Enhancing Ecosystem Services of agricultural landscapes under scenarios for land conversion to vegetative buffers with a digital decision support system

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Abstract

To investigate the role of digital decision support system in enhancing agroecosystem health, this study assessed a 25km^2 landscape in Brandenburg, Germany. Four ecosystem services—erosion potential, biodiversity, biomass, and pollination—were quantitatively analyzed for field-scale land conversion to vegetative buffers. Four conversion scenarios (Erosion Protection, Pollination Enhancement, Biodiversity Enhancement, Balanced ES) were evaluated, showing improvements in ecosystem services, including reduced erosion, increased pollinator abundance and enhanced habitat richness under minimal reduction in production area. Integrating this approach into decision support systems offers development opportunities of flexible tools for sustainable agroecosystem management.

Introduction

To investigate the challenges in managing agroecosystems across multiple scales, this research delved into the utilization of digital tools for spatially planning field-scale land use conversion. This strategic approach not only influences the immediate field but also holds a pivotal role in shaping the broader landscape-scale agroecosystem health, a fundamental determinant of success in the practice of organic farming.

Identifying a research gap in the space between commercial field-scale productivity tools and academic landscape-scale environmental tools (Mouratiadou et al., 2023, Grêt-Regamey et al., 2017), a multi-scale methodology is presented here aimed at bridging this divide and managing the complexities of agroecosystem health. This methodology includes management options for land use conversion to vegetative buffers, flower-striips & grassland buffers, referred to as use cases, and aligns them with specific management goals in the form of four conversion scenarios - Erosion Protection, Pollination Enhancement, Biodiversity Enhancement and Balanced ES. The method is intended for use by multiple agricultural stakeholders with differing spatial scale priorities.

The study aimed to answer the following research question: How can landscape-scale Ecosystem Service enhancement be achieved through the application of digital methods for geospatial analysis and site-specific land use conversion scenarios?

Methodology

A 25km^2 landscape window was chosen in the Märkisch-Oderland of Brandenburg, Germany for an assessment of four ecosystem services: water erosion potential, biodiversity, biomass potential and pollination services. Each ecosystem service was

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quantitatively thresholded to identify field-scale hotspots for conversion to either of two identified conversion 'use cases' - grassland buffers and flower strips, collectively vegetative buffers - with distinct conversion criteria, or 'rules', for each ecosystem. Four conversion scenarios were analysed: Erosion Protection (EP), Pollination Services Enhancement (PS), Biodiversity Enhancement (HR) and Balanced ES (BES) with distinct landscape management goals.

Results

Land conversion to vegetative buffers succeeded in enhancing field-scale ecosystem services and the scenarios were effective in achieving landscape-scale ecosystem goals. The Erosion Protection scenario showed the greatest decrease in mean erosion potential for conversion hotspots from 9.3 t / Ha.yr to 5.5 t / Ha.yr. The Pollination Service enhancement scenario showed a 36% increase in mean pollinator abundance for pollinator dependent crop locations. The Habitat Richness enhancement scenario notably increased mean habitat richness from 4.0 to 5.0 habitat types per 250m buffer radius. The Balanced ES scenario achieved a balance of ecosystem services, improving habitat richness, erosion control and pollination services with minimal production area loss.

Table 1: Percentage change in ecosystem service indicators under each scenario.

Scenario	Water Erosion Potential	Habitat Richness	Pollination Services	Production Area
Scenario 1: Erosion Protection	-41%	+15%	+31%	-17%
Scenario 2: Pollination Enhancement	-35%	+15%	+36%	-17%
Scenario 3: Habitat Richness Enhancement	-37%	+24%	+33%	-17%
Scenario 4: Balanced ESS	-25%	+24%	+19%	-10%

Conclusion

The integration of this multi-scale methodology into decision support systems has potential for significant and targeted impacts on agroecosystem sustainability. This can be particularly powerful when coupled with scenario analysis, offering a management tool for field-scale and landscape-scale ecosystem service enhancement that is flexible to the goals of land managers.

Literature

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