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Balancing Feed Demand and Energy Supply: Technical Potential of Permanent Grassland Biomass in Poland

Magdalena Borzęcka

Department of Geomatics, Institute of Soil Science and Plant Cultivation—State Research Institute, 24-100 Puławy, Poland; mborzecka@iung.pulawy.pl

Abstract

This study presents a comprehensive methodology for assessing the technical potential of hay biomass from permanent grasslands (TUZ) in Poland, aimed at evaluating its energy use possibilities. This research was based on detailed data from the Agency for Restructuring and Modernization of Agriculture (ARiMR) and included both environmentally subsidized and non-subsidized parcels. Using statistical hay yield values adjusted for drought impacts through the Climatic Water Balance (KBW), a realistic estimation of technical hay potential was obtained. Results show a total theoretical hay potential of 15 million tonnes in 2024. The results indicate that the total theoretical hay potential in the country in 2024 amounted to 15 million tons, but its technical potential is reduced to almost zero. The methane productivity of this biomass could generate 3.5 Mt CH_4 (at STP) if most of it could not be used for animal feeding purposes. The findings highlight the underutilized energetic potential of grasslands and the critical role of land use policy in unlocking sustainable bioenergy resources. Research into the potential of biomass is important in view of supporting energy independence, sustainable use of agricultural resources and agroecological synergy by combining production, energy and environmental objectives. It should be remembered that biomass potential studies are subject to limitations resulting from the uncertainty of statistical data, variability of climatic and soil conditions and model assumptions, which may affect the accuracy and comparability of the obtained results.

Keywords: hay; biomass potential; methane

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1. Introduction

The area of permanent grasslands in Poland has significantly decreased over the past decade. Currently, it covers 3,014,295 ha, including meadows and pastures [1]. In Poland, the management of permanent grasslands is usually carried out extensively. The production potential of these areas is utilized domestically at approximately 60% [2], which is reflected in the low yield levels. Average hay yields from meadows are about 5.1 t·ha^{-1}, and green mass from pastures is 18.8 t·ha^{-1} [2,3]. Considering the production potential of meadows, estimated at 7–8 t·ha^{-1}, the obtained yields can be considered relatively low [4]. In Poland, the dominant method of preserving meadow sward remains hay drying. According to data from the Central Statistical Office (GUS) [5], in 2019 as much as 55.4% of harvests from permanent meadows was used for hay. Statistics, however, indicate a growing popularity of ensiling meadow sward; this method is currently applied to over 21.1% of the harvest, compared to just 3% in 2000 [6].

Meadows and pastures play a vital role in protecting the natural environment, influencing landscape shaping, water retention, and protecting soil against erosion [7]. Preserving them in unchanged form requires regular management through grazing, mowing, and the removal of hay. Properly managed agriculture therefore supports the conservation of biodiversity. However, excessive exploitation of meadows and pastures, combined with intensive fertilization, leads to the impoverishment of vegetation and a reduction in species richness, both in flora and fauna. The survival of their populations is possible only through the protection of natural meadow and pasture habitats and their proper management [8].

