STUDIES ON THE ECONOMIC EFFICIENCY OF THE PRODUCTIVITY OF AGROSILVOPASTORAL SYSTEMS WITH SESSILE OAK (*QUERCUS PETRAEA*) IN SOUTH-EASTERN TRANSYLVANIA

Teodor MARUȘCA[1], Elena MIHĂILĂ[2]*, Elena TAULESCU[3], Dorina DRĂGAN[4], Paul Marian ZEVEDEI[5]

Abstract. *Agro-silvo-pastoral (ASP) systems have been widely established on the pastures of Transylvanian localities, mainly to provide shade for animals during the grazing season. In view of global climate change, ASP systems play a crucial role not only for livestock and grass cover but also for biodiversity in general. The studies were carried out in the Herculian locality in the Baraolt Mountains, on a pasture with 77% sessile oak (Quercus petraea) and 23% pedunculate oak (Quercus robur), with a canopy cover of 22% of the pasture area. Cow milk production in the ASP system was evaluated at 5,790 l/ha, 12% higher than on treeless pasture. In addition, over 120 years, construction timber, firewood branches, and acorns are harvested in the ASP system; together with milk production, this amounts to €3,737/ha/year, 44% higher than the value of milk production alone on treeless pasture. These results support the conservation and expansion of ASP systems in areas affected by climate aridification.*

Keywords: agrosilvopastoral systems, milk and wood production assessment, milk and wood price evaluation

DOI 10.56082/annalsarsciagr.2025.2.36

1. Introduction

As a result of global climate change, it is necessary to adopt measures to prevent negative effects, similar to those taken in countries with dry and hot climates that maintain agrosilvopastoral (ASP) systems known as "dehesa," "montado," "agroforestry," etc. [5;16;17].

[1] PhD, Eng., Senior Researcher, Research and Development Institute for Grasslands Brașov, Romania, Full Member of Academy of Romanian Scientists (e-mail: maruscat@yahoo.com).
[2] PhD, Eng., Junior Researcher, National Institute for Research and Development in Forestry "Marin Drăcea", Bucharest, Romania (e-mail: elena.mihaila@icas.ro).
*Corresponding Author: elena.mihaila@icas.ro
[3] PhD student, Transilvania University of Brașov, Romania (e-mail: taulescuelena@yahoo.com)
[4] [2]Geographer, National Institute for Research and Development in Forestry "Marin Drăcea", Bucharest, Romania (e-mail: drgdra26@yahoo.com)
[5] PhD, Eng., Junior Researcher, Research and Development Institute for Grasslands Brașov, Romania (e-mail: paul.zevedei@pajisti-grassland.ro)

In our country, these pastures with scattered trees are called open woodland - "rariște" or grove - "dumbravă," and are found on communal grazing lands to provide shade for animals [8;14].

The first studies and syntheses on the existence of these ASP systems in Romania have highlighted their importance under conditions of global climate change [12;14].

These studies on the productivity of pastures without trees and those under tree canopies, based on floristic relevés, have highlighted the importance of ASP systems for livestock during the grazing season [10;13].

The present paper provides a comprehensive economic assessment of milk, timber and firewood, and acorns in the ASP system dominated by sessile oak (*Quercus petraea*) in the southern Baraolt Mountains.

2. Materials and methods

The study of the ASP system with sessile oak was conducted on the village pasture of Herculian, Bățanii Mari commune, Covasna County, where a preliminary study on pasture productivity was carried out (Figure 1) [11].

Fig. 1. The Herculian pasture with trees, adjacent to the pasture without trees

The ASP system dominated by sessile oak, extending over approximately 85 ha at an altitude of 660 m, featured pasture grass cover that varied in structure (species

diversity and organization) and in the chemical quality parameters of the fodder, both in open areas and beneath the tree canopy (Table 1).

Table 1. General data on sessile oak ASP systems [18]

Pasture condition	Soil		Dominant species	Fodder		
	pH (indicator)	Humus (%)		CP	CF	OMD
Open field (Sun)	5.2	5.33	*Festuca rubra* *Nardus stricta* *Agrostis capillaris*	13.1	34.3	47.8
Under trees (Shade)	5.5	6.20	*Festuca rubra* *Agrostis capillaris* *Trifolium repens*	15.4	31.5	57.2
Difference Shade-Sun (%)	106	116	X	118	92	120
Symbols: CP – crude protein; CF – crude fiber; OMD – organic matter digestibility						

Pasture productivity was assessed based on floristic relevés carried out both in open fields and under trees [10;11].

