BARC e-Update

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Special Edition – Global Climate Change

A Sampling of Research at BARC Addressing Global Climate Change

DYNAMICS OF PLANT COMMUNITIES AND ALLERGENS ALONG AN URBAN-RURAL TRANSECT

For the past 6 years, Dr. Lew Ziska and collaborators have been evaluating the micrometeorological effects of urbanization on the composition of plant communities, using the same soil and seed bank along an urban-rural transect beginning in downtown Baltimore and extending to Buckeystown, Maryland. The seed bank consisted of over 40 different plant species, annuals and perennials, herbaceous and woody. An interesting finding is that the levels of temperature and carbon dioxide experienced by downtown Baltimore now are similar to the Intergovernmental Panel on Climate Change (IPCC) projections for short-term global change. Demographic changes in the plant communities are being documented as a function of urban-induced changes in micrometeorology. As part of this documentation, shifts in pollen production have been observed. *Such shifts are interesting, not only as a means of assessing reproduction in annual weeds, but also in determining the pertinent aspects of pollen-based allergies related to human health.* For *ragweed*, the principal source of fall-based allergies, urban areas, with higher levels of carbon dioxide and warmer temperatures, could produce, on average, a plant that was 3 to 5 times bigger and capable of producing 8 to10 times more pollen than plants growing in a rural area. However, after two years, shifts in demographics of plant communities resulted in a greater population of trees relative to annual weeds (like ragweed) at the urban site, with a corresponding shift to tree-based pollen and allergens by the fifth year of the experiment. Ragweed however, remains ubiquitous to urban areas. The differences in the plant communities between year one and five at the rural and urban sites are depicted below. It is speculated that this may be due, in part, to continual land disturbance associated with urban sprawl. (Contact: L.Ziska@ars.usda.gov)

First year response, rural vs. urban, annual weeds.

Fifth year response, rural vs. urban, pollen sources have switched from ragweed (rural), to trees (urban)

CROP PRODUCTIVITY CHANGES

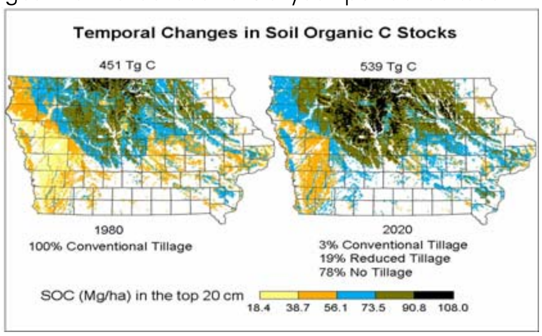
There is a growing interest in the possible shifts in productivity of major crops under the predicted changes in global climate. Dr. James Bunce is studying possible shifts in productivity using alfalfa as a model. The increase in plant growth with rising atmospheric carbon dioxide concentrations is expected to be larger at warm temperatures. He tested whether elevated carbon dioxide would shift the production of alfalfa toward warmer times of the year. Such a shift would benefit farmers by evening out seasonal variations in alfalfa production, which is usually low in mid summer. To test this idea, alfalfa was grown at the current ambient carbon dioxide concentration (averaging 378 parts per Million day/455 parts per million night) and 350 parts per million higher concentrations at Beltsville, Maryland, using open top chambers in field plots. Such an increase in carbon dioxide concentration could occur by the end of this century. No shift in the seasonal pattern of production occurred, as there was no relationship between the stimulation of yield at elevated carbon dioxide and the mean temperature during the re-growth interval. This lack of change in the seasonal pattern of production resulted from some unusual properties of photosynthesis in alfalfa, which made the stimulation of photosynthesis by elevated carbon dioxide independent of temperature. *This work demonstrates that predicting crop yields under global change conditions requires detailed information on each crop species. Each crop will respond differently to changes in carbon dioxide concentration and elevated temperatures*. (Contact: James.Bunce@ars.usda.gov)

