What is the Effect of Sheep Grazing for Cover Crop Termination on Associated Biodiversity?

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ABSTRACT: Targeted sheep grazing of cover-crops could potentially benefit agriculture by enhancing nutrient cycling, soil conservation, and pest management. Because grazing represents an ecological filter, it is important to understand the impacts this practice may have on the associated biodiversity of agroecosystems. We compared the effects of sheep grazing and mowing for cover-crop termination on plant and carabid beetle (Coleoptera: Carabidae) community structure at Towne's Harvest Farm in Bozeman, MT. Metrics for plant communities included plant diversity, weed biomass, and cover-crop biomass. Metrics for carabid beetle communities, which are beneficial generalist predators in agroecosystems, included activity-density, species richness, and diversity. In six 10 m × 15 m plots, we seeded a cover crop of buckwheat (*Fagopyrum esculentum* Moench), beet (*Beta vulgaris* L.), sweetclover [*Melilotus officianalis* (L.) Lam.], and pea (*Pisum sativum* L.). We allowed the sheep to graze until plots had ≥ 90% of the biomass removed, which we determined by visual inspection. For the mowing treatment, we mowed plots using a tractor mowing deck and ensured that vegetation within each plot was homogeneously cut. Plant biomass samples were estimated prior to cover-crop termination and again one month post termination. Carabid beetles activity-density was assessed throughout the growing season using pitfall traps. We did not detect any significant treatment differences in plant biomass and diversity ($P > 0.10$) and carabid beetle activity-density and diversity ($P > 0.37$). Our results suggest that sheep grazing for cover crop termination has a similar affect on associated biodiversity as that of mowing. Thus, farmers choosing to implement sheep grazing for cover crop termination should not experience adverse changes in plant community composition or carabid beetle assemblages.

Figure 1: Methods of cover crop termination. **(Left)** Tractor mowing. **(Right)** Sheep grazing.

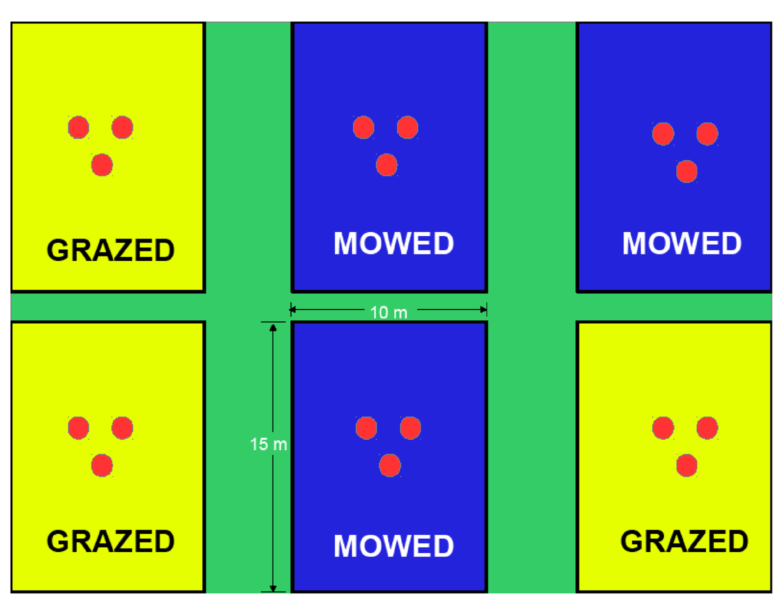

Figure 2: Schematic Diagram of Experimental Design. Yellow boxes represent sheep grazed plots. Blue boxes represent mowed plots. Red circles represent pitfall traps.