The most important tools for protecting permanent grasslands are the CAP instruments: conditionality, eco-schemes, and agri-environment-climate programs. They are complemented by the EU nature conservation framework (Natura 2000 [9]), as well as horizontal strategies such as the European Green Deal [10]. In practice, the effectiveness of these tools depends on the level of their implementation in Poland—for example, whether farmers are willing to undertake agri-environmental commitments [11,12]. However, the literature highlights that the effectiveness of CAP varies and depends on the implementation at the Member State level. In Poland, a special role is played by variants of Natura 2000 habitat protection and ecological obligations, which are crucial for the preservation of meadows and pastures [13,14]. Some of the biomass from these areas can be used for energy purposes. One way to utilize surplus biomass from permanent grasslands is biogas production. This solution can not only provide affordable energy but also support the protection of these areas against environmental degradation. The efficiency of biogas and methane production from meadow biomass depends on many factors, such as management practices, species composition of the vegetation, and preservation method. A key factor affecting biogas production efficiency from grasslands is the level of their exploitation. Biomass from extensively used meadows is not suitable for animal feeding due to its low feed quality, hence, its energy use does not cause social conflict related to the allocation of food raw materials for energy purposes. The suitability of biomass from permanent grasslands for energy purposes depends primarily on the quality of the raw material, determined by mowing date, botanical composition, and lignin, cellulose, and mineral content. Intensively used, fresh, and moist meadows with high yields and a high content of easily fermentable carbohydrates can be a substrate for biogas production [15]. However, they are also a good source of animal feed, so in this case, only the surplus biomass from these types of meadows should be used for biogas. On the other hand, biomass from semi-natural meadows, peat bogs, and naturally valuable habitats, mown late and characterized by high fiber, lignin, and ash content, is of little use in biogas plants. However, it can be burned (especially in the case of tall and woody grasses) or alternatively used as mulch or compost [16]. Biomass obtained from peat bogs and wet meadows has low feed value and high moisture content due to late mowing dates and a plant composition dominated by sedges, reeds, and wet grasses. For this reason, it is increasingly being used for biogas production, compost, or as an energy source in the form of briquettes and pellets. Semi-natural fresh and wet meadows, on the other hand, are characterized by higher productivity and higher feed value, with fresh meadows receiving the greatest share in agri-environmental-climate programs and being best suited for animal feed production [17].

Similar limitations apply to other habitats, such as calcareous grasslands, Molinia meadows, alluvial celery meadows, and halophytic swards. Due to their poor fodder value, biomass from these ecosystems also has little application in agriculture but can be considered a feedstock for renewable energy production. Semi-natural wet meadows are regarded as relatively productive grasslands, yet they are undervalued in forage production because

of the high proportion of low-quality species, including perennials, tall herbs, sedges, and rushes. By contrast, semi-natural fresh meadows represent anthropogenic grassland communities with the highest agricultural potential. These assemblages are dominated by tall and medium-height soft-leaved grasses and feature multi-layered vegetation. Within agri-environment-climate schemes, semi-natural fresh meadows cover about 42% of all grassland areas enrolled in such programs. Owing to their high forage value, biomass harvested from these meadows can be effectively used for livestock feeding [16].

The aim of this study was to develop and apply a comprehensive methodology for assessing the technical potential of hay biomass from TUZ in Poland, taking into account climatic variability, agri-environmental restrictions under the CAP, and spatial distribution of livestock density, in order to realistically evaluate the technical biomass potential of hay available for energy use without compromising feed requirements. A novel methodology for integrating ARiMR, KBW, and crop statistics data was developed, including the first-in-Poland combination of the TUZ–CAP databases with livestock density information. This enabled a realistic estimate of biomass availability for energy purposes. Spatial analysis enabled the identification of areas with the greatest potential for biomass utilization, and the results provide the basis for strategic recommendations supporting energy independence and sustainable land use within the national agricultural and energy policy.

2. Materials and Methods

2.1. Calculation of the Theoretical Potential of Hay

The theoretical potential of hay was understood as the maximum amount of biomass that can be harvested from TUZ. The process of estimating yields from permanent grassland was based on data from the ARiMR regarding crops for 2024. The process began with identifying appropriate agricultural plots meeting the permanent grassland criteria. Then, based on data from GUS presented in the table below, regarding estimated hay yields by cut (Table 1), average yields were calculated for three cuts in 2021–2024, where

1st cut = 2.8 t·ha^{-1}.

2nd cut = 1.94 t·ha^{-1}.

3rd cut = 1.18 t·ha^{-1}.

This gives an average yield of 5.92 t·ha^{-1} of biomass from permanent grassland, calculated as hay.

Based on the calculated data, the total theoretical yield was estimated for all grassland plots; then, these values were aggregated to the NUT 5 level to visualize the hay biomass potential on a national scale (Figure 1).

