ECONOMIC EFFICIENCY OF PRODUCTIVITY OF AGROSILVOPASTORAL SYSTEMS WITH OAK (*QUERCUS ROBUR*, Mattuschka Liebl) IN THE BRAȘOV DEPRESSION

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Abstract

Studies on oak pastures (Quercus robur, Mattuschka Liebl) as the agrosilvopastoral (ASP) system in the Brașov Depression (550 m altitudine), highlight their superiority from all perspectives compared to treeless pastures. On a surface of 45.0 ha in Dobolii village (Ilieni commune, Covasna County), 292 oak and wild pear trees were inventoried, in a ratio of 9:1, unevenly distributed, with an average crown projection of 1,811 m² per hectare. The grass cover under the tree crowns, dominated by Lolium perenne, has a yield of 16.66 t/ha of green mass (GM), a pastoral value index (PV) of 82.9, and 9,020 liters of milk per hectare. On the treeless pasture, dominated by Agrostis capillaris, a yield of 14.92 t/ha GM, a PVI of 77.3, and 7,420 liters of milk were assessed. The total wood volume per hectare is 56.7 m³ for oak and 1.3 m³ for wild pear. The total economic value (milk, wood, acorns) of the ASP system reaches €4,879/year/ha, which is 32% higher than that of the treeless pasture.

Keywords: agrosilvopastoral system with *Quercus robur*; milk production; wood volume; economic value

INTRODUCTION

Agrosilvopastoral (ASP) systems with oak (*Quercus robur*, Mattuschka Liebl), sessile oak (*Quercus petraea*), beech (*Fagus sylvatica*), and wild pear (*Pyrus pyraster*) are widespread in Transylvania, providing shade for livestock during the grazing season on communal pastures. Used for centuries, and still today, these systems are particularly valuable for both livestock and the herbaceous layer, especially in the context of global climate warming and its negative effects on pasture productivity and animal products.

ASP systems (pastures with trees) are well represented in the warm and arid climates of Mediterranean countries, known as "dehesa" in Spain and "montado" in Portugal, and as "agroforestry" in English-speaking countries (Sharrow et al. 1994; Olea et al. 2006; Hartel et al. 2017). In Romania, such pastures are traditionally known as "rarişte" or "dumbravă" (Mihăilă et al. 2010; Maruşca 2012). In recent years, the first studies have assessed the yield and forage quality of the herbaceous layer beneath the tree canopy and in

open pasture, highlighting the productivity of ASP systems (Taulescu et al. 2024), with these data also supporting the economic evaluation of such systems (Marușca et al. 2025a, b). The present work continues the comprehensive economic assessment of vegetation productivity expressed through milk, timber (construction and firewood), and acorn production in ASP systems with oak in the Brașov Depression.

MATERIAL AND METHOD

The productivity studies of the herbaceous pasture layer and the assessment of both primary and secondary woody biomass production were conducted on the communal pasture of Dobolii village, Ilieni commune, Covasna County, on a 45.0-ha area of private land belonging to the "Înfrățirea" Association (Figure 1).

Fig. 1. Dobolii Pasture with trees, Ilieni Commune, Covasna County, Romania

The oak ASP system, located at 550 m altitude presents site-specific characteristics, herbaceous layer composition and several forage quality parameters that are improved under the trees crown (table 1).

From these data, a small difference can be observed between the soil characteristics and the floristic composition of the herbaceous layer in open field and under trees, because in both situations the vegetation is dominated by highly valuable forage species such as *Lolium perenne*, *Agrostis capillaris*, and *Cynosurus cristatus*.