CROP PLANT MODELING AS A PREDICTIVE TOOL

By the year 2050 the world population is predicted to double and the demand for food and other plant-based commodities is expected to triple. Added to this is the uncertainty introduced by the possibility of future global environmental changes. Potential global environmental change includes atmospheric carbon dioxide concentration, temperature, rainfall, and ultraviolet radiation intensity. Some of these changes will have substantial direct impact on crop production, carbon fixation and storage, and water availability around the world. In addition, regional increases in soil erosion and atmospheric pollution could also have negative impacts on ecosystem productivity. With existing scientific knowledge it is impossible to predict how these changes will affect productive potential of economically important crops. The **Crop Systems and Global Change Laboratory** is presently conducting an array of studies using Soil Plant Atmosphere Research (SPAR) growth chambers (see photo) to evaluate the impact of global climate change variables and their interactions on crop productivity at physiological process level. From these studies, databases are developed on various physiological and physical processes in the soil-plant-atmospheric system related to crop productivity, and the resulting mathematical equations are integrated into crop system models. *Presently we are concentrating on cotton, soybean, potato and corn. These models are capable of predicting the impacts of climate change on crop productivity at the mechanistic level*. (Contact: VR.Reddy@ars.usda.gov)

CARBON MANAGEMENT IN AGRICULTURAL SYSTEMS

Cropland agriculture can be a source of greenhouse gas (GHG) emissions, with the magnitude of emissions determined, in part, by land management practices. However, agricultural soils can also mitigate GHG emissions through the biological uptake of organic carbon in soils, resulting in CO2 removal from the atmosphere. Long-term field experiments have shown the potential for reducing emissions and increasing soil carbon sequestration through adoption of specific soil and crop management practices that are suited for specific soil-climate relationships. **Dr. Paul Doraiswamy** and collaborators have used parameters derived from satellite imagery such as land cover/landuse, crop residue and tillage practices, with ground-based models for simulation of changes in soil carbon sequestration. The simulations were conducted across the U.S. Corn Belt at and changes monitored over a 50-year period between 1970-2020. Selected simulations results were calibrated using field level measurements and regional level yield assessments. The impacts of changes in soil and crop management practices across the Corn Belt have been incorporated in a web-based decision support system for optimizing soil carbon management. The figure shows the baseline total soil organic carbon (SOC) in the crop area of Iowa for the top soil layer in 1970 and model-predicted soil organic carbon for 2020. Tillage practices gradually changed from total conventional in 1985 to adoption of reduced till and no-till. *The simulations suggest gradual restoration or increase in soil carbon with conversion to conservation tillage*. (Contact: Paul.Doraiswamy@ars.usda.gov).



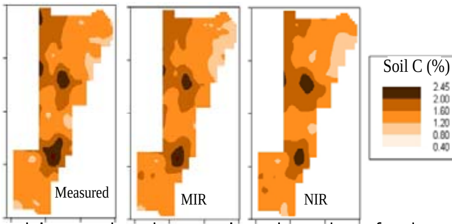
CARBON MANAGEMENT IN RIPARIAN SYSTEMS

Typical riparian buffer ecosystem with high biomass C productivity

There is considerable debate concerning the impact of soil erosion on carbon dynamics within the terrestrial ecosystem. Soil erosion has a well established negative impact on soil quality and productivity of agricultural lands, but its impact on balance of carbon stocks within terrestrial ecosystems is unclear. Recent models have indicated that soil redistribution (erosion) within agricultural ecosystems can actually stimulate carbon sequestration within the landscape. On a global basis, it has been estimated that 75 billion tons per year of soil is subject to water erosion, which results in the displacement of ~0.50 billion tons per year of soil carbon. Landscape redistribution of soil carbon is common within agricultural ecosystems including wetlands often associated with riparian buffers. It is important to understand the impacts of upland sediment deposition on carbon dynamics and storage within riparian systems in order to understand impacts of the terrestrial carbon cycle on climate change. To assess sedimentation impact, **Drs. Greg McCarty and Jerry Ritchie** obtained profile samples of riparian wetland soil and tested for existing radioisotopes as chronological markers to determine rates of carbon sequestration and mineral deposition over the history of the wetland. The wetland was within a first-order catchment under agricultural management at a watershed site at BARC. Substantial post-settlement deposition of sediment in the wetland soil was evidenced by a substantial layer of mineral soil that buried the original soil. Soil profiles had a minimum in carbon content within the top 14" of the profile, which originated from a rapid deposition from upland soils with relatively low initial carbon content. Radiocarbon (14C) dating showed that the zone of increasing soil carbon content above the depth of minimum carbon was the result of carbon sequestration after upland sediment deposition. Modeling the kinetics of modern carbon dynamics using existing radioisotopes as markers within these surface profiles provides strong evidence for accelerated carbon sequestration associated with mineral sediment deposition in these riparian wetland ecosystems. **These findings indicate that at the ecosystem level, dilution of ecosystem carbon by import of low carbon upland sediment stimulates carbon sequestration and that over the history of the wetland, rates of carbon accretion may be linked to mineral soil deposition**. These relationships between upland soils and riparian areas many change with expected higher intensity rainfall events and higher ambient temperature. (Contact: Greg.McCarty@ars.usda.gov)