INTRODUCTION:

- Agriculture has responded to growing demands for food fiber and fuel with industrialized land management practices such as monoculture cropping and off-farm synthetic input use in an effort to increase production(Matson et al. 1997). However, practices often have deleterious environmental consequences (Foley et al. 2005).
- Cover cropping is an ecologically-based agronomic practice in which a producer seeds a suite of non-marketable plants to improve soil quality (Dabney et al. 2001). Cover cropping can also enhance habitat heterogeneity and consequently may have important impacts on associated biodiversity (Tillman et al. 2012). However, cover cropping does not provide a direct source of revenue for producers.
- Sheep grazing for cover crop termination could provide an alternative source of revenue for producers during seasons in which they cover crop. However, the effects of sheep grazing cover crop on associated biodiversity need further development (Thiessen Martens and Entz 2011).
- Carabid beetles (Coleoptera:Carabidae) are a ubiquitous beneficial taxon in agroecosystems. The majority of carabid beetles are generalist predators and consume a variety of prey including pests such as aphids (Hemiptera:Aphiidae), weevils (Coleoptera:Curculionidae) and sawflies (Hymenoptera:Symphyta) (Tooley and Brust 2002). Some carabids are seed-predators and may be important in regulation of weed populations (Menalled et al. 2007). Because carabid beetles are highly habitat selective and are sensitive to changes in their environment, they are considered a bioindicator taxon (Lovei and Sunderland 1996). Thus, changes to the carabid beetle community may have important consequences for conservation biocontrol and may reflect the response of the arthropod community in general.
- Undesirable plant species (weeds) are often considered an impediment to production (Aldrich 1987). However, weeds may provide ecological services such as N-fixation, soil moisture retention, erosion control, and habitat for beneficial organisms (Jordan and Vatovec 2004). Thus, changes to plant species assemblages could affect the practicality of sheep grazing cover crops on ecologically-managed farms.

MATERIALS AND METHODS:

- In June 2012, we plant cover crop of buckwheat (*Fagopyrum esculentum* Moench.), beet (*Beta vulgaris* L.), sweet clover [*Melilotus officianalis* (L.) Lam.], and pea (*Pisum sativum* L..)
- Between August 3, 2012 and August 6, 2012, we terminated the cover crops prior to fruiting. Half of the plots were mowed and half were grazed **(Figure 1)**.
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- We collected aboveground biomass from four randomly placed 0.40m^2 quadrats prior to cover crop termination in late July 2012 and again in mid September 2012 after regrowth.
- For plants, we measured total biomass, biomass by plant class (cover crops or weeds) and species biomass. For carabid beetles we measured total activity-density, species specific activity-density and species richness. For both plants and carabid beetles, we calculated diversity using the Shannon-Weaver Index of Diversity (1) and the Simpson's Diversity Index (1 – D) (2)

$$H' = -\sum_{i=0}^{n} p_i \ln(p_i) \qquad (1)$$

$$D = \sum_{i=0}^{n} \frac{(n_i)(n_i - 1)}{(N)(N-1)} \qquad (2)$$

- We used a two-sample permutation to compare treatment effects and a paired-permutation to compare pretreatment and post-treatment plant community metrics.
- For carabid beetle metrics, we used a repeated measures analysis of variance (ANOVA). For significant ($p < 0.05$) main effects and interactions, we used Tukey's HSD for mean comparisons.

	Period	
Treatment	Pretreatment diversity	Post-treatment diversity
Grazed	1.13 ± 0.20	0.82 ± 0.16
Mowed	1.67 ± 0.05	1.06 ± 0.22

Table 1: Plant diversity.