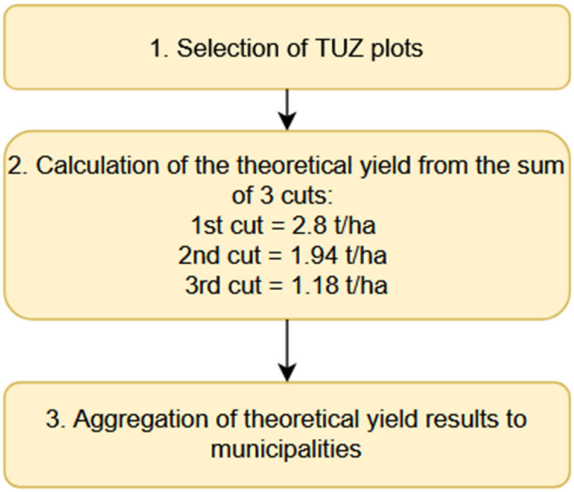


Figure 1. Steps for calculation of theoretical hay potential.

Table 1. Estimated hay yields by cut according to GUS data.

Year	Total (t·ha^{-1})	1st Cut (t·ha^{-1})	2nd Cut (t·ha^{-1})	3rd Cut (t·ha^{-1})
2021	5.92	2.85	1.95	1.12
2022	5.98	2.81	1.96	1.21
2023	5.80	2.74	1.89	1.17
2024	5.95	2.79	1.95	1.21

2.2. Methodology for Calculating the Technical Potential of Hay

The theoretical hay potential of each permanent grassland (TUZ) plot was calculated as a baseline value, which was subsequently reduced according to the methodological assumptions for estimating technical potential. TUZ data from ARiMR were used to classify plots into two groups: (i) those enrolled in agri-environment-climate or other payment schemes, and (ii) "conventional" plots without such support. Plots without program information were assumed to allow up to three cuts per year, while plots under payment schemes were assigned attributes reflecting program obligations (e.g., permitted mowing frequency, required unmown share). For plots participating in agri-environment-climate intervention programs, additional attributes were assigned based on program obligations, which served as reduction factors for the potential yield. In contrast, under the Organic Farming program, all permanent grassland (TUZ) plots are subject to obligations requiring that the yield be allocated for ecological purposes, i.e., as animal feed or fertilizer [18,19]. This requirement was not applied as a reduction in technical potential, since hay allocated to animal feed offsets fodder demand, which is considered at a later stage.

The variants relevant to TUZ, together with their management requirements which served as the basis for yield reduction, are listed in Table 2. First, the number of possible cuts per year was considered, which reduced yield values to one or two cuts. The next reduction factor was the unmown area, whose percentage share decreased the final yield within each plot. Subsequently, information on mowing dates was used to adjust the initial theoretical yield by a loss coefficient reflecting the occurrence of drought, thereby providing a more realistic estimate of the potential yield. Data on grass cutting times were obtained from GUS preliminary reports on major crop production, with the first cut assigned to the second half of May, the second cut to the second half of July, and the third cut to the second half of September. These dates were then linked to the corresponding KBW periods during the grass growth cycle. KBW expresses the difference between precipitation and potential evapotranspiration [20]. It is calculated using the following formula:

$$KBW = P - ETP$$

where

KBW—climatic water balance (mm);

P—total precipitation (mm);

ETP—potential evapotranspiration (mm).

The data on KBW related to 2024 for the analyzed location in accordance with the methodology adopted in the drought monitoring system [21].

After all corrections, final yields were calculated for each plot and aggregated to the municipal level, enabling analysis in an administrative context. The aggregated results also allowed for the estimation of hay biomass surpluses, taking into account the quantities required for livestock feeding [22]. The entire process is illustrated in the block diagram (Figure 2).

For the calculation of hay allocated to animal feeding, a daily ration of 20 kg of hay per livestock unit (LU) (Table 3) was assumed, regardless of whether the dominant feeding practice in a given region was grazing, hay feeding, or silage feeding. On an annual scale, including a 20% reserve, this corresponds to 8.76 t of hay per 1 LU. These estimates were adopted following Winnicki et al. [23].

Table 2. Program requirements for individual variants of agri-environment-climate interventions, compiled on the basis of the official information brochure [18].