Table 1

General data on ASP systems with oak (*Quercus robur*)

Pasture condition	Soil		Dominant species	Fodder		
	pH (indicator)	Humus (%)		CP	CF	OMD
Open field (Sun)	5.50	6,15	*Agrostis capillaris Lolium perrene Cynosurus cristatus*	17.5	27.9	63.0
Under trees (Shade)	5.60	7,09	*Festuca rubra Agrostis capillaris Trifolium repens*	18.8	27.0	63.4
Difference Shade-Sun (%)	102	115	X	107	97	101
Symbols: CP – crude protein (Nitrogen x 6.25); CF – crude fiber; OMD – organic matter digestibility						

This confirms the very good management of the studied grasslands, which are capitalized through rational grazing with cattle. The grasslands are grazed by dairy cows of the "Romanian Spotted" (*Simmental*) breed and "Angus" cattle, for a period of approximately 160 days. The actual assessment of grassland productivity, highlighted by the pastoral value (PV) and the green mass (GM) yield under trees and in open fields, was carried out based on a floristic survey (Marușca 2019, Marușca et al. 2020).

The potential milk production was evaluated using the formula:

Milk production (L/ha) = PV x GSD x 0.6 (Marușca et al. 2018, Marușca 2022)

where:

- PV = pastoral value index
- GSD = grazing season duration (days)
- 0.6 = milk coefficient achieved on pasture, determined after 20 years of long-term experiments with dairy cows.

After establishing the projection of the tree crown on the pasture, the weighted average of milk production under trees and in open fields (without trees) was calculated. The determination of the number of trees by species, the volume of timber and firewood, and the acorn production was carried out for the entire area under study (45.0 ha).

The benefits of trees on pastures are both ecological, economic, and social, and therefore the services provided by tree-covered pastures include both quantifiable and non-quantifiable elements.

The microclimate created by trees on the pasture is an important ecological benefit, but difficult to quantify. By contrast, the timber and non-timber products obtained from

trees on pastures are quantifiable, and their economic evaluation is important for promoting the maintenance and care of existing pastures or the establishment of new ones. Tree products frequently used by local communities include: acorns for feeding pigs or sheep, as well as for handicraft work, and foliage for supplementing animal feed when grass is scarce during certain periods. However, the highest revenues can be obtained from the sale of timber resulting from the selective removal of certain trees from pastures, as long as these removals do not affect the stability and ecological balance of the existing pastures. To quantify the revenues that can be obtained from the sale of timber harvested from pastures, it is necessary to determine the volume of wood mass of the removed trees.

The volume of trees can be calculated using formulas that take into account the trunk diameter and the height of the tree. The most commonly used general formula for calculating the volume of a tree is:
where:
$V = BA \times H \times f = 0.7854 \times DBH^2 \times H \times f$ (Giurgiu 1979, Leahu 2001)

- V = tree volume (m^3)
- BA = basal area (m^2)
- DBH = diameter at breast height (cm)
- H = total tree height (m)
- f = form factor, accounting for trunk shape (typically ranging from 0.4 to 0.7 for forest trees).

Given the fact that the isolated trees in pastures are generally old, over 100 years, the value of the form factor "f" was adjusted to 0.40–0.35. It should also be noted that the volume calculated with this formula does not include the volume of branches and secondary limbs, but only the volume of the tree trunk, from the base up to the tip of the main stem. To include the volume of branches, an additional correction coefficient must be added, which for broadleaf species is 0.30–0.45% of the trunk volume. For the ASP system at Dobolii, the trunk volume of the oak and wild pear trees present on the pasture was determined by applying the formula presented above, using a form factor value of f = 0.38 for oak and f = 0.35 for wild pear, since their trunks show, in some specimens, defects such as hollows, rot cavities, or irregular shape.

However, oak and wild pear provide fruits (acorns and pears) that are important sources of nutrients such as proteins, lipids, carbohydrates, mineral salts, and vitamins. (Corlățeanu, 1984; Nesterov et al., 2006). In pastures where oak trees have more light and space, they fruit more frequently and abundantly, although the acorns may be smaller than those produced by oaks in forests. Oak typically begins to produce fruit at 30–40 years of age. It fruits abundantly every 5–8 years in the so-called "mast years," but produces smaller quantities of acorns almost every year. Heavy fruiting depends on factors such as climate (temperature, drought), soil, and tree stress (dryness, pruning, diseases). No estimates were made of the acorn production in the analyzed areas, but forest oaks produce, depending on the fruiting cycle, between 600 and 1,200 kg per hectare (Nesterov et al., 2006).

