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Linking hydrodynamics, conservation biology, and economics in choosing naturalization alternatives for the Illinois River, USA

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With 4 figures and 2 tables in the text

Abstract: Major investments have been made recently along the Illinois River in habitat rehabilitation and enhancement, stream bank stabilization, and conversion of former agricultural drainage and levee districts back to floodplains. Past efforts included intense site-specific habitat management, such as manipulation of water levels in floodplain lakes to provide feeding and resting habitat for migratory waterfowl; and broad-based programs of financial incentives and technical assistance for landowners to control erosion and provide wildlife habitat. Innovative approaches to recover systemic river functions require decisions in the face of uncertainties, and hydraulic, ecological, and economic models are being developed to aid analysis of alternatives. Early biophysical modeling results indicate that location (for example, distance from dams) can be important to the likely success and cost of naturalization. Economic modeling indicates that impacts that are beneficial at the regional and state scale may be either negative or positive for local communities along the rivers. The analytical tools and multi-disciplinary approaches being developed are relevant to river rehabilitation or naturalization in other developed countries, and also to river conservation in developing countries that wish to sustain natural goods and services while undertaking commercial development.

1. Introduction

In 1993 and 1995, there were major, damaging floods on both the Upper Mississippi River and in the major rivers of Western Europe, which caused a re-examination of river management and many recommendations, including "giving rivers room" to convey flood waters on their floodplains (Interagency Floodplain Management Review Committee 1994; Hendriksen 1999; Klijn et al. 2004). Simultaneously, there was increasing public interest in "naturalizing" these regulated rivers and their

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floodplains, to maintain and recover valued plants and animals and provide opportunities for outdoor recreation. RHOADS & HERRICKS (1996) defined "naturalization" as the return of selected characteristics of an ecosystem to a more natural condition while retaining beneficial social and economic uses. The term "naturalization" has been applied to rehabilitation efforts in the Upper Mississippi River (SPARKS et al. 1998) and is adopted in this paper, because the term implies an effort to regain sufficient functions of a "natural" system to recover and maintain native species (as opposed to their propagation in zoos or botanical gardens), while other socially desired uses (such as transportation) are maintained or even enhanced.

Actions such as reconnecting rivers with their floodplains can result in "win-win" situations, because they can improve habitat for native plants and animals as well as reduce future flood damages by increasing flood conveyance and storage on floodplains. However, in intensively developed catchments and floodplains there are significant economic consequences to making changes in land use, so even if there are complementary objectives, it is important to predict, with some precision, the costs and benefits of various alternatives. Location is also critical so that sites are chosen that will have the greatest benefits for the costs and other social disruptions caused by the change.

Here we report on an on-going project that links hydraulic and ecological models, and economic analyses, to evaluate alternatives for selective reconnection of the Illinois River and its floodplain. Our selection of what to model was governed by efficiency: i.e., making the best use of the limited resources of time, money, and available expertise to model and analyse **essential components** or **indicators** of the ecosystem and local economies. We chose to analyse those aspects of the economy that are actually used currently by decision-makers, particularly local decision-makers: jobs and the value of goods and services (output).

Our emphasis on efficiency and timeliness is necessitated by the urgent need for information by the agencies that are currently planning and undertaking naturalization of the Illinois and Upper Mississippi Rivers, including: federal agencies (U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Natural Resources Conservation Service); state agencies (the natural resource agencies of the five states in the Upper Mississippi Basin); and non-governmental conservation organizations. Among the many non-governmental organizations are The Nature Conservancy and the Wetlands Initiative which have bought out three agricultural drainage and levee districts along the Illinois River and are currently in the early stages of restoring them as functioning floodplains. Both organizations would like these projects to become models for floodplain naturalization in the entire Upper Mississippi Basin. The largest of these, the 3,046-ha Emiquon Floodplain Restoration Project, was purchased for 18.3 million U.S. dollars in 2000 by The Nature Conservancy, which plans to turn off the drain pumps and allow the area to begin filling from rainfall and groundwater sources in the fall of 2005.

At issue is the extent to which Emiquon and other leveed areas should be reconnected to the river, because unnaturally rapid water level fluctuations occur in the regulated river that harm vegetation growing on the banks and other low-lying areas that remain connected to the river. The fluctuations are attributable to reduced infiltration of rain water in the highly developed basin, rapid delivery of water by channelized tributaries, loss of flood storage and conveyance capacity on the developed floodplains, and operation of the navigation dams, a situation common to most rivers in the developed countries of the world (Tockner & Schiemer 1997; Koel & Sparks 2002; Klijn et al. 2004). If these excessive fluctuations persist in the newly-reconnected floodplains, the benefits to the ecosystem and to local communities will not be fully achieved. If the floodplains are not reconnected, fishes and other aquatic organisms will not have access to spawning and nursery areas during seasonal floods.

