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Editorial: Introduction to themed section—supporting ecosystem services with conservation agricultural approaches

Ecosystem services are the properties and processes of the natural world that contribute to the well-being of plants, animals and humans in a holistic and global context. For too long, members of the agricultural community have been solely focused on the provision of food, feed and fiber. Of course, this essential human innovation has provided hugely important products engineered for mass production that serves all of human society. However, agriculture and the ecosystems in which it is practiced provide numerous other services that are becoming increasingly relevant to its very survival and the survival of humans that it supports. Several recent reviews have expressed the need to balance production and environmental goals to create a sustainable future[1–3].

Ecosystem services have been categorized into four key components, including supporting, regulating, provisioning and cultural services (Fig. 1). Agricultural landscapes have a large and sometimes dominating influence on several essential ecosystem services, including biomass production (i.e., food, feed, fiber and fuel production), air purification and climate regulation through greenhouse gas exchange, soil formation and retention, water cycling, nutrient cycling, wildlife habitat provision and aesthetic experience.

Biomass production is a key goal for agricultural systems in the form of high-quality food products, fodder production for consumption by ruminant animals and wood and fiber as raw materials for shelter, manufacturing and textiles. Renewed interest has emerged in deploying agricultural systems for the production of biofuels to meet growing energy demands and reduce reliance on fossil fuels[4].

Air purification and climate regulation through greenhouse gas exchange is a key characteristic of all vegetated landscapes, including agriculture. The ability of plants to fix CO_2 and emit O_2 is a vital ecosystem process. Agricultural lands contribute to drawing down CO_2 in the atmosphere via photosynthesis, but also storing some of the fixed carbon in soil as organic matter. Historically, however, with exploitive inversion tillage practices, soil organic matter has been severely lost in many agricultural soils.

Soil formation and retention is an ecosystem service that is too often neglected by historical agriculture, resulting in severe erosion and loss of fertility of agricultural landscapes. However, regenerative agricultural practices can maintain and build rich, new soil that can be utilized for generations to come.

Water cycling, water quality and water infiltration are processes and properties greatly influenced by agriculture. Limited production focus on short-season crops without sufficient cover cropping and diverse crop rotations has often led to inefficient water utilization, loss of nutrients during non-growing periods, and poor surface characteristics through intensive tillage that leads to surface crusting and lack of stable aggregation that limits water infiltration.

Nutrient cycling is vitally important in agricultural systems, since nutrients are often the key limiting factor that separates naturally occurring ecosystems with closed nutrient cycling from agricultural systems that have enormous harvest outputs, which must be replenished with nutrient inputs either through cultural manipulations of cropping systems in time and space or through technological interventions of organic and inorganic nutrient applications.

Wildlife habitat provision in agricultural ecosystems is too often viewed as either an ancillary benefit if it occurs, not important in the grand scheme of biomass production goals, or simply not a priority in designing a sustainable agricultural landscape. Wildlife habitats can be enhanced with permanent surface cover, a landscape mosaic of managed crops and unmanaged natural and riparian areas, limited soil perturbations and limited pesticide applications.

Aesthetic experience is a cultural feature that is increasingly appreciated by society, given our desires and propensity to see the beauty of the world and its people. Should not our local and regional landscapes be something to be appreciated and highlighted for their intrinsic natural beauty?

Ecosystem services can be either degraded or enhanced with contemporary agricultural practices. Degradation of water sources can occur with aggressive soil management practices that cause soil loss and pollution of waterways with excessive sediment and nutrients. Waterways in agricultural settings can be further polluted with 'chemicals of emerging concern' when excessive therapeutic treatments are used, such as antibiotics and hormones from animal waste pathways. Degradation of air can occur with dust and chemicals from exposed agricultural fields without sufficient cover to maintain integrity against wind erosion. In addition, global air quality can be impaired with rising greenhouse gases emitted through carbon oxidized from soil as carbon dioxide, through nitrous oxide emitted from soil with excessive nitrogen

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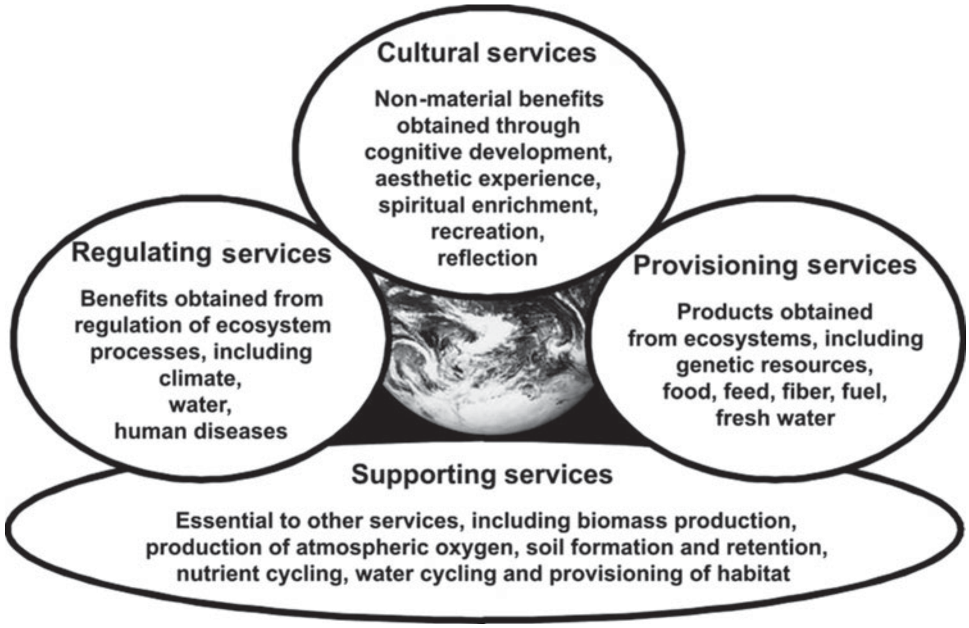

Figure 1. Categories of ecosystem services provided by nature, of which agricultural systems are a vital human component. Adapted from Millennium Ecosystem Assessment[5].

application to agricultural fields, and through methane emitted by ruminant animals and cultivation of wetland soils. Degradation of soil can occur with excessive tillage and non-renewing agricultural practices that deplete soil organic matter and cause poor condition in the chemical, physical and biological properties of soil.

