Does liming grasslands increase biomass production without causing negative impacts on net greenhouse gas (GHG) emissions?

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Introduction

- Liming of grasslands is often neglected, especially when the overall profit of grassland is low (1).
- It is still unknown how lime exactly influences grass productivity and nutrient use efficiency in different soil pH, botanical and agro-climatic conditions.
- This review aims to use the global available literature to assess the impacts of liming grasslands on soil pH, biomass production and net GHG emissions.

Materials and Methods

- Web of Science database
  - Peer reviewed publications from 1980 to 2021 on liming effect on soil pH, grass biomass and GHG emissions.
  - Only field studies with a control treatment.
- From 12,470 papers
  - 33 papers on soil pH and grass production.
  - 24 papers on SOC and GHG emissions.
- Lime materials were converted to calcium carbonate equivalent (CCE) which is a neutralizing value of a liming material compared to pure calcium carbonate.
- Datasets referred to moist cool (MC) or moist warm (MW) climates (2).
- Impacts of liming on Net GHG were analysed/ summarized qualitatively due to scarcity of data.

Results

Fig. 1: Dry matter production responses to liming in the different climatic zones (a), number of species (b), soil types (c) and amounts of N fertilisation (d). Effect size = the response ratio between treatment and control.

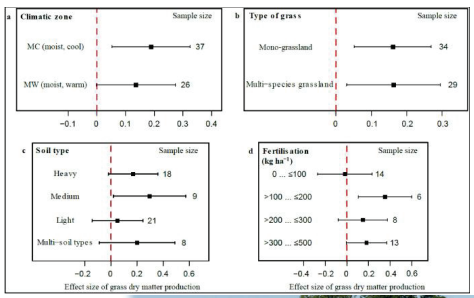


Table 1: Effects of liming on soil pH and dry biomass production (t ha^{-1}) under different climatic zones (MC = moist, cool; MW = moist, warm) and number of grass species. N is the number of observations.

		Control (Mean±SD)	Limed (Mean±SD)	N	t-value	p-value
Soil pH	All data	4.93±0.71	5.70±0.84	85	16.36	<0.001
	MC	4.87±0.74	5.56±0.96	55	10.94	<0.001
	MW	5.04±0.66	5.96±0.49	30	14.94	<0.001
	Monocul. grass	4.87±0.67	5.81±0.77	48	13.69	<0.001
	Multi-sps	5.00±0.77	5.55±0.92	37	4.68	<0.001
Dry biomass	All data	5.21±2.64	6.18±2.93	63	6.39	<0.001
	MC	4.66±2.12	5.70±2.69	37	3.89	<0.001
	MW	5.99±3.13	6.86±3.17	26	4.45	<0.001
	Monocul. grass	5.49±2.29	6.37±2.67	34	5.66	<0.001
	Multi-Sps	4.88±3.02	5.95±3.24	29	4.31	<0.001

Fig. 2: Relationships between soil pH and clay (a) silt (b) and sand (c) contents. Clay and silt were positively correlated with changes in soil pH. Sand showed no correlation with the changes in soil pH.

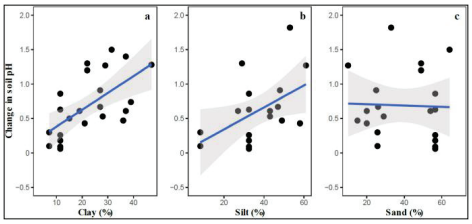


Fig. 3: Relationships between grass dry matter production and (a) amounts of lime in calcium carbonate equivalent and (b) mean annual precipitation.

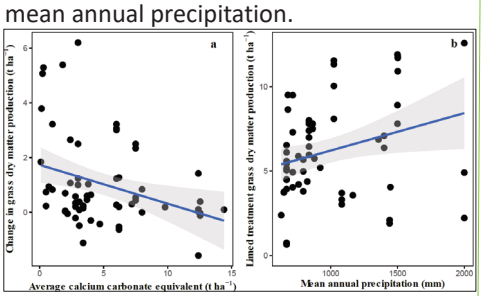
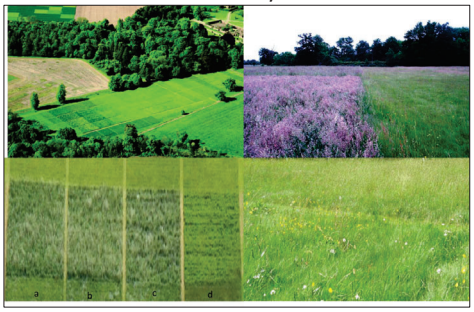


Fig. 4: Plot boundaries and differences in the type and number of plant species in the Park Grass Experiment (2005) due to differences in N fertiliser/ lime treatments.



References:
1. Goulding, K.W.T. (2016). Soil acidification and the importance of liming agricultural soils with particular reference to the United Kingdom. *Soil Use and Management*, 32, 390-399.
2. Smith, P., Martino, D., Cai, Z. (2008). Greenhouse gas mitigation in agriculture. *Philosophical Transaction of the Royal Society B: Biological Sciences*, 363, 789-813.

- Decreases/ no impacts on N_2O emissions
  - Increases soil pH and thereby, improves the capacity of denitrifiers to reduce N_2O to N_2.
  - Increases *nosZ* gene abundance in soils causing lower N_2O emissions.
- Decreases/ no impacts on CH_4 emissions
  - Soil acidity directly impacts methanotrophs.
  - At low soil pH, the accumulation of NO_2^- and NH_2-OH, and the presence of ammonia and toxic Al^{3+} ions negatively impacts methanotrophs.
- Increases net CO_2 emissions
  - Liming increases organic matter mineralisation due to favourable soil pH.
  - Liming is a source of inorganic C.

Conclusions

- Liming grasslands significantly reduces soil acidity.
- Liming grasslands increases grass dry matter production, reduces fertiliser requirement and increases species richness.
- Liming grasslands either reduces or has no impacts on N_2O and CH_4 emissions.
- The impact of liming grasslands on total net GHG emission is minimal.
- Acid soils should be moderately limed within the context of specific climates, soils and management.
- The scarcity of data represents a significant gap in knowledge which needs to be filled to better understand the benefits and impacts of grassland liming practices.

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