The Lake Winnipeg Bioeconomy Project

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I will describe an interesting example of how we can use agricultural biotechnology to address a major regional environmental systems problem. The Lake Winnipeg Bioeconomy Project is founded on the idea that a lake—in this case, Lake Winnipeg—can serve as the focus for a transformed agenda around innovative agricultural water management, with the potential to yield economic benefits.

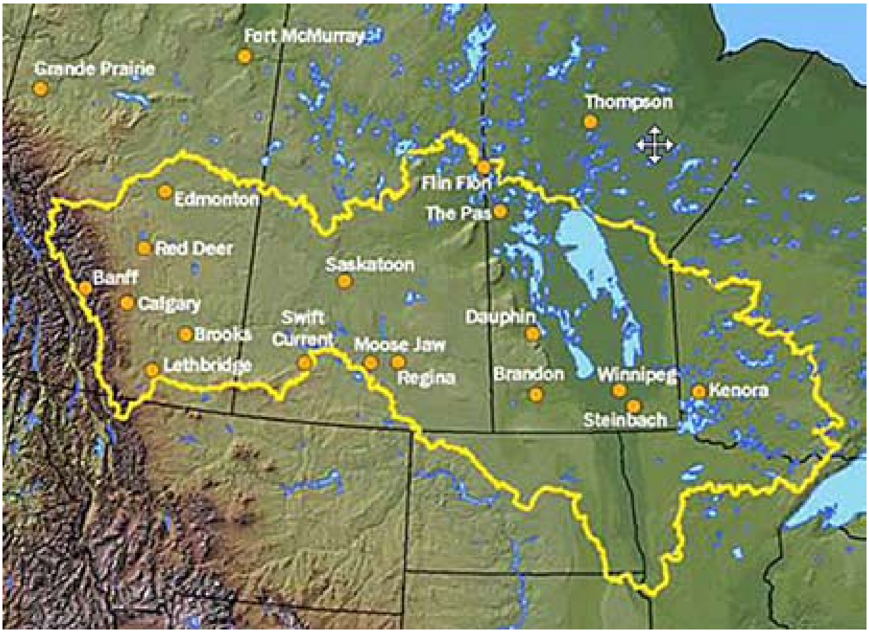

Figure 1. Lake Winnipeg's watershed.

The Project is located at the northern edge of arable land in the upper Great Plains. The watershed draining into Lake Winnipeg straddles the major agricultural provinces of Canada—Manitoba, Saskatchewan and Alberta—and it dips into Montana and South Dakota, and includes large parts of Minnesota and North Dakota (Figure 1). Lake Winnipeg has the interesting property of having the largest watershed area to surface area in the world. It is the 10th largest lake in the world, with an enormous catchment area that includes a huge expanse of agricultural land. Figure 2 provides a view from space, revealing discoloration due to bluegreen algal blooms. It's the freshwater analog of hypoxia in the Gulf of Mexico, which is caused by the farmer-applied nutrient flow into the Mississippi Basin.

Figure 2. Lake Winnipeg showing algal blooms.

A Problem of Impossible Proportions

On face, amelioration of Lake Winnipeg is a problem of impossible proportions. On the other hand, the words of Secretary of Health, Education and Welfare John Gardner, in 1965, come to mind:

> *What we have before us are some breathtaking opportunities disguised as insoluble problems.*

The key message is that, with the promise of innovative agricultural water management and biotechnology, we have an enormous regional economic development opportunity masquerading as a difficult environmental problem. The problems of cultural eutrophication and non-point-source pollution do not lend themselves easily to simple regulatory tools. Unlike Lake Erie—which also suffered phosphorus eutrophication issues in the 1960s and 1970s, but which could be addressed by simple regulatory measures controlling wastewater-treatment-plant effluent—these vast agro-ecological and cultural issues are much less amenable to regulatory approaches.

The Limits to Growth, a 1972 book commissioned by the Club of Rome, suggested that resource limitations would, at least eventually, pose limits to growth. One of the authors of that report, Donella Meadows, described "layers of transformation" in the late 1990s (Figure 3) as starting with a change in mindset, *i.e.* seeing a problem for which there is no solution as a major opportunity. All transformation starts with that recognition. The outer rings of transformation involve changing the rules of how the system operates and then monitoring the system and adjusting it as new information is gained.

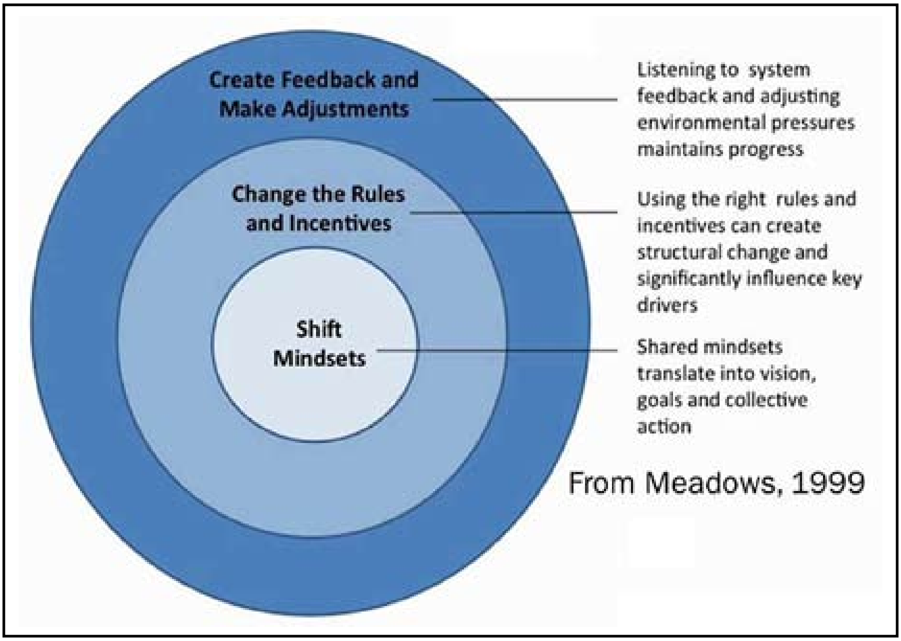

Figure 3. Layers of transformation.

Climate and Ecosystem Destabilization

The crisis goes beyond Lake Winnipeg. It's a crisis that overlaps with destabilization of regional climate. Figure 4 shows data generated by the Intergovernmental Panel on Climate Change, revealing that the upper part of North America is a climate-change hot spot. This is not a projection, this is the instrumental record since 1901, and we have a rate of temperature increase in the order of 2°C per century. Some data indicate that it's greater than that. Our part of North America is also at a transition zone between sub-humid and semi-arid (Figure 5), implying that climate-change projections will become more variable.

Our ecosystem has been homogenized and atomized; the distribution of landscape features and what we now call ecosystem services have been modified, and many lost. The sectional mile system is similar to that in the United States (Figure 6).