Potential cow milk production was evaluated using the formula:

Milk production (L/ha) = PV x GSD x 0.6 [9, 12]

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 determining tree density on the pasture, a weighted average of milk production under trees and in treeless areas was calculated.

The assessment of tree numbers, component species, the volume of timber and firewood, as well as acorn production was carried out by inventorying the trees in 14 plots of 10,000 m² each. The plots are representative in terms of tree density and vegetation condition. In these plots, all trees were inventoried, and for each tree the diameter, height and crown projection in two perpendicular directions were measured.

The horizontal crown projection, determined from crown diameters, is an essential indicator for assessing crown development, the health of pasture trees, and estimating forest vegetation cover and density.

Soil cover degree is given by the cover index (Ic), calculated using the formula:

$$\mathbf{Ic = \sum Acr\ N\ /\ A\ pasture}\ [1]$$

Where:

- Acr N = total horizontal crown projection area of trees (N)
- A = total pasture area

Tree volume was calculated using formulas that take into account trunk diameter and tree height. The most commonly used general formula for the volume of a tree is:

$$\mathbf{V = BA\ x\ h\ x\ f = 0.7854\ x\ DBH^2\ x\ h\ x\ f\ [4, 6]}$$

where:

- 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 that the trees present on pastures are generally old and grow in isolation, without competition, with wide crowns and thick trunks, their shape no longer follows the cylindrical form of forest trees. Therefore, the form factor ”**f**” was adjusted downward, ranging from 0.40 to 0.35. As a result, volume estimates may have a margin of error in the absence of precise field data on the volume of isolated pasture trees.

It should also be noted that the volume calculated using this formula does not include the volume of branches and secondary limbs, but only the trunk volume from the base to the tip of the main axis. To include branch volume, an additional correction factor is added, which for broadleaf species is 0.30–0.45% of the trunk volume.

The value of firewood for the population is around 750–850 lei/m^3, for cut and trimmed timber delivered to distribution centers. The value of industrial timber, as rough logs of medium quality, is over 1000 lei/m^3. For firewood volume calculated only for the trunk, the volume of thick branches and secondary limbs – called mixed firewood – is added, representing on average 25%.

Thus, the total tree volume (main trunk plus branches) is:

$$\mathbf{Vtotal = Vtrunk + Vtrunk \times 0.25}$$

where, V total – total tree volume (m^3) and Vtrunk – the trunk volume from the base to the tip of the main axis.

However, the sessile oak provides fruits (acorns). The labor cost for harvesting one kilogram of acorns was calculated using the Unified Time and Production Norms for forestry works [7], under conditions of average fruiting.

3. Results and Discussions

The economic evaluation of silvopastoral systems also highlights the potential of these pastures from an economic perspective. Thus, the economic assessment of sessile oak ASP systems includes, first of all, green forage mass production, pastoral value, cow's milk production during the grazing season, as well as timber and firewood at 120 years, and annual acorn yield.
Final milk production was evaluated both in an open field (without trees) and under the tree canopy of the pasture (Table 2).

Table 2. Evaluation of the main pasture productivity indices in the sessile oak ASP system during the 160-day grazing season

Specification	Open grassland	Under trees	Difference (%)
Green forage mass production (t/ha)	9.15	12.97	142
Optimal livestock load (LU/ha)	0.88	1.25	142
Pastoral value (Ind)	54.1	83.0	153
Cow milk production (L/ha)	5190	7970	153

These results show that the production of green biomass and milk is 142–153% higher under trees than on treeless pasture, which represents large differences between the two pastoral systems.

With regard to the woody vegetation, the Herculian pasture with trees (Figure 1) is adjacent to a forest stand and originates from a forest that has been thinned over time, with many high-value specimens extracted. It is located near the village of Herculian and consists only of sessile oak (*Quercus petraea*) and pedunculate oak (*Quercus robur*) with large heights and diameters.

Following the inventory of trees within the sample plots, tree density on the pasture was found to be 15 trees/ha, which is at the lower limit of tree densities on oak pastures in countries with a tradition of developing wooded pastures, such as

Spain, Portugal, Italy, and Greece. In these countries, the number of trees per hectare ranges from 10 to 40 in the first two, and from 10 to 100 in the latter two [3].

A total of 199 trees were inventoried in 14 sample plots of 1 ha each across the pasture. Of these, 154 were sessile oaks and 45 pedunculate oaks, the proportion of the species being 77% and 23%, respectively. It can be said that the pasture has a composition of 8 Go 2 St.