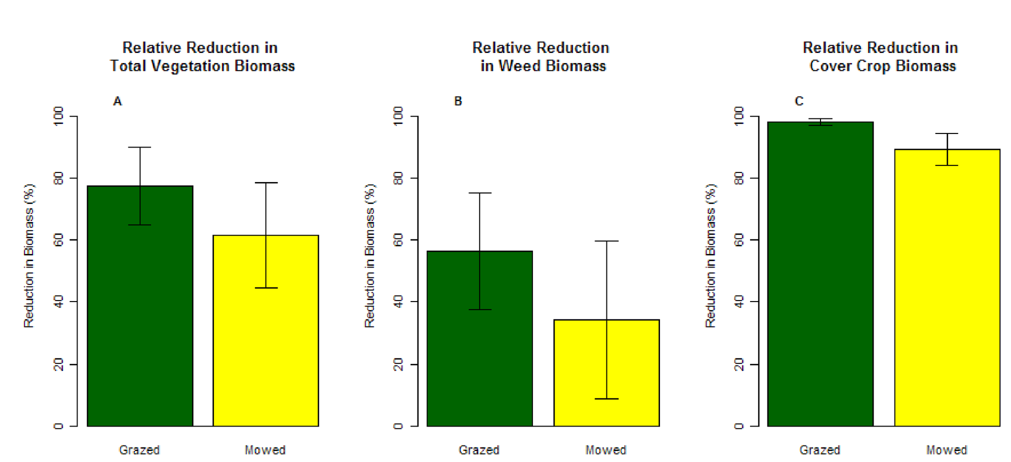

Figure 4: Proportion of biomass removed. Grazing and mowing reduced **(A)** total plant biomass, **(B)** weed biomass and **(C)** cover crop biomass by similar amounts.

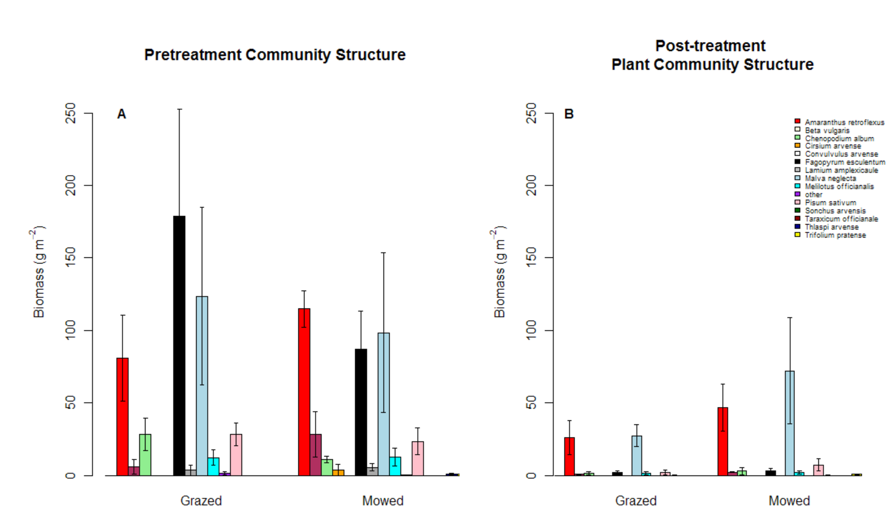

Figure 6: Plant Community Structure. **(A)** pretreatment plant community structure was similar between the grazed and mowed plots. **(B)** Post-treatment plant community structure was also similar between grazed and mowed plots. While the biomass of most plant species was reduced, *A. retroflexus* (L.) and *M. neglecta* biomass did decline.

