

ECONOMIC ASSESSMENT OF PRODUCTIVITY IN OAK (*QUERCUS ROBUR*) AGROSILVOPASTORAL SYSTEMS IN THE HOMOROADELOR PLATEAU

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Abstract

The oak (*Quercus robur*) agrosilvopastoral system (ASP) from Mercheașă-Homorod, covering approximately 1,000 ha, is one of the most representative systems of this type in southeastern Transylvania, providing shade for livestock during the grazing season. The herbaceous layer beneath the tree canopy, dominated by *Festuca rupicola*, *Lolium perenne*, and *Trifolium repens*, produced 14.42 t ha⁻¹ of green mass and achieved a pastoral value of 70.7, compared with 9.60 t ha⁻¹ and 56.6, respectively, on the treeless pasture. The tree stand consisted of 16 trees ha⁻¹, belonging to four species, with crowns covering an average of 2,980 m² ha⁻¹. Milk production reached 1,712 L ha⁻¹, representing a 19% increase over the treeless pasture. At a harvesting age of 120 years, the woody component provides annually 0.65 m³ ha⁻¹ of timber and 0.45 m³ ha⁻¹ of fuelwood, in addition to acorn production. The total economic value of the ASP was estimated at €1,441 ha⁻¹ year⁻¹, nearly double that of the treeless pasture.

Keywords: oak (*Quercus robur*) agrosilvopastoral system, cow milk production, forestry production, economic value.

INTRODUCTION

Climate change is particularly affecting permanent grasslands and grazing livestock in Romania, as well as in other countries with warmer and drier climates where agrosilvopastoral systems (ASP) are known under names such as “dehesa”, “montado”, and “agroforestry” (Scharrow and Flechter, 1994; Olea and San Miguel, 2006; Hartel et al., 2017). In Romania, grasslands with scattered trees are locally known as “rariște” and “dumbravă” and occur

on communal pastures, especially in Transylvania and Banat, where they provide shade for grazing animals (Mihăilă et al., 2010; Marușca, 2012).

Productivity studies of permanent grasslands based on floristic surveys have enabled the assessment of pastoral value (PV) and green mass (GM) production in open grasslands and beneath tree crowns, highlighting the importance of ASP systems for animal welfare during the grazing season (Marușca,

2019; Marușca et al., 2020, 2025). The development of zoopastoral indices for estimating milk production, together with the economic valuation of timber and tree products (acorns, beechnuts, wild pears, etc.), has made it possible to compare the economic performance of ASP systems with that of treeless grasslands

(Corlățeanu, 1984; Marușca, 2025, 2026; Nesterov et al., 2006).

This study provides a comprehensive economic assessment of milk, construction timber, firewood, and acorn production in an oak (*Quercus robur*) dominated agrosilvopastoral system located in Mercheașa–Homorod, Homoroadelor Plateau, Brașov County, Romania.

MATERIAL AND METHOD

The economic study of the oak agrosilvopastoral system (ASP) was conducted on the communal pasture of Mercheașa village, Homorod commune, Brașov county. The system covers an area of 1,000 hectares, located at an altitude of 530 m in the Homoroade Plateau.

The wooded pasture is surrounded by forest stands on almost all sides. The existing forest vegetation was analyzed within three experimental plots of 1 ha each, considered representative in terms of tree density and their vegetative state (Figure 1).

