Economic evaluation of agronomic productivity and ecosystem services in agroforestry systems

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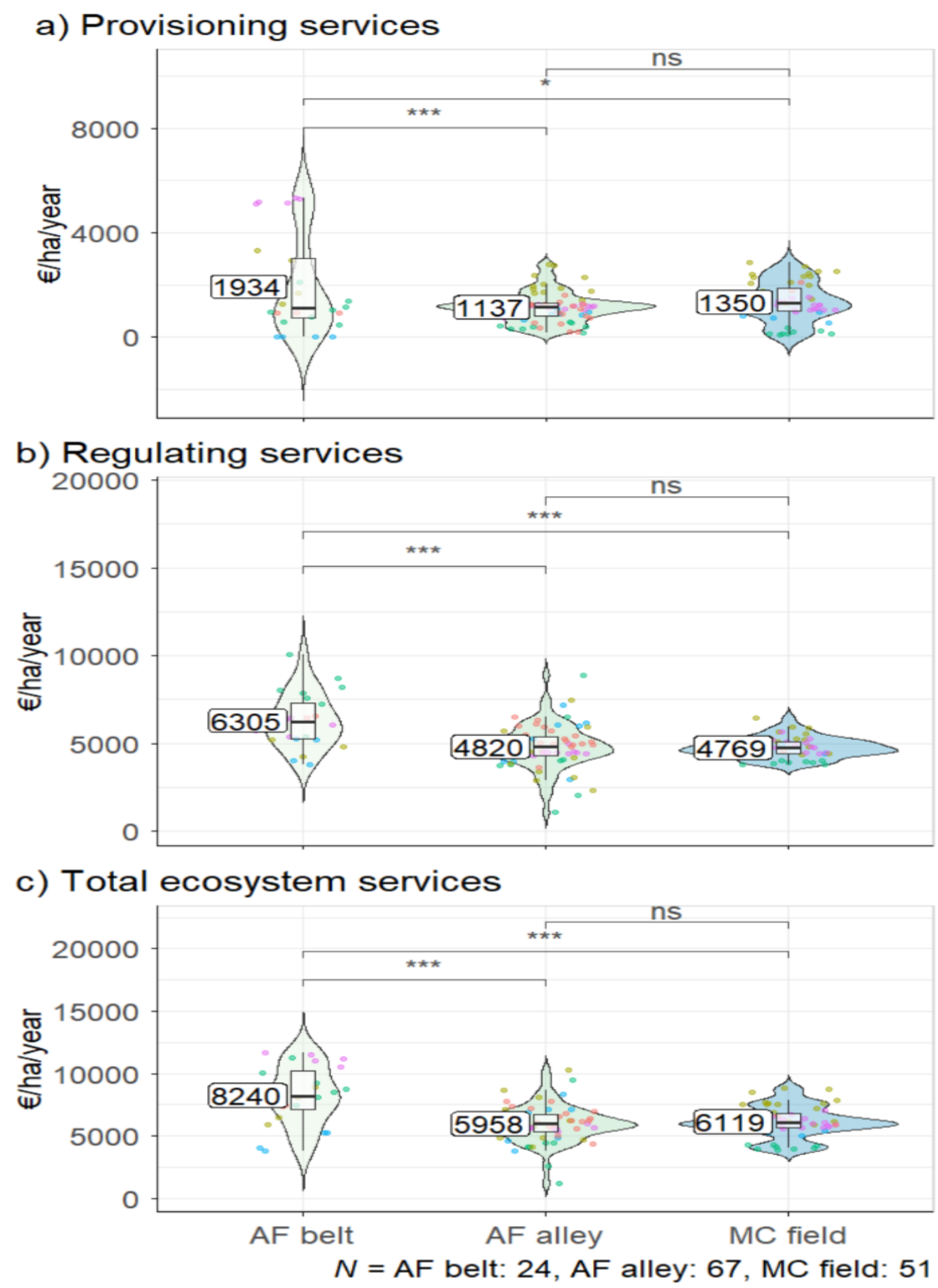
Introduction: Agroforestry (AF) systems are increasingly recognised in Europe to enhance farm-resilience due to buffering effects on micro-climate, particularly at times of extreme climatic events like drought and temperature extremes. The buffering effects are due to the multiple ES provided by agroforestry systems and there is a need to account for these ES by economic valuation for holistic assessment .

Objective: Economic evaluation of agronomic productivity and ecosystem services in agroforestry systems compared to monoculture practices .

Keywords: Silvo-arable agroforestry, provisioning and regulating ES, monoculture, product diversification, economic valuation

Materials & Methods

Comparisons of AF, consisting of AF tree belts (AF belts) and AF alleys (crop component) and monoculture annual crop and grass production (MC), were investigated by quantification of provisioning and regulating ES, in 6 silvo-arable AF and corresponding MC in Belgium (Inagro), Germany (Hof Lebensberg Fruit & Hof Lebensberg Nut), Denmark (CFE), and United Kingdom (Wakelyns in UK-South & Gibside in UK-North) during 2024 growing season. The provisioning ES consisted of grain, grass, fruits and nuts and wood yields and data was provided by the farm managers whereas regulating ES consisted of soil erosion, water holding capacity, nutrient mineralization, soil formation and carbon sequestration. Provisioning and regulating ES were quantified using a mix of methods including field sampling of soil, crop and tree yields, allometric equations for wood and woodchip yield (Bunce, 1968; Magarik et al., 2020; Ghaley and Porter 2014), Revised Universal Soil Loss Equation (RULSE; Panagos et al., 2014) for soil erosion, effective precipitation (FAO, 1986) for water holding capacity, pedo-transfer functions (Schomberg et al. (2009) for nutrient mineralization, earthworm cast yield for soil formation (Le Bayon et al., 2002) and measurement of soil carbon changes and stock of above and belowground carbon in biomass for carbon sequestration. After the provisioning and regulating ES were quantified, the ES were monetized with economic valuation. For monetization of provisioning ES, current prevailing prices in Eurostat (2025) were used to derive the economic valuation whereas for regulating ES, indirect methods were used as these are non-marketable ES. For soil erosion, cost of replacement of equivalent topsoil was used. Avoided costs were used for nutrient mineralisation (value of equivalent nitrogen fertilizer), water holding capacity (cost for equivalent irrigation quantity), soil formation (cost for equivalent compost application) and voluntary carbon credits for carbon sequestration. Data was analyzed for statistical differences between AF belts, AF alley and MC using a combination of linear and mixed-effects models with post-hoc tests for multiple comparisons.



Results:

1. Provisioning ES valuation was 3x times than provisioning ES value in AF belt, AF alley and MC
2. The total economic valuation of provisioning and regulating ES in AF belt was significantly higher ($p< 0.001$) valued at 8240 €/ha/yr (Fig. 1c) compared to AF alley (5958 €/ha/yr) and MC (6119 €/ha/yr)
3. AF belt provisioning ES valuation was significantly higher (1934 €/ha/yr) (Fig. 1a) compared to AF alley and MC
4. AF belt regulating ES valuation was significantly higher (6305 €/ha/yr) compared to AF alley and MC (Fig. 1b)

Conclusions

1. AF belt recorded the highest provisioning and regulating ES underscoring the multifunctional role of AF compared to AF alley and MC
2. There was huge variations of ES from diverse AF system due to differences in crop and tree species and their configurations in the field, age of the AF system and the effects of local pedo-climatic factors
3. The field evidence of AF multifunctionality provides the basis for rewarding farmers for ES provision through CAP subsidies and payment for ecosystem services to mainstream AF adoption.

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