Perennials in Flood-Prone Areas of Agricultural Landscapes: A Climate Adaptation Strategy

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> "Floods are 'acts of God,' but flood losses are largely acts of man."
>
> —Gilbert White (1942)

Extreme precipitation events will become more frequent in the future for large areas of the United States. Meanwhile, agricultural landscapes have lost resilience to flooding because we have drained wetlands and constrained rivers. US farmers have frequently experienced catastrophic losses from flooded croplands over the past decade, raising concerns about the future sustainability of an economy based on growing annual row crops in flood-prone areas.

In the present article, we suggest a climate adaptation strategy that involves planting perennials into flood-prone areas of agricultural landscapes. Wet-adapted perennial prairie grasses and riparian-adapted trees and shrubs are tolerant of wet conditions and have the flexibility to be used for food, feed, fuel, fiber, and bioplastics. Furthermore, integrating perennials into agricultural landscapes as riparian buffers can provide multiple ecosystem services while giving rivers more room. Integrating deep-rooted perennial crops in wet areas can increase both economic and environmental resilience under future climate conditions.

Climate models concur that precipitation events will become more frequent and intense across the central and northeast United States over the next several decades (US Global Change Research Program 2017). By mid-century, a combination of rising temperature and extreme precipitation events is expected to reduce US agricultural productivity back to levels of the 1980s (US Global Change Research Program 2018), with annual row crop yields decreasing by up to 46% (Araya et al. 2017).

Future risk to croplands is exacerbated by the fact that we have reduced the water-storage capacity of US landscapes. In many areas, wetlands were drained to increase row-crop yields, whereas rivers were straightened to improve navigation and reclaim land. More than half of US wetlands have been drained and 90% of floodplain area is currently in cultivation (Zedler and Kercher 2005). This loss of natural storage capacity has reduced climate resilience and increased the risk of significant flood damage.

In addition to the loss of storage, other important ecosystem services provided by wetlands have been lost. Wetlands remove excess reactive nitrogen and phosphorus from water. According to the Ramsar Convention, wetlands store more carbon than any other ecosystem. Without floodplains and wetlands, agricultural landscapes are less able to remove excess nutrients, contributing to downstream hypoxia. Furthermore, the loss of wetlands removes habitat for numerous forms of wildlife, ranging from juvenile fish and shellfish to ducks and other migrating water birds.

Recent events in the US corn belt foreshadow future trends. The magnitude and frequency of precipitation events in the Central United States has increased over the past 50 years; unusually large floods occurred in 5 of the past 10 years (figure 1). Persistent wet conditions in 2019 resulted in acute crop losses (more than 10 million acres of corn and soybean). According to data collected by the US Department of Agriculture's Risk Management Agency, indemnities for US acreages eligible for prevented planting compensation exceeded $1 billion in 2019 and in each of five previous major flood events. These severe floods also washed away significant quantities of topsoil, which could have long-term effects on productivity.

In a future characterized by more frequent and extreme floods, rivers will require more room. Future flood damage can be avoided by carefully planning compatible land uses along rivers. Importantly, wetland ecosystems may be more readily preserved if they have economic value. This is where perennial crops come in. By integrating perennials into wetter portions of the agricultural landscape, it may be possible to add water storage by removing drains from lowlands, reconnecting rivers to their floodplains, and restoring oxbows (Schilling et al. 2019). The prospect that growing perennial crops in floodplains and other wet areas could help to protect and expand wetlands is therefore worth exploring (Melts et al. 2019). This could be done in ways that are consistent with the Ramsar Convention, which provides a framework for national action and international cooperation for the conservation and wise use of wetlands.

The integration of perennial crops into existing agricultural landscapes could also improve their economic resilience. Growing corn and soy in flood-prone areas will become even riskier and unprofitable under future climate conditions, whereas perennial crops will have a better chance of achieving full yields. Seasonal flooding is better suited for lands planted in perennial grasses, riparian species of trees and shrubs (e.g., willow and

Figure 1. Quincy, Illinois, 20 June 2008. Fields of corn are flooded, and crops may be ruined for the year by the flooding waters of the Mississippi River in southern Illinois. Photograph: Robert Kaufmann/Federal Emergency Management Agency Photo Library.

cottonwood), and rice than for corn, soy, and other conventional crops. A variety of wetland-adapted biomass feedstocks show promise, including willow, switchgrass, cordgrass, *Spartina*, reeds, and coppiced mangroves in coastal areas. Research has suggested that these crops may be more efficiently managed in smaller fields with wet areas in which smaller tractors can be used (Zilverberg et al. 2014). Another advantage is that perennials rarely require replanting and have a flexible harvest window that can adapt to weather delays.

Perennials have the flexibility to supply multiple markets. Ongoing efforts have been directed at developing perennial varieties of wheat, sorghum, sunflower, wheatgrass, and other food crops for human consumption. Markets for perennial biofuels are also developing. For example, Ayoub and colleagues (2019) recently estimated that nearly a quarter of the United States' electricity demand and all of its jet-fuel demand could be met by planting perennial feedstocks in the riparian corridor along the mainstem Missouri and Mississippi Rivers alone. On the horizon, perennials may serve as feedstocks for other bioproducts. The World Economic Forum recently identified bioplastics as one of the top ten emerging technologies.

The integration of perennial crops into wet areas and along riparian corridors in existing agricultural landscapes would have other benefits as well. Trees, shrubs, and native grasses filter nutrients from water and stabilize soil through their long root systems. Regardless of whether perennials survive a flood, their deep rooting structures will persist and continue to hold soil. As a result, perennials reduce the loss of soil and nutrient loadings during flood events and improve downstream water quality (Jager and Efroymson 2018).

To conclude, we advocate for a two-pronged climate-adaptation strategy that involves planting perennials in flood-prone areas of agricultural landscapes while restoring wetlands, floodplains, and oxbows along rivers. The prospects for successfully and continually harvesting perennial crops under future climate variability in the United States exceed those of annual crops, making perennials a more resilient feedstock for agricultural biomass production in flood-prone areas. Perennials planted in unprofitable wet areas of fields can increase farmer profit (Bonner et al. 2014). Market support for perennial biomass crops can diversify agricultural production, reduce exposure to uncertainty in commodity crop prices, and support farm incomes while restoring climate-resilient wetland elements to agricultural landscapes.

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