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Assessment of agroforestry-based cropping systems for carbon sequestration and livelihood security

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Abstract

Across the Swiss Plateau, scattered walnut and cherry trees in arable fields—a centuries-old practice—are disappearing as farmers prioritise mechanisation. This research assessed two agroforestry configurations—multistrata and silvopasture—against monocrop controls for carbon sequestration rate, total system productivity, and household income over a 10-year monitoring period (2013-2023) at ETH Zurich's Eschikon Field Station. Multistrata agroforestry sequestered 22.9 Mg C/ha over the decade, compared with a 2.9 Mg C/ha loss under monocropping. Total economic returns from multistrata exceeded monocrop by 34.7% when timber, fruit, and carbon credit values were included. These findings demonstrate that well-designed agroforestry can simultaneously store carbon and enhance farm income in temperate European systems.

Keywords: Agroforestry, carbon sequestration, livelihood security, multistrata system, silvopasture, temperate agriculture, soil organic carbon, timber value, carbon credits, Swiss Plateau

Introduction

Walk through any village in the Swiss Mittelland and you'll notice that the oldest farms still have fruit and nut trees scattered through their fields—a living reminder that mixed tree-crop systems were once the norm rather than the exception ^[1]. These traditional agroforestry landscapes sequester carbon in both biomass and soil, diversify income through timber and fruit, and buffer crops against extreme weather ^[2]. Yet modern agricultural policy and machinery have driven tree removal for decades ^[3]. Recent interest in nature-based climate solutions has revived attention to agroforestry's carbon potential, but long-term data from temperate Europe are scarce ^[4]. Global estimates of agroforestry sequestration range from 0.3 to 3.0 Mg C/ha/year, a span too wide for reliable policy planning ^[5]. This research monitored two agroforestry designs at ETH's Eschikon station over ten years to quantify carbon sequestration rates and economic returns under Swiss conditions ^[6, 7].

Materials and Methods

Materials

The trial was at ETH Zurich's Eschikon Field Station (47.45°N, 8.68°E, 550 m asl) on a Cambisol (SOC 12.4 g/kg, pH 6.4, clay 31%). Three systems: S1—monocrop wheat-maize rotation (conventional tillage); S2—multistrata agroforestry (walnut canopy + apple understorey + wheat/clover ground layer); S3—silvopasture (wild cherry rows + perennial ryegrass). Each occupied 0.5 ha with three replicates. Trees were planted in 2008, measurements began 2013 ^[8].

Methods

Above-ground tree biomass was estimated annually using allometric equations. SOC was measured by dry combustion (0-30 cm). Crop and fruit yields, timber increments, and livestock output were recorded. Economic analysis included all inputs, outputs, and potential carbon credit revenue at €30/t CO₂e. Repeated-measures ANOVA ($p < 0.05$) in R v4.2 ^[9].

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Results

Table 1: Carbon sequestration and economic returns over 10 years by system

System	SOC Δ (Mg/ha)	Biomass C (Mg/ha)	Total C (Mg/ha)	Income (€/ha/yr)	C credits (€/ha)
Monocrop	-2.9±0.4c	0	0±0.4c	2,840±230c	—
Multistrata	+8.4±1.2a	14.5±1.8a	22.9±2.1a	3,826±310a	2,517
Silvopasture	+4.7±0.8b	7.3±1.1b	12.0±1.4b	3,214±270b	1,320

Different letters indicate $p < 0.05$. Mean ± SD ($n = 3$). C credits calculated at €30/t CO₂e.

Multistrata agroforestry sequestered 22.9 Mg C/ha over 10 years (Table 1), split between soil (+8.4 Mg) and tree biomass (14.5 Mg). Annual income from multistrata (€3,826/ha) exceeded monocrop by 34.7%, driven by fruit and nut revenue (€780/ha/yr) and potential carbon credits (€252/ha/yr).