RAPID DETERMINATION OF SOIL CARBON

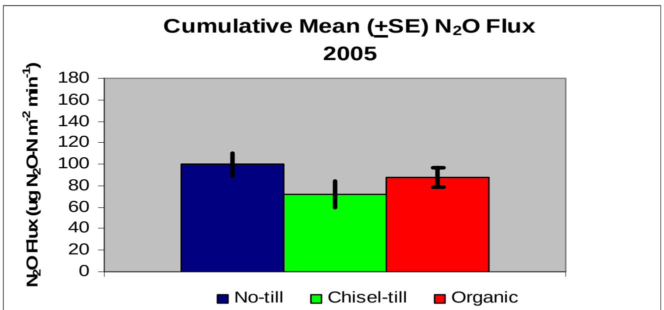
For the past 12 years **Dr. James Reeves** and collaborators have done pioneering work in the use of diffuse mid-infrared spectroscopy (MIRS) and near-infrared spectroscopy (NIRS) for the determination of the composition of agricultural products. These methods can largely replace chemical methods by relating spectra (pattern of light absorption by the sample) to chemical determinations; the results (calibrations) can then be used in the future to determine composition from spectra alone. *Rapid methods for measuring soil carbon are needed when processing the many samples required for determining soil composition*. While it had been known that (NIRS) could be used for such determinations, it had been widely believed that MIRS would not work. Efforts have demonstrated that MIRS is more accurate and robust than NIRS for the determination of soil composition. More recent efforts have concentrated on the feasibility of on-site determinations using the portable instrument shown above. Results in the U.S. and Mexico have determined that on-site operations are feasible. Results have also demonstrated that sample drying in the sun and grinding on the spot are sufficient soil preparation to produce accurate determinations of soil carbon content. Work with soils obtained in a field moist state has shown that NIRS can be used to analyze such samples with accuracy comparable to dried samples, but that further work is needed to determine the feasibility of using MIRS with such samples. Finally, research has demonstrated that either method can be used with dried and ground samples to accurately map the carbon concentrations in fields (see description below), although again MIRS-based calibrations appear to be more accurate. (Contact: james.reeves@ars.usda.gov).