Innovative farmers and agricultural researchers continue to explore a diversity of management approaches to renew natural resources within their local and regional areas. One categorization of agricultural practices designed to protect and invigorate soil, water and air quality and increase productivity and rural livelihood is conservation agriculture. Conservation agricultural systems are diverse, but have three key principles that can be used and modified to improve ecosystem services: (1) minimizing soil disturbance, (2) maximizing soil surface cover and (3) stimulating biological activity. Conservation agricultural systems were first developed with the development of conservation- or no-tillage management of croplands. However, it became increasingly evident that conservation tillage alone was not enough to elevate agricultural systems to a sustainable level. Crop diversity and crop rotations are needed to manage surface residues and weeds, cycle nutrients efficiently and utilize available water efficiently. Utilizing all available nutrient sources through integrated nutrient management or organic and inorganic sources is viewed as necessary to achieving high productivity and maintaining environmental quality. Managing pests with an integrated approach is essential through timing and type of cultural practices, knowledge of pest life-cycle history, threshold management and targeted biocidal applications.

Conservation agricultural practices can have an enormous impact on improving water cycling, quality and infiltration, all of which have cascading effects on other ecosystem properties. Conservation agricultural systems aim to close nutrient cycling to mimic natural ecosystems by minimizing nutrient losses to the environment, but sustainably replenishing nutrient harvests. Improving soil biological activity to limit nutrient losses to the environment must be a priority. Another key goal is to close nutrient cycling more on the landscape level rather than only individually on the field or farm level. Better systems are needed to return nutrients transported off the farm via harvested products back to agricultural fields. Conservation agricultural systems focus on providing surface cover, not disturbing soil, and utilizing biological diversity to improve agricultural system performance, but which also helps improve ecosystem functioning and wildlife habitats. Spatial design of agricultural landscapes using riparian buffers, wildlife corridors, cover crops and a diversity of crops, animals and phenological diversity will require stakeholder cooperation at local, regional and state levels.

Climate change, food security, water quality, soil degradation and renewable energy are our contemporary grand challenges interlinked with regulating, provisioning, cultural and supporting services provided by ecosystems. Hence, greater appreciation is needed of the value of a diversity of conservation agricultural approaches to meet the growing interest of farmers, scientists and society in developing a more productive and healthier environment with robust ecosystem functioning, not only within traditionally cropped fields, but also in a broader view of a spatially diverse landscape that includes grasslands, forests and wetlands.

A symposium was convened at the Annual Meetings of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America in San Antonio, Texas in October 2011 to describe ecosystem services from conservation agricultural approaches. Noted experts expounded on various conservation approaches that can enhance ecosystem services derived from agricultural production systems. Presentations addressed specific components of agricultural systems, such as conservation tillage, crop diversity, pasture management, organic agricultural approaches and wetland management. Practical experiences on the farm, as well as insights from ecosystem modeling and opportunities through government programs, were explored to foster new ideas and new approaches toward making agricultural systems more robust and ecologically resilient within watersheds and regional landscapes. Four papers from this symposium are presented in this themed issue:

Lal describes benefits and limitations of no tillage to enhance ecosystem functions and services, including through soil carbon sequestration, biodiversity, elemental cycling and resilience of food production systems to natural and anthropogenic perturbations. The argument is made that undervaluing ecosystem services provided by conservation agricultural systems will jeopardize finite natural resources and aggravate disservices.

Liebman et al. use the results of three long-term field experiments in Iowa to illustrate that diversifying cropping systems can substantially reduce chemical and energy inputs. Additionally, strategic placement of perennial buffers on the landscape can greatly improve soil and water conservation, nutrient retention and biodiversity. Perennial forages can be harvested for production of biofuels and contribute to significant soil carbon sequestration.

Sanderson et al. describe how crop diversity can be used to improve ecosystem services from managed grasslands and integrated crop–livestock systems. Tradeoffs among ecosystem services are also discussed. Dynamic cropping systems can optimize crop and soil-use options to attain production, economic and resource conservation goals by using sound ecological management principles. Integrated crop–livestock systems may increase complexity of management, but also create synergies among the components to improve resilience and sustainability.

Cavigelli et al. outline how organic grain cropping systems can enhance ecosystem services compared with conventional grain systems. Specifically, soil carbon sequestration and nitrogen mineralization potential can be greater in organic systems with manure and cover crops than in no-tillage cropping. A need was recognized for more data to assess greenhouse gas emissions in organic systems. Expanding crop rotations to include greater crop phenological diversity, improving nutrient management and reducing tillage intensity and frequency were identified as ways to further enhance ecosystem services in organic cropping systems.

It is my hope that these papers will stimulate discussion and instigate new research and development into agricultural practices and systems to meet the urgent needs of society for food, feed, fiber and fuel on the one hand, and strong environmental integrity and quality on the other. Our needs today and in the immediate future must be balanced with the needs of our heirs far into the future—a necessary goal of renewable agriculture and food systems!

'Treat the earth well: it was not given to you by your parents, it was loaned to you by your children. We do not inherit the earth from our ancestors, we borrow it from our children.'—Ancient Native American Proverb.

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