukraine that form a natural "export corridor" for agricultural products. This cluster stands out for having the highest average maximum summer temperatures (28.89°C) and the lowest average annual precipitation (460 mm) among all clusters, indicating a high risk of drought but also a long growing season and high solar activity - ideal for sunflower, and other drought-resistant crops. According to the State Statistics Service of Ukraine, in 2024, 15,101.7 thousand centners of sunflower were harvested in Odesa and Mykolaiv regions (State Statistics Service of Ukraine). This confirms the predominance of the oilseed in crop rotations and indicates the need to focus agronomic recommendations on increasing the yield and quality of sunflower.The lowest logistics tariff (1100 UAH/ton) is due to direct proximity to the Black Sea ports (notably Chornomorsk and Yuzhnyi), which are major export hubs for agricultural products. Additionally, the smallholder index is high (13.07%), pointing to a strong presence of the OpenAgriClub's target audience.

Based on these characteristics, Cluster 6 is the most promising zone for scaling up the export-oriented OpenAgriClub model. With already established logistics infrastructure, Kernel can minimize transport costs and integrate small producers into supply chains without requiring significant investment in new infrastructure.

A strategy of mass farmer involvement is proposed using incentive tools: bulk discounts on agro-inputs via group purchasing, access to priority loading schedules at ports, and bonuses for meeting quality standards (e.g., ISCC certification) (Kernel Holding S.A., Annual Report for FY2024). This approach would create a quick economic incentive for smallholders, lower the entry barrier, and secure Kernel with a stable supply of high-quality raw materials.

At the same time, the climatic conditions require a focus on adaptive practices: moisture retention, drought-tolerant crop varieties, and early sowing planning. Kernel can involve its internal R&D centers to provide tailored agronomic support to farmers in these regions (Kernel Holding S.A., Annual Report for FY2024 47). In the future, this could position the cluster as a center for climate-adaptive agricultural production.

Given Kernel's high level of digitalization, this is also an ideal location to launch pilot technological solutions such as automated logistics platforms, agri-technical scoring, and satellite-based planning for sowing and harvesting.

From an economic perspective, low logistics costs allow for maximization of export margins for both Kernel and farmers. This lowers the entry threshold to the program and enables rapid returns. The high concentration of small farms supports the achievement of scale effects, which are critical for the sustainability of digital platforms and services.

Thus, Cluster 6 represents an ideal space for intensive deployment of an export-focused, climate-adaptive, and digitally enabled OpenAgriClub. Successful implementation here would create a flagship model for replication in other southern and eastern regions of Ukraine.

5.7 Cluster 7 – northern transition belt

Oblasts: Volyn, Rivne, Zhytomyr

This cluster is located in northern Ukraine and serves as a transitional zone between the humid western regions and the drier central and eastern ones. According to the analysis, Cluster 7 has cooler summer temperature (average of maximum temperatures at summer: 25.99°C), moderate winter (average of minimal temperatures at winter: -2.59°C), relatively high precipitation (615 mm), moderate logistics costs (1833 UAH/ton), but a low proportion of smallholders (4.43%). This points to a lower intensity of small-scale agricultural production, limited diffusion of independent farms,a greater role of large agricultural enterprises, and larger proportion of forest area.

In the context of implementing the OpenAgriClub, this cluster is not a priority in terms of immediate scale effect or rapid engagement of the target audience. However, it holds strategic importance for long-term development and geographic coverage of the initiative. Its climate stability and moderate infrastructural accessibility provide a favorable environment for pilot projects focused on education, demonstration farms, and technological testing.

Cluster 7 is recommended to be used as a base for promoting sustainable farming practices and digitalization through:

Establishing demonstration fields and agri-education centers, where farmers can observe the benefits of modern technologies and solutions offered by the OpenAgriClub.

Launching seasonal support programs, such as spring sowing planning or autumn soil analysis, which require minimal investment but build trust in the system.

Focusing on certification and environmental standards, including organic farming, biointensification, which match the ecological profile of the region.

Economically, it is feasible to use Cluster 7 as a testing ground for new OpenAgriClub business models, such as subscription-based online services or fixed-rate consulting packages. This will allow demand modeling in a controlled environment and prepare the platform for scaling.

Moreover, this cluster lies in a geographical corridor adjacent to EU countries, making it a suitable location for implementing elements of harmonization with European standards in agricultural production, certification, soil fertility preservation, and climate reporting. This will allow Kernel to test mechanisms for integrating Ukrainian smallholders into international value chains.

Thus, although Cluster 7 is not the most profitable or populous in terms of current outreach, it acts as an ecosystem incubator for the long-term development of the OpenAgriClub, supporting institutional growth, result demonstration, and technological readiness of other regions for transitioning to new agri-cooperation models.

5.8 Conclusions

The spatial clustering approach presented in this thesis bridges the gap between high-level agribusiness strategy and the on-the-ground realities of Ukraine’s diverse regions. By segmenting the country into seven data-driven clusters, Kernel gains actionable insights to deploy OpenAgriClub in a way that is both cost-efficient and sensitive to local conditions. The resulting recommendations—ranging from immediate wartime relief in Kharkiv to export-focused scaling in Odesa and Mykolaiv—demonstrate how a large agribusiness can act as a catalyst for inclusive, sustainable rural development.

In a broader sense, this work illustrates the power of combining geospatial analysis with private-sector strategy: it is possible to reconcile economies of scale with contextual relevance, even under the strain of war and environmental stress. As Kernel proceeds to pilot and refine these interventions, the evidence generated will not only guide its own expansion but also offer a replicable template for agribusinesses in other transitional economies.

Ultimately, OpenAgriClub’s success will depend on continuous feedback loops: data from pilot projects should flow back into the clustering model, prompting recalibration of cluster definitions, service portfolios, and partnership structures. In doing so, Kernel can transform a static segmentation into a living blueprint—one that evolves with Ukraine’s post-war reconstruction, climate adaptation needs, and aspirations toward European integration.

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