A stakeholders' group consisting of local planners, business people, and conservationists, sensitized us to their concerns about the likelihood of success of naturalization and the potential effects of either success or failure on local quality of life, jobs, income, and tax revenues. Their concerns are justified, as indicated in our initial assessment of the economic impacts of the basic land-use change, loss of levee-protected agriculture. However, we go on to analyse the compensatory effects of potential economic development that would be compatible with naturalization (e. g., recreation or ecotourism).

We focus on one plant community, the moist-soil plant community, which is a good indicator of a natural water regime, because it grows only in the aquatic-terrestrial transition zone, ATTZ (sensu Junk et al. 1989) and requires a seasonal flood pulse. This plant community is not only an indicator, it is a key component of a healthy floodplain-river ecosystem because it provides habitat and food for many species of water birds, fishes, and macroinvertebrates. Moreover, the moist-soil vegetation is regarded as more attractive by local residents and tourists than the barren mud flats that result from unnatural water level fluctuations that currently occur in the Illinois River. Finally, plants strongly influence flood heights by changing the flow resistance of the floodplain, so prediction of plant succession is important to predicting future performance of floodways (Darby & Thorne 1996; Darby 1999; Baptist et al. 2004).

We regard our analysis of the Illinois River as a case study but believe the general approach is applicable to other rivers, recognizing that all simulation models require local data and calibration. Our effort is also a case study in multi-disciplinary research, since we include two ecologists, two engineers, one hydrologist, a geologist, a planner, and two economists. Each of us has learned to supply information needed by another discipline, rather than just pursuing our traditional disciplinary topics. The management scenarios we examined were arrived at by consensus and by considering how quickly we could generate the information needed by decision-makers. Multi-disciplinary interactions are noted in the text that follows, and may be of benefit to other groups that are planning similar coordinated analyses that must be delivered in a timely manner to decision-makers.

2. Test site

The 135-km-long La Grange Reach of the Illinois River is defined by dams at Peoria and La Grange (Fig. 1). These are low navigation dams that consist of a series of large wickets which are pivoted up from the riverbed during low water periods to maintain a navigation channel 2.7 m deep (Sparks et al. 1998). The wickets are lowered during high flows, so that commercial barges and migratory fishes pass directly over the structures without going through the locks, so these dams have much less of an effect on the river and its biota than high storage dams do on rivers elsewhere. In contrast to the Rhine and the Mississippi rivers, the Illinois River does not have the numerous groynes (termed "wing dikes" in the U.S.) that confine the river to a central channel. Approximately half the floodplain in the La Grange Reach has been leveed and drained for row crop agriculture.

3. Methods

Our project group agreed to several constraints on ourselves, in the interest of developing practical approaches and tools, and to avoid inordinate data and analytical requirements that could make the approaches unfeasible for planners and decision-makers. First, each component (hydrology, ecology, economics) agreed to help define and then to produce the information needed by other components, rather than focus on information of more narrow disciplinary interest. For example, for the economists and planners it was sufficient to determine whether an area would be sufficiently naturalized to attract people interested in sight-seeing and birding. There was no need to develop models for a variety of species and species interactions, as interesting as those topics are for ecologists. Second, we agreed to rely on existing data sets and use empirical analyses whenever possible, shifting to simulation modeling only when data were lacking and we had to use expert knowledge of how components of the floodplain-river ecosystem function. Third, we recognized the central role that variability plays in the natural functioning of the floodplain-river system. Naturalization means having to deal with uncertainties. We sought to express ecological as well as hydrological outcomes as probabilities, using flood frequency forecasting as a model (e. g., a record of a flood magnitude occurring four times in a 100-year history suggests that there is a 4 % chance of it occurring next year).

We chose to start our analyses with the extreme scenario of reconnecting most of the floodplain in the La Grange Reach with the river. If wholesale reconnection produced no reduction in flood heights or improvements in biota, then there would be little point in developing scenarios for less reconnection. If the extreme case **did** produce benefits, then there would be value in testing smaller scale efforts, in locations where potential benefits are expected to be high and/or costs exceptionally low, and where the land use change would be politically acceptable. We also

