BIOMIMICRY
GLOBAL DESIGN
CHALLENGE
FOOD SYSTEMS

Land Institute Design Brief

Design an agroecological approach to crop succession—replacing perennial crops with other perennial crops without disrupting the soil, its food web and without releasing significant amounts of carbon dioxide.

Problem and scope

Annual grains provide 70% of humanity's caloric needs, and they occupy a majority of cropland on the planet. In order to produce grains, farmers use brute strength (the plow) or chemicals (herbicides) or both every year to knock back native and weedy vegetation that competes with grain-producing annual grasses, such as wheat, maize, rice and sorghum. While remarkably productive from the perspective of yields, this approach to growing food is unsustainable in terms of soil loss and degradation, as well as the monetary, energetic, and environmental costs of synthetic fertilizers and pesticides. Examples of impacts from high input monocropped grain agroecosystems include:

- Nitrate leaching from cropped fields into rivers and ultimately downstream into marine ecosystems where it fertilizes large algae populations, which grow and then crash causing"dead zones."
- Runoff and leaching of phosphorus into freshwater bodies, which fertilizes toxic outbreaks of blue-green algae.
- Precipitous declines in soil organic matter. This occurs for two primary reasons: 1) roots of annual crops contribute far less carbon to soil organic matter than the original perennial vegetation that the crops replaced, and 2) tillage stimulates microbial decomposition of soil organic matter. Lower inputs and greater losses of soil carbon result in greatly reduced levels of soil organic matter.
- Following rains or irrigation events, soil nitrate is converted to various gases, including the potent greenhouse gas nitrous oxide (N_2O).
- Extensive stands of single crop species are vulnerable to the buildup of specialist insects and diseases, which are commonly addressed with toxic pesticide treatments.

Ecologically there are many differences between agricultural ecosystems and the native ecosystems they replace, but two characteristics stand out in their universality and importance—native ecosystems are made up of multiple plant species, and the dominant plant species are perennial, whereas grains are grown as annual monocultures. Ecological intensification is increasingly being used to describe supplanting the use of purchased inputs with ecological processes. Achieving ecological intensification in annual crop agriculture is challenging given the inherently compromised nature of the ecosystems. By integrating diversity and perenniality into agroecosystems, ecosystem functions such as soil building, nutrient retention, pest suppression, and carbon sequestration will happen *as a result of* such an agroecosystem, which behaves much more like the native ecosystem that was replaced.

The Challenge

While perennial polycultures hold considerable promise for addressing many of the intrinsic shortcomings of present-day annual grain production, we envision a long stretch of time when fields cropped to perennial grains will need replacement every five to ten years. This could occur simply because improved crop varieties have become available, or because a crop has accumulated a pathogen load or genetic load that suppresses yield, or the economics of particular crop choices have shifted. Regardless of the reason, the approach to replacing stands of perennial crops will prove to be critical, as neither of the two common approaches that exist today—the plow and the herbicide—are desirable in the long run.

Replacing perennial crops by terminating the old stand with a moldboard plow will result in substantial loss of soil organic matter, and a disruption of the later-successional soil microbial community, not to mention greater vulnerability to erosion. Replacing perennial crops by terminating the old stand with herbicides introduces a dependency on purchased, fossil-fuel based chemicals, most likely in potent mixtures or “cocktails” in order to kill well established perennial vegetation. While less detrimental to the soil resource, herbicides have their own Achilles’ heel. The recent finding that Roundup is a likely carcinogen, coupled with older conclusive reports detailing the health hazards associated with herbicides such as atrazine and 2-4-D, render chemical-facilitation of crop replacement a temporary solution at best.

The biomimicry design challenge we pose is this: how can we harness ecological processes to essentially promote “crop succession” in order to periodically renew perennial polycultures. The list that follows is not intended to be exhaustive or restrictive, rather it simply provides examples of what design solutions to this challenge might look like:

- Mimicking natural processes to weaken or kill extant perennial crops, opening up windows to introduce new seed.
- Designing a means to cut or remove perennial crowns just below the soil surface, killing the stand with minimal disturbance to the soil.
- Managing the annual cycle of perennial vegetative growth and senescense so that dead standing organic matter remains on and ultimately smothers the old crops while new seeds or seedlings are introduced into the plant community.
- Managing the timing and thickness of crop residues to effectively eliminate strips or patches of old crops with mulch. A complete replacement of the crop stand would happen over multiple years.