Variant	Mowing Frequency	Unmown Area	Mowing Date	KBW Period
1.1, 2.1, 4.1, 5.1	1 cut	5–20%	1 September–31 October	R13
1.2, 2.2, 4.2, 5.2	Max. 2 cuts	5–20%	15 June–30 September	R7, R13
1.3, 2.3, 4.3, 5.3	1 cut	5–20%	1 August–31 October	R13
1.4, 2.4, 4.4, 5.4	Max. 2 cuts	5–20%	15 June–30 September	R7, R13
1.5, 2.5, 4.5, 5.5	Maks. 2 cuts	5–20%	15 June–30 September	R7, R13
1.6, 2.6, 4.6.1, 4.6.2, 5.6.1, 5.6.2	1 cut	Do 20%	15 August–15 February	R13
1.7, 2.7, 4.8	2 cuts	5–10%	15 June–10 July 15 August–31 October	R7, R13
1.8, 2.8, 4.10	2 cuts	5–10%	1 July–31 July 15 August–31 October	R7, R13
1.9, 2.9, 4.9	1 cut	5–85%	15 August–15 February	R13
1.10, 2.10, 4.11	1 cut	5–10%	1 August–31 October	R13
3.1	Max. 2 cuts	5–20%	15 June–30 September	R7, R13

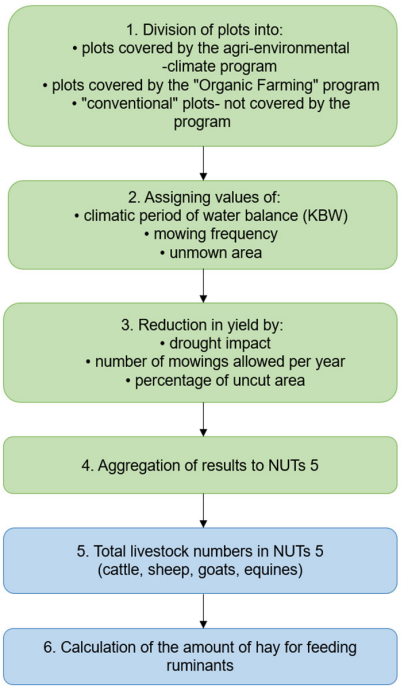


Figure 2. Steps for calculation of technical hay potential.

Table 3. Number of animals expressed in livestock units (LU), ratio LU/TUZ and total amount of hay allocated for their feeding by voivodeship.

Voivodeship	Livestock (LU)	Ratio LU/TUZ	Hay Allocated to LU (SK) [kt]
Dolnośląskie	95,052.8	0.82	832.7
Kujawsko-Pomorskie	376,896.9	5.15	3301.6
Lubelskie	277,925.7	1.58	2434.6
Lubuskie	81,158.9	0.75	711.0
Łódzkie	337,184.9	3.01	2953.7
Małopolskie	142,297.5	1.03	1246.5
Mazowieckie	947,069.9	2.62	8296.3
Opolskie	107,418.7	3.26	941.0
Podkarpackie	85,579.7	0.55	749.7
Podlaskie	798,395.3	2.33	6993.9
Pomorskie	185,507.1	1.70	1625.0
Śląskie	113,148.5	1.93	991.2
Świętokrzyskie	108,433.3	1.24	949.9

Table 3. *Cont.*

Voivodeship	Livestock (LU)	Ratio LU/TUZ	Hay Allocated to LU (SK) [kt]
Warmińsko-Mazurskie	363,500.1	1.29	3184.3
Wielkopolskie	891,662.3	4.76	7811.0
Zachodniopomorskie	96,085.6	0.54	841.7
Total	5,007,317.1	1.99	43,864.1

2.3. Methodology for Calculating the Energy Potential of Permanent Grasslands

One of the possible uses of surplus biomass from permanent grasslands is its conversion into biogas. This solution can not only provide relatively inexpensive energy but also contribute to the protection of areas against degradation. The efficiency of biogas and methane production from meadow biomass depends on several factors, including management practices, species composition of the vegetation, and conservation methods. A key factor influencing the biogas yield from grasslands is the intensity of their use. Intensively managed grasslands (mown 3–4 times per season) can produce up to two to three times more methane than extensively used areas. In this context, the botanical composition of the vegetation is of secondary importance [22].