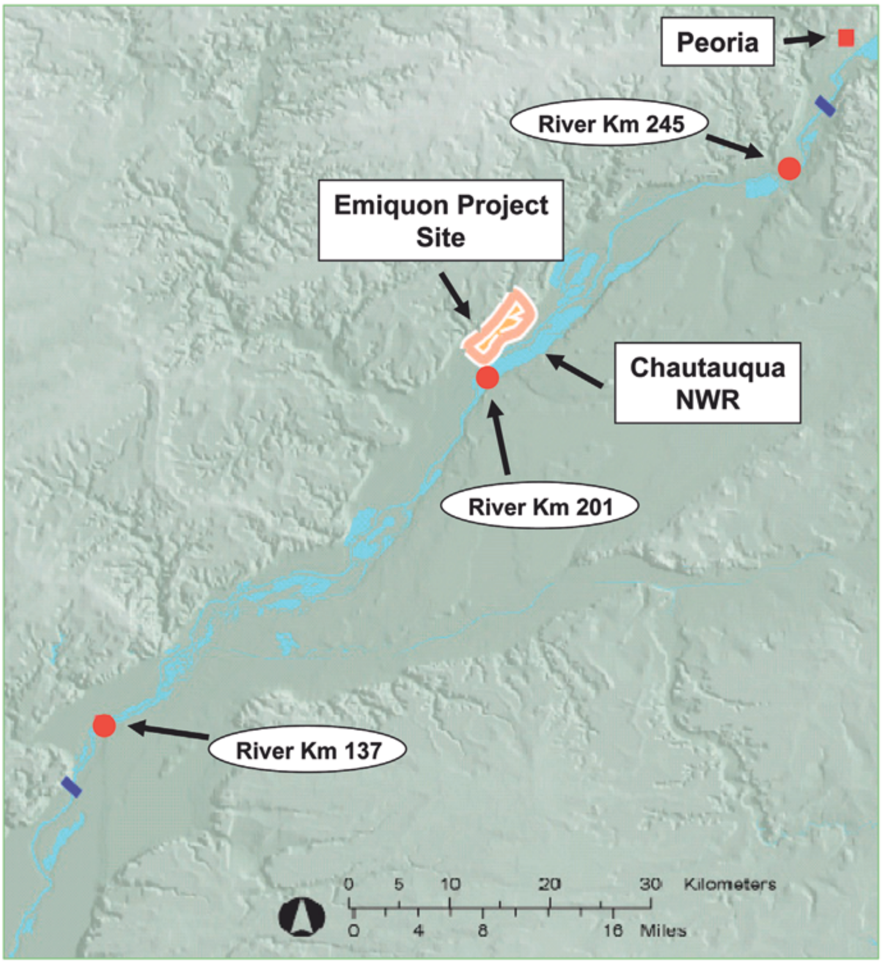


Fig. 1. Location of three 9-km subreaches where moist soil vegetation was modeled. Locations are center points of the subreaches, in km upstream from the confluence with the Mississippi River. The La Grange Reach is bounded upstream at River km 254 and downstream at River km 129 by navigation dams (blue rectangles). The 3,046-ha Emiquon Project Site is an agricultural drainage and levee district purchased by The Nature Conservancy and the 969-ha Chautauqua National Wildlife Refuge (NWR) is operated by the U.S. Fish and Wildlife Service. Peoria, with a population of 200,000, is the largest city in the region.

modeled one scenario in which the wickets were lowered during the summer growing season, in addition to removing the levees to reconnect the floodplain.

Most of the leveed area in the La Grange Reach is currently used for agriculture, but two relatively small levee districts that protect the towns of Beardstown and Liverpool were not included in the reconnection because of the societal costs associated with exposure of those towns to increased flood risk.

Hydraulic model

In our approach, the heart of the floodplain-river system is the river's hydrograph – its day-to-day change in stage throughout the year. UNET (HEC 1993) simulates one-dimensional unsteady flow through a defined, or bounded, network of open channels. We used the model to estimate historical river stages at locations within the La Grange Reach where river gauges do not exist and to predict how river stages would change if flows entering the reach changed or if the capacity of the channel were altered by opening levees. The simulated hydrographs were then used as input for a vegetation response model.

Vegetation model and analyses

The vegetation of the Illinois River floodplain can be crudely divided into three classes, based on flood tolerance: (1) forests, which grow at the higher, hence less-flooded, elevations; (2) moist soil plants, that germinate and populate mud flats following floods and tolerate periodic soil saturation, but not complete inundation of the plants during the growing season; and (3) aquatic plants, that tolerate having their roots or even the entire plant submersed throughout the growing season, as long as the water is sufficiently shallow and clear that the plants receive enough light to grow.

We chose to model moist soil plants, represented by millets (*Echinochloa* sp.), which are summer annual plants that grow up to 1.5 m tall. Our moist-soil plant model simulates plant growth on a one square meter site at a specified elevation in response to changes in daily water levels (Ahn et al. 2004a). We also determined the elevation of the tree line from aerial photographs and topographic maps, because it is the upper elevation boundary for moist soil plants. To validate the model we compared model predictions to vegetation inventories made at three sites in several different years (19 inventories in all). The historical vegetation records included years of success (presence) and failure (absence) for moist-soil plants. The model correctly predicted what was actually observed in all 19 cases, although this validation must be considered qualitative, rather than quantitative, because agreement between the model and observation was limited to whether the plants were present or absent (Ahn et al. 2004a).