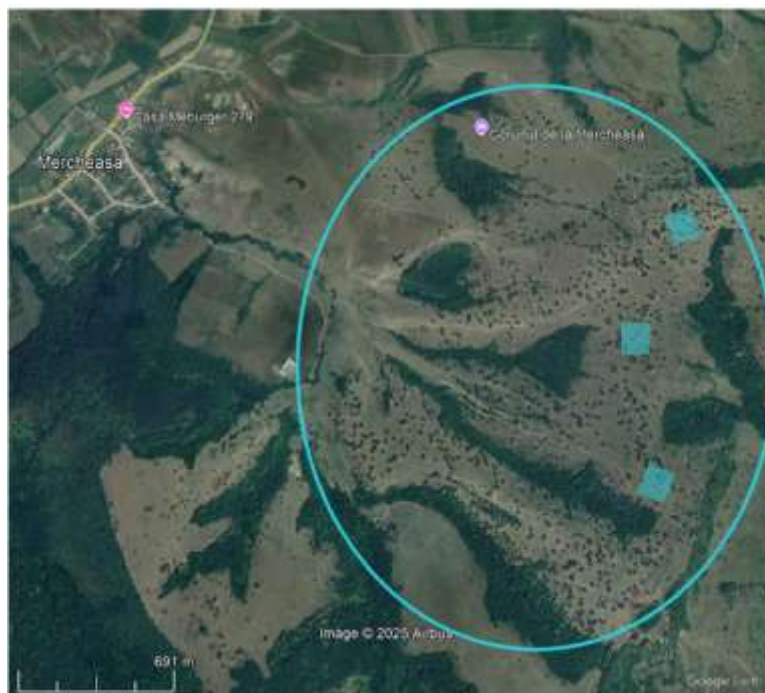


Fig. 1. Mercheașa Pasture and the location of the experimental plots, ■

From a pedological and floristic perspective, the soil characteristics, dominant species structure, and fodder quality indicators under both

conditions (open grassland vs. under trees' crowns) are summarized in Table 1.

Table 1
General data on the oak (*Quercus robur*) agrosilvopastoral system (ASP) from Mercheaşa–Homorod, Braşov County (Maruşca et al., 2020)

Grassland condition	Soil		Dominant species	Forage			
	pH (index)	Humus (%)		CP	CF	OMD	
Open grassland without trees (sun)	5.20	7.01	<i>Festuca rupicola</i> <i>Agrostis capillaris</i> <i>Trifolium repens</i>	17.1	28.5	58.6	
Under tree crown (shade)	5.35	7.19	<i>Festuca rupicola</i> <i>Lolium perenne</i> <i>Trifolium repens</i>	19.7	27.3	65.9	
Difference	+, -	+ 0.15	+ 0.18	x	+ 2.6	- 1.2	+ 7.3
	%	103	103	x	115	96	113

Legend: CP = crude protein (N x 6.25); CF = crude fiber; OMD = organic matter digestibility

The evaluation of pasture productivity was carried out using the floristic relevé method (Maruşca, 2019, Maruşca et al., 2020). Having available data regarding the pastoral value (PV), the production of green forage mass (GM), and the duration of the optimal grazing season (days), formulas were applied to evaluate milk production (Maruşca, 2025, 2026):

Milk Yield (L/ha) = GM Yield (Kg/ha) / GM Consumption (kg) required for 1L of milk
GM Consumption (kg) required for 1L of milk = 9.5 – 0.05 x VP

Where:

GM = green forage mass production (kg/ha)

PV = pastoral value index

The baseline economic value for one liter of cow's milk at the EU level was set at 0.5 Euro (according to MADR, 2025).

To determine the stem volume, the standard general formula factoring in trunk diameter and height was utilized:

V=BA·h·f=0,7854·d²·h·f

Where:

V = stem volume (m³)

BA = basal area at a breast height of 1.3 m (m²)

d = tree diameter at breast height (DBH)

h = total tree height (m)

f = stem form factor

Due to the exceptionally wide crowns and relatively short trunks characteristic of isolated ancient trees on wood-pastures, the form factor (f) was estimated at relatively low values: 0.35 for oak and sessile oak with a diameter under 100 cm; 0.30 for oak and sessile oak with a diameter over 100 cm (as the form factor decreases as diameter increases in ancient trees); 0.34 for wild pear and wild apple.

To account for total tree biomass (firewood from large branches and secondary boughs), additional correction coefficients were applied relative to the stem volume: 70% (0.70) of the stem volume for oak species (oak, sessile oak) due to highly developed crowns and 80% (0.80) of the stem volume for wild apple and wild pear (where the trunk is shorter, the crown begins very low, and branching is robust)

Market prices and unified labor standards used for the economic evaluation were as follows:

- Medium-quality raw log (construction/furniture timber): 1,000 – 2,000 lei/m³.

- Processed firewood (cut to 30–50 cm and delivered to commercial centers): 700 – 1,000 lei/m³. In the calculations, a baseline average of 850 lei/m³ applied for low-quality stem wood, and 350 lei/m³ for

mixed firewood from branches and boughs.