The mean trunk diameter at 1.30 m, the average tree height, and the mean crown projection area (Smed) are important for the production function of the tree component within the agroforestry system, even if this is secondary, and for fulfilling the protective function by providing shade for the animals. The values of these biometric parameters are presented in Table 3.

Table 3. The main dendrometric parameters of the Herculian pasture

Analyzed characteristic	GO	ST	Total
No. of trees / 14 ha	154	45	199
Mean DBH (cm)	68	76	
Min	49	47	
Max	90	114	
CV (s%)	13	18	
Mean H (m)	19	21	
Min	10,0	12,4	
Max	25,4	25,9	
CV (s%)	16	16	
Mean crown projection area (m²)	143	183	**152**
Min	39	108	***39***
Max	278	304	***304***
CV (s%)	31	29	**33**
Σ A crown projection /ha (m2)	1567	594	2161

Symbols: GO – sessile oak, ST – pedunculate oak
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

Although the differences are not significant, oak trees show larger biometric characteristics than sessile oak, which can be explained by a better adaptation to the site conditions.

The sum of the tree crown projections (ΣS) was also calculated. It was estimated that the 199 trees within the analyzed areas cover the pasture by 21.61%. Accordingly, the total crown projection area per hectare amounts to 2161 m². This result indicates a soil cover degree expressed through the cover index (Ia) = 0.22, a value that falls within the category of medium consistency (0.2) for pastures with trees, where consistency may reach up to 0.40.

The health status of the trees in the tree pasture is generally good, and when necessary, sanitary operations are carried out to remove trees that are dead or severely dried.

The sessile oak acorns are important for supplying nutrients (proteins, lipids, carbohydrates, mineral salts, and vitamins) [2; 7; 15]. On pastures where sessile oaks have more light and space, they fruit more frequently and abundantly, although the acorns may be smaller than those of forest-grown oaks.

They generally begin to fruit at 30–40 years of age. They produce abundant crops every 4–6 years, during the "mast years," but yield smaller quantities of acorns almost every year. Large fruiting events depend on: climate (temperature, drought), soil, and tree stress (dryness, pruning, diseases).

No estimates have been made for acorn production from the analyzed areas, but forest-grown sessile oaks produce, depending on the fruiting years, between 600–1,200 kg per hectare [15]. The labor cost for harvesting one kilogram of acorns ranges from 8 to 10 lei. To this is added the commercial markup of the seller, resulting in the final price of one kilogram of sessile oak acorns.

According to data extracted from the silvopastoral management plan, since its implementation in 2017 until the present, 19 m³ of firewood have been harvested from the studied perimeter. Moreover, in a year with good fruiting, around 13 tons of acorns were collected, which were exported to Hungary for nursery seedling production.

Having data on pasture productivity, expressed as cow milk yield, from the agroforestry system (ASP) with trees and from the tree-free pasture, as well as wood volume (trunk and branches) and acorn production, along with their value in Euros (1 € = 5 lei), it was possible to carry out a preliminary integrated economic analysis of all ASP components (Table 4).

Table 4. The comparative economic value of the ASP system dominated by sessile oak versus treeless pasture (TLP)

Specification	***Pasture system***		
	ASP	*TLP*	*%*
Cow milk production (L/ha/an)	5790	5190	112
Value (x 0,5 €/Liter)	**2895**	**2595**	**112**
Timber m^3/ha at 120 years old	419	-	X
Timber m^3/year	3.5	-	X
Value (x 160 €/m3)	**595**	-	X
Firewood m^3/ha at 120 years old	25.2	-	X
Firewood m^3/year	0.21	-	X
Value (x 60 €/m3)	**13**	-	X
Acorn kg/ha/year	130	-	X
Value (x 1.8 €/kg)	**234**	-	X
Total annual value (€)	**3737**	**2595**	**144**
TLP – treeless pasture – open field			

After weighted average calculations in the ASP system, with 2,161 m² per hectare under the tree canopy and the remaining 7,839 m² without trees, the average milk production was 5,790 L/ha, which is 600 L/ha (112 %) higher than on the tree-free pasture.

The woody vegetation, represented by trunks for construction, branches for firewood, and acorns, has an annual value of 842 €, which, when added to the milk value of 2,895 €, results in a total of 3,737 € in the ASP system, 44 % higher than on the tree-free pasture.

The pasture with trees can also be valued in terms of ecosystem services, such as improving the microclimate and providing shade for grazing animals.

Conclusions

- Pastures in agroforestry systems (ASP) dominated by **Quercus petraea** are superior in terms of productivity and economic value compared to tree-free pastures.