Linking the hydrological and vegetation models

For a given year's hydrograph of daily river stages, the plant model was run repeatedly as the elevation of the simulated growing site was lowered at 10-cm intervals until the model predicted that less than 90 % of the maximum potential biomass would be produced by the end of the growing season. This step-wise process allowed us to determine, for each year, the **lowest** elevation at which moist-soil plants were successful. That **lowest successful elevation** became, in effect, an annual hydrologic parameter (like "maximum daily flow" or "7-day low flow").

Repeating this process for the daily river stages for the 61 years since the modern dams became operational provided us with a historical distribution of the **lowest successful elevation** parameter. This distribution enabled us to employ frequency analysis, a commonly used technique in hydrology (CHOW 1964), to make statements about the probability of plant success at a given elevation in the future (AHN et al. 2004b). The purpose of this modeling is to enable us to compare alternative naturalization strategies, by computing a probability distribution for each new scenario. We reduced the computational requirements of scenario assessment by about two-thirds while retaining the full range of underlying weather variability by selecting the first, last and every 5th percentile observation (21 years in all) from the historical distribution and modeling only those years.

Economic analyses

We analysed the effects of removal of levee-protected agriculture at three spatial scales: (1) removal of agricultural levees along the entire lower 254 km of the Illinois River; (2) along only the 129-km length of La Grange Reach; and (3) at the single 3,046-ha Emiquon Floodplain Restoration Site located within the La Grange Reach. Economic impacts at two different scales, statewide and regional, were assessed for each of these three scenarios. The statewide assessment includes all 102 counties of Illinois. The area covered in the regional assessment varied with the area affected by each respective scenario: 13 counties for the entire lower 254 km of the Illinois River (includes La Grange Reach); 7 counties for the La Grange Reach; and 2 counties adjacent to Emiquon (one county includes Emiquon and the other is across the Illinois River from Emiquon, but linked by a highway bridge).

We used an economic input-output model (IMPLAN 1999) to estimate the resulting changes in economic activity within the statewide and regional economies. The model was developed by the U.S. Forest Service and is widely used by U.S. government agencies to estimate the impact natural resource use can have on the economies of surrounding communities (JOHNSON & MOORE 1993). IMPLAN represents the internal flows of goods, services and employment among more than 500 sectors within the economy and provides estimates of the overall change in U.S. dollars of economic output and number of people employed. When a change is introduced to the model, such as taking a portion of the farmland out of production, the model generates direct, indirect and induced responses throughout the economy, eventually reaching a new equilibrium. It then reports new estimates of output and employment.

The scenarios we initially analysed simply removed the levee-protected areas of agriculture from production, without replacing the agriculture with some other land use that would be compatible with floodplain naturalization. To gain further insights into the level of economic activity that might be regained after naturalization, we introduced likely economic activities that could accompany naturalization. We analysed this kind of replacement economy for only the Emiquon site, and only at the regional level. Our analysis was based on expected increases in recreation use and development described by Wagner & Beck (1991), in their assessment of a proposal by the U.S. Fish and Wildlife Service to acquire the existing agricultural levee district and naturalize the site.

4. Results

Effects of reconnection on floods

Modeling the scenario of reconnecting the entire floodplain, except for urban areas, indicated that peak flood heights of the large floods would be reduced substantially, by as much as 2 m (1993 flood, Fig. 2). Since such wholesale reconnection is politically unlikely, there is value in exploring less extensive and more politically acceptable scenarios for reconnection. However, we leave further study of large, infrequent floods that cause economic damage to the appropriate

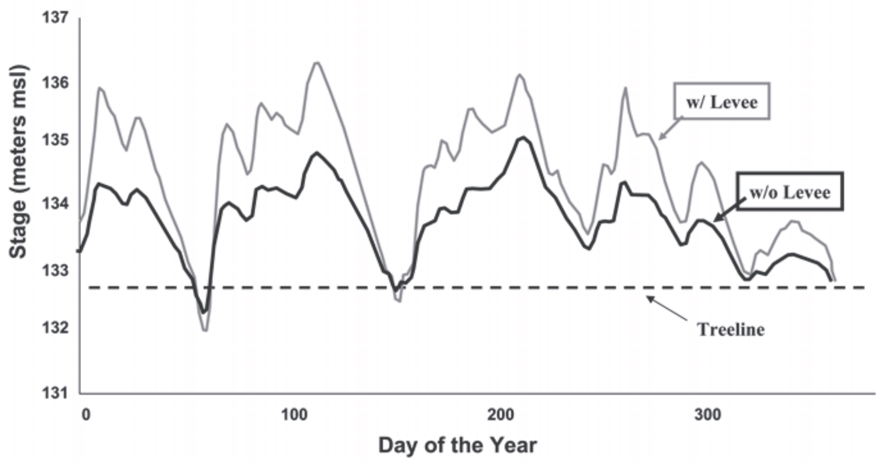


Fig. 2. Simulated daily water levels in the Illinois River at River km 201, with agricultural levees (w/ levee) and without levees (w/o levee), using flow data from 1993, when major, damaging floods occurred.