To estimate the potential methane production, coefficients characterizing hay as a substrate in the anaerobic digestion process were applied. The energy potential was thus calculated based on the following parameters: dry matter content of 87.8% of input, organic dry matter content of 89.6% of DM, and a methane yield of 417.9 m^3 per tonne of organic dry matter [24].

3. Results

3.1. The Theoretical Potential of Hay

The theoretical hay yield potential from permanent grasslands for 2024 amounted to nearly 15 million tonnes in total (Figure 3). According to the table, the largest quantities of hay are found in the Mazowieckie and Podlaskie voivodeships, where values exceed 2 million tonnes. These are followed by the Warmińsko-Mazurskie, Wielkopolskie, and Lubelskie voivodeships, with yields ranging from 1 to 1.7 million tonnes. The remaining voivodeships report smaller yields, oscillating around 500 thousand tonnes. Those regions are characterized by a high proportion of TUZ due to favorable habitat conditions (organic soils, river valleys, wetlands). Maintaining permanent grasslands is also supported by the CAP's agri-environmental-climate programs, which promote the preservation of biodiversity and the water retention functions of these ecosystems.

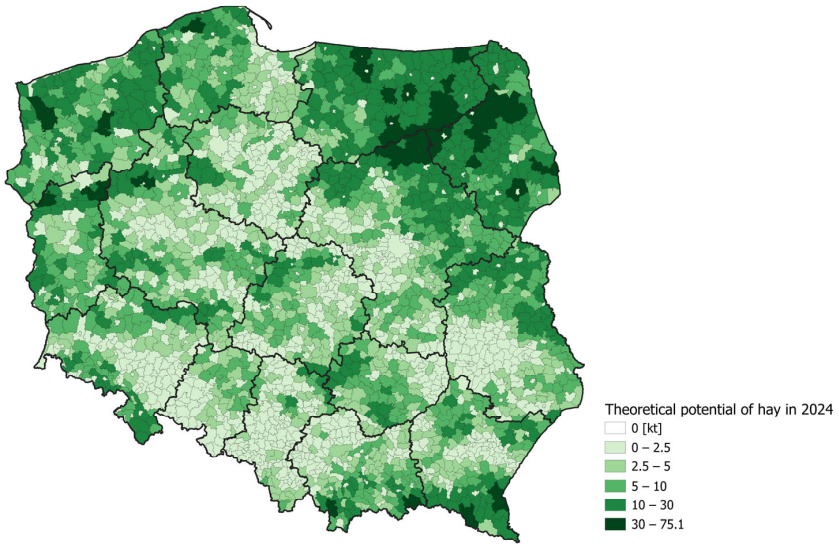


Figure 3. Theoretical potential of hay in 2024 at NUT 5 level.

3.2. The Technical Potential of Hay

The technical potential of hay from TUZ for 2024 amounted to a total of 86 thousand tonnes (Figure 4). According to the data, the largest hay surpluses are found in the Podkarpackie and West Pomeranian voivodeships, where values reach 54 and 32 thousand tonnes, respectively. In the remaining voivodeships, the total technical potential of hay is already negative; therefore, positive surpluses should be sought at the municipal level (NUT 5). The low potential for hay surpluses is due to the high number of animals in large units and high demand for hay intended for their feeding (Table 3).

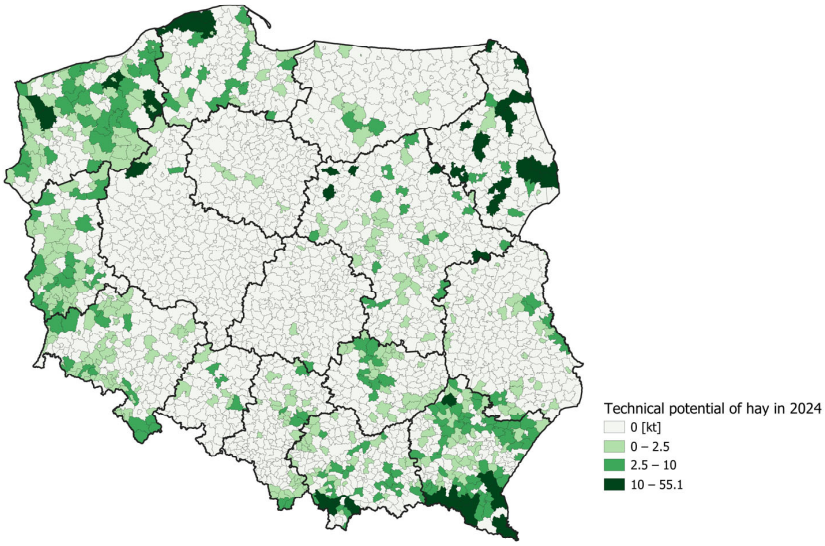


Figure 4. Technical potential of hay yield in 2024, broken down by municipalities.