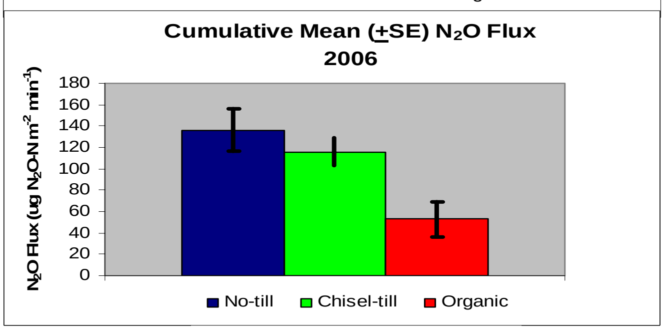


CARBON MANAGEMENT AND NITROGEN EMISSIONS

Agricultural activities account for about 20% of the total human-induced warming effect due to emission of carbon dioxide, methane, and nitrous oxide (N_2O). Instead of being a net source of greenhouse gas (GHG) emissions, agriculture could be a net sink by making changes in management, including minimizing or eliminating tillage, adding more organic matter (e.g. crop residues, animal and green manures, composts) to soils, and improving nitrogen management. These changes could directly reduce GHG emissions and, in the case of carbon (C) sequester it as soil organic matter. While there is increasing interest among land managers, policy makers, GHG-emitting entities, and C brokers in using agricultural lands to sequester C and reduce GHG emissions, **precise information is lacking on how specific management practices in different regions of the U.S. impact soil C sequestration and the mitigation of GHG emissions.** USDA-Agricultural Research Service initiated a national project, GRACEnet (Greenhouse Gas Reduction through Agricultural Carbon), to address this need in 2005. GRACEnet scientists are providing information on the soil C status and GHG emissions of current agricultural practices and developing new management practices to reduce net GHG emissions and increase soil C sequestration. At Beltsville, **Dr. Michel Cavigelli** is measuring soil C sequestration in five cropping systems and GHG emissions in some of these plots that are part of a long-term cropping systems trial, the Beltsville Farming Systems Project (FSP). **One challenge in designing optimal cropping systems is that increasing C sequestration can also increase N_2O emissions.** Thus, while no-till (NT) cropping systems are often shown to increase soil C sequestration in surface soils, we have limited information on the potential increase in N_2O emissions from these systems. Results from the FSP corn plots show that in some years N_2O emissions are similar among NT, conventional till and organic systems, but that in other years emissions are lowest in the organic system. High emissions occur only when both soil nitrate level is high and soils are wet—soil moisture content at or above about 30%. Since soil C changes slowly and since GHG emissions are strongly dependent on weather conditions in a given year, final conclusions from this study, as for other GRACEnet studies, will be available after about five years of measurements. (Contact Michael.Cavigelli@ars.usda.gov. For more information on GRACEnet, see http://www.ars.usda.gov/research/projects/projects.htm?accn)

Captions: 1. Sampling greenhouse gases in a corn plot at the Beltsville Farming Systems Project. 2. Cumulative N_2O production from no-till, chisel-till, and organic cropping systems in 2005 and 2006.





REMOTE SENSING FOR CROP RESIDUE COVER & SOIL CARBON

Figure1. Standard technique for measuring crop residue cover is counting the number of points along a line that intersects surface crop residues.

Crop residue is the portion of a crop left in the field after harvest. Management of crop residues is important for reducing soil erosion and sequestering soil carbon. Traditional methods of measuring residue cover are best suited for a few individual fields, but are too labor intensive for regional surveys (Figure 1). In the past, remote sensing approaches for measuring crop residue cover have often been thwarted because crop residues change after harvest and can be brighter or darker than most soils. An alternative approach for discriminating crop residues from soils is based on a broad absorption band in the infrared wavelength region (near 2100nm) that is associated with cellulose and lignin in crop residues. A remotely-sensed cellulose absorption index was developed at BARC that is linearly related to crop residue cover using ground-based sprectroradiometers (Figure 2). These techniques have been scaled-up using aircraft and satellite sensors over Maryland, Indiana, and Iowa. Conventional and conservation tillage classes were correctly identified in over 80% of the fields (Figure 3). These classes are based on National Resource and Conservation Service (NRCS) tillage intensities where conservation tillage has >30% residue cover. Regional surveys of crop residue management practices that affect soil conservation and soil carbon appear possible using advanced imaging systems. (Contact: Craig.Daughtry@ars.usda.gov).

Figure 2. Measuring reflectance spectra of crop residues at BARC using a portable spectroradiometer and digital camera.