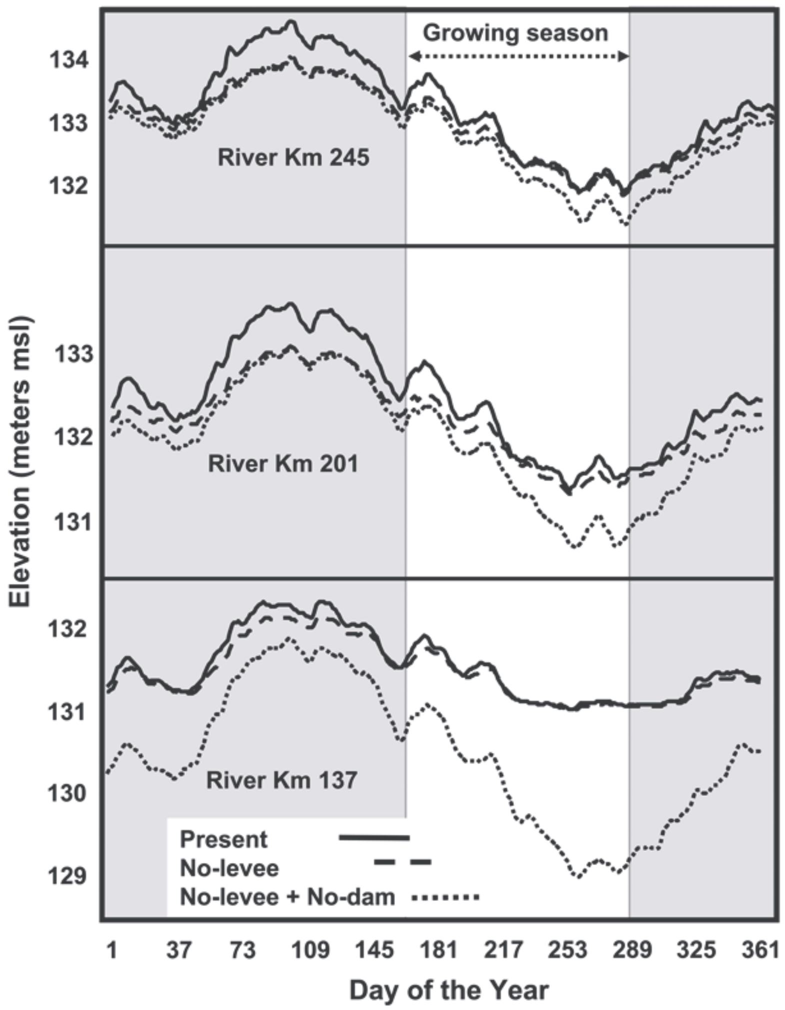


Fig. 3. Simulated mean daily water levels at three locations in the La Grange Reach of the Illinois River, under three scenarios: 1) present conditions, with agricultural levees; 2) no agricultural levees; and 3) no agricultural levees and the water level control wickets lowered at the downstream navigation dam (no-dam condition). The growing season for moist soil plants extends from 15 June to 15 October. Flow data for the UNET hydraulic model were obtained for 21 representative years by sampling from a 61-year daily discharge record (1940–2001, see text for explanation).

federal agencies and instead turn our attention to the effects of previously neglected small, but unnaturally frequent water level fluctuations that kill moist-soil vegetation (Fig. 3). These small fluctuations are typically below flood stage as defined by the U.S. Army Corps of Engineers and the Federal Emergency Management Agency, which is the stage at which economic damage begins to occur.

