CONTRIBUTIONS TO THE ECONOMIC EVALUATION OF THE PRODUCTIVITY OF AGROSILVOPASTORAL SYSTEMS WITH WILD PEAR (*PYRUS PYRASTER*) IN TRANSYLVANIA

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Abstract. *Agrosilvopastoral (ASP) systems are among the most effective measures for protecting pastures and animals during the grazing season from the impacts of global climate warming. Pastures with 25 wild pear (Pyrus pyraster) trees per hectare in southeastern Transylvania have a green forage mass (GM) production of 13.25 t/ha, which is 101.3% higher compared to pasture without trees. Additionally, one wild pear tree produces on average 25–50 kg of fruit, resulting in approximately 860 kg/ha, priced at 0.5–0.7 Euro/kg, representing an income of 516 Euro/year. The total wood volume harvested at 80 years is 18.56 m³/ha (trunk), at a price of 160 Euro/m³, and 5.57 m³/ha of firewood at a price of 60 Euro/m³, totaling 41.4 Euro/ha/year. Cow milk production in this ASP system is 6,960 liters/ha, priced at 0.5 Euro/liter, totaling 3,480 Euro/year. Summing the values of milk, wood, and fruit from the ASP systems results in 4,037 Euro/year, to which additional benefits are added, such as animal welfare, biodiversity, carbon sequestration, and landscape improvement, which are harder to quantify. The nearby treeless pasture produces on average 6,920 liters/ha/year of milk, valued at 3,460 Euro/ha. The economic value of the ASP systems with wild pear was over 17% higher than treeless pasture, with multiple other environmental and animal benefits that require further evaluation.*

Keywords: agrosilvopastoral systems, milk, wood and fruit production, economic evaluation

DOI 10.56082/annalsarsciagr.2025.1.59

1. Introduction

Agrosilvopastoral (ASP) systems are especially widespread in countries with warmer and drier climates around the Mediterranean Sea, such as Spain, Portugal,

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Italy, Greece, etc., aiming to protect the grass cover of pastures and animals during the grazing season [4, 7, ,12]. In our country, several ASP systems have been researched so far in terms of pasture productivity, where the woody vegetation consisted of species such as *Quercus robur*, *Quercus pubescens*, *Quercus petraea*, *Carpinus orientalis*, *Fagus sylvatica*, and *Pyrus pyraster* [10, 11].

Based on results concerning green forage mass production and pastoral value, it was possible to assess optimal livestock load (LU/ha) and milk production (liters/ha) in open field conditions and under tree canopy (shade). Ultimately, a comprehensive economic evaluation of ASP systems is needed, one that includes the value of construction timber and firewood, fruits (acorns, beechnuts, pears, apples, etc.), and other benefits related to animal welfare, biodiversity, carbon sequestration, landscape value, etc., which are harder to quantify [2]. This study aims to provide an initial evaluation of the ASP system with wild pear (*Pyrus pyraster*) in Transylvania.

2. Materials and methods

The research was conducted in the wild pear pasture of Jimbor, located within the administrative territory of Homorod Commune, Brașov County. This pasture is situated in the southeastern part of the Transylvanian Depression.

In a first stage, floristic surveys were conducted in both open fields and under tree crown [9], based on which the green forage mass production and its pastoral value were assessed. The calculation of these indicators was performed using a new method published in the Annals of AOȘ-R, vol. 11, no. 1 [16]

Cow milk production per hectare was evaluated using the formula:

$$\text{Milk prod. (L/ha)} = PV \times GSD \times 0.6 \text{ [8, 11]}$$

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 [11].

Milk production was evaluated based on the forage consumption from the herbaceous layer in the open field and the herbaceous vegetation under the tree crown.

Ultimately, milk production in the ASP system with wild pear was evaluated by calculating the weighted average of the pasture under the canopy (shaded) and the open field (sunny).

For the study of trees on the pasture, three sample plots of 10,000 m² each were established. These plots were selected as representative in terms of tree density and vegetation condition (Figure 1).