3.3. Assessment of Energy Potential from Permanent Grasslands

In Poland, the theoretical potential of hay biomass corresponds to approximately 3.5 Mt CH_4 (at STP). However, when accounting for the feed requirements of ruminants, the national-scale technical potential decreases to zero. A positive energy potential is observed only in the Podkarpackie and West Pomeranian voivodeships. The results, broken down by voivodeship, are presented in Table 4.

Table 4. Regional breakdown of technical biogas production potential of hay.

Voivodeship	Dry Matter [kt]	Dry Organic Matter [kt]	Methane [kt o.d.m (at STP)]
Dolnośląskie	0.0	0.0	0.0
Kujawsko-pomorskie	0.0	0.0	0.0
Lubelskie	0.0	0.0	0.0
Lubuskie	0.0	0.0	0.0
Łódzkie	0.0	0.0	0.0
Małopolskie	0.0	0.0	0.0
Mazowieckie	0.0	0.0	0.0
Opolskie	0.0	0.0	0.0
Podkarpackie	47.2	42.3	0.0127
Podlaskie	0.0	0.0	0.0
Pomorskie	0.0	0.0	0.0
Śląskie	0.0	0.0	0.0
Świętokrzyskie	0.0	0.0	0.0
Warmińsko-mazurskie	0.0	0.0	0.0
Wielkopolskie	0.0	0.0	0.0
Zachodniopomorskie	28.3	25.4	0.0076

To better capture these spatial differences, results are presented at the NUT 5 level (Figure 5), allowing for a high-resolution assessment of local variability in biomass availability. This spatial scale shows that although the aggregated national potential is marginal, individual municipalities can still demonstrate positive technical potential, especially in regions with extensive grasslands and low livestock pressure. Presenting results at such a

detailed scale allows for the identification of local hotspots of high energy potential that would otherwise be invisible in more aggregated analyses (regional or national).

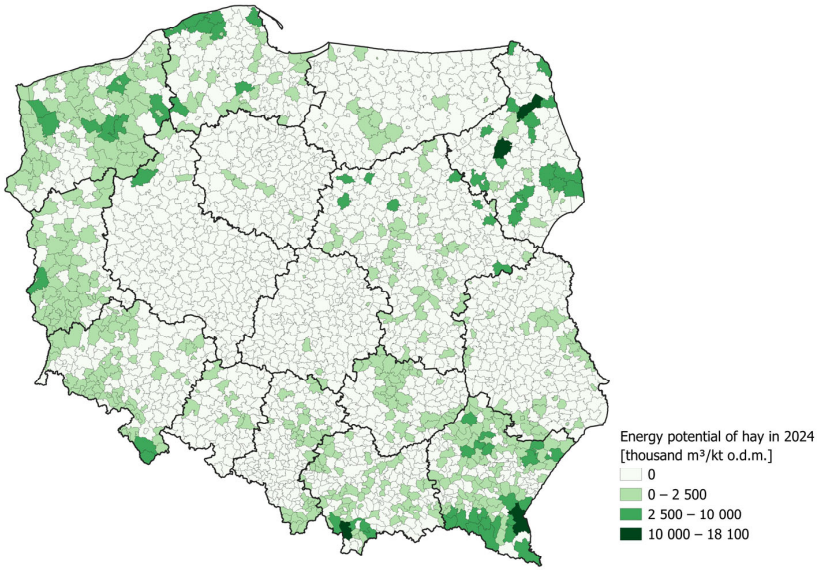


Figure 5. Biogas production potential from hay in 2024.