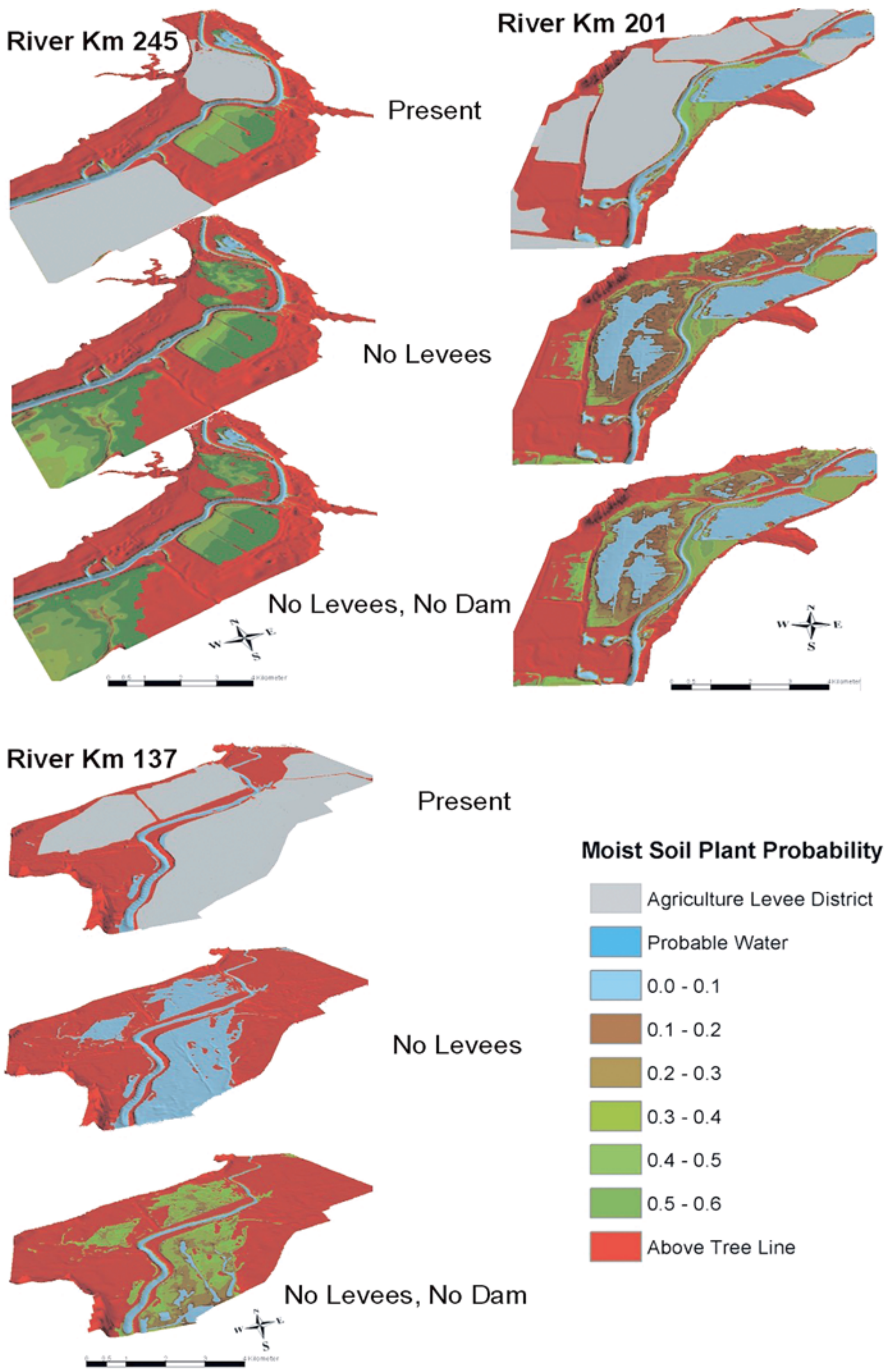
Effects of reconnection and location on moist soil plants

The predicted response of moist soil plants varies dramatically with location within the navigation reach. At the upper end of the navigation reach, farthest from the downstream dam (in the vicinity of River km 245), moist soil plants do well in the floodplains that are reconnected to the river. Lowering the downstream dam has little additional effect (Fig. 4, top left). Half way upstream from the dam (in the vicinity of River km 201, including the Emiquon site), the plants again do well (Fig. 4, top right). Here there is a slight increase in plant success with the lowering of the dam. In the downstream reach (River km 137) results were initially surprising: here, virtually no moist soil plants occur when the floodplain is reconnected. Instead, trees are predicted to occupy the reconnected floodplain all the way to the low water line (Fig. 4, bottom left), and moist-soil plants appear only when the dam is lowered (Fig. 4, bottom right).

The results are explained by the effect of dam operations. During the summer growing season, which is the season when the unregulated Illinois River was naturally low, the wickets of the navigation dams are raised to create a nearly flat pool that maintains the 2.7-m navigation depth. This impoundment inundates the adjacent floodplain to the treeline. Because of the operation of the dam, there simply are no mud flats available for the moist soil plants to grow.

At the upstream end of the pool (River km 245) the summer water surface is well below the treeline, and there are mud flats available. However, summer water levels are much less stable here than downstream because of water releases from the upstream dam to control the depth of water in the upstream impoundment. These releases create little "spikes" that gradually dampen out with distance downstream. Removing the levees has an additional damping effect on fluctuations, by providing more lateral capacity to store water.