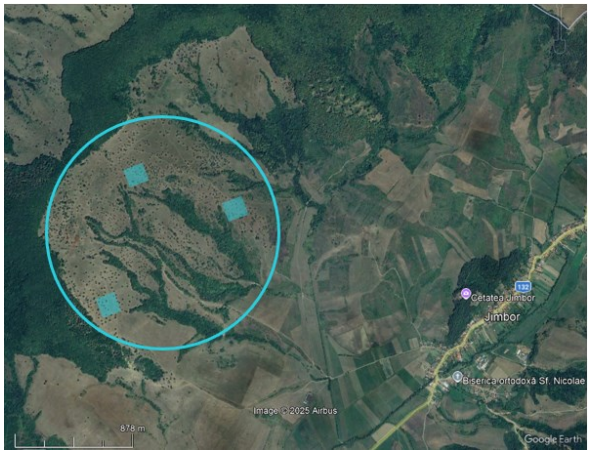

Fig. 1. Jimbor Pasture (O) and the location of the experimental plots,

Each plot was delimited in the field by marking boundary trees and establishing their geographic coordinates using GPS. In the permanent sample plots set in pastures with trees, all trees were inventoried. Measurements included: i) diameter at 1.3 m; ii) total height and height to the base of the crown; iii) crown projection lengths in perpendicular directions: north–south and east–west. Thus, four distances (crown radii) were measured from the trunk base center. The inventory of all specimens within the plots allowed the determination of composition and estimation of the number of trees per surface unit in the analyzed plots.

Composition was determined as the ratio between the number of trees of each species and the total number of trees in the pasture with trees.

Based on diameters measured at breast height (1.3 m), the arithmetic mean diameter was calculated for each sample plot, the entire pasture, and the participating species in the composition of pasture with trees, this being an important indicator for assessing forest vegetation structure at a given time. Measuring heights is equally important, as the average height of trees in pastures influences both the pasture and the microclimate. The taller the trees, the larger the area they protect, providing increased shading, better microclimate regulation, and more effective soil conservation

The crown height, calculated as the difference between total height and height to the base of the crown, together with crown projection in the mentioned directions, represents important indicators of crown development and the health status of pasture trees. Recording crown radii allowed estimation of the horizontal

projection surface of the crown, and thus determination of forest vegetation cover and density.

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

$$Ic = \sum Acr\ N / A\ pasture\ [5]$$

Where:

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

Using the four distances (crown radii), the crown projection surface was calculated, being approximated as a circle. The radius used was the average of the four directions – $\mathbf{r_m}$. Since these distances varied, the crown projection surface is an estimate of the real projection, yet remains a key indicator of the average soil cover degree.

The crown projection area was calculated using the formula:

$$Acr = \pi \bullet r_m^2 \bullet \cos \alpha\ [1] \quad (1)$$

where:

Acr – is the crown area, approximated in the horizontal plane as a circle

r_m – the radius of the circle approximating the crown's projection on the ground

α – the slope of the surface within the area of the crown's ground projection.

The pasture area was estimated using the Google Earth Pro application, considering grassland with trees as those areas where trees are sparsely distributed on the grassland. In some cases, the estimation of wooded pasture also included small patches of dense forest vegetation that do not qualify as actual forest stands.

The standard deviation and the coefficient of variation were calculated for tree diameter and height. The coefficient of variation provides an indication of the degree of variability among the measured values within the analyzed areas, contributing to the biometric characterization of the trees within the studied pastures.

Tree volume was determined based on diameter at breast height and total height, using the following formula:

$$V = BA \times h \times f = 0.7854 \times DBH^2 \times h \times f\ [3] \quad (2)$$

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).

Considering that the trees present in pastures are generally old and grow in a scattered pattern, without competition, developing wide crowns and thick trunks, their shape no longer conforms to the forest form typical of forest-grown trees. Consequently, the form factor (f) was empirically adjusted, with lower values ranging between 0.35 and 0.40. Therefore, volume estimates may include a margin of error due to the lack of precise field data on the volume of isolated trees within the pasture. It should also be noted that the volume calculated using this formula includes only the stem volume, measured from the base to the apex of the main axis, and excludes the volume of thick and secondary branches. To account for the branch volume, an additional correction coefficient is applied, which, for broadleaf species, typically ranges from 30% to 45% of the stem volume.

3. Results and Discussion

To assess the economic productivity of pastures within the ASP system featuring wild pear trees, green forage mass production, pastoral value, and potential cow milk production were calculated both for open grassland areas without tree cover and for areas under the tree crown projection (Table 1).

These data show that the herbaceous vegetation under tree cover has a productivity that is 4–9% higher than that of the open pasture, a relatively small difference, as the pastures were well managed across the entire area.