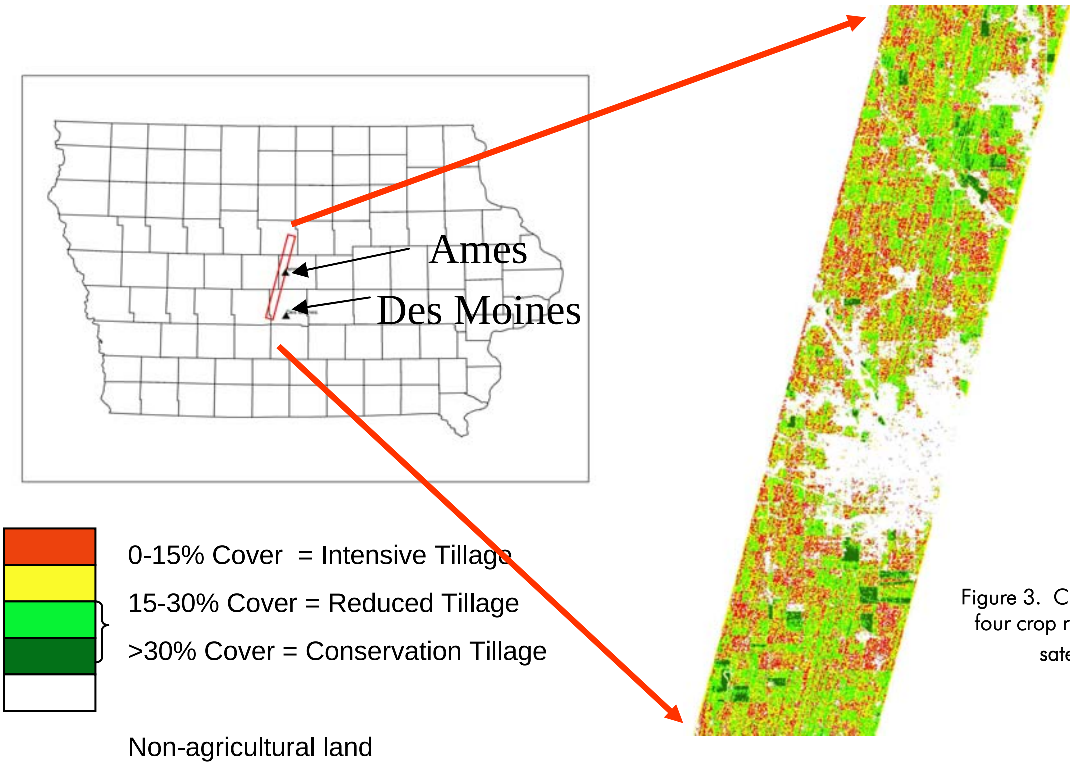


Figure 3. Cropland near Ames, IA classified in four crop residue categories using Hyperion satellite data for May 2004.

PLANT NITROGEN EFFECTS

Plant growth is generally increased by elevated atmospheric carbon dioxide but the nitrogen content of treated plants is often lower than that of the ambient controls. *For unknown reasons, nitrogen uptake and assimilation do not respond to carbon dioxide enrichment to the same extent as total biomass formation.* This can have serious negative consequences for plants grown in elevated carbon dioxide, including decreases in chlorophyll, soluble protein, photosynthetic capacity and seed nitrogen content. Some plants that use high levels of nitrogen (e.g., tomato) may actually show nitrogen stress under enriched carbon dioxide treatment due to reduced chlorophyll levels. Drs. Richard Sicher and James Bunce have studied metabolic nitrogen changes in barley types and dwarf soybeans due to elevated carbon dioxide levels. With barley, using a wild type barley and a mutant barley lacking the ability to reduce nitrogen within the leaves, it was found that glutamine was decreased by carbon dioxide enrichment (~980 parts per million) and also was further decreased in the mutant barley. Glutamine is the most prevalent amino acid in barley leaves when plants are fertilized with nitrate. It is widely known that carbon dioxide enrichment decreases photorespiration in barley leaves, which in turn inhibits the production of ammonia. The end product of nitrate reduction in leaves is ammonia, the synthesis of which is blocked in the mutant barley. Therefore, it is proposed that the effects of carbon dioxide enrichment are due to decreased foliar ammonia levels. Under similar carbon dioxide enrichment MiniMax (a dwarf soybean developed at BARC) showed a 2% decrease in protein content compared to control plants. There was a concomitant increase in soybean seed oil content. (Contact: Richard.Sicher@ars.usda.gov and James.Bunce@ars.usda.gov)

HUMAN NUTRITION EFFECTS

Soybeans are one of the major sources of vitamin E (alpha-Tocopherol) in the American diet and the main source of isoflavones, compounds with estrogenic activity. Elevated temperature during seed development has large effects on these important phytochemicals in soybean seeds. Vitamin E increased several-fold in soybeans that developed at 28°C compared to those at 18°C. In contrast, isoflavones decreased more than 90% over the same temperature range. In both cases, **the effects of elevated temperature were reduced in plants grown from seed at elevated atmospheric CO2 concentration simulating levels expected by the end of this century, consistent with many other studies showing that atmospheric CO2 can ameliorate environmental stress.** More recent experiments determined that short-term heat "spells" or drought simulating realistic local weather patterns elicited smaller but significant changes in seed composition when given midway through seed development. In these cases, however, elevated CO2 did not affect the response. Our results show the effects of atmospheric CO2 concentration can depend on interactions with other environmental variables such as temperature and drought and that the timing of exposure may be critical. Moreover, testing of plant responses to atmospheric CO2 concentration needs to be performed under realistic climate/weather conditions. (Contact: Steve.Britz@ars.usda.gov)

Environmental stress (rising temperature) effects on soybean seed composition reduced by elevated carbon dioxide