Enhancing Biodiversity and Multifunctionality of an Organic Farmscape in California's Central Valley

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Abstract

Organic farmers in the USA increasingly manage the margins of previously monocultured farmed landscapes to increase biodiversity, e.g. they restore and protect riparian corridors, plant hedgerows and construct vegetated tailwater ponds. This study attempts to link habitat enhancements, biodiversity and changes in ecosystem functions by: 1. inventorying the existing biodiversity and the associated belowground community structure and composition in the various habitats of an organic farm in California's Central Valley; and 2. monitoring key ecosystem functions of these habitats. Two years of inventories show greater native plant diversity in non-cropped areas. While nematode diversity did not differ between habitats, functional groups were clearly associated with particular habitats as were soil microbial communities (phospholipid fatty acid analysis). Earthworm diversity did not differ between habitats, but biomass was higher in non-cropped areas. Habitats with woody vegetation stored 20% of the farmscape's total carbon (C), despite their relatively small size (only 5% of the total farm). Two years of monitoring data of farmscape C and nitrogen (N) through emissions, run-off and leaching showed distinct tradeoffs in function associated with each habitat. Clearly habitat restoration in field margins will increase both landscape biodiversity and the multifunctionality of the farmscape as a whole.

Introduction

Deviations from the standard practice of monoculture food production through planned diversity could have a significant impact on associated biodiversity and ecosystem function (Vandermeer et al. 1998). Farmers manage habitat heterogeneity temporally with crop rotations or spatially through intercropping, or through "farmscaping". By farmscaping farmers retain or restore natural riparian tree corridors to protect waterways, plant hedgerows (shrubs and grasses along edges of farm fields) to attract beneficial organisms, establish tailwater ponds to reduce the nutrient content of irrigation water released into waterways and let previously denuded soil re-vegetate. Although these practices are increasingly being employed around the country there

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has been little scientific quantification of the effects of farmscaping on biodiversity or associated multifunctionality (Tscharntke et al. 2005).

Although field margins may represent a relatively small area of the overall farmed landscape, alterations of their ecosystem function may be significant enough to impact the multifunctionality of the landscape as a whole. Not only does the vegetation in these margins provide habitat for pollinators and birds, and store nutrients such as C and N, but it provides habitat for organisms belowground. These belowground organisms in turn mediate ecosystem functions such as atmospheric gas exchange, soil C storage, and water quality dynamics.

This study provides an opportunity to establish linkages between nutrient cycling, greenhouse gas (GHG) emissions, aboveground biodiversity and belowground communities and quantify the relative contributions of farmscaping management options to the overall multifunctionality of the farm. Yolo County, California is an ideal region for a landscape study that examines the complex relationship between land use and ecological function. Located in the Sacramento Valley, which typifies intensive, diversity poor, industrial agriculture, Yolo County is the home of numerous growers involved in farmscaping as a means of land stewardship. The Rominger organic farm was selected for this study as it embodies several farmscaping management options on a single soil type within the context of a typical mid-sized organic processing tomato farm (Figure 1). This study attempts to link habitat enhancements, biodiversity and changes in ecosystem functions by: 1. inventorying the existing biodiversity and the associated belowground community structure and composition in the various habitats of an organic farm in California's Central Valley; and 2. monitoring key ecosystem functions of these habitats.

Materials and methods

In the spring of 2005 and again in 2006, GIS (Arcview, ESRI 2005) was used to create a stratified random sample in each of the 6 habitat polygons (riparian corridor, hedgerow, north field, south field, drainage ditches, and tailwater pond) of the Rominger farm. Using each randomized point as the center, 16 m^2 plots were established which included four 50 x 50 cm^2 subplots (Figure 1).

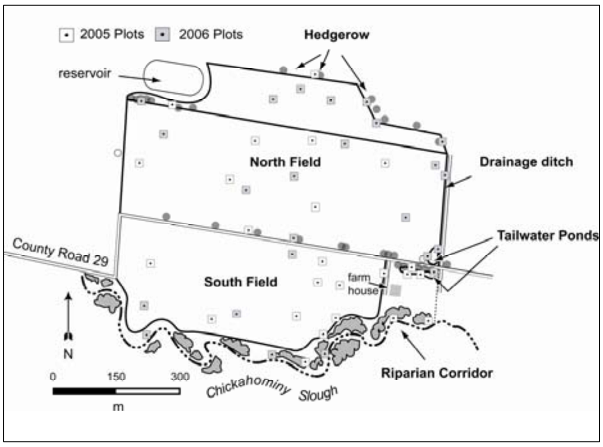

Figure 1: Map showing sampling points from 2005-06 in six farmscape habitats

Biodiversity: Vegetation cover (%) for each plot was recorded by species at each canopy layer. Soil microbial community structure was analyzed using phospholipid fatty acid (PLFA) analysis. Nematodes were extracted from 500g of sub-sampled soil, identified to family, and classified into functional groups. Adjacent to each of these 24 sampling points, a 30 cm^3 pit was excavated and sorted for earthworms which were identified to species and weighed in the laboratory.

