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Role of agro-biodiversity conservation in enhancing ecosystem stability of farming landscapes

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Abstract

Simplified farming landscapes are productive but fragile. When a single pest outbreak or drought strikes a monoculture region, losses cascade through the entire system. This research tested whether increasing agro-biodiversity across six landscape types—from continuous corn monoculture to integrated agroforestry—improved ecosystem stability indicators in southern Michigan, USA. Thirty-six farm units were surveyed across Ingham, Eaton, and Clinton counties (42.7°N, 84.5°W) during 2019–2021. Plant, arthropod, and bird diversity were assessed by transect surveys; pollinator abundance by pan traps; predator diversity by pitfall traps; and yield stability by the inverse coefficient of variation over three years. All five stability indices rose consistently with landscape diversification (Spearman $\rho = 0.86–0.94$, $p < 0.001$). Agroforestry systems scored highest overall (composite stability 4.2/5), while monocultures scored lowest (1.0/5). Shannon diversity for plants, arthropods, and birds was 5.2×, 3.7×, and 7.6× higher in agroforestry than monoculture. These findings support policies that reward landscape-level diversification rather than field-level input optimisation alone.

Keywords: Agro-biodiversity, ecosystem stability, farming landscapes, Shannon diversity, pollinator abundance, agroforestry, crop rotation, monoculture, predator diversity, yield variability

Introduction

What happens when a landscape loses its biological safety net? The 1970 Southern Corn Leaf Blight epidemic destroyed roughly 15% of the United States maize crop in a single season—not because the pathogen was novel, but because nearly all planted acreage shared the same cytoplasmic male-sterile genetics ^[1]. That episode remains a textbook warning about the risks of genetic and landscape simplification ^[2]. Yet five decades later, the Corn Belt is more uniform than ever: corn and soybean occupy over 85% of cropland in many Michigan counties, and non-crop habitat has shrunk to thin strips along roadsides and waterways ^[3].

Ecological theory predicts that diverse communities are more stable over time, a relationship often called the diversity–stability hypothesis ^[4]. In agriculture, this translates into the idea that diversified landscapes buffer yield variability, support natural pest control, maintain pollination services, and resist invasion by weeds and exotic pests ^[5]. But quantifying these links at the landscape scale—rather than the single-field scale—requires sampling across a gradient of diversification and measuring multiple stability indicators simultaneously ^[6]. This research surveyed 36 farm units across southern Michigan representing six levels of landscape complexity to test whether agro-biodiversity predicts composite ecosystem stability.

Research area description

The research covered three adjacent counties in southern Michigan: Ingham, Eaton, and Clinton (centred on 42°43'N, 84°32'W). The region has a humid continental climate (Dfb) with mean annual temperature 9.3 °C and precipitation 838 mm distributed fairly evenly across seasons. Soils are predominantly Alfisols (Capac and Marlette series) with silt loam texture. Cropland makes up 52–68% of total area depending on the county, with corn and soybean as the dominant crops.

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Material and methods

Material

Six landscape types were identified: (i) continuous corn monoculture, (ii) corn–soybean rotation, (iii) three-crop rotation (corn–soy–wheat), (iv) diversified five-crop system, (v) integrated crop–livestock, and (vi) agroforestry with alley-cropped hardwoods. Six replicate farm units per type were selected using USDA Cropland Data Layer records from 2016–2018 to verify management history. Equipment included yellow pan traps for pollinators, dry pitfall traps (10 cm diameter) for ground-dwelling predators, and Nikon Monarch 7 binoculars for bird transects.