- Cow milk production in the ASP system reaches 5,790 L/ha, 12 % higher than in tree-free pastures.
- The total economic value of the sessile oak ASP, consisting of milk (2,895 €), timber and firewood (608 €), and acorns (234 €) at a parity of 1 € = 5 RON, totals 3,737 €, 44 % higher than the tree-free pasture, where value comes exclusively from milk (2,595 €), in addition to the ecological value and the aesthetic beauty of the pastoral landscape.

REFERENCES

[1] Ciubotaru, A., Păun, M., Structura arboretelor. Editura Universității Transilvania din Brașov. (2018).

[2] Corlățeanu, S., Produsele accesorii ale pădurii, Editura Ceres, București. (1984).

[3] Eichorn, M.P., Paris, P., Herzog, F., Incoll, L.D., Liagre, F., Mantzanas, K., Mayus, M., Moreno, G., Papanastasis, V.P., Pilbeam, D.J., Pisanelli, A., Dupraz, C. Silvoarable systems in Europe – past, present and future prospect. Agroforestry system 67. (2006).

[4] Giurgiu, V., Dendrometrie și auxologie forestieră, Editura Ceres, București. (1979).

[5] Hartel, T., Măcicășan, V., Maloș, C., Rákosy L., Lessons learnt: Wood-pastures in Transylvania, Romania, (2017) https://www.agforward.eu/documents/LessonsLearnt/WP2_RO Transylvania_Lessons_learnt.pdf, Accessed on 10 March 2025.

[6] Leahu I, Amenajarea pădurilor. Editura Didactică şi Pedagogică, Bucureşti, 616 p (2001).

[7] MAPPM_RNP, Norme de timp si producție unificate pentru lucrări din silvicultură (1997).

[8] Maruşca, T., Sistemul agrosilvopastoral durabil, în contextul încălzirii globale a climei. Revista de Silvicultură şi Cinegetică, Anul XVII, nr. 30, Editat de Societatea Progresul Silvic, Braşov (2012).

[9] Marușca, T., Blaj, V. A., Andreoiu, A. C., Zevedei, P. M., Long term influence of botanical composition of alpine pastures on cow milk production, Proceeding of the 27th General Meeting of the European Grassland Federation, EGF, Volume 23, Pp. 283-285, Cork, Ireland, 17-21 iunie 2018.

[10] Marușca, T., Contributions to the evaluation of pasture productivity using the floristic releve, Romanian Journal of Grassland and Forage Crops BDI Nr. 19, Cluj – Napoca, pp. 33- 47, (2019).

[11] Marușca, T., Taulescu, E., Memedemin, D., Preliminary study of agrosilvopastoral systems from Romania, Romanian Journal of Grassland and Forage Crops Nr. 22, Iași, pp. 25-32, (2020).

[12] Marușca, T. Praticultură și pastoralism în cercetarea științifică, Editura Universității Transilvania din Brașov, 311 pagini (2022).

[13] Marușca, T., Mihăilă, E., Taulescu, E., Zevedei, P.M., Tudora, A., Contributions to the economic evaluation of the productivity of agrosilvopastoral systems with wild pear (Pyrus pyraster) in Transylvania, Annals of the Academy of Romanian Scientists Series Agriculture, Silviculture and Veterinary Medicine Sciences, Volume 14 (1), 59 (2025).

[14] Mihăilă, E., Costăchescu, C., Dănescu, F., Drăgoi, S., Sisteme agrosilvice, Editura Silvică, București, (2010).

[15] Nesterov, V., Negruțiu, A., Ionescu, O., Gărgărea, P., Adămoaia, I., Furaje și ogoare pentru vânat. Editura Orion (2006).

[16] Olea, L., San Miguel-Ayanz, A., The Spanish dehesa. A traditional Mediterranean silvopastoral system linking production and natural conservation, 21st. General Meeting of EGF, pp. 3-13, Badajoz, Spain (2006).

[17] Sharrow, S.H., Flechter, R.A., Trees and Pastures: 40 years of agrosilvopastoral experience in Western Oregon, USA, Agroforesty Symposium, National Agroforesty Center (1994).

[18] Taulescu, E., Marusca, T., Research Concerning the Agrosilvopastoral System Dominated by Sessile Oak (Quercus Petraea, Mattuschka Liebl) from Baraolt Mountains, Journal of Mountain Agriculture on the Balkans, 25 (6), pp 270-292, Research Institute of Mountain Stockbreeding and Agriculture, Troyan, Bulgaria (2022).