Paper 2: Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands (Ryals & Silver, 2013)

BACKGROUND: Grasses, like all plants, perform photosynthesis, a process by which they absorb carbon dioxide from the air and turn it into carbohydrates which they use to build their bodies and share with the microbial and mycorrhizal communities in the soil. Animals eat the grasses and humans in turn benefit from consuming the animals. Grasslands occur in areas where there is insufficient water for forests. Grasslands which are grazed, or have been grazed in the past, are called rangelands.

Rangelands cover more than one-quarter of the world's land surface and store about one third of the planet's terrestrial (land based) carbon (C). They are the dominant land cover type in California, covering around 50 million acres. Rangelands are important to economies around the world as they support the production of meat, dairy, leather, and fibers such as wool. The profitability of rangelands depends on the amount and the quality of the grass growth, and thus the amount of forage and feed for livestock. However, because of historic overgrazing, introduction of invasive plant species, and current destabilization of seasonal weather patterns due to climate change, rangeland soils have lost C and productivity and value has decreased.

Spreading manure has been shown to increase grass growth, increase C and moisture, decrease temperature, and change pH in rangeland soils. It also increases the release of greenhouse gas emissions including methane (CH_4) and nitrous oxide (N_2O) from the soil and can have negative effects on local air and water quality. In addition, manure can carry weed seeds and undesirable pathogens. The science team tested if the application of compost would have similar effects as manure, increasing the net primary productivity (NPP)[1] of treated land. They also tested if these increases would be partially or wholly offset by higher rates of soil greenhouse gas emissions (CO_2, N_2O, and CH_4) thus negating the benefits from C sequestration (also similar to manure).

GOALS: Amending grassland soils with compost has been proposed as a way to enhance the productivity of rangelands and increase soil C storage, while simultaneously reducing the upstream greenhouse gas emissions that come from the landfilling, burning, or rotting of organic waste (e.g. food scraps, yard or tree trimmings, manure). The effects of organic matter additions on greenhouse gas dynamics in rangelands was largely unstudied. The goal of this study was to look at the immediate and on-going effects of a one-time surface application of ½ inch of compost on plant growth, soil C sequestration and greenhouse gases emissions in California Mediterranean rangelands.

METHODOLOGY: A thermophilic compost was chosen to test the hypothesis that a one-time, surface (unincorporated[2]) application could increase soil C in access of the greenhouse gas emissions in CO_2 equivalents (CO_2e). The compost was an organic OMRI certified green waste product from Feather River Organics in Marysville, California . It had a nitrogen (N) concentration of 1.87% and C:N[3] ratio of 11. Two locations, a drier and wetter region within California Mediterranean grasslands, were selected for field trials: the Sierra Foothill Research and Extension Center in Browns Valley, CA[4], and The Nicasio Native Grass Ranch in Nicasio, CA[5]. Replicate plots consisted of untreated controls and composted organic matter amendments. Plots were 25 x 60 m, buffered by a 5 m strip arranged in three randomized complete blocks per site. Treatment plots were amended only once at the beginning of water year 1 in October 2008. The study continued for three growing seasons until August 2011.

Process Details: This study consisted of both field and lab experiments and analyses to measure above- and belowground net ecosystem C fluxes. The study tracked net ecosystem C in a robust way, assessing a mass balance of inputs and outputs. This was done by combining detailed and ongoing monitoring of greenhouse gas emissions and physical soil samples, prior to and following application at weekly, daily and hourly intervals over time. The following in field metrics were tracked: soil organic C, C added from the compost, soil CO_2, CH_4 and N_2O fluxes, soil moisture, soil temperature, aboveground net primary productivity, belowground net primary productivity, and net ecosystem C storage. Soil bulk density was also

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[1] NPP: How fast and how much (net) carbon plants add to an ecosystem as they grow

[2] Unincorporated: not tilled or dug in

[3] C:N is the ratio of carbon to nitrogen. The C:N ratio of compost relates to residue decomposition and nitrogen cycling in soils. With a lower C:N ratio decomposition can occur faster and more N is available for plant growth.

[4] Browns Valley receives 28.7 inches of rain per year, local soil types inceptisols and alfisols; the site has been grazed by cattle for at least 150 years

[5] Nicasio receives 37.4 inches of rain per year, local soil types are mollisols; the site has been grazed since at least 1900

measured by digging and analyzing one pit on each plot.

In addition to infield measurements, soils were brought back to the lab where maximum potential greenhouse gas fluxes from compost with and without water addition was estimated under controlled conditions.

FINDINGS: A single application of composted organic matter significantly increased grassland C storage, and the effects of the one-time application continued into the following two years. Net ecosystem storage increased by 25-70% without including the direct addition of compost C[6]. The continuation of C sequestration after the first year of application is likely derived from the increased water-holding capacity observed in all but one of the treated plots, and a slow-release "fertilization" effect from compost decomposition. Both of these factors support increased productivity of the ecosystem.

There were large increases in grassland productivity in both Browns Valley and Nicasio: a forage increase of 78% was measured in the drier valley site, while the wetter coastal zone saw an average increase of 42%. The availability of ample and quality forage contributes to the feasibility and sustainability of associated C sequestration. A sustained increase in forage production was measured and these long lasting effects may help buffer impacts of decreasing precipitation predicted for some regions with climate change.

Wet-up events, like rainfall or irrigation, can cause trace gas emissions, particularly in dry, organic-rich soils. Contrary to the hypothesis posed in this study, CH_4 and N_2O emissions did not increase significantly on treated plots. Slightly elevated rates of N_2O were observed on amended soils, but lasted only four days following rainfall or other watering. Methane fluxes were negligible and did not respond to the addition of water.[7] The vast majority of the greenhouse gas emissions lost from treated soils was from CO_2. However, the C losses that were observed were significantly less than the total gained from the sequestration created by greater and more vigorous plant production.

The soils were brought back to the lab for an incubation experiment to further test the potential for greenhouse gas emissions from amended and control soils during wet-up events. In the lab, N_2O was produced for a short time period following soil wetting, but rates of N_2O emissions as a global warming potential were insignificant. In contrast, soil N_2O emissions from temperate grasslands amended with a range of chemical fertilizers and manures were orders of magnitude higher.

Also unexpected, but notable in the study, was that the control plots (which were grazed in the same way as the treated plots) appeared to be losing C. Ecosystem C balance is highly variable over time and space, and, in general, the observed losses of C in these and other rangeland soils may be caused by shifts in vegetation, historical degradation and erosion from overgrazing, and climate change.

The study concludes that the effects of a single application of compost on rangeland soils showed multiple years of net C sequestration, higher NPP, and increased soil water holding capacity. Organic matter additions to rangelands can provide a pathway to divert organic waste from landfills or manure from nearby dairies, thereby reducing greenhouse gas emissions from traditional waste management.

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[6] Compost was hand sorted out of all samples following its application. The study assumed that much of the mass of carbon from the compost would be lost to the atmosphere in the first year. However, carbon from compost decomposition continued to be present over all three years of the study.

[7] Lack of significant N2O emission with compost additions could be due to relatively slow decomposition of organic matter, slow rate of N release from decomposition and greater plant N uptake - not N20 leaching (as with chemical fertilizers and manure) (evidenced by increased biomass production)