Is agricultural liming a CO_2 source or sink?

Integrating research on agronomy, watershed acidification, and N cycling at the KBS LTER

Photos courtesy of Agricultural Liming Association

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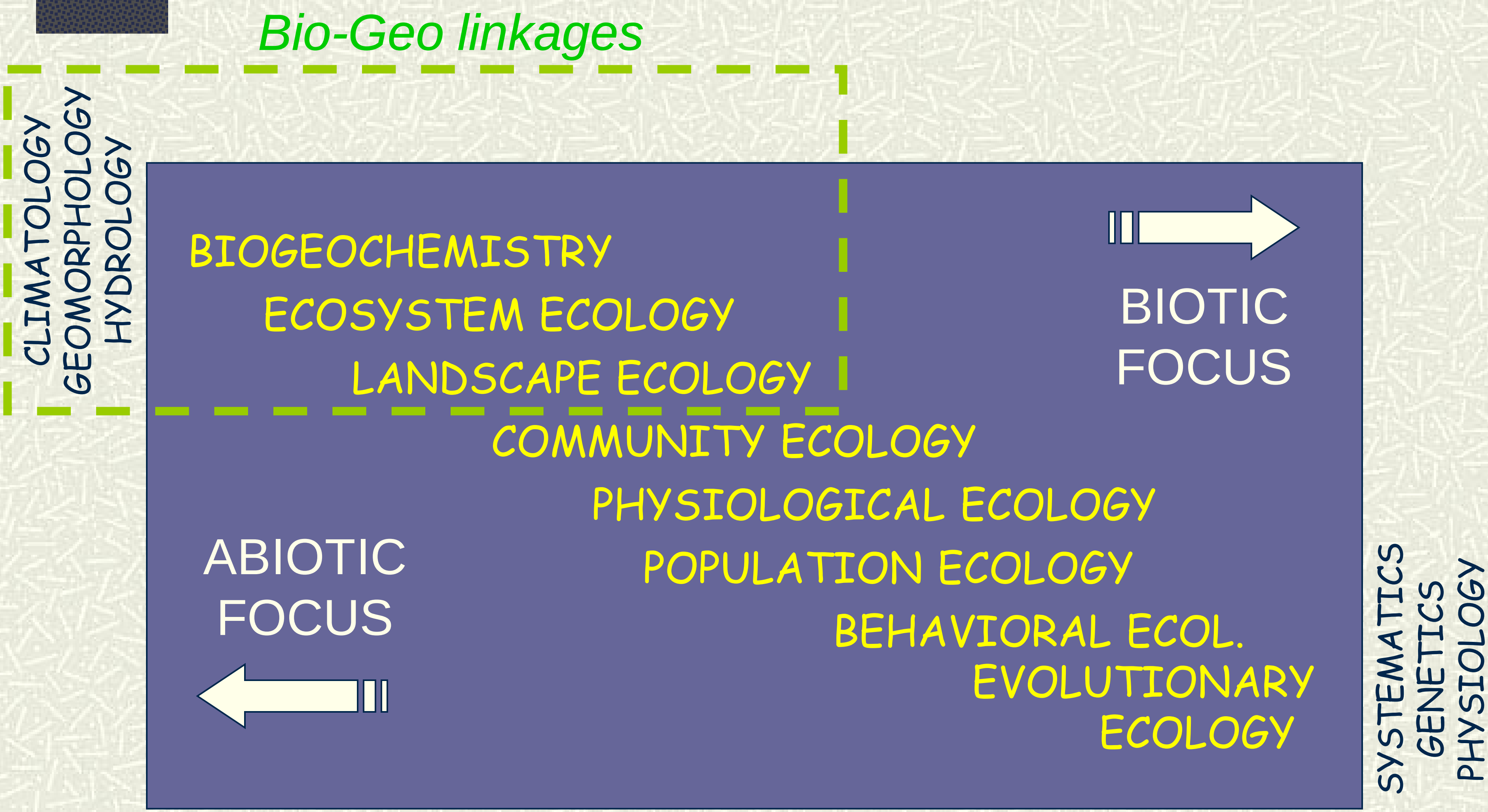
LTER, the spectrum of ecological sciences, and allied Earth Science disciplines



Adapted from Likens (1992)

Agricultural lime applications: A foundation of modern agriculture

- Crops require soil pH of ca. 5.5-7.0
- Some soils are naturally acidic
- Fertilization and harvest acidify soils
- Intensification of agriculture
- Liming neutralizes soil acidity and maintains soil fertility

Agricultural lime applications: Significance to global C cycle?