The labor cost for harvesting one kilogram of acorns varies between 8 and 10 lei, the higher value being due to the difficulty of collection. These values were calculated using the Unified Time and Production Norms for Forestry Operations Unified (MAPPM_RNP, 1997), assuming average fruiting conditions. The labor cost is increased by the commercial markup of the seller, resulting in a final price of approximately 15 lei/kg of oak acorns. As for wild pear, it produces fruit regularly starting from 8–10 years of age and yields between 25 and 50 kg of fruit per tree annually (Nesterov et al., 2006; Stănescu et al., 1997, Șofletea and Curtu, 2001). The labor cost for harvesting one kilogram of pears ranges from 2.5 to 3.5 lei, calculated using the above-mentioned standards, under conditions of average fruiting. A commercial markup is added by the seller, resulting in a final price of 4–5 lei/kg for wild pears. The fruits are used as feed both for wildlife and for domestic animals.

Due to the very small number of pear specimens in the ASP system at Dobolii, their fruits have no economic relevance; most likely, the fruits are consumed by domestic or wild animals. It is important to note that both oak and wild pear are valued for their silvoprotective and landscape functions in pastures. They can be valued for their ecosystem services, such as improving the microclimate and providing shelter for grazing animals.

RESULTS AND DISCUSSIONS

The main components underlying the economic evaluation of the ASP system with oaks were: green mass (GM) production, pastoral value (PV), cow milk production during the grazing season, the quantity of construction-grade timber and firewood, acorns and wild pears, as well as the annual yield. The productivity of the grassland in the ASP system was ultimately expressed through milk production (Table 2).

Table 2

Evaluation of the main pasture productivity indices in the oak ASP system during the 160-day grazing season

Specification	Open grassland	Under trees	Difference (%)
Green forage mass production (t/ha)	14.92	16.66	112
Optimal livestock load (LU/ha)	1.43	1.60	112
Pastoral value (Ind)	77.31	82.91	107
Cow milk production (L/ha)	7420	7960	107

From these data, it follows that the green mass production beneath the trees is 12% higher than on a treeless pasture, due to the higher concentration of animal droppings and the protection from intense heat. The floristic composition under the trees,

dominated by *Lolium perenne*, has a higher fodder value compared to that of open pasture without tree protection, which is dominated by *Agrostis capillaris*. Under these conditions, 7,960 liters of milk were estimated under the tree canopy, representing a 7% increase compared to the treeless pasture. To this, one must add the improved animal welfare provided by tree shade during periods of excessive summer heat, which can contribute an additional 20–40% increase in milk production compared to pastures without trees. Regarding the economic evaluation of the woody vegetation in the ASP system under study, a series of measurements and assessments were performed to determine tree composition and volume (Table 3). On the pasture, a total of 292 oak (*Quercus robur*) and wild pear (*Pyrus pyraster*) trees are unevenly distributed, corresponding to an average density of 8 trees/ha. A number of 103 trees were inventoried across the entire pasture, representing approximately one third of the total tree population. Of these, 94 are oak and 9 are wild pear, giving a species ratio of 91% and 9%, respectively. Therefore, the pasture composition can be expressed as 9Oak 1Pear.

Table 3

Main dendrometric parameters of the Dobolii oak ASP system

Analyzed characteristic	**ST**	**PĂ**	**Total**
No. of trees / 15 ha	94	9	103
Mean DBH (cm)	**96**	**53**	
Min	51	12	
Max	150	73	
CV (s%)	17	41	
Mean H (m)	**20,9**	**12,5**	
Min	14,4	6,0	
Max	28,9	18,4	
CV (s%)	17	32	
Crown (% of total height)	**84**	**77**	
Min	77	70	
Max	91	85	
CV (s%)	19	26	
Σ A crown projection (m2)	**15 315,5 / 51 trees**	**590,0 / 6 trees**	**15 905,5/ 57 trees**
Mean crown projection (m²)	**300,3**	**98,3**	**279,0**
Min	112	79	
Max	518	117	
CV (s%)	31	18	
Σ A crown projection / ha (m²)	**1742**	**69**	**1811**