Fig. 4. Maps showing probability zones of moist soil plant success at three locations in the La Grange Reach of the Illinois River, under three scenarios: 1) present conditions, with agricultural levees; 2) no agricultural levees; and 3) no agricultural levees and stage control wickets lowered at the downstream navigation dam (no-dam condition). Probabilities are based on the same 21-year sample as in Fig. 3. The probability zones correspond to elevation contours in a range bounded by open water on the low end and the tree line at the high end.


River Km 245
Present
No Levees
No Levees, No Dam
River Km 201
River Km 137
Present
No Levees
No Levees, No Dam
Moist Soil Plant Probability
Agriculture Levee District
Probable Water
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
Above Tree Line

Economic effects of reconnection

The economic impacts of removing agriculture from the floodplain are very small at both the regional and state-wide scales, because the proportion of total crop land (and associated labor force) that is in the floodplain is so small (Table 1). If the levee-protected farmland along the entire floodplain were put into a National Floodplain Park, as was done on a portion of the Danube River in 1996 (TOCKNER & SCHIEMER 1997), the impact of the lost agriculture on the statewide, and even on the regional economy, would be very small (much less than a 1 % reduction). However, these results reflect responses of economies that include two or more counties (Table 1). There remain important economic impacts to be considered at geographic scales smaller than a county (counties in Illinois range from about 500 to 2,600 km^2).

In Illinois there are a number of government entities that tax and provide services below the county level, including: school districts, fire protection districts, park districts, drainage districts, and townships and villages that maintain roads

Table 1. Impact of levee agriculture.

	Entire Illinois River	La Grange Reach	Emiquon site
Farm land	114,292 ha	59,569 ha	2,550 ha
	5 % of region*	3 % of region	0.9 % of region
	1 % of state	0.50 % of state	0.02 % of state
Labor	1,514 jobs	646 jobs	17 jobs
	0.53 % of region	0.28 % of region	0.084 % of region
	0.02 % of state	0.009 % of state	0.00 % of state
Output value	$ 148,000,000	$ 48,084,088	$ 1,251,031
	0.56 % of region	0.2 % of region	0.097 % of region
	0.02 % of state	0.006 % of state	0.00 % of state

* Region varies with the scale of the analysis. For Entire Illinois River, region is 13 counties. For the LaGrange Reach, region is 7 counties. For Emiquon site, region is 2 counties.

Table 2. Potential naturalization impacts.

	Farming eliminated	Refuge management	Refuge with recreation	Potential net change
Land	– 2,550 ha	2,550 ha	2,550 ha	2,550 ha
Labor	– 17 jobs	10 jobs	66 jobs	+ 49 jobs
Output value	$ – 1,251,031	$ 500,000	$ 3,2280,000	$ + 2,028,969

and provide police protection. Such local entities would be dramatically affected if a farm the size of the Emiquon site were removed from the tax base. To compensate the local districts for loss of tax revenue, it is an administrative policy, but not a legal requirement, of both the U.S. Fish and Wildlife Service and The Nature Conservancy to continue payments to local districts, in lieu of taxes, when lands are purchased and converted. In addition, some, but not all the jobs and output value associated with the farm, would be replaced by jobs and outputs related to management of the naturalization site (Table 2). Adding recreational development has the potential to turn the loss into a substantial gain, but requires planning and prioritization of sites to promote both naturalization and recreational development.

5. Discussion

The moist soil plant model we developed proved useful in evaluating naturalization options for the La Grange Reach of the Illinois River that included modified dam operations and reconnection of the river with its floodplain. The moist soil plants are a key component of the floodplain-river ecosystem, providing food and habitat for many species, including migratory and resident birds, mammals and fishes, and also for the macroinvertebrates that many of the vertebrates feed upon. Since the plants (and our model) respond to conditions during the summer growing season, other indicators should be used to assess impacts of environmental conditions, including the water regime, in the rest of year. For example, Schiemer (2000) reports that fish communities integrate the effects of many changes in habitat richness related to reconnecting floodplains. In the Illinois River, some fishes overwinter in floodplain backwaters and use the spring flood to access spawning sites on the floodplain well before the moist soil plants even germinate. Koel & Sparks (2002) used the Index of Hydraulic Alteration (Richter et al. 1996) and the Range of Variation approach to define characteristics of the water regime, including the spring flood, that were associated with good production of young-of-the-year fishes. They generated specific recommendations for operation of the dams on the Illinois River that would enhance fish recruitment while not disrupting navigation or flood protection. These modified operations would reduce the frequency and amplitude of unnatural water level fluctuations and are congruent with our recommendations for improving moist soil plant success.

Water level fluctuations that our model predicts would harm moist soil plants are likely to be unsuitable for aquatic plants as well. Bellrose et al. (1979) noted that both the moist soil plants and the aquatic plants are adversely affected by excessive water level fluctuations in the Illinois River. In years with excessive fluctuations, vegetation is reduced or absent in both the ATTZ and in the permanent water bodies connected to the river.