- "Lime" is often crushed limestone or dolomite
- Liming in U.S. amounts to ca. 17 Tg/y (~ 2 Tg C/y)
- Net C flux associated with changing U.S. agricultural practices (e.g., to no-till) is ca. 4-40 Tg/y
- Compared to soil organic matter, liming is significant and could increase 3-fold worldwide in next 50 years

Weathering of limestone

I. Dissolution in soil water by carbonic acid attack *takes up* CO_2 and yields dissolved Ca, Mg and HCO_3:

$$CaMg(CO_3)_2 + 2CO_2 + 2\,H_2O \Rightarrow$$

$$Ca^{2+} + Mg^{2+} + 4HCO_3^-$$ *CO_2 Sink*

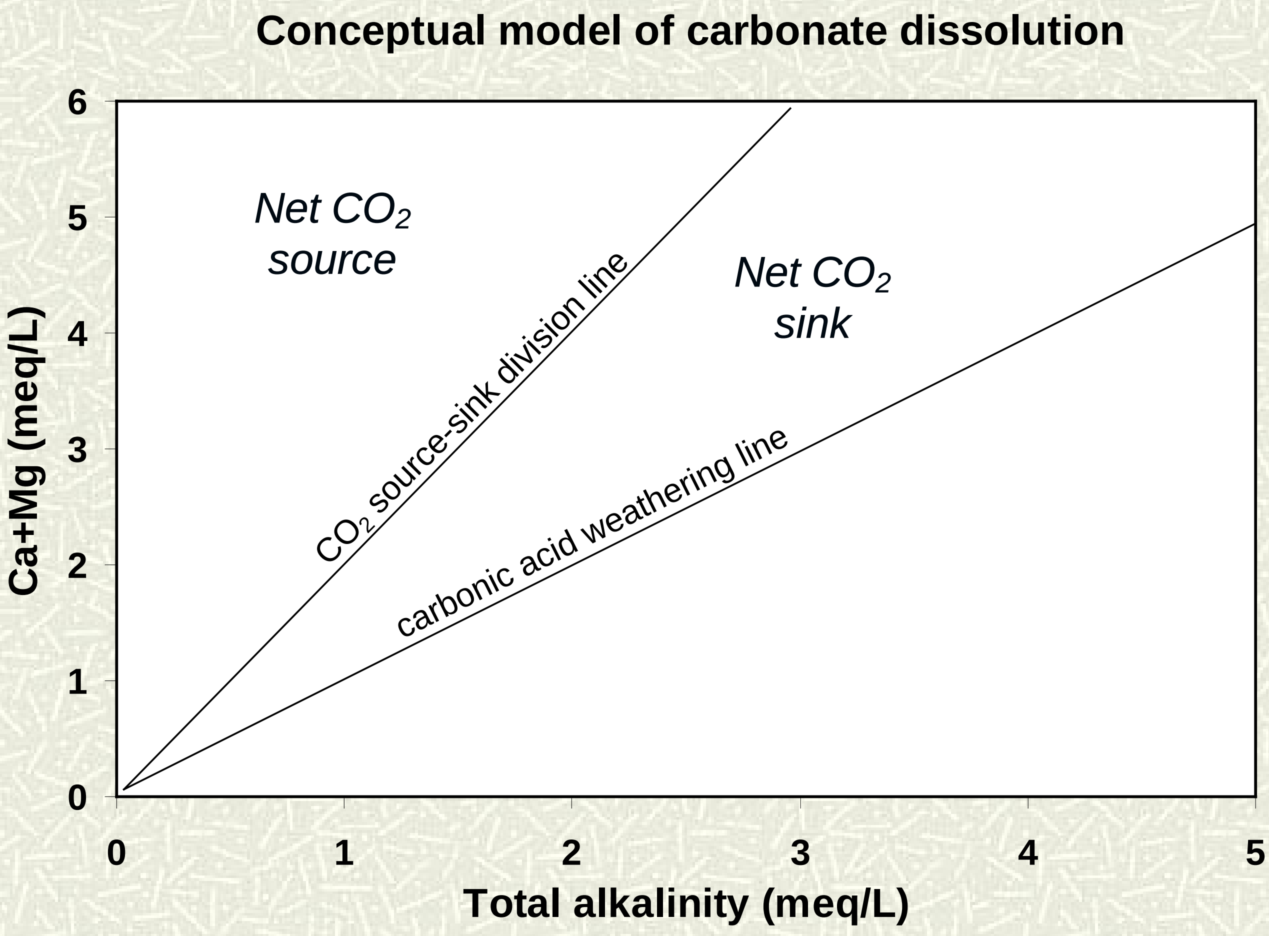
II. If sources of strong acidity exist, then the lime C will be converted to CO_2 but Ca and Mg remain in solution:

$$CaMg(CO_3)_2 + 4HNO_3 \Rightarrow$$

$$Ca^{2+} + Mg^{2+} + 4NO_3^- + 2CO_2 + 2H_2O$$

CO_2 Source

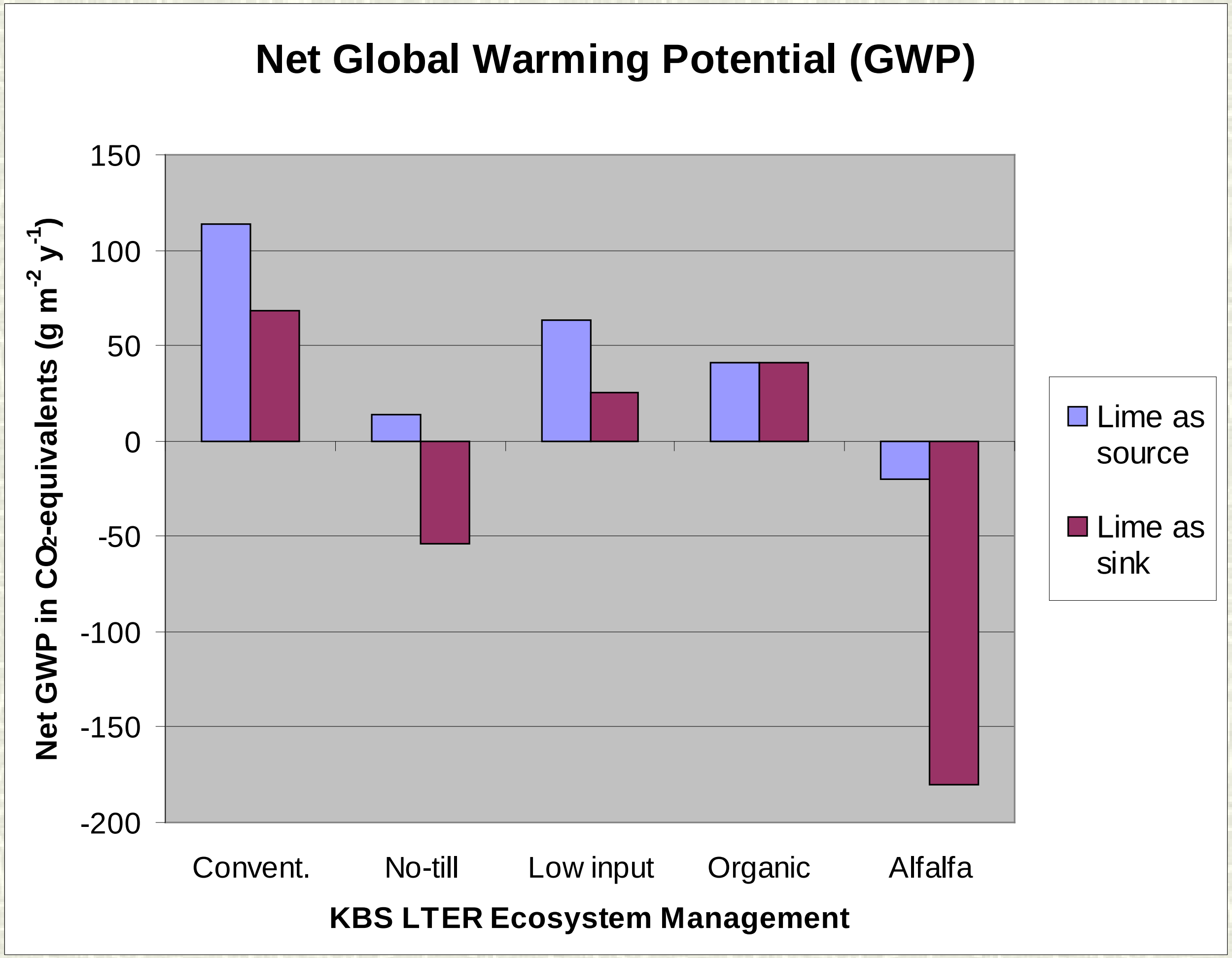
Weathering of limestone: Dissolved solute products



