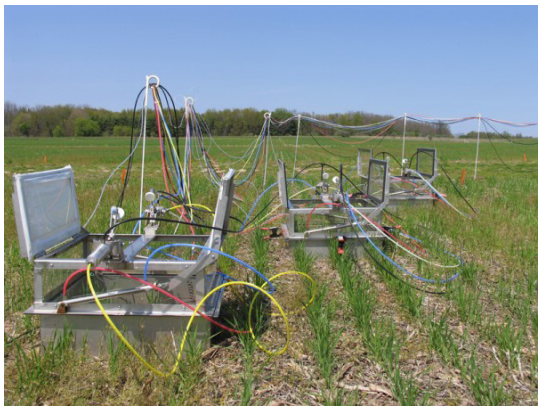
Research Highlights

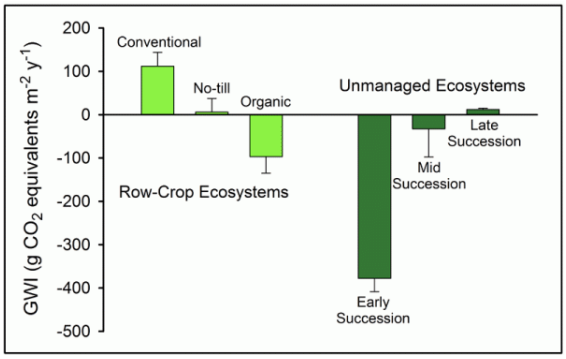


A series of automated chambers for measuring fluxes of greenhouse gases from a wheat field at the Kellogg Biological Station LTER site. Credit: J.E. Doll

Climate Change

AGRICULTURE AND CLIMATE CHANGE — KBS researchers were the first to develop a full accounting of the global warming impacts of different cropping practices and discovered novel opportunities for greenhouse gas mitigation by agriculture. These findings inform agricultural greenhouse gas policies worldwide.

Since 1992 scientists at the KBS LTER site have studied fluxes of the major, naturally occurring greenhouse gases (GHGs)—carbon dioxide (CO_2), methane, and nitrous oxide—in the cropped and natural ecosystems of the Main Cropping System Experiment. These data, coupled with concurrent measurements of soil carbon and fuel and agrochemical use, enabled KBS scientists to calculate the global warming impact (GWI) for each ecosystem expressed in CO_2-equivalents. This analysis, originally published in *Science* in 2000 and updated in a 2013 *Nature* paper, determined how much each cropping system contributes to global warming or, conversely, to global warming mitigation. The analysis also identifies how individual cropping practices within each system contribute to the system's GWI. Conventional cropping methods, for example, have an average annual GWI of about 82 CO_2-equivalents per square meter. This positive GWI indicates a net emission of GHGs. Nitrous oxide production alone accounts for more than half of this impact—more than the combined impact from fuel use and agrochemical inputs, including commercial fertilizer, agricultural lime, and pesticides. KBS LTER research further found nitrous oxide emissions to increase exponentially with nitrogen fertilization, and scientists continue to examine best practices for fertilization to reduce GHG emissions without affecting crop yield.



The net global warming impact (GWI) of cropped and unmanaged ecosystems at the KBS LTER site. Row crops include corn, soybean, and wheat rotations. Unmanaged ecosystems include fields abandoned from agriculture 20 (Early) to 60 (Mid) years ago that are undergoing natural succession toward native deciduous forest (Late). Source: Gelfand et al., In Press, based on an update of data in Robertson et al. 2000.

KBS LTER analyses have shown that different cropping practices can have markedly different GWIs and that the GWI of farming can be mitigated by a change in management strategy. No-till cultivation has an annual GWI that is negative, or net-mitigating. When left untilled, soil organic matter increases and this carbon storage offsets the GWI from related fuel and agrochemical use. Organic farming methods have an

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even greater mitigation potential—mainly due to soil carbon storage from the long-term use of cover crops such as red clover, which also reduces the need for nitrogen fertilizer and agricultural lime. Adoption of such agronomic practices could help mitigate GHG production in general—sufficient enough to offset the U.S. annual increase in GWI from the emission of fossil fuel CO_2.

Comparison of cropland and natural communities at KBS further showed that land abandoned from agriculture for 20 years has a higher mitigation potential (a more negative GWI) than any of the other systems, even greater than mature deciduous forest. Converting marginal cropland into conservation easements could thus be an additional strategy for mitigating GHG production elsewhere in the economy—and as Gelfand et al. (2013) show—especially if the biomass produced is used for biofuels that offset fossil fuel use.

Long-term observations are needed to reveal and quantify GWI trends in cropping systems. Many ecosystem processes change slowly. Changes in soil carbon over less than a decade, for example, are very difficult to detect. Other processes are affected by year-to-year climatic variability, making short-term predictions of annual GHG fluxes uncertain.

The GWI analysis of these ecosystems was not anticipated when KBS LTER measurements were first initiated. But an ecosystems approach to taking measurements and a commitment to long-term sampling meant that when crucial measurements were needed they were available. The KBS LTER database has proven to be a valuable resource for revealing long-term trends.

For Further Reading

Robertson, G. P., E. A. Paul and R. R. Harwood. 2000. Greenhouse gases in intensive agriculture: Contributions of individual gases to the radiative forcing of the atmosphere. *Science* 289: 1922-1925.

Millar, N., G. P. Robertson, P. R. Grace, R. J. Gehl, and J. P. Hoben. 2010. Nitrogen fertilizer management for nitrous oxide (N2O) mitigation in intensive corn (Maize) production: An emissions reduction protocol for US Midwest agriculture. *Mitigation and Adaptation of Strategies for Global Change* 15:185-204.

Robertson, G. P., S. K. Hamilton, W. J. Parton, and S. J. Del Grosso. 2011. The biogeochemistry of bioenergy landscapes: Carbon, nitrogen, and water considerations. *Ecological Applications* 21:1055-1067.

Gelfand, I. and G. P. Robertson. In press. Mitigation of greenhouse gas emissions from cropping systems. In S. K. Hamilton, J. E. Doll, and G. P. Robertson, editors. The ecology of agricultural ecosystems: long-term research on the path to sustainability. Oxford University Press, New York, New York, USA.

Gelfand, I., R. Sahajpal, X. Zhang, C. R. Izaurralde, K. L. Gross, and G. P. Robertson. 2013. Sustainable bioenergy production from marginal lands in the US Midwest. *Nature* 493:514-517.