- Acorn production: Estimates were based on the average yields of natural forest ecosystems (600 – 1,200 kg/ha in mast years), establishing a baseline average of 150 kg/ha/year for the ASP system. Harvesting labor costs were calculated according to the Unified Time and Production Standards for Forestry Operations (MAPPM_RNP, 1997) at 8–10 RON/kg. The final market value used in the model was 1.8 €/kg.

- Wild fruit (apples and pears): Annual yield was estimated at 25 – 50 kg/tree, assuming basic annual crown pruning. Harvesting labor was evaluated at 2.5 – 3.5 RON/kg.

RESULTS AND DISCUSSIONS

Within these three experimental plots, 49 trees scattered across the pasture were identified, with a higher count in one plot (25 trees) and lower counts in the others (14 and 10, respectively), corresponding to an average of 16 trees/ha. This value falls within the lower half of the density range for oak-dominated wood-pastures in countries with a long-standing tradition in wood-pasture development, such as Spain, Portugal, Italy, and Greece. In these regions, the number of trees per hectare varies from 10 to 40 in the case of the first two countries, and from 10 to 100 for the latter two (Eichorn et al., 2006).

The species found on the pasture are: oak, which is predominant, with 9 specimens per hectare; sessile oak and wild pear, each with 3 specimens per hectare; and wild apple, with 1 specimen per hectare. The species proportions in the composition of the pasture are 56% St (Oak), 19% Go (Sessile oak), 17% Pă (Wild pear), and 8% Mă (Wild apple), resulting in the composition formula: 6St 2Go 2Pă and scattered wild apple (Mă). The wild apple and wild pear are medium-sized trees that contribute to the diversification and aesthetic enhancement of wood-pastures. Shrubs such as hawthorn, wild rose, and juniper are also present.

The analysis of structural dendrometric parameters (Table 2) highlights the old-growth character of this ecosystem. Oak exhibits the largest diameter values, while sessile oak records the largest crown projection area. Both oak and sessile oak have similar heights. Pear and apple trees exhibit lower values of diameter, height, and crown projection area compared with the oak species; however, pear shows greater diameter and height than apple. The crown projection area is larger in the wild apple tree than in the wild pear tree (Table 2).

The canopy cover index of the forest vegetation (excluding shrubs) was calculated at $I_a = 0.30$ (a canopy density of 0.3), representing a medium-to-high consistency for wood-pastures. The

high crown ratio (78–83% of total tree height) indicates extensive crown development and substantial foliar biomass. The high coefficients of variation for diameter and crown area show a high structural variability, pointing to a slight non-homogeneity in the development of these ancient pasture trees.

Regarding tree health, approximately 45% of the trees display signs of degradation or stagnation, including dry or broken branches, trunk tumors, heavy lichen colonization, and cavities. Mistletoe is frequently present on the oaks. Without targeted conservation measures to protect natural regeneration (especially of oak species and, to a lesser extent, wild pear, which occurs in specific patches), much of it will disappear due to intense grazing pressure from cattle, goats, and sheep.

The main economic product of the oak-dominated agrosilvopastoral (ASP) system in Mercheașa is cow's milk, which was evaluated based on the VP index, green mass (GM) production, and grazing season length under both open-field conditions and trees canopy cover (Table 3). The assessment of productivity indices over a 172-day grazing season indicates a clear superiority of shaded/tree-influenced areas compared with open-field areas (Table 3).