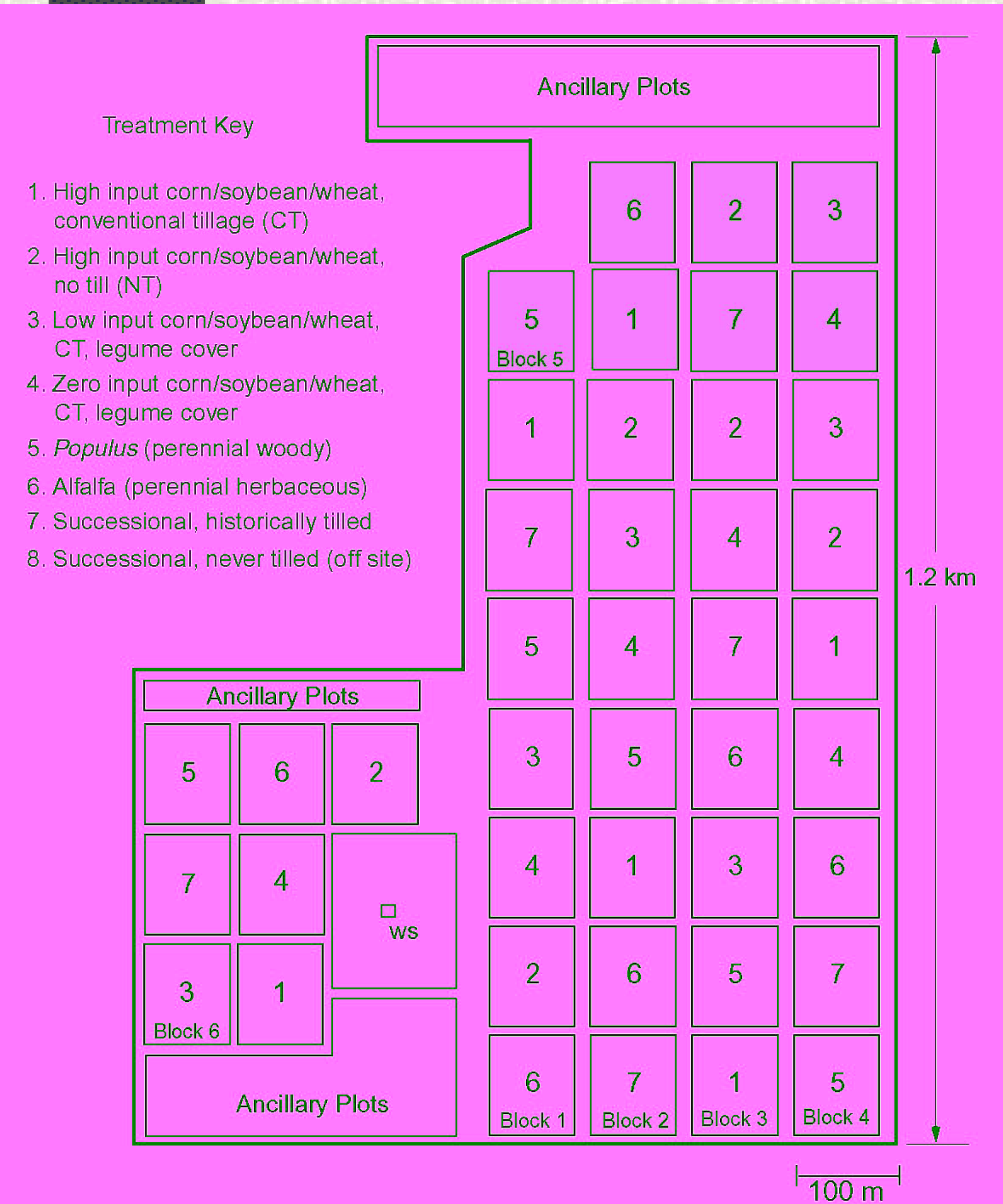
- HCO_3^- is measured by total alkalinity
- CO_2 source-sink division is the elemental stoichiometry of the lime

