New Roots for Ecological Intensification

by Timothy Crews, Thomas Cox, Le e De Haan, Sivaramakrishna Damaraju, Wes Jackson, Pheonah Nabukalu, David Van Tassel, and Shuwen Wang

To meet the global food challenge of 2050, and well beyond, there is a growing consensus that farmers will need to produce more food using fewer and fewer chemical, energy, and machine inputs. In order to achieve this, numerous researchers have called for a transition from input intensification to ecological (or sustainable) intensification. Agroecosystem characteristics that have been targeted for improvement through ecological intensification include fertilizer and water uptake efficiencies, greenhouse gas emissions, soil quality including nutrient stocks and organic matter, and crop loss to insects and pathogens.

For ecological intensification to deliver on the high hopes and expectations that have been identified by agronomists and ecologists, it will be necessary to address the very nature of our annual crop ecosystems. Low nutrient retention, loss of soil organic carbon, inefficient use of water, and high prevalence of pest organisms are inherent attributes of low-diversity ecosystems held at early stages of succession or ecosystem development—i.e., annual single-genotype monocultures. In contrast, landscapes that are further along in succession or ecosystem development—i.e., landscapes with perennial vegetation and greater interspecies and intraspecies diversity—are generally superior with respect to their numerous regulating, supporting, and

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provisioning ecosystem services relevant to agriculture, including nutrient and carbon retention and water uptake efficiency, regulation of pest populations, and net primary productivity.

The goal of shifting agriculture toward a higher functional stage of ecosystem development is limited by the availability of perennial crops. The Land Institute (www.landinstitute.org) and collaborating researchers from numerous institutions around the world are working to develop unique genetics that allow high grain yields from herbaceous perennial plants. Breeding approaches include (1) wide hybrid crosses between annual grains and related perennial species in order to introgress the perennial habit into the annual grain, and (2) rapid domestication—i.e., cycles of selection and inter-mating to fix and improve on traits such as nonshattering, free threshing, increased seed size, and reduced dormancy.

Soil profile showing roots of the new domesticated perennial grain Kernza on the left and annual winter wheat on the right. The soil profile has a depth of ~2.5 m. Kernza has been domesticated from intermediate wheat grass (*Thinopyrum intermedium*). It can be milled into flour and then blended with or substituted for wheat flour. *Photo courtesy of Jim Richardson and Jerry Glover.*

Perennial rice, wheat, and sorghum are examples of the wide-hybridization efforts, while Kernza wheatgrass and Silphium oilseed crops are examples of rapid domestication. These perennial crops are unlike any ever seen in wild ecosystems or in agricultural fields, and thus we anticipate unique challenges in developing a new set of management practices for them. As perennial grains are planted at larger scales, they must be studied carefully to document the expected benefits and identify additional challenges. Watershed-scale advantages of perennial grains will need to be documented to inform policy.

Over the next 10 years, we must lay the groundwork for additional perennial grain, pulse, fiber, and oilseed crops. New domestication efforts directed at current wild perennials require many years to select promising domesticates. Similarly, establishing wide-hybrid populations that would be useful to conventional breeding programs requires numerous generations. In order to achieve ecological intensification with perennials by 2050, a long-term global effort will be essential.

In August 2013, the UN's Food and Agriculture Organization hosted an expert workshop on perennial crops for food security. Attendees included almost every researcher from around the world who is doing genetics, breeding, agronomic, ecological, or socioeconomic work related to perennial grains. That meeting made three things clear: (1) the need for cropping systems based on combinations of perennial species is widely recognized; (2) that need is not being filled, largely because most (but not all) of the people doing research on perennial grains are doing it as a supplement to their larger research programs on annual crops; and (3) with sufficient funding, many more programs focused full-time on development of perennial grains could be initiated.

For several years, we have been urging public and private funding institutions, both national and international, to help fill that gap, making it possible for the informal worldwide network of perennial-grain researchers to strengthen and expand. With such support, we envision a network of research "clusters" in as many as a dozen agriculturally strategic locations distributed across all continents. Each cluster would include breeders, geneticists, crop ecologists, and others with a clearly defined research agenda for developing and deploying a set of perennial cereals, grain legumes, and other species appropriate for the region where that cluster is located.

The most important benefit that perennials confer is protection of the soil. In addition, farmers in more developed economies are expected to benefit from significantly lower input and energy costs. In less developed economies, ecological intensification can become accessible to subsistence farmers and growers who have limited access to capital since the beneficial ecosystem services are derivatives of the crop ecosystem itself.

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achieve a sustainable food future by itself, and the relevance of individual menu items will vary between countries and food supply chains. But all are necessary.

Fortunately, there are signs of progress. Here are three examples from Niger, Brazil, and the U.K.:

Farmers in Niger have managed the natural regeneration of native trees growing in farm fields across five million hectares. Trees such as *Faidherbia albida* fix nitrogen in the soil, protect fields from wind and water erosion, and drop their leaves, contributing organic matter to soils. Yields of maize in such agroforestry systems can be double those of conventional farms in the country.

Brazil is exploring approaches to increase the productivity of existing grazing lands to both meet beef production needs and avoid conversion of forests into pastures. Increasing cattle grazing intensity across the country to just one-half of the sustainable carrying capacity would enable Brazil to meet its beef production needs through 2040 without converting another hectare.

In the U.K., the Waste and Resources Action Programme (WRAP) and major food retailers have been providing tips on food storage, adjusting promotions from "buy one get one free" to "buy one get one later," and changing package labeling so that households will not confuse "sell by" dates with "consume by" dates. As a result of these and other activities, household food waste in the U.K. declined by 21% from 2007 to 2012.

At the global scale, a partnership has formed to develop a Food Loss and Waste Protocol, which will become the global standard and guidance for measuring food loss and waste. It will enable countries and companies to quantify in a consistent manner how much food is lost and wasted and identify where the loss and waste occur. Partners include the World Resources Institute (WRI), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), the Consumer Goods Forum, EU FUSIONS, the World Business Council for Sustainable Development, and WRAP.

Despite these developments, there is a long way to go. The food gap is significant. Consumption patterns are difficult to change, and diffusion of new food production methods can take time. And climate change will increasingly hamper food production if left unchecked. Consequently, governments, the private sector, and civil society will need to act quickly and with conviction to implement this menu of solutions. If they do, the world just might be able to achieve a sustainable food future.

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