Results

Table 1: Ecosystem stability indicators (mean scores, scale 0–5) across six landscape types

Landscape	Plant	Pollin.	Predat.	Soil	Yield	Composite
Monoculture	1.0	1.3	0.9	1.2	0.8	1.0
Corn–soy	1.8	2.1	1.6	1.9	1.5	1.8
3-crop rotation	2.7	2.9	2.4	2.6	2.3	2.6
Diversified (5)	3.4	3.7	3.2	3.5	3.1	3.4
Crop–livestock	3.8	3.6	3.9	4.1	3.4	3.8
Agroforestry	4.3	4.1	4.2	4.4	3.8	4.2

All stability indicators increased monotonically from monoculture to agroforestry (Table 1). The composite index differed significantly among all pairwise comparisons except

Methods

Each farm unit was surveyed three times per growing season (May, July, and September) during 2019–2021. Plant diversity was assessed along four 50 m transects per unit. Pollinator traps ($n = 8$ per unit) were deployed for 48 h at each visit. Pitfall traps ($n = 10$ per unit) operated for 72 h. Bird surveys followed 500 m fixed-width transects at dawn. Shannon–Wiener index was calculated for plants, arthropods, and birds. Yield data (three years) from farm records were used to calculate the coefficient of variation (CV); stability was expressed as $1/\text{CV}$. A composite stability index (mean of five normalised indicators) was computed for each unit. Kruskal–Wallis tests followed by Dunn’s post-hoc were used to compare landscape types ($\alpha = 0.05$).

crop–livestock versus agroforestry (Dunn’s $p = 0.11$). Yield stability showed the weakest gradient, suggesting that economic returns diversify less sharply than ecological returns.

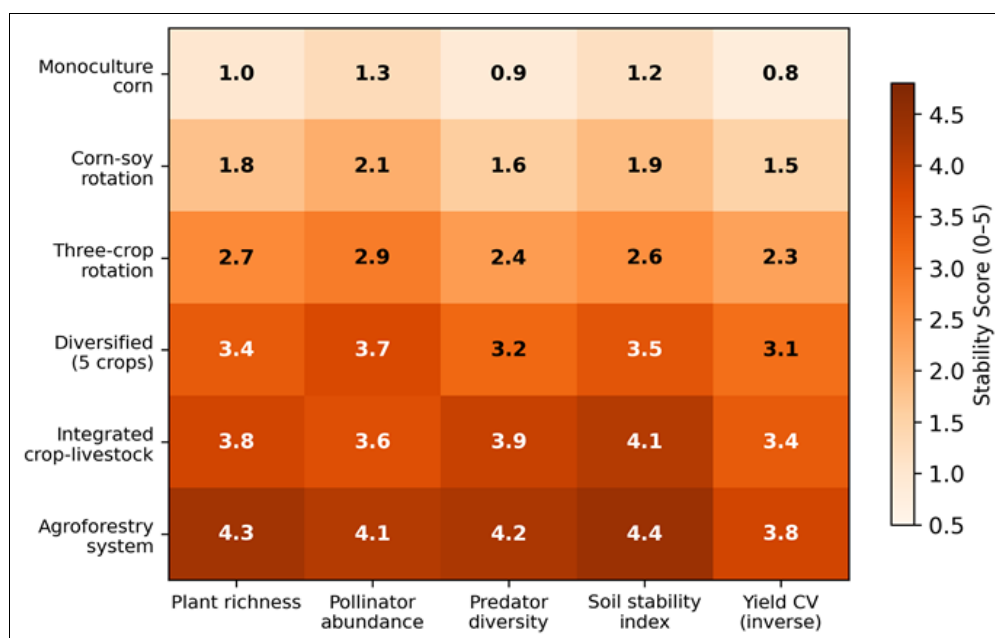


Fig 1: Ecosystem stability scores across six landscape types and five indicator categories

Table 2: Shannon diversity index (H') for plants, arthropods, and birds by landscape type

Landscape	Plant H'	Arthropod H'	Bird H'
Monoculture	0.42 ± 0.08	0.68 ± 0.11	0.31 ± 0.07
Corn–soy rotation	0.87 ± 0.12	1.14 ± 0.15	0.63 ± 0.10
3-crop rotation	1.34 ± 0.16	1.57 ± 0.18	1.08 ± 0.14
Diversified (5 crops)	1.82 ± 0.19	1.96 ± 0.21	1.47 ± 0.17
Crop–livestock	2.13 ± 0.22	2.28 ± 0.24	1.89 ± 0.20
Agroforestry	2.61 ± 0.25	2.54 ± 0.23	2.37 ± 0.22

Birds showed the steepest diversity gradient: agroforestry H' was 7.6 times that of monoculture (Table 2). Arthropod diversity

plateaued somewhat above the 5-crop level, while plant diversity continued climbing through agroforestry.

