LAND USE

Sustainable Floodplains Through Large-Scale Reconnection to Rivers

If riverside levees are strategically removed or repositioned, the result can be reduced flood risk and increased goods and services.

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Flooding is the most damaging natural disaster worldwide, and the flood-vulnerable population is expected to grow in coming decades (*1*). Flood risks will likely increase because of both climate change (*1*) and shifting land uses, such as filling of wetlands and expansion of impervious surfaces, that lead to more rapid precipitation runoff into rivers. In the United States, annual river flood losses continue to rise (*2*), punctuated by major events in the Midwest (1993, $30 billion in total costs; 2008, $15 billion) and California's Central Valley (1995 and 1997; $4 billion each event) (*3*). Meanwhile, pressure to develop new housing in flood-prone areas near rivers (floodplains) continues (*4*), even as levee-system maintenance is chronically underfunded (*5*).

Flood-control infrastructure (e.g., levees) prevents high flows from entering floodplains, thus diminishing both natural flood-storage capacity and the processes that sustain healthy riverside forests and wetlands. As a result, floodplains are among the planet's most threatened ecosystems, even though functioning floodplains—those connected to rivers—are among the most valuable ecosystems for supporting biodiversity and providing goods and services to society (*6*, *7*). We propose that a large-scale shift in land use and policy is urgently needed to achieve economically and environmentally sustainable floodplain management. The area of floodplains allowed to perform the natural function of storing and conveying floodwaters must be expanded by strategically removing levees or setting them back from the river.

Floodplain reconnection will accomplish three primary objectives: flood-risk reduction, an increase in floodplain goods and services, and resiliency to potential climate-change impacts. Efforts should focus on strategic reconnection of large areas of floodplain

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The Yolo Bypass while flooded. [Photo by William Harrell, California Department of Water Resources]

currently used for agriculture, as large-scale reconnection of densely populated floodplains would be considerably more expensive. The changes we propose will confront considerable socioeconomic and political challenges, but we believe these can be overcome by promoting floodplain land uses that are consistent with private ownership and a vibrant agricultural economy. Although our specific recommendations are for the United States, this vision is applicable worldwide. Similar calls for change have been made in several countries [e.g., (*8*)].

Reduced Risk, Enhanced Benefit

Large-scale floodplain reconnection will reduce flood risk in two ways. First, land use within reconnected floodplains will move toward activities compatible with periodic inundation. Flood-tolerant land uses (described below) will be much less vulnerable to flood damages and therefore less likely to require disaster relief payments. Second, reconnection increases the area available to store and convey floodwaters and can reduce flood risk for nearby areas. In most of the United States, this benefit occurs haphazardly through levee failure. For example, during 2008 floods in the U.S. Midwest, a town was spared because a nearby levee protecting croplands failed, allowing floodwaters to inundate fields and alleviating pressure on the town's levees (*9*). But strategic reconnection of floodplains, designed and implemented to maximize public-safety benefits, holds great promise for reducing local and regional flood risk (*8*). For example, a study of the Illinois River found that reconnection of 8000 hectares (ha) of floodplain would improve protection for 26,000 ha of farmland by halving the probability of inundation from major floods (*10*).

Large-scale reconnection of floodplains may also increase flexibility and resilience of water-management infrastructure. Globally, thousands of large, multipurpose dams provide (or are being built to provide) flood control and water supply and/or hydropower. The need for partially empty reservoirs (to store floodwaters) must be balanced with the benefits from full reservoirs (water supply, hydropower, recreation, and environmental flows to maintain healthy ecosystems). Climate-change models suggest that many regions of the world will experience increased frequency

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of both floods and droughts, exacerbating the challenge of balancing these multiple objectives (*1*). Large-scale floodplain reconnection provides floodwater storage and conveyance, reducing the need for upstream reservoirs to remain partially empty and thus increasing the benefits they could provide when full. Increased resiliency of water management systems through floodplain reconnection is a promising example of ecosystem-based adaptation to climate change.