4. Discussion

The concentration of theoretical biomass potential in Mazowieckie and Podlaskie, each exceeding 2 Mt in 2024, suggests a spatial polarization of grassland productivity in Poland, driven by favorable environmental conditions and land use patterns, while the markedly lower yields elsewhere underscore regional disparities in grassland management intensity. This was confirmed by research indicating that the key determinant of management intensity in permanent grasslands, regardless of the farming system, is livestock density, expressed as livestock units (LU) per hectare of agricultural land [4]. Similar differentiation in grassland productivity across Poland has been noted [25], highlighting that eastern voivodeships generally maintain higher proportions of permanent grasslands compared to central and western regions. Such regional variability is also consistent with broader European assessments of biomass supply potential [26].

As can be seen, Poland is not uniform in terms of animal husbandry. There is a clear concentration of livestock in the center and northeast, which results from environmental conditions related to the high rate of permanent grasslands in these regions. However, Wielkopolska and Kujawy are regions with very intensive animal husbandry. For historical reasons, the West Pomeranian and Lubuskie Voivodeships are dominated by large, commercial farms focused on plant production. Despite a moderate ratio of permanent grasslands to permanent grasslands, Podlaskie has a very large livestock population, which indicates a large area of permanent grasslands (meadows and pastures). These results are confirmed by studies indicating that regional differences in natural and organizational-economic conditions influence the development and regionalization of agricultural production [27].

A key finding is that, at the municipal level, hay surpluses are generally negligible, with most production allocated to livestock feeding. This confirms the strong competition between the fodder and energy use of grassland biomass. The limited surplus biomass is a major barrier to large-scale energy mobilization in Poland [17,28]. Similarly, it was observed that in the EU, the majority of grassland biomass is locked in animal husbandry, leaving only a small fraction available for bioenergy without affecting feed security. This underlines the necessity of targeting low-quality biomass, produced under late mowing schemes, as a realistic energy resource [26].

Despite limited overall surpluses, certain regions, notably Podkarpackie and Zachodniopomorskie, exhibit positive municipal balances. These areas may provide opportunities for localized bioenergy initiatives, particularly biogas plants or pelletization facilities. Similarly, it has been reported that marginal grassland biomass, especially in regions of low livestock density or partial land abandonment, can be mobilized for energy purposes without jeopardizing feed supply [29,30]. Such localized potentials should be prioritized in regional energy strategies.

Although the calculated technical potential of hay biomass approaches zero nationwide, this result should be interpreted primarily as a methodological result, not a literal lack of available resources. This value reflects the model's equilibrium assumption, where ruminant feed demand takes precedence over energy consumption. Consequently, the "zero potential" results not from a lack of data, but from the model's structure, which deliberately excludes competition between feed and energy functions. However, at the local level (NUT 5), positive potentials appear, indicating the existence of biomass surpluses in regions despite the overall national equilibrium. Similar results were obtained in the case of hay surplus and manure modeling for Europe, where the surpluses occur in small concentrations [22]. The estimated national theoretical potential of hay biomass (15 Mt) translates into 3.1 Mt CH_4 (at STP), which could significantly contribute to Poland's renewable energy mix. Grassland biomass, while dispersed, represents a stable and underutilized substrate for biogas production [31]. On the EU scale, grassland biomass could provide 6–12% of total biogas feedstock, underscoring its strategic value [32]. Importantly, using surplus or low-quality hay for energy contributes to greenhouse gas mitigation and supports circular bioeconomy principles [33].

From a policy perspective, the results highlight the need to adapt CAP instruments to better integrate the energetic use of low-quality biomass from permanent grasslands. Introducing targeted incentives for energy-oriented mowing, particularly in areas with low livestock density, could help mobilize underutilized resources without compromising feed security or ecological functions. Measures such as agri-environmental payments for late mowing combined with energy valorization, or pilot schemes for decentralized biogas production, could create a synergy between rural development, renewable energy generation, and biodiversity conservation. In this context, the ongoing CAP reforms provide an opportunity to strengthen the bioenergy dimension of grassland management within national strategic plans.