Symbols: ST – pedunculate oak, PĂ – wild pear
Mean DBH – Mean of diameter of breast height; Mean H – Mean height; Min –Minimum recorded value, Max – Maximum recorded value, CV – Coefficient of variation, %, Σ A crown projection – Cumulative sum of crown area projection

Analysis of dendrometric parameters indicates a good vegetation condition of the trees on the pasture, with high coefficients of variation for both diameter and height (17–19%), a perfectly normal condition for oak specimens growing outside forest stands. Horizontal crown projections were measured for 57 trees distributed across the entire pasture (45.0 ha), representing 19.5% of the total 292 trees. The total sum of crown projection areas was 15,905.5 m², corresponding to an average projection of 279 m²/tree. Since they did not grow in dense stands, the trees developed crowns in all directions (N, S, E, W), and tree heights are also high, ranging from 11.7 to 25.5 m, with a coefficient of variation of 19%. The degree of ground coverage is expressed through the canopy coverage index (Ia), calculated as the ratio between the total crown projection area (15,905.5 m²) and the total pasture area (450,000 m²) (Ciubotaru and Păun, 2018). Thus, Ia = 3.53, corresponding to a stand density of 0.35 — a medium–high density typical for tree–pasture systems. Crown projection per hectare was estimated at 1,811 m² (1,742 m² for oak and 69 m² for wild pear). Milk production per hectare in the ASP system was determined using a weighted average between the milk production assessed under tree cover and in open pasture.

Additionally, for cows benefiting from shade in the ASP system, it was estimated that shade contributes at least 20% additional milk yield compared to cows grazing and resting in open sun, where a considerable share of energy is redirected towards thermoregulation during periods of excessive heat in the grazing season. Furthermore, ASP systems support nesting of numerous bird species that feed on insects and rodents harmful to both pasture productivity and biodiversity. Using available data on pasture productivity, expressed as cow milk yield in ASP systems with and without trees, together with wood volume (stem and branches), acorn production, and their economic value in Euro (1€ = 5 lei), an integrated economic evaluation of all ASP components was carried out (Table 4). From these data, it follows that milk production calculated strictly based on the pastoral value of the grass cover, 7,520 L/ha, is only 2% higher in the ASP system compared to treeless pasture, as a result of rational management and sustainable use of the studied area by the beneficiaries.

Table 4

The comparative economic value of the ASP system dominated by oak versus a treeless pasture (TLP)

Specification	***Pasture system***		
	ASP	*TLP*	*%*
Cow milk production (L/ha/an)	7520	7420	101,3
Value (x 0,5 €/Liter)	**3760**	**3710**	**101,3**
Timber m^3/ha at 120 years old	35,4	-	X
Timber m^3/year	0,30	-	X
Value (x 170 €/m3)	**51**	-	X
Firewood (Oak & Wild Pear), m^3/ha/year	0,80	-	X
Value (x 60 €/m3)	**48**	-	X

Acorn kg/ha/year	150	-	X
Value (x 1.8 €/kg)	**270**	-	X
Estimated additional milk production under tree shade, minimum 20% (l/year/ha)	1500	-	-
Milk value (x 0,5 €/Liter)	**750**	-	-
Total annual value (€)	**4879**	**3710**	**131,5**
Symbol: TLP – treeless pasture – open field			

When including the estimated 20% additional milk production for cows benefiting from tree shade, the yield reaches 9,020 L/ha, which is 22% higher than in the treeless pasture. Ultimately, in the ASP system with oaks, milk production accounts for 92.4% and woody vegetation for 7.6% of the total value of €4,879/ha.

CONCLUSIONS

- Pastures in oak-dominated agrosilvopastoral (ASP) systems (*Quercus robur*) are superior in both productivity and economic value compared to treeless pastures.
- Cow milk production in the ASP system is estimated at 9,020 L/ha on pastures dominated by *Lolium perenne*, which is 22% higher than that of treeless pastures dominated by *Agrostis capillaris*.
- The economic value of milk production in the ASP system, €4,510/ha/year, together with the value of wood production, €369/ha/year, is 32% higher than that of neighboring treeless pastures, with additional benefits that are harder to quantify, such as enhanced biodiversity and improved pastoral landscapes.

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