Linkage between liming and greenhouse-gas emissions

- Robertson et al. (2000) full-cost accounting of GWP (**blue bars**)
- Lime was second only to N_2O as a source of GWP in annual cropping systems
- Calculations assumed strong acid attack (all lime C emitted as CO_2)
- If lime dissolves by carbonic acid weathering (CO_2 sink), the results differ (**red bars**)



Adapted from Robertson et al. (1992) Science 289: 1922



KBS LTER site

Agricultural Ecology

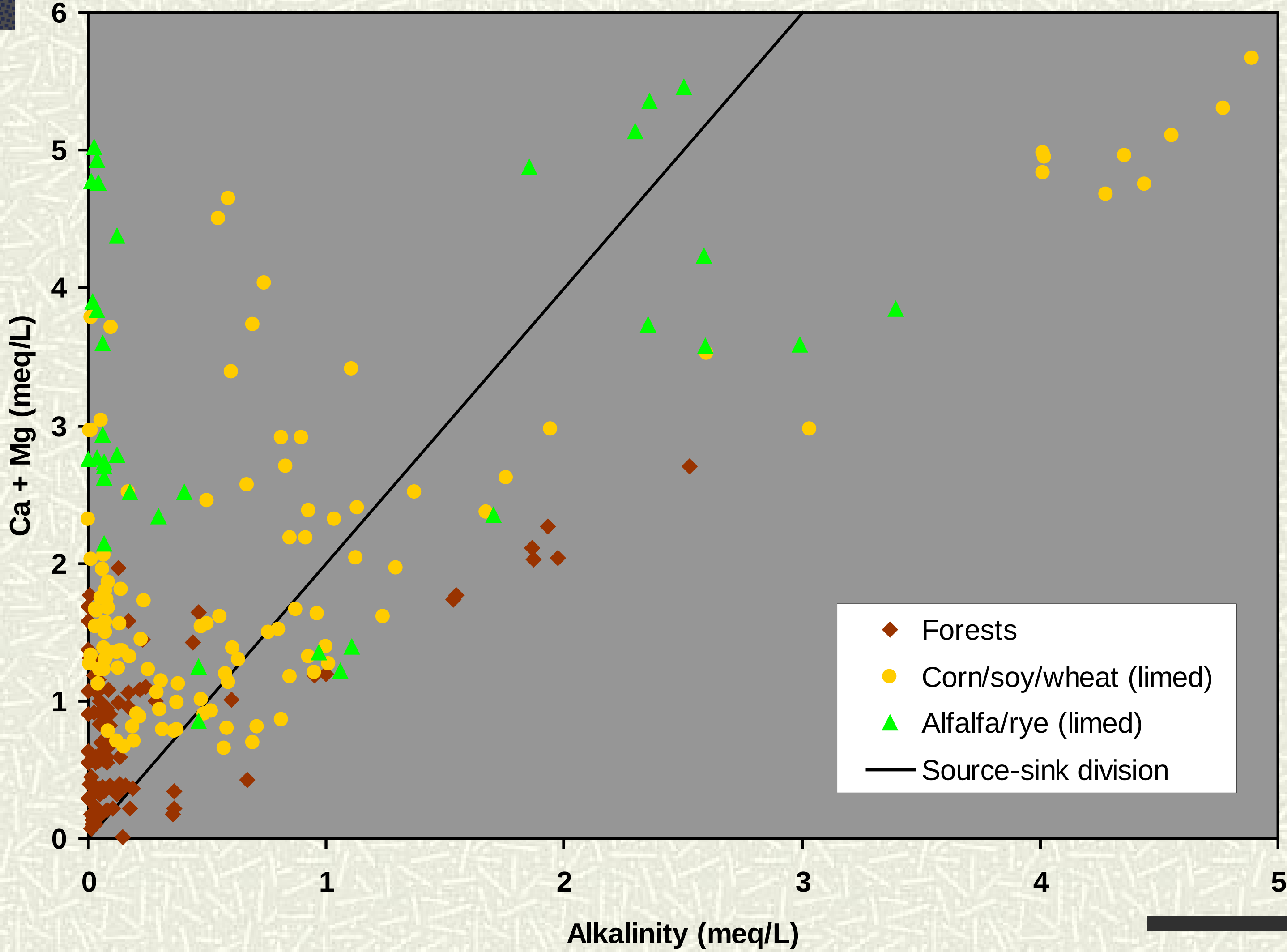
- Represents row crops of the corn belt
- Replicated 1-ha treatments include various row cropping systems
- We also study nearby unmanaged forests and old fields