Finally, the results emphasize that grassland biomass must be considered within a multifunctional framework. Grasslands deliver not only fodder and energy feedstock but also crucial ecosystem services such as biodiversity support, carbon sequestration, and water regulation [34]. Therefore, large-scale diversion of biomass from fodder to energy is neither feasible nor sustainable. Instead, energy strategies should prioritize the utilization of surpluses and low-value hay from conservation management [17], ensuring synergies between agriculture, energy, and biodiversity conservation.

This study is subject to several limitations that should be acknowledged. First, the estimation of hay biomass potential relied on statistical yield coefficients and KBW to approximate drought impacts. While this approach provides a realistic national-scale estimate, it does not capture fine-scale variability in biomass yields arising from soil heterogeneity, management intensity, or local climatic anomalies. Second, the analysis of theoretical potential incorporated agri-environmental and CAP 2023–2027 restrictions but did not include potential future changes in policy or local implementation practices, which may substantially influence biomass availability. Third, the assessment of surpluses was based on livestock density at the municipal level. However, feed demand is dynamic and may fluctuate with market trends, herd structures, and changes in feed substitution practices.

Another limitation concerns the energetic evaluation, which assumed average methane productivity values for hay biomass. In practice, methane yields are strongly influenced by species composition, cutting time, and pre-treatment technologies. This may lead to deviations between theoretical potential and actual biogas production performance. Furthermore, the study did not assess the economic feasibility or logistical aspects of biomass collection, transport, and processing, which represent critical determinants of practical bioenergy use.

Future research should focus on improving the spatial resolution of biomass yield assessments by integrating remote sensing, local field measurements, and farm-level data. Scenario-based analyses incorporating alternative policy frameworks, climate change projections, and technological advances in biomass conversion would provide a more comprehensive outlook on the role of permanent grasslands in bioenergy systems. Finally, interdisciplinary studies addressing trade-offs between energy production, fodder supply, biodiversity conservation, and ecosystem services are essential to inform sustainable strategies for the utilization of grassland biomass.

5. Conclusions

The present study quantified the theoretical and technical potential of hay biomass from TUZ in Poland for the year 2024. The total theoretical potential was estimated at over 15 million tonnes, with the highest contributions identified in Mazowieckie and Podlaskie voivodeships. However, when local livestock demand was incorporated into the assessment of technical potential, surpluses proved limited across most municipalities. Only in specific regions, such as Podkarpackie and selected areas of western and southern Poland, were positive municipal-level balances identified, indicating potential availability of hay biomass beyond agricultural use.

The conversion of this biomass to energy, based on dry matter and methane productivity parameters, was calculated to yield approximately 3.5 Mt CH_4 (at STP) annually. These results confirm that hay from TUZ constitutes a non-negligible substrate for renewable energy production. At the same time, they highlight the fact that the resource is spatially fragmented, regionally variable, and constrained by both fodder requirements and environmental regulations.

The findings suggest that the energetic use of biomass from permanent grasslands should be regarded as a complementary component of sustainable resource management, rather than a substitute for its primary function as animal feed. It is recommended that low-quality biomass derived from conservation mowing and areas with reduced agricultural demand be systematically integrated into national renewable energy strategies. Such an approach enables the utilization of otherwise underused resources while simultaneously supporting environmental objectives and maintaining the ecological and agricultural multifunctionality of grassland ecosystems.

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Data Availability Statement: The results of the work can be found on the geoportal being developed as part of task 6.1 entitled "Analysis of the biomass supply potential in 2025 at the national and regional level" from budget subsidies intended for the implementation of the tasks of the Ministry of Agriculture and Rural Development in 2025 under https://geoportal.biogospodarka.iung.pl/index.php/view/map?repository=dc6&project=biomasa1#1.142008,46.313244,37.431620,55.534435%7Cwojewodztwa%7Cdomy%C5%9Blny%7C1 (accessed 3 October 2025).

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Conflicts of Interest: The author declares no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

The following abbreviations are used in this manuscript:

TUZ	Permanent grasslands
ARiMR	Agency for Restructuring and Modernization of Agriculture
KBW	Climatic Water Balance
CAP	Common Agricultural Policy
OTOP	Polish Society for the Protection of Birds
o.d.m	Organic dry matter

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