A key to the economic and political viability of this approach is that reconnected floodplain areas can remain largely under private ownership, generating revenue such as through productive agriculture. Agricultural practices consistent with periodic inundation include pasture, timber, and cultivation of flood-tolerant crops (e.g., biomass fuel sources such as switchgrass and willow) (*11*). Where there is strong seasonality in floods, such as the western United States, annual crops can be grown during the dry season. Even where floods are coincident with the growing season, a broader variety of crops could be cultivated on reconnected lands that are inundated less frequently (e.g., less than once per decade).

Connected floodplains under natural vegetation support high levels of biological productivity and diversity (*7*) and provide numerous ecosystem services, second only to estuaries among ecosystem types in terms of value per hectare (*6*). For example, perennial plants, in either restored habitats or biomass crops, increase carbon sequestration (*12*) and improve water quality by reducing soil erosion and increasing nutrient retention (*11*).

Funding Management and Reconnection

The vision outlined here is based on the premise that new floodplain land-use patterns, allowing periodic conveyance and storage of floodwaters, will produce substantial societal benefits, including reduced flood risk or increased benefits from multipurpose reservoirs. Achieving these benefits will incur large upfront costs for levee setbacks, flow easements, land acquisition, and restoration, along with periodic compensation for flood damages. State or federal governments will need to support institutional or financial mechanisms that link floodplain landowners with beneficiaries of reduced flood risk, reservoir reallocation, and ecosystem services.

For example, beneficiaries (or, by proxy, government) could compensate landowners for increased flood risk or lost economic productivity on reconnected lands, similar to a proposal from the Sacramento Area Flood Control Agency to compensate farmers whose land floods during large storms, serving as "relief valves" and easing pressure on developed areas (*13*). Ecosystem services could potentially generate revenue through emerging markets for carbon and nutrient sequestration. Other services—such as providing wildlife habitat, open space, or groundwater recharge—can be supported by public sources of funding (e.g., Wetland Reserve Program), or, for example, through hunting leases and "banks" for wetlands, endangered species habitat, or groundwater (*14*, *15*).

As an indication of the potential demand for floodplain reconnection, the U.S. Department of Agriculture (USDA), which received $145 million under the American Recovery and Reinvestment Act to acquire floodplain easements, received applications for >10 times the area of land (192,000 ha) than they were able to enroll (14,400 ha) (*16*). Current legislative and policy-making processes for water [e.g., forthcoming revisions to the federal Principles and Guidelines for water development (*17*)], as well as energy, agriculture, and climate change provide opportunities to promote floodplain reconnection as a flood-risk reduction tool.

Demonstrating Success: The Yolo Bypass

Although to date rarely implemented, this vision of large-scale floodplain reconnection is not unprecedented. California's Yolo Bypass conveys 80% of Sacramento River floodwaters during large events, routing water away from the city of Sacramento (see figure, page 1487) (*18*). The bypass was created in the 1930s by reconnecting a 24,000-ha floodplain when it became apparent that a "levees only" approach would not sufficiently reduce flood damages (*19*). By conveying large volumes of floodwaters, the bypass increases the flexibility of California's water management infrastructure. During a March 1986 flood, the bypass conveyed ~12.5 billion cubic meters (bcm) of water, more than three times the total flood-control storage volume in all Sacramento basin reservoirs (3.5 bcm). This occurred during a period when the flood-control system was operating near maximum capacity (*20*). Without the bypass floodplain, California would need to build massive additional flood-control infrastructure or allocate more of its already strained water-supply storage capacity to flood control.

Two-thirds of the bypass is privately owned, productive agriculture. During inundation, the bypass provides habitat for birds and native fish (*18*). The bypass provides additional ecosystem services, such as open space for a rapidly growing region, recreation (including revenue-producing duck-hunting clubs), and groundwater recharge (of great value as a water bank during droughts) (*14*).

Conclusion

Unsustainable floodplain land use is common throughout the industrialized world, and developing countries are following the same trajectory (*7*). The vision outlined here is not a call to empty the floodplain of human activity. Rather it is an approach that would reduce unsustainable uses while maximizing floodplain benefits for both society and private landowners.

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