Table 2

Main dendrometric parameters of the trees on the Mercheașa Wood-Pasture

Parameters	ST	GO	PĂ	MĂ	Total
Number of trees / 3 ha	27	9	8	4	48
Mean DBH (cm)	117	85	58	49	
Min	57	68	44	38	
Max	195	156	79	67	
Coefficient of variation (%)	32	32	18	27	
Mean H (m)	19	20,3	12,2	9,5	
Min	9	16,7	9,6	6,6	
Max	24	23,6	15,3	12,0	
Coefficient of variation (%)	19	13	19	25	
Mean crown H (m)	15,7	16,8	10,0	7,5	
Min	6,6	13,2	7,1	4,9	
Max	20,5	20,7	13,3	9,8	
Coefficient of variation (%)	21	17	25	29	
Crown ratio (%)	82	83	81	78	
Min	69	63	73	74	
Max	90	88	87	82	
Coefficient of variation (%)	7	9	7	5	
Mean crown projection area (m ²)	208	241	86	117	
Min	95	138	63	70	
Max	334	412	127	217	
Coefficient of variation (%)	31	36	27	58	
Σ S crown projection/ha (m ²)	1872	723	229	156	2980
Symbols: ST – <i>Quercus robur</i> , GO – <i>Quercus petraea</i> , PĂ - <i>Pyrus pyraster</i> , MĂ – <i>Malus sylvestris</i> , Mean DBH – Mean diameter at the breast height; Mean H – Mean height; Min – Minimum recorded value, Max – Maximum recorded value, Crown ratio (%) - ratio of crown length to total tree height, expressed as a percentage, Mean crown projection area (m ²) - mean area of the vertical crown projection onto the ground (m ²), Σ S crown projection / ha (m ²) - total area of vertical crown projections per hectare					

The increase in green mass (GM) production beneath tree crowns (+48%) is promoted by the concentration of nutrients derived from livestock manure beneath tree crowns, where animals seek shade and shelter. Changes in microclimatic conditions and soil properties (an increase of 0.15 pH units and a 0.18% higher humus

content) favor the dominance of the valuable species *Lolium perenne* over *Agrostis capillaris* (Table 1). This results in forage of higher quality, with increased crude protein content (+2.6%) and greater digestibility (+7.3%), thereby reducing the amount of herbage required per litre of milk produced (Table 1).

The VP index of 70.7 recorded in the agrosilvopastoral system is 25% higher than that of treeless pasture, while the green mass requirement of 6.0 kg L⁻¹ of milk is 10% lower than under open-field conditions without

trees (Table 3). The estimated milk production reaches 2,370 L ha⁻¹ beneath tree crowns, representing a 65% increase compared with open-field pasture.

Table 3
Evaluation of the main grassland productivity indicators in the ASP system with oak (*Quercus robur*) during a 172 day grazing season

Specification	Unit	Open grassland	Under trees	Difference	
				+, -	%
Green mass (GM) production	t/ha	9.60	14.22	+ 4.62	148
Optimal livestock load	LU/ha	0.86	1.27	+ 0.41	159
Pastoral value (PV)	Ind.	56.6	70.7	+ 14.1	125
GM Consumption for 1L of milk	Kg/L	6.7	6.0	- 0.7	90
Cow milk production	L/ha	1433	2370	+ 937	165

The total tree volume (main trunk and branches) is:

$V_{total} = V_{trunk} + V_{trunk} \times 0,60$.

The trunk volume for the three experimental plots is: 27.14 m³ for sessile oak, 127.97 m³ for pedunculate oak, 6.82 m³ for wild pear, and 2.17 m³ for wild apple.

The volume of thick branches, secondary branches, and the tree top per hectare is 9.05 m³ for sessile oak, 42.66 m³ for pedunculate oak, 2.41 m³ for wild pear, and 0.77 m³ for wild apple. Reported per hectare, the volumes structured by species and assortment categories are presented in Table 4.

Table 4
Timber volume and economic value estimation in the Mercheașa ASP system

Analyzed Indicators / Economic Parameters	Species			
	Go	ST	PĂ	MĂ
V_trunk/ ha	12,92	60,94	2,84	0,91
Average price/m3	850	850	850	850
Average_price_V_trunk_processed_cut_delivered	10982	51799	2414	773,5
V_branches_boughs/ha	9,05	42,66	2,41	0,77
Average price /m3	350	350	350	350
Average_price_V_branches_boughs	3167,5	14931	843,5	269,5
Total price_ Total tree V	14150	66730	3258	1043

Although pedunculate and sessile oak wood is a hardwood, normally intended for construction or fine furniture, the quality of isolated trees in this pasture is medium to poor due to knots, sweeps (crooks), and rots. For this reason, the economic calculation was based on a mixed valuation or as firewood. Given the fundamental ecological and landscape role of these ancient trees, their total extraction is not economically or ecologically justified; the model serves only as an inventory of natural capital, recommending exclusively the harvesting of completely dried specimens.