Ecosystem Functions: We inventoried soil C and N pools, soil aggregation, and infiltration rates of each of the 24 points. Each habitat was monitored for both gaseous and aqueous C and N losses throughout the two year experiment. The GHG, CO_2 and N_2O, were sampled monthly using closed chambers and a continuous monitoring device (LiCOR 8100). Ceramic cup suction lysimeters where deployed at 30 and 60 cm depth to monitor dissolved organic C (DOC) and nitrate (NO_3^--N), while cumulative

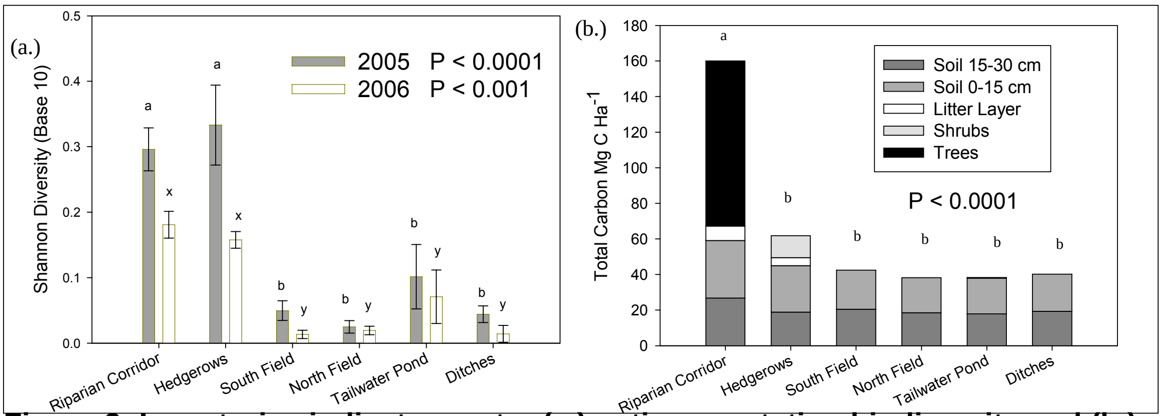

Figure 2: Inventories indicate greater (a.) native vegetation biodiversity and (b.) carbon storage in non-cropped areas of the farm

NO_3^--N was assessed using anion exchange resin bags buried at 75 cm depth. Surface runoff from the north and south crop fields was monitored using automated collection samplers (ISCO units) during stormwater and irrigation events.

Soil cores were taken from each sub-plot at 0-15 and 15-30 cm depths, and analyzed for gravimetric moisture, KCl-extractable NO_3^--N and NH_4^+-N, potentially mineralizable N, microbial biomass carbon (MBC), electrical conductivity (EC), and pH.

In the spring of 2005 and 2006, understory aboveground biomass was harvested from each subplot and shrubs were clipped. Crops were similarly harvested at the end of each summer. Ground, dry plant, fruit and soil sub-samples were sent to the UC DANR laboratory (http://danranlab.ucdavis.edu) and analyzed for total C, N, P and K (http://danranlab.ucdavis.edu). Shrub and tree C was estimated using measured heights and diameters and allometric biomass regression equations.

Statistical Analysis: Differences between habitats were analyzed using analysis of variance (ANOVA) followed by pair-wise comparisons using Tukey Honestly Significant Differences. Relationships between soil organisms and habitats were analyzed using Canonical Correspondence Analysis (CCA).

Results

There were clear differences between the six habitats in terms of above- and belowground biodiversity and ecosystem functions. Plant inventories showed similar patterns of native diversity following the extremely wet winter of 2005 and the extremely dry winter of 2006 (Figure 2a). Non-native plant diversity, however, was much higher in the ditches and tailwater ponds particularly after the drier winter.