Reconnection of the river and its floodplain would not only increase the area available for key plant communities, including the moist soil vegetation, it would improve the water regime as well. The increased hydraulic storage and conveyance capacity would dampen the harmful, low-level water level fluctuations and also reduce the crests of major, damaging floods (up to 2 m, according to our results). Akanabi et al. (1999) determined that if just 14 % of the floodplain along a 200-km reach of the Illinois River (including our 135-km study area) were utilized to store flood crests, an additional 44 % of the floodplain would gain protection from a 100-year flood. Even greater gains from relatively small areas might be possible if flood **conveyance**, rather than just flood storage, were provided in areas where levees or highway/railway berms currently constrict floods and raise their heights upstream. Conveyance capacity is credited with reducing the flood height in 1993 at St. Louis, where the flood walls were saved when levees broke downstream (Changnon 1996).

Climate change

Predicting probabilities based on hydrology assumes that the climate in the future will be the same as in the observed past. In the case of the Illinois River watershed, there is uncertainty regarding its future climate. The records indicate that rainfall, run-off, and flood frequencies and durations have been increasing over the past several decades (Singh & Ramamurthy 1990). At the same time, climate models suggest that any increased precipitation due to global warming will occur during the winter, with summer rainfall remaining the same or less (Wuebbles & Hayhoe 2004). If that is true, summer river flows will remain the same or decrease and the dams will still be needed to maintain river stages for navigation, with the accompanying risks to moist-soil plants suggested by our model. Any projected lengthening of the growing season (perhaps 4 to 5 weeks; Wuebbles & Hayhoe 2004) could increase the annual production of moist soil vegetation and seeds, which would benefit animal consumers, but the species composition of the moist soil community might change, for better or worse depending on the food preferences of wildlife and the nutritional quality of the different plants.

There is geologic evidence that climate changes could have even more dramatic effects on river flows in the upper Midwest than projected by Wuebbles & Hayhoe (2004). Sediment cores from the Mississippi River and the Gulf of Mexico record several episodes of “megafloods” in the Mississippi River (flows equivalent to what are regarded as 500-yr or greater floods today, but that recurred much more frequently in the geologic past) – the most recent occurring around 1,000 BC and from about 1250 to 1450 AD (Knox 1993; Brown et al. 1999). Knox (1993) concludes that these episodes were triggered by increases in mean annual temperatures of only 1 to 2 ºC and changes in mean annual precipitation of only 10 to 20 %, well within the increases projected to occur in the next century (Wuebbles & Hayhoe 2004). Increases in flood frequencies, stages, or durations would strengthen the case for reconnecting rivers and their floodplains to better convey floods and reduce damages.

Economics

Economic analyses with the IMPLAN model indicate that development of ecotourism and other recreational uses could more than make up for the loss of jobs and output value associated with removal of agriculture (Table 2). However, ecotourism is unlikely to be a panacea for every town along a major floodplain-river. Local governments may not have the resources to insure that development does not degrade the environment, overload local services, or preclude public access to views, trails, canoe landings, etc. Towns that are distant from major population centers and interstate highways will receive fewer visitors than towns that are closer and communities may find themselves competing with each other for a finite number of visitors who enjoy river-based recreation.

A regional planning perspective is needed that can do more than just identify competitors and problems. It should seek opportunities to achieve greater benefits through cooperation. The Emiquon site described in this paper is located on the west side of the Illinois River in one county, but the effects of naturalization will also be felt in the county across the river, which is connected by a highway bridge. Optimal site selection for ecotourism development projects ideally should be done with the participation of both counties (and the towns and smaller units of government within the two counties) and with the population centers to the north (Peoria) and the southeast (Springfield, the capital of Illinois) that are most likely to furnish the visitors. One example of such a regional opportunity would be a boat landing coupled with a resort hotel that would furnish a destination for the paddlewheel steamboats operating out of Peoria. There are planning tools now available that can assist communities who want to consider these complex regional and local factors in their analysis of scenarios (Kwartler & Bernard 2001; Orton Family Foundation 2002).

In summary, our analyses and simulations indicate that reconnection of the Illinois River with its floodplain could reduce the stages of large, damaging floods; decrease the unnatural water level fluctuations in the summer that currently damage floodplain vegetation; and diversify and enhance some of the economies along the river. These results support recommendations to "enhance the floodplain environment and provide for natural storage in bottomlands and uplands" and to "fund ... acquisition of needed lands from willing sellers" that were made by the Interagency Floodplain Management Review Committee (1994) following the 1993 flood in the Upper Mississippi River. Similar studies and modeling approaches are under way in western Europe, as reported in this supplement and elsewhere (Schiemer 2000; Klijn et al. 2004). Of course the choice of indicators or key ecosystem components are specific to each floodplain-river system and models must be parameterized for individual systems.

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