# Use of LPIS data to estimate the potentials for valorisation of agricultural by-products

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**Abstract**

**This study explores the use of Land Parcel Identification System (LPIS) data to estimate the spatial potential for valorising agricultural by-products in Slovenia. By integrating LPIS crop and livestock data with residue generation coefficients, spatial biomass availability was calculated and classified using geospatial tools. Results highlight livestock excreta and cereal residues as the largest by-product streams, with significant variation in spatial concentration. Findings underscore the importance of localized, high-value valorisation strategies due to structural and logistical constraints. The approach offers a replicable method for supporting bioeconomy planning by addressing data gaps and informing efficient biomass collection and processing infrastructure development.**

## Introduction

The efficient collection of agricultural by-products for further valorisation by closing material and energy loops (eg. bioenergy, fertilizers and biostimulants, biobased materials) is shaped by a complex interplay of structural, logistical, and systemic factors. A key challenge lies in the dual farm structure prevalent across the EU, where small-scale farms coexist with large commercial operations (Eurostat, 2025). This fragmentation complicates scalable and cost-efficient the aggregation of residues such as straw, husks, and pruning waste (Lehtinen et al., 2021). Additionally, the seasonal and spatially dispersed nature of biomass generation, coupled with variability in moisture content and perishability, poses significant logistical hurdles (Socas-Rodríguez et al., 2021). Even in technologically advanced regions, the cost-effectiveness of collection is undermined by the need for timely harvesting, drying, and transport infrastructure. While Europe has made strides in developing bioeconomy markets and circular systems, the lack of reliable, granular data on by-product availability remains a critical bottleneck (ECA, 2022).

Agricultural statistics in the EU typically focus on primary production, offering limited insight into the volume, type, and location of by-products (Camia et al., 2018). This data gap hampers the design of efficient logistics and investment in processing infrastructure. A promising solution lies in leveraging administrative data, particularly the Land Parcel Identification System (LPIS), a geospatial database used under the EU's Common Agricultural Policy (CAP). LPIS provides detailed, parcel-level information on land use and crop types, which can be cross-referenced with residue generation coefficients to estimate spatial biomass availability (Bedoić et al., 2019). When integrated with agricultural production statistics and farm-level reporting, LPIS can support spatially explicit biomass mapping, enabling planners and processors to optimize collection routes, reduce costs, and ensure a steady supply of raw materials.

## Materials and Methods

Data acquisition and calculations were done in two parallel processes in the Microsoft Excel and Esri ArcMap environments. One process consisted of geospatial analyses of polygon layers with land use and crop data. The data for plant production was obtained from administrative data source, LPIS (Land Parcel Identification System), a digital map-based system used to identify and manage agricultural land eligible for CAP area-based payments. The data basis for estimating of the quantity of by-products in livestock production also came from the same administrative source, namely point layers of agricultural holdings reporting on livestock status (AKTRP, 2023). Both processes have in common a final stage where we performed the final calculations on blocks of the same size and the classification of the results into five classes according to the Jenks method.

Layers of land use and crop data are vector polygonal in their original form. Layers for selected crops (wheat, barley, oats, triticale, spelt, rye) and plantations (apples) were converted into raster layers with a raster resolution of 1 m x 1 m in the first phase. In the next step, the *Zonal Statistics* tool was used to calculate the values of each zone by counting the individual cells and multiplying the latter by respective AWCB (Agricultural Waste, Co-products and By-products) indices (Bedoić et al., 2019) to obtain the quantities of by-products of crop production. In the final stage, the results were displayed by block [kg/block].

**Table 1.** Studied agricultural by-products and their AWCB indices

| Element | Unit | Value in $kg/m^2$ or kg dry matter/$m^2$ |
|---|---|---|
| Straw (barley) | kg dry matter/$m^2$ | 0.275 |
| Straw (oats) | kg dry matter/$m^2$ | 0.250 |
| Straw (wheat, triticale, spelt, rye) | kg dry matter/$m^2$ | 0.300 |
| Spelt husks | kg dry matter/$m^2$ | 0.045 |
| Apple prunings | kg dry matter/$m^2$ | 0.190 |
| Sludge (dairy cows) | $m^3$/ livestock unit | 15 |
| Sludge (beef cattle) | $m^3$/ livestock unit | 12 |
| Sludge (pigs) | $m^3$/ livestock unit | 15 |