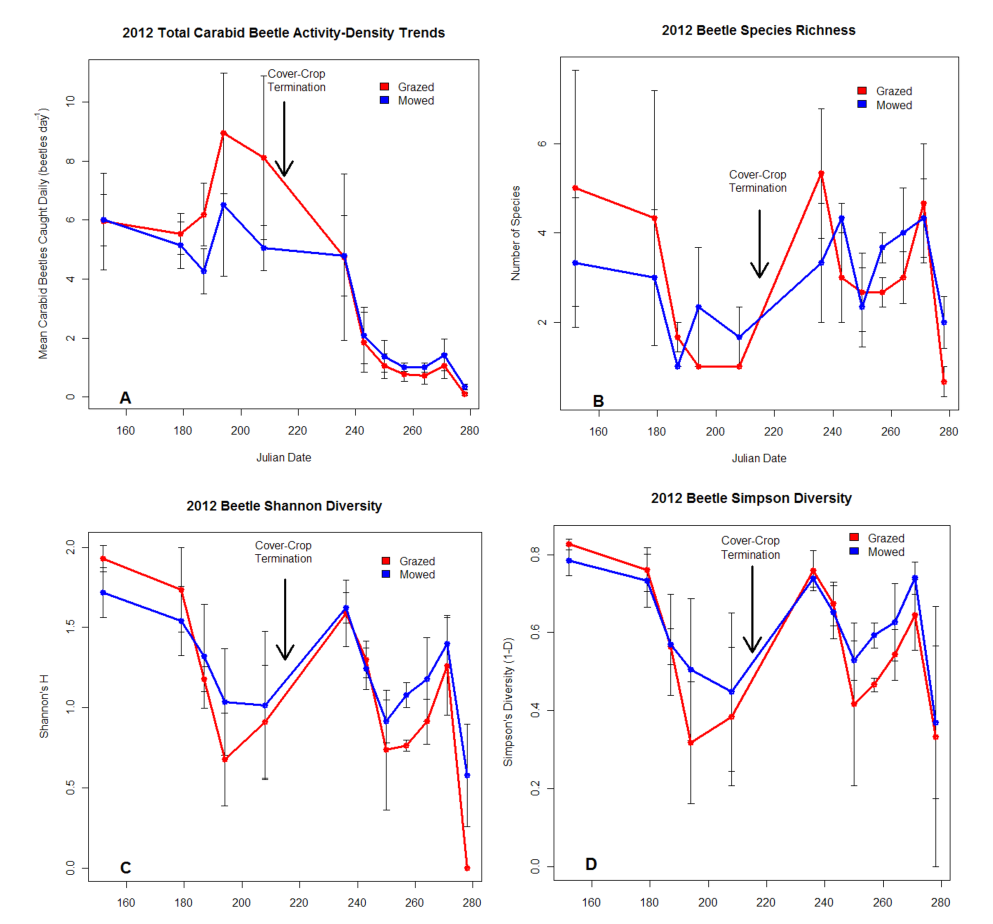

Figure 5: Carabid beetle community dynamics. **(A)** Total Activity-Density **(B)** Species Richness **(C)** Shannon Diversity **(D)** Simpson's Diversity. While activity density, species richness and diversity changed throughout the season, none of these metrics differed between mowed and grazed plots.

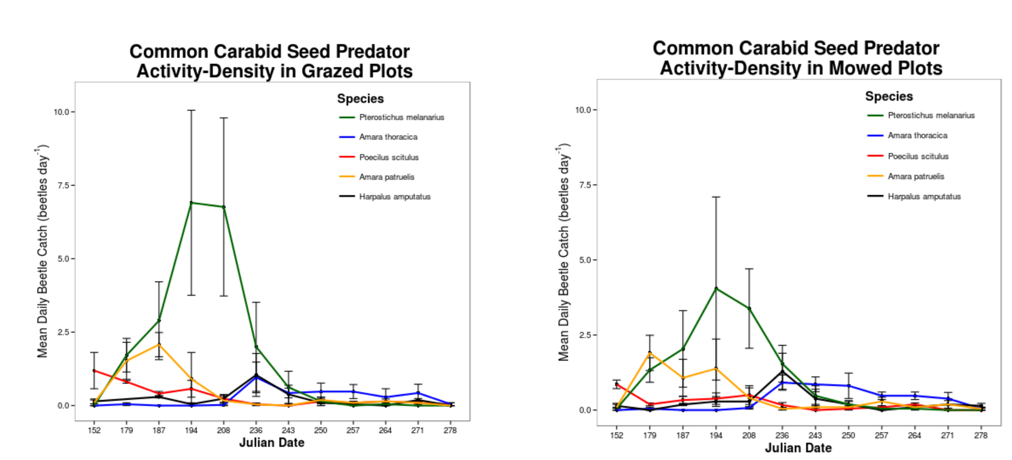

Figure 6: Activity-density of most frequently captured carabid beetles in **(A)** grazed plots and **(B)** mowed plots. *Pterostichus melanarius* (Illiger), the most dominant carabid species, became increasingly active-dense as the cover crop canopy grew, but declined precipitously following termination. *Amara patruelis* (Dejean) was the second most active-dense carabid species in the earlier half of the growing season, but became less common in the latter half of the growing season. By contrast, *Amara thoracica* (Hayward) became more active-dense after crop termination.

