“A Lifecycle Model to Evaluate Carbon Sequestration Potential and Greenhouse Gas Dynamics of Managed Grasslands” (DeLonge, Ryals & Silver, 2013)

BACKGROUND: Grasslands cover 25% of the Earth’s land surface and are the dominant land-type globally. Grasslands occur in areas with regular periodic drought. Much of the plant matter in grasses is allocated belowground to their roots, indicating significant soil carbon (C) sequestration potential in grasslands across the globe. Despite the environmental and economic importance of these lands, soil degradation and erosion are widespread and many regions are losing soil C. Previous studies conducted with the Marin Carbon Project showed significant potential to reverse soil degradation and increase C sequestration in Mediterranean grassland soils from a single application of compost. Other organic fertilizers including manure, biosolids, and green wastes are already used on rangelands to enhance forage production. The application of synthetic fertilizers increases above-ground plant growth, however it can also contribute to water and air pollution. Non-synthetic fertilizers, like manure, have also been shown to increase above-ground plant growth and have positive co-benefits that include increased soil fertility, soil water holding capacity, and drought resistance. However, while the land application of manure successfully disposes of waste and increases soil nutrients it has been implicated as a major contributor to greenhouse gas emissions from the livestock sector and can increase nitrate leaching into streams. Furthermore, manure can spread weed seeds and pathogens.

GOALS: The goal of this study was to evaluate opportunities for climate change mitigation from the application of three common soil amendments: manure, compost, and inorganic nitrogen (N) fertilizer.

METHODOLOGY: Drawing from previous Marin Carbon Project studies and peer-reviewed literature, a field-scale life cycle assessment model was built to quantify greenhouse gas emissions - carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) - from common soil amendments. Greenhouse gas emissions were evaluated from the following activities: production of the amendment, transportation, application rates, ecosystem responses to amendments, greenhouse gas impacts of grazing cows (including feed), and avoided emissions due to organic waste diversion. Net sources or sinks (in CO_2e) were determined by subtracting emissions from sinks and from offsets. Direct C additions to the soil from compost and manure were not included.

FINDINGS: Composted manure and plant waste produced less greenhouse gas emissions than either the application of manure slurries or the application of inorganic N fertilizer to grasslands over their life cycle in a variety of conditions. With regards to manure application, the high emissions of CH_4 and N_2O outweighed the C gained from above- and belowground plant growth and soil C sequestration. Inorganic N fertilizer resulted in lower greenhouse gas emissions than the manure, assuming equal rates of N addition and NPP response.

A variety of scenarios were run in the model. These different scenarios highlighted a set of variables that had significant effects on total greenhouse gas emissions. Hauling of compost materials or manures, even for long distances, had a relatively small impact on all scenarios. The model was most sensitive to the rate at which N was applied, the concentration of N and type of amendment, the emissions capture rate at landfills, and types of manure management systems used at dairies. The composting manure and plant waste significantly reduced overall greenhouse gas emissions by diverting these materials from traditionally high emitting landfills and manure lagoons. Compost also had positive greenhouse gas benefits associated with increased plant productivity, reduced need for commercial feeds, and soil C sequestration.

IMPLICATIONS: Over a county-level region (65,000 ha), compost applications as described in the initial Marin Carbon Project case study led to a reduction in the net greenhouse gas flux of 1.5 million metric tons (MMg) CO_2e over 3 years. This is nearly equivalent to an offset of 10% of the annual emissions from the California commercial sector, which is the economic sector that includes categories such as food services, health care, education, and retail (CARB 2011). Extended to 5% of California rangelands (1,275,000 ha), this strategy would offset nearly 1 year of emissions from the California agriculture and forestry sectors (over 28 MMg CO_2e, CARB 2011).

If all the plant waste (including food) was diverted from California landfills and composted it could be used to treat over 150,000 ha annually. Based on estimates of manure production for this study, over 400,000 ha could also be treated annually with composted manure.

A NOTE ON NITROGEN: There are two primary forms of nitrogen (N) in soil amendments, inorganic and organic. Manure has both organic and inorganic forms of N. Compost has mostly organic. Synthetic fertilizers are generally only inorganic. Organic N is bound up within organic material and strongly chemically bonded to C. Organic N mineralizes (meaning it is released) at slower rates than inorganic N. Composted organic matter releases N very slowly and thus has lower associated emissions (N_2O) than fresh organic N or inorganic N. Because of this, adding the same total N from an inorganic fertilizer and from compost does not translate to there being equal plant-available N in the soil. For this study, the authors assumed that 1% of added inorganic N (or manure-N) and 0.25% of compost-N was converted directly to N_2O. Leaching losses from inorganic fertilizer were estimated as 0.0075 kg N_2O-N kg-1 leachate-N, where leachate contained 0.3 kg N kg-1 amendment-N. Leaching rates were lower (by 75%) for manure-N and there were *no significant* leaching losses from compost applied to grasslands.