Evidence for the fate of lime C from soil solutions at the KBS LTER site

- Soil solutions from the C horizon span the range from precipitation to groundwater
- Forest and old-field ecosystems show less ionic enrichment
- In cropping systems, soil solutions show influence of lime (and other soil amendments)

Soil solution chemistry

Low-tension soil water samplers below rooting zones in main treatments



Liming and C sequestration: Global hypotheses

- Differences across treatments in the fate of lime carbon are explained primarily by acidifying reactions mediated by microbes
- Nitrification associated with fertilization or N fixation is the most important acid source
- The net carbon balance associated with liming can be shifted from a CO_2 source to a CO_2 sink via the promotion of carbonic acid weathering (e.g., by liming at a higher rate)

Experimental approaches

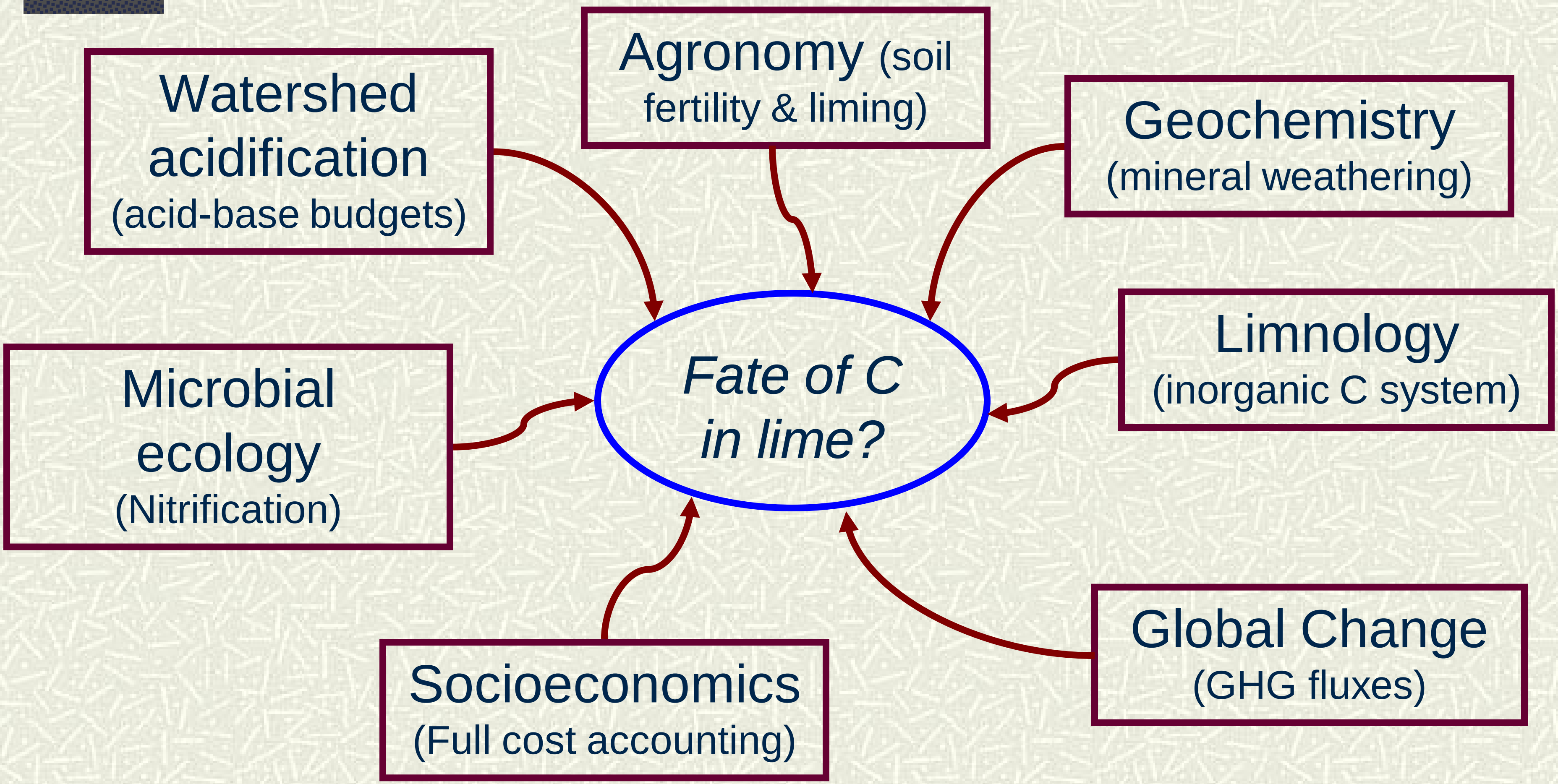
- Controlled lime additions over monolith lysimeters and across a N fertilization gradient
- Monitor for at least 3-5 years:
  - Precipitation inputs and leaching and harvest outputs
  - Soil solution chemistry
  - Mineral carbonate in soils
  - Nitrification rates
  - CO_2 and N_2O emissions
  - Elemental mass balances

Research needs:	Microbial transformations
A farm	Soil coring equipment
Some farmers	Gas sampling & analysis
Agronomist	Soil characterization
Crops (diverse kinds)	Soil moisture (TDR)
Tractors & lime spreaders	Isotope geochemistry
Fertilizer & lime	Soil solution chemistry
Monolith lysimeters	Meteorological station
Past agronomic records	Precipitation chemistry
Crop yield monitoring	Socioeconomic dimensions

Advantages of using the KBS LTER site for this research

- Farming infrastructure, expertise, records of past agronomic actions
- Extensive background data and ancillary monitoring
- Experimental plots equipped with soil moisture samplers
- Enclosed monoliths allow mass-balance of water and elements
- Precipitation monitoring (NADP)
- Need several years of sustained monitoring after lime is applied

New research on liming must draw on many disciplines…



…all of which are represented in the LTER network

Broader implications

- Insights into biogeochemical processes that regulate soil acid-base status and linkages between C and N cycles in agricultural ecosystems
- Full-cost accounting of agricultural activities
- Possibility for mitigation (carbon credits?)