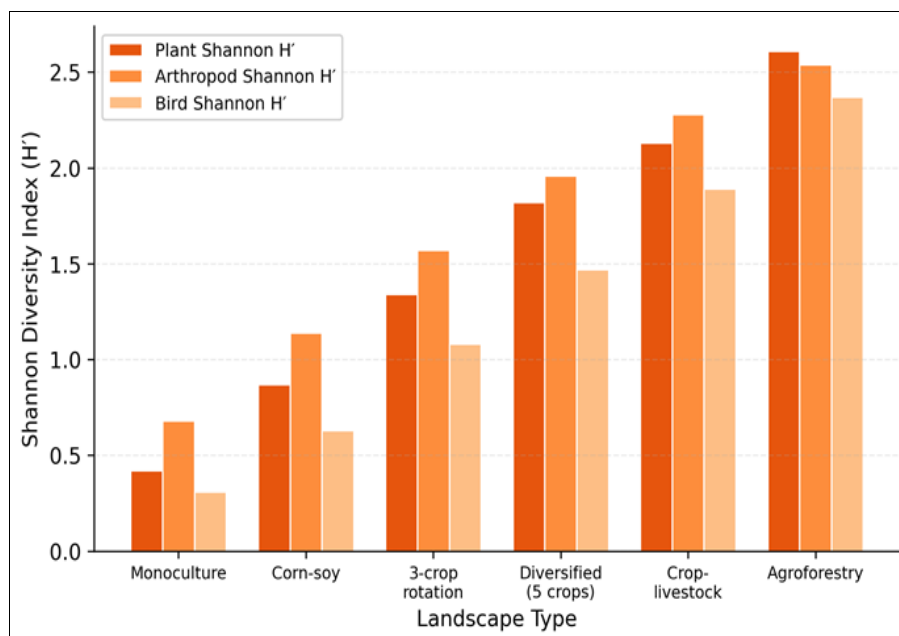


Fig 2. Shannon diversity index for plants, arthropods, and birds across six farming landscape types

Comprehensive interpretation

Spearman rank correlation between the composite stability index and total landscape crop richness was 0.92 ($p < 0.001$). The relationship was steepest between monoculture and three-crop rotation, then levelled off slightly, suggesting diminishing marginal returns beyond moderate diversification.

Discussion

The near-linear rise in stability across the diversification gradient is consistent with theoretical predictions from the insurance hypothesis, which holds that functionally redundant species buffer ecosystem processes against environmental fluctuations^[4]. In practical terms, moving from monoculture to a three-crop rotation more than doubled the composite stability score at relatively low management cost, which may represent the best cost–benefit entry point for conventional growers^[7].

Bird diversity proved most sensitive to landscape complexity, likely because birds respond to structural habitat features (hedgerows, tree canopy, pasture) that only appear in the more diversified systems^[8]. Arthropod diversity, by contrast, saturated earlier—once three or more crop types provided a rotation of flowering and residue resources, additional crops added fewer new arthropod niches^[9]. Yield stability improved less dramatically, partly because even monoculture farms in Michigan benefit from crop insurance and irrigation access that buffer economic volatility artificially^[10].

Limitations

The observational design means that landscape type was confounded with farmer management philosophy; growers who choose agroforestry may also employ other conservation practices. The three-year window captured only moderate weather variability and no extreme drought events. And the six-unit replication per landscape type, while adequate for detecting large effects, limits power for detecting subtle interactions between biodiversity components.

Conclusion

Increasing agro-biodiversity from monoculture to agroforestry raised all five ecosystem stability indicators in southern Michigan farming landscapes. The composite stability score

quadrupled across the gradient, and Shannon diversity for birds increased 7.6-fold. Even modest diversification to a three-crop rotation delivered meaningful gains. These results support incentive programmes that target landscape-level diversification rather than field-level input efficiency alone.

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