RESULTS:

- Plant diversity did not differ between grazed and mowed plots neither prior to ($P = 0.105$) nor following cover crop termination ($P = 0.396$). **(Table 1)**
- Both treatments reduced total biomass ($P = 0.302$), cover crop biomass ($P = 0.105$), and weed biomass ($P = 0.399$) by similar amounts **(Fig 3)**.
- Prior to cover crop termination, buckwheat (Fagopyrum esculentum), redroot pigweed (Amaranthus retroflexus), and common mallow (Malva neglecta) were the most abundant plants in both grazed and mowed plots **(Fig 4A)**. F. esculentum biomass declined in both mowed and grazed plots following treatment, however, both the biomass of *A. retroflexus* and *M. neglecta* did not change following treatment in neither grazed plots nor mowed plots **(Fig 4B)**.
- There were no treatment differences in activity-density ($F = 4.51$; df = 1,4; $P = 0.63$), species richness ($F = 0.05$; df = 1,4; $P = 0.95$) and diversity (for Shannon's H: $F = 1.017$; df = 1,4; $P = 0.37$; for Simpson's D: $F = 0.945$; df = 1,4; $P = 0.39$) throughout the growing season **(Fig 5)**.
- The five species with the highest activity-density were *Pterostichus melanarius* (Illiger), *Poeclius scitulus* (Leconte), *Amara patruelis* (Dejean), *Amara thoracica* (Hayward) and *Harpalus amputatus* (Say). The activity-densities of these five species fluctuated similarly throughout the growing season for both treatments **(Fig 6)**.

CONCLUSIONS:

- Sheep grazing is an effective means of cover crop termination
- Sheep grazing and mowing seem to have similar effects on plant community structure and carabid beetle community structure.
- Therefore, producers sheep grazing cover crops likely will not observe dramatic changes in weed community.
- Both methods of cover crop termination, however, may systematically avoid targeting certain species, therefore increase propagule pressure from those species. A similar study, found that this could lead to exacerbated infestations of such weeds (Miller et al, In press)

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REFERENCES:

Aldrich, R. J. 1987. Predicting Crop Yield Reductions from Weeds. Weed Technology 1:199–206.
Dabney, S. M., J. A. Delgado, and D. W. Reeves. 2001. Using Winter Cover Crops to Improve Soil and Water Quality. Communications in Soil Science and Plant Analysis 32:1221–1250.
Foley, J. A., R. DeFries, G. P. Asner, C. Barford, G. Bonan, S. R. Carpenter, F. S. Chapin, M. T. Coe, G. C. Daily, H. K. Gibbs, J. H. Helkowski, T. Holloway, E. A. Howard, C. J. Kucharik, C. Monfreda, J. A. Patz, I. C. Prentice, N. Ramankutty, and P. K. Snyder. 2005. Global Consequences of Land Use. Science 309:570–574.
Jordan, N., and C. Vatovec. 2004. Agroecological benefits from weeds. Weed Biology and Management:137–158.
Lovei, G. L., and K. D. Sunderland. 1996. Ecology and Behavior of Ground Beetles (Coleoptera: Carabidae). Annual Review of Entomology 41:231–256.
Matson, P. A., W. J. Parton, A. G. Power, and M. J. Swift. 1997. Agricultural Intensification and Ecosystem Properties. Science 277:504–509.
Menalled, F. D., R. G. Smith, J. T. Dauer, and T. B. Fox. 2007. Impact of agricultural management on carabid communities and weed seed predation. Agriculture, Ecosystems & Environment 118:49–54.
Thiessen Martens, J., and M. Entz. 2011. Integrating green manure and grazing systems: A review. Canadian Journal of Plant Science 91:811–824.
Tillman, P. G., H. A. Smith, and J. M. Holland. 2012. Cover Crops and Related Methods for Enhancing Agricultural Biodiversity and Conservation Biocontrol: Successful Case Studies. Biodiversity and Insect Pests: Key Issues for Sustainable Management:309–327.
Tooley, J., and G. E. Brust. 2002. Weed seed predation by carabid beetles. Pages 215–229 The agroecology of carabid beetles.
Miller, Z., Menalled F.D,,Sainju U. M., Lenssen A.W., Hatfield, P.G. (in review) Effects of Targeted Sheep Grazing and Diversifying Crop Rotation on Spring Wheat Yields and Weed Pressure. Submitted to Renewable Agriculture and Food Systems