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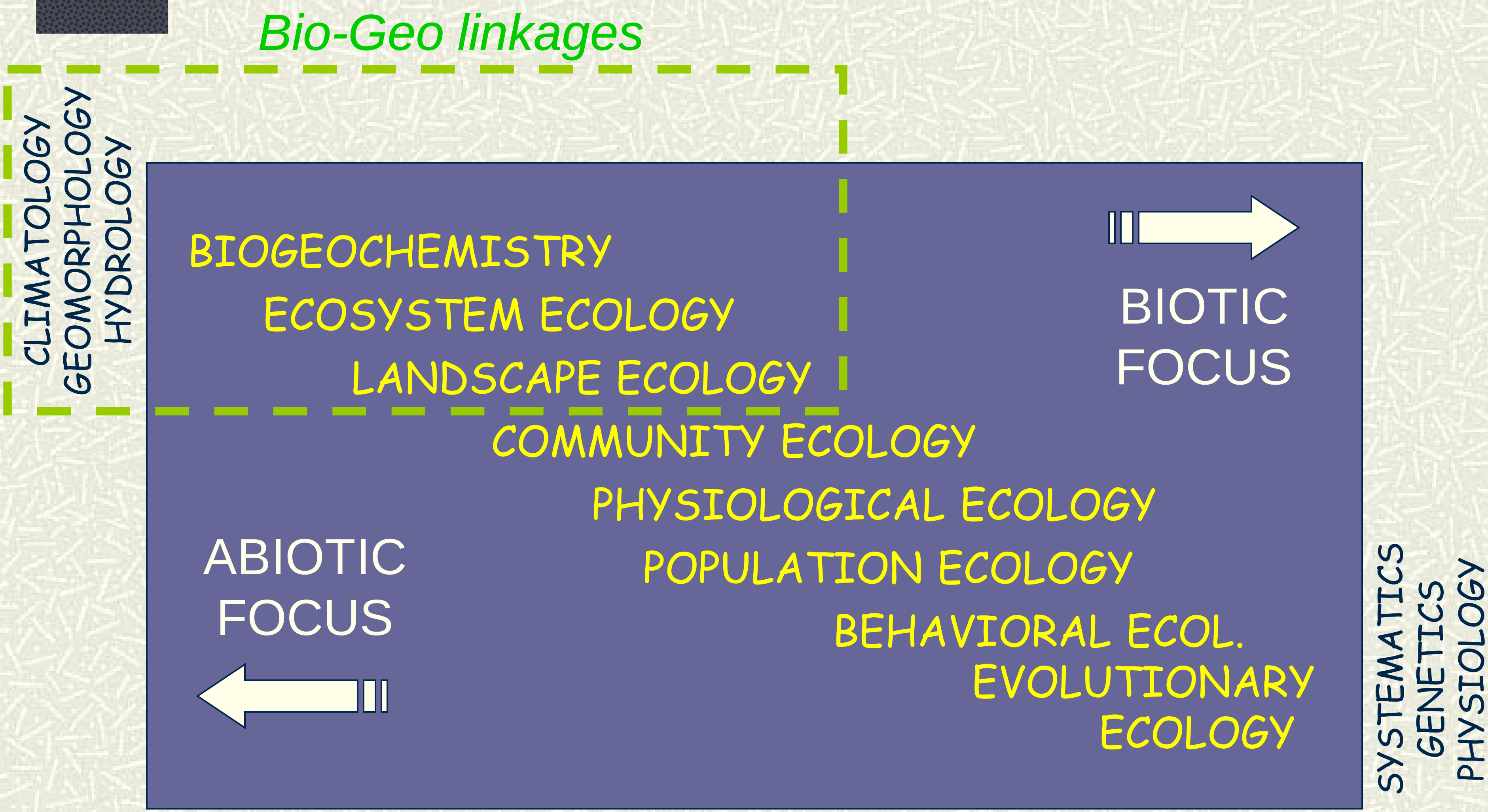

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