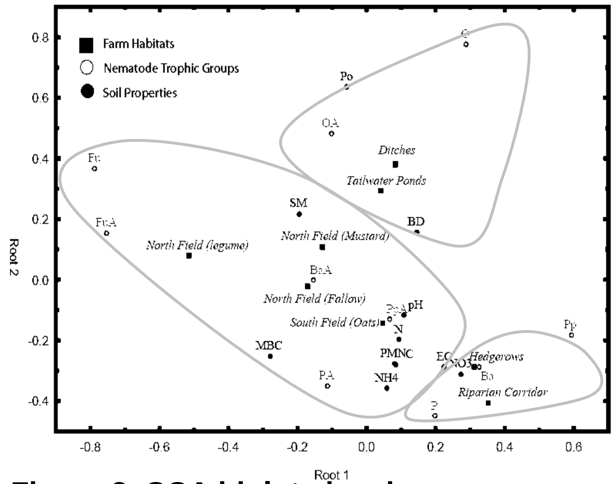

Figure 3. CCA biplot showing associations between nematode trophic groups, soil properties and farm habitats

The PLFA analysis showed only small differences between microbial communities across habitats with the exception of the drainage ditches which harboured several distinct PLFA markers. Although there were no differences in the diversity of earthworms (over all only four species were found) more earthworms were found in the non-cropped habitats.

Nematode inventories showed clear separation of species among habitats (Figure 3) (Sánchez-Moreno et al. 2007).

The drainage ditches were an extremely "leaky" habitat in that both GHG emissions and NO_3^--N leaching were high. Leaching losses in the ditches averaged 17.9 g N m^{-2}, higher than all other habitats except the tailwater pond, with the lowest mean loss of 2.0 g N m^{-2} in the riparian corridor. There were only small differences in total soil C among habitats, but when the contributions from woody vegetation were considered, large differences were observed (Figure 2b). Total C storage in the riparian corridor was estimated to be 160 Mg C ha^{-1} while the crop fields only stored 40.1 to 42.4 Mg C ha^{-1}. Together the riparian corridor and hedgerows account for 20% of the total estimated C stored on the farm despite being only 5% of the total area.

Discussion

While the non-cropped habitats account for only a small fraction of the farmed landscape, they play a crucial role both in terms of habitat for above- and belowground organisms as well as locations of dynamic nutrient cycling (e.g. higher CO_2 emissions in the riparian corridor as well as carbon production). There are numerous studies that have compared both the biodiversity and ecosystem function of organic vs. conventional production fields, but few have studied this in relation to managed edges of fields, and fewer still consider associations between the two. We have found that in some habitats, there may be functional tradeoffs (e.g. increased NO_3^--N leaching associated with food production). While each habitat may provide many subtle functions and are best evaluated by the overall contribution to multifunctionality, some functions are quite pronounced. For example, the important role of C storage in the habitats with woody species overshadows soil C storage at the landscape level. While organic management typically stores more soil C than conventional, e.g. at a nearby research station, the highest soil C levels were in an organic tomato maize rotation (22.8 Mg C ha^{-1} at 0-15 cm) compared to 9 other cropping systems (Kong et al. 2005), our study shows this can be further increased in at an organic farm by farmscaping. The soil C at the 0-15 cm depth at the Rominger farm's organic crop fields ranged between 19.7 and 21.8 Mg C ha^{-1}, increased to a mean of 23.4 Mg C ha^{-1}, when the total C storage for all the farm habitats was considered.

Conclusions

Managing agricultural field margins can not only increase the biodiversity of organic farming systems but also significantly contribute to increased multifunctionality of the agricultural landscape, providing a variety of ecosystem services of human value.

Acknowledgments

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References

Kong, A. Y. Y., J. Six, D. C. Bryant, R. F. Denison, and C. van Kessel. 2005. The relationship between carbon input, aggregation, and soil organic carbon stabilization in sustainable cropping systems. Soil Science Society of America Journal **69**:1078-1085.

Sánchez-Moreno, S., S. Smukler, H. Ferris, A. O'Geen, and L. Jackson. 2007. Nematode diversity, soil food web conditions, and soil chemical and physical properties in different soil habitats of an organic farm. Biology & Fertility of Soils **submitted**.

Tscharntke, T., A. M. Klein, A. Kruess, I. Steffan-Dewenter, and C. Thies. 2005. Landscape perspectives on agricultural intensification and biodiversity - ecosystem service management. Ecology Letters **8**:857-874.

Vandermeer, J., M. Van Noordwijk, J. Anderson, C. Ong, and I. Perfecto. 1998. Global change and multi-species agroecosystems: Concepts and issues. Agriculture Ecosystems & Environment **67**:1-22.