Milk production in the ASP system was calculated based on the ground-projected crown area of the 23 wild pear trees per hectare, which totaled 1,614 m² (representing 16.14% of the total area), as indicated in Table 2.

Tabel 1. Evaluation of the main productivity indicators of pasture in the ASP system with wild pear trees over a 170-day grazing season

Specification	Unit	Open grassland	Under trees	Difference (%)
Green forage mass production	t/ha	13.07	14.20	109
Optimal livestock load	LU/ha	1.18	1.29	109
Pastoral value	Ind.	67.90	70.30	104
Cow milk production	L/ha	6,920	7,170	104

After calculating the weighted arithmetic mean in the ASP system with trees, taking into account the milk production from both the open field and the area under wild pear trees, a total milk yield of 6,960 L/ha was obtained.

The forest vegetation on the Jimbor pasture is represented by wild pear trees, with age differences between specimens, reflected in their diameter and health condition. A total of 75 trees were identified, scattered across the pasture, with 10, 28, and 37 trees per plot, corresponding to an average density of 25 trees/ha. Among the 75 trees, one specimen is a cherry plum (*Prunus cerasifera* Ehrh.), measuring 5.8 m in height and 24 cm in diameter. Outside the designated sample plots, scattered individuals of wild apple (*Malus sylvestris* L.) and wild cherry (*Prunus avium* L.) were also identified. Consequently, the tree composition of the pasture can be described as 10 wild pears (Pă), with scattered individuals of cherry plum (Co), wild apple (Mă), and wild cherry (Ci).

Although less common, shrubs are also present on the pasture, including dog rose (*Rosa canina)*, hawthorn (*Crataegus* spp.) and blackthorn (*Prunus spinosa*), which are predominant, as well as common dogwood (*Cornus sanguinea*), common privet (*Ligustrum vulgare*), and juniper (*Juniperus* spp.). These shrubs appear as small thickets, generally not exceeding 1 m in height.

In terms of dendrometric parameters, there is low variability in diameter (ranging from 21 to 77 cm) and height (ranging from 5.7 to 13.8 m), but greater variability in crown projection area, which ranges from 16 to 159 m² (Table 2).

The ground cover with forest vegetation, excluding shrubs occurring on grasslands, expressed as the cover index, was found to have a value of Ic = 0.16 in the analyzed areas. This corresponds to a canopy density class of 0.1–0.2, which is considered low for pastures with trees.

The crown ratio, defined as the proportion of crown height relative to the total height of the tree, ranges between 70% and 89%.

Table 2. The main dendrometric parameters of the pear trees on the Jimbor pasture

Dendrometric parameters	*Values*				
	N	*Mean*	*Min*	*Max*	*CV (s%)*
Mean DBH (cm)	*73*	*50*	*21*	*77*	*21*
Mean H (m)	*73*	*10.3*	*5.70*	*13.80*	*16*
Mean crown H (m)	*73*	*8.6*	*5.20*	*12.00*	*18*
Crown ratio (%)	*73*	*83*	*70*	*89*	*4*
Mean crown projection area (m²)	*69*	*70*	*16*	*159*	*43*
Σ A crown projection /3ha (m²)	*69*	*4,841*			
Σ A crown projection /1ha (m²)	*23*	*1,614*			

N – Number of trees inventoried
Mean DBH – Mean of diameter of breast height; Mean H – Mean height; Min –Minimum recorded value, Max – Maximum recorded value, Crown ratio (%) of total tree height, Mean crown projection area (m²), Σ A – Cumulative sum of areas

The ground cover with forest vegetation, excluding shrubs occurring on grasslands, expressed as the cover index, was found to have a value of Ia = 0.16 in the analyzed areas. This corresponds to a canopy density class of 0.1–0.2, which is considered low for wooded pastures.

The crown ratio, defined as the proportion of crown height relative to the total height of the tree, ranges between 70% and 89%.

With regard to tree health status, approximately 65% of the individuals exhibit signs of decline or physiological stress, such as dead or broken apices and branches, mechanical injuries, basal burns, lichens, and the presence of cavities. Fruiting was observed in 17% of the trees, while mistletoe infestation was detected in only a few specimens. Although grazing is not continuous in the area, in the absence of protective measures for natural regeneration, which is present in certain patches, there is a high risk that part of this regeneration will be lost over time.