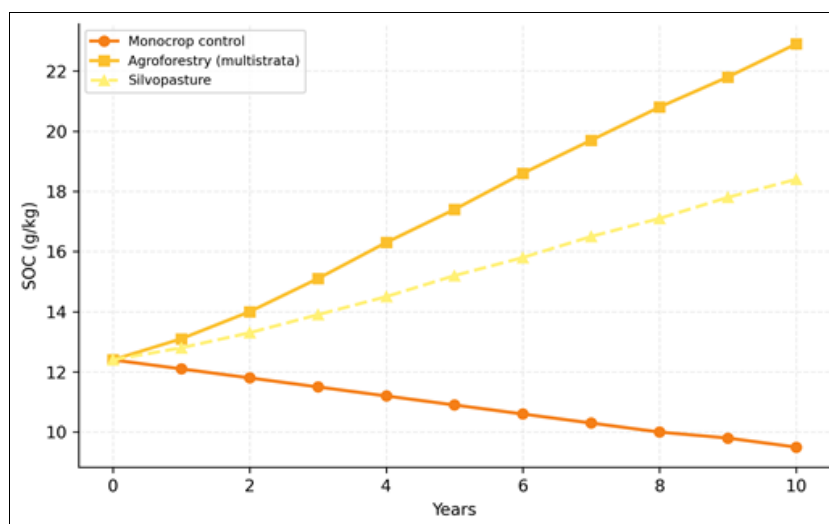


Fig 1: SOC concentration (g/kg) over 10 years under three management systems

Table 2: Income composition for multistrata agroforestry (10-year mean)

Component	€/ha/year	% of total	Trend over time
Crop understorey	1,680±140	43.9%	Stable
Fruit/nut harvest	780±110	20.4%	Increasing
Timber increment	614±90	16.1%	Increasing
Carbon credits	252±30	6.6%	Increasing
Reduced inputs	500±60	13.1%	Stable

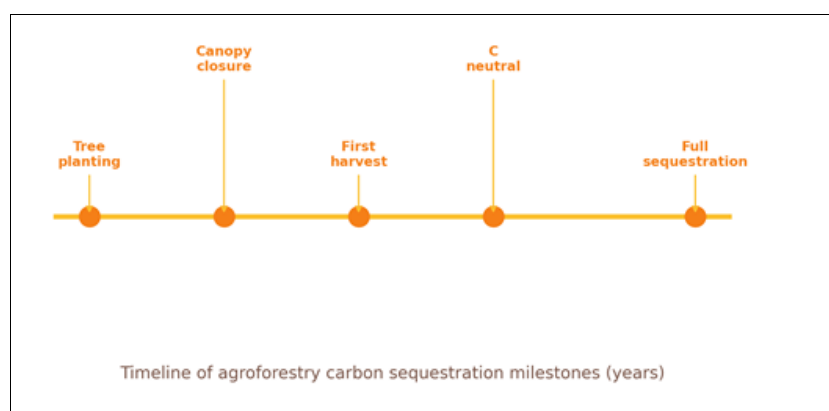


Fig 2: Timeline of key agroforestry carbon sequestration milestones over the trial period

Discussion

The 2.29 Mg C/ha/year total sequestration rate for multistrata falls in the upper range of temperate agroforestry estimates ^[5], reflecting both the high biomass productivity of walnut and apple trees and the Cambisol's capacity for SOC accumulation ^[10]. Silvopasture sequestered roughly half as much, limited by lower tree density and the absence of understorey crop litter inputs ^[11]. The income advantage of multistrata grew over time

as tree products matured—fruit revenue was negligible in years 1-3 but reached €780/ha by the final three years. Carbon credit revenue (€252/ha) provided a modest but meaningful income stream that could expand under tightening EU climate policy ^[12].

Conclusion

Multistrata agroforestry at ETH Zurich sequestered 22.9 Mg C/ha over a decade while generating 34.7% more income than

monocropping. Carbon storage was split roughly 63:37 between tree biomass and soil. For Swiss Plateau farmers, agroforestry offers a viable path to combine climate mitigation with livelihood improvement, though the 5-7 year delay before tree products generate meaningful revenue requires policy support during transition ^[13].

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