In addition to wood, pedunculate and sessile oaks provide fruits (acorns), which are important for their nutrient content (proteins, lipids, carbohydrates, mineral salts, and vitamins) (Corlăţeanu, 1984, Nesterov et al., 2006). On pastures, where the oak has more light and space, it fructifies more frequently and abundantly, but the acorns may be smaller than those from forest oaks. It generally begins to bear fruit from 30–40 years of age for pedunculate oak and 40–50 years for sessile oak. It fructifies abundantly every 4–6 years for sessile oak and 5–8 years for pedunculate oak during "mast years" (heavy fruiting years), but produces acorns in smaller quantities almost every year. Heavy

fruiting depends on: climate (temperatures, drought), soil, and tree stress (dieback, pruning, diseases). As for the wild pear and wild apple, they have constant fructification, with a progressive production starting from the age of 8–10 years. The fruits are used as food for both wildlife and domestic animals. In the past, they were also used for preparing alcoholic beverages.

It is important to mention that sessile and pedunculate oak, as well as wild pear and wild apple, are highly valued species in terms of forest protection and landscape value on pastures. They can be harnessed for their ecosystem services, among which improving the microclimate and providing shelter for grazing animals prevail.

The synthesis of all quantifiable metrics (livestock yields, annualized silvicultural volumes, and non-timber forest products) reveals a doubled financial return for agrosilvopastoral systems over conventional open pasture monocultures (Table 5).

It is mentioned that the timber values were analyzed by reporting the total accumulated volume to an estimated average rotation age/harvest cycle of 120 years.

Table 5

Comparative annual economic value of ASP systems versus tree-less pastures (TLP)

Specification	Pasture system			Difference ASP-TLP	
	ASP	%	TLP	+, -	%
Cow milk production (L/ha/year)	1712		1433	+279	119
Value (x 0,5 €/Liter)	856.00	59	717.00	+ 139.00	119
Timber m ³ /ha at 120 year	77.61		-	-	x
Timber m ³ /year	0.65		-	-	x
Value (x 160 €/m ³)	110.50	8	-	-	x
Firewood m ³ /ha at 120 year	54.89		-	-	x
Firewood m ³ /year	0.45		-	-	x
Value (x 60 €/m ³)	33.30	2	-	-	x
Acorn kg/ha/year	150		-	-	x
Value (x 1.8 €/kg)	270.00	19	-	-	x
Additional Milk (20% crown shade effect)	342		-	-	x
Valoare (x 0.5 €/an)	171.00	12	-	-	x
Total annual value (€)	1440.80	100	717.00	+ 723.80	201
TLP = treeless pastures – open fields					

The total annual revenue generated within the ASP system reaches **1,441 €/ha/year**, compared to only **717 €/ha/year** for the tree-less pasture, representing a 101% increase. Within the ASP revenue structure, livestock products generate the dominant share at 71% (comprising 59% base milk and 12% additional milk gained through microclimatic buffering). The secondary products of the trees

represent the remaining 29% (19% the value of acorns, 8% construction timber, and 2% firewood). Beyond these tangible returns, the system offers unquantifiable ecosystem services: improved livestock health, stabilized atmospheric and soil moisture, and enhanced biodiversity (such as insectivorous birds that naturally suppress pasture canopy pests).

CONCLUSIONS

Pastures integrated into agrosilvopastoral (ASP) systems dominated by oak (*Quercus robur*) are twice as valuable economically compared to conventional treeless pastures.

The real and potential milk production within the oak ASP system achieves an optimal level of 1,712 L/ha/year compared to 1,443 L/ha/year in open pastures, representing a 19% increase driven

by higher forage quality and increased pastoral value under the tree canopies.

The consolidated annual economic value of the ASP system reaches 1,441 €/ha/year (at a calculated parity of 1 € = 5 RON), comprising 71% dairy products, 19% acorns, 8% construction

timber, and 2% firewood. In addition to direct financial benefits, the presence of scattered ancient trees provides major ecological returns by maintaining a pastoral landscape of high aesthetic value and supporting regional biodiversity conservation.

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