For the wild pear trees, a form factor of f = 0.35 was used, adjusted to reflect the specific characteristics of pasture-grown trees, which typically present short, defective trunks and often irregular shapes. Accordingly, the total trunk volume of the 74 wild pear trees inventoried on the Jimbor pasture, trees with diameters ranging from 21 cm to 77 cm and heights between 3.8 m and 13.8 m, was estimated at 55.69 m^3, for the total surveyed area of 3 hectares. Per hectare, the trunk volume corresponding to an average of 25 trees was 18.56 m^3. Additionally, for the same 3-hectare area, the volume of thick branches, secondary branches, and tree tops was calculated at 16.7 m^3, which corresponds to 5.57 m^3 per hectare.

Wild pear is a light-demanding species characteristic of wooded pastures, occurring from the forest-steppe zone to hilly regions. It shows good tolerance to frost and adapts well to dry soil conditions [14]. This species possesses valuable properties, its wood is attractively colored, dense, and homogeneous, making it suitable for wood carving, decorative veneers, and musical instrument manufacturing [14,15].

In the absence of specific market data for wild pear wood, its firewood price can be estimated based on the average market value of hardwood species, under which wild pear is categorized. The estimated price is approximately 160 Euro per cubic meter, subject to variations depending on quality, processing, delivery conditions (e.g., cut, split, and delivered), seasonality (cold or warm period), and regional factors. In comparison, the price of mixed firewood, consisting of thick branches and secondary twigs, is estimated at approximately 60 Euro per cubic meter.

Due to trunk defects and the advanced age of the trees, only a small portion of the trunk volume, no more than 20% can be classified as higher-grade timber suitable for value-added uses. The remaining 80% is typically considered firewood. For the higher-grade timber assortment, the price may exceed that of firewood, particularly if the logs are of superior quality.

The total price of merchantable timber and firewood from wild pear, as well as the price of cow's milk, the main product of ASP systems, are presented in Table 3.

The wild pear exhibits regular fruiting, with a gradually increasing yield beginning at 8–10 years of age. When subjected to annual pruning and maintenance practices, individual trees can produce between 25 and 50 kilograms of fruit per year [13].

The labor cost for harvesting one kilogram of wild pears ranges from 0.5 to 0.7 Euro and is calculated according to the Unified Standards for Time and Production in Forestry [6], assuming average fruiting conditions. To this, the commercial markup applied by the seller is added, resulting in the final retail price of one kilogram of wild pears.

Table 3. Comparative economic value of the ASP system versus treeless pasture (FA)

Specification	***Pasture system***		
	ASP	*FA*	*%*
Cow milk production (L/ha/an)	*6,960*	*6,920*	*100.6*
Value (x 0.5 €/Liter)	***3,480***	***3,460***	***100.6***
Timber m^3/ha at 80 years old	*18.56*	_	*X*
Timber m^3/year	*0.23*	_	*X*
Value (x 160 €/m^3)	***37***	_	***X***
Firewood m^3/ha at 80 years old	*5.57*	_	*X*
Firewood m^3/year	*0.07*	_	*X*
Value (x 60 €/m^3)	***4***	_	***X***
Wild pears kg/ha/year (Fruits)	*860*	_	*X*
Value (x 0.6 €/kg)	***516***	_	***X***
Total annual value (€)	***4,037***	***3,460***	***117***

The fruits serve as a food source for both wild game and domestic livestock. Historically, they were also utilized in the production of alcoholic beverages [4].

Beyond these production outputs of milk, timber and fruit, agrosilvopastoral (ASP) systems provide numerous additional benefits. These include improved animal welfare, enhanced biodiversity conservation, regulation of thermal and hydric balance, preservation of the delicate pastoral landscape, and a wide range of other ecological and socio-economic advantages.

Conclusions

1. Pastures in the agrosilvopastoral system (ASP) with wild pear are superior to those located in open fields from all points of view, productivity, biodiversity, landscape protection, economic value.

2. Milk production in the ASP system reaches 6,960 liters/ha, 1% higher than in the treeless pasture, both being well managed.

3. The total economic value of milk, wood, fruit in the ASP system is over €4,000/year, 17% higher than in the pasture without trees, to which is added the welfare of the animals, biodiversity, and the aesthetics of the landscape, which are more difficult to quantify and express in value.

R E F E R E N C E S.

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