The layers of Livestock Unit (LU) coefficient values derived from animal weights (i.e. for pigs, beef cattle and dairy cows) were obtained by first performing the basic calculations with the condition that the livestock status exceeds the value of 10, and merging the data with the holdings layer, which is a vector point layer. In doing so, we applied the criterion that if, for example, the total Livestock Unit count from pig farming exceeded that from cattle farming (i.e. not only the total number of pigs exceeded the total number of cattle), we classified the individual holding as a pig farm. The others were assumed to be cattle farms (where they could also have poultry, small livestock, etc.), and within them, the classification was determined based on the secondary criterion of whether the total livestock status is dominated by cows or animals under two years of age. In the latter cases, farms were classified as fattening farms. The values of the strata according to the spatial unit were calculated using the *Zonal Statistics* tool and the totals were displayed by block.

The size of the blocks was determined in accordance with the principle of the critical logistics measure, which is the cost of transport, since for a larger distance than this, the value of the biomass does not bear the cost. Applying the estimated distance thresholds for cost-effective transport of agricultural biomass (Börjesson et al., 1996) to the context of (small and dispersed) landholding structure in Slovenia block size of 5 km x 5 km was determined.

The results of each element studied were classified by the Jenks method into five classes. The values of each class were displayed in the blocks where these elements are located. In the final stage, for each element studied (i.e. crop or value within each livestock unit category), we summed its values in the three classes above and calculated the proportion of the values of these three compared to the total value of all five classes. For this purpose, the geo-information data were exported to Excel, where the calculations of the proportions were carried out.

## Results

After performing the Jenks classification method, the results per bloc are distributed in five classes (Figure 1).

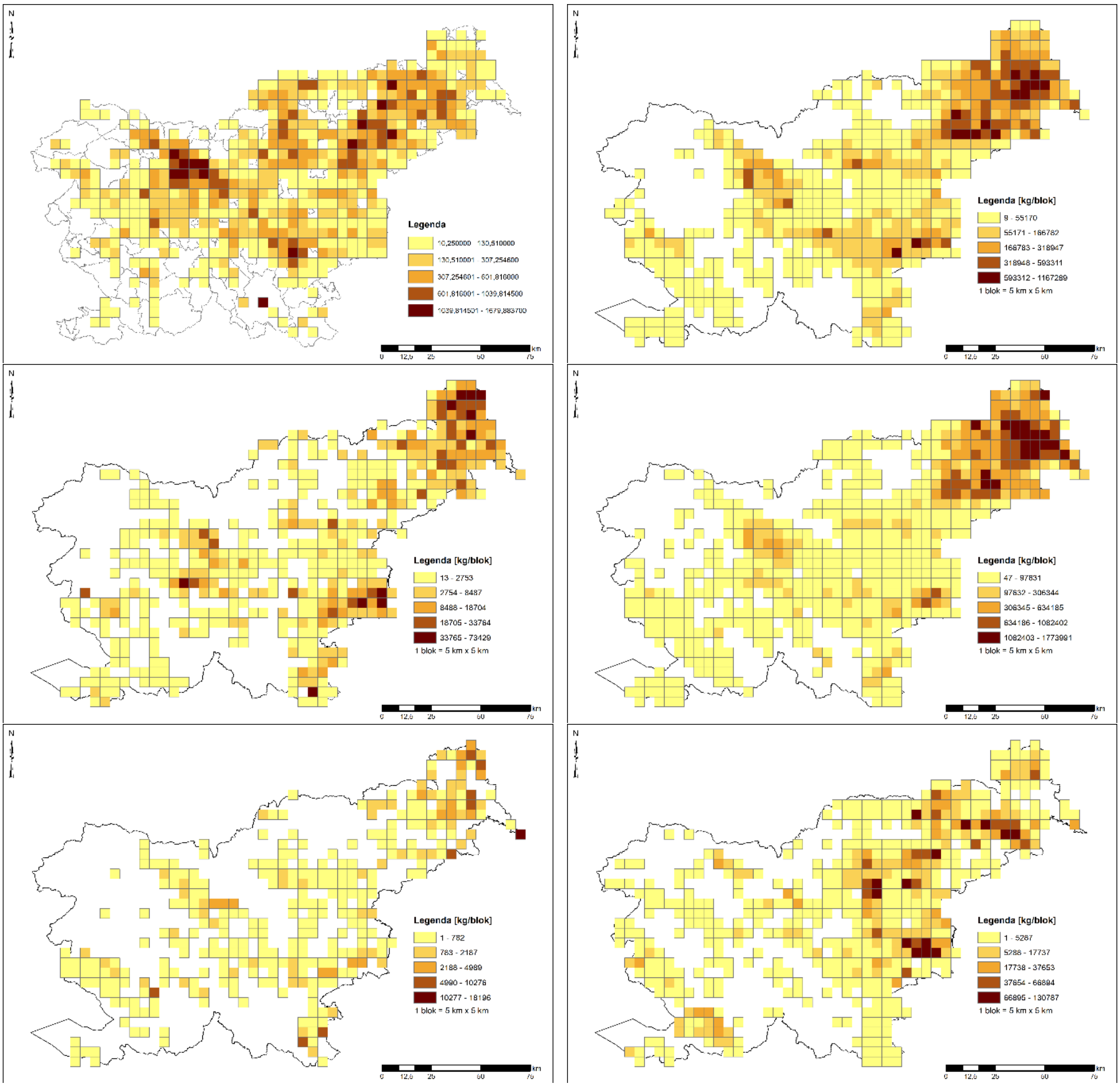


**Figure 1.** Spatial distribution of blocks in a specific class according to Jenks classification (dairy cattle (top left), barley (top right), oats (centre left), mixed crops (centre right), spelt (bottom left) and apples (bottom right).

For each element (e.g. dairy cows), we calculated the proportion of the top three classes of the total sum of the block values of all five classes (Table 2).

**Table 2.** Estimated total quantity and spatial concentration of studied agricultural by-products

| Studied agricultural by-products | Estimated quantity (units) | Estimated total quantity | Proportion of the sum of the values in the blocks in the upper 3 classes, % |
|---|---|---|---|
| Cereal straw | t | 164,650 | 74.2 |
| Spelt husks | t | 274 | 47.6 |
| Pruning residues | t DM | 21,958 | 65.5 |
| Apples (inferring apple pomace) | t | 500 | 70.9 |
| Dairy cows (inferring slurry) | t DM | 336,505 | 67.5 |
| Beef cattle (inferring slurry) | t DM | 68,431 | 67.1 |
| Pigs (inferring slurry) | t DM | 26,569 | 42.1 |

## Discussion

By far the most extensive by-product of agricultural production in Slovenia is livestock excreta. In the context of their more efficient utilization, special attention is given to slurry, whose annual quantity amounts to approximately 500,000 tonnes of dry matter, with nitrogen losses due to improper fertilization exceeding 20% (Verbič, 2022). In addition to improved fertilization technology (which is not the subject of this contribution), there is also potential to improve management through the production of heat and electricity (and potentially biogas), as its current utilization is well below 10% of its potential. A relevant alternative is combining slurry management with the energy use of woody biomass (e.g., biochar, which enables carbon sequestration in soils). These improvements require significant investments and are therefore unattainable for most farms. However, the relatively favourable spatial concentration of slurry quantities suggests the relevance of collective investments in this area. To enable this, legal barriers in the area of fertilization must first be addressed, as the current regulation limits the application of processed manure (e.g., digestate) solely to the farmer's own land, thus excluding collective investments de facto.

Among secondary crops and post-harvest residues, the residues from cereal harvesting stand out by quantity, with annual volumes amounting to approximately 300,000 tonnes of dry matter. There are various ways to add value to harvest residues: from niche products (e.g., building materials, packaging, growing substrates) to energy uses (heat, biofuels). Under the conditions in which Slovenian agriculture operates (low share of arable land, fragmented land use), it is reasonable to continue using most harvest residues to maintain soil organic matter balance. The dominant use (ploughing in, bedding) could be replaced by conservation practices, such as using residues as mulch. Only a few areas have sufficient spatial concentration and volume of residues; even there, niche strategies with high added value should be prioritized.

In fruit production, in the context of closing material loops through the valorization of by-products or co-products, a key issue is their high water content and consequent perishability. Therefore, for their efficient further use, it is necessary either to enable rapid batch processing of the residues or to introduce various measures to extend the stability of agricultural by-products. A specific challenge here is the small quantities involved, which lead to difficulties in organizing processing and an unfavorable cost-to-price ratio. Their economic viability is thus limited to high-end niche products (e.g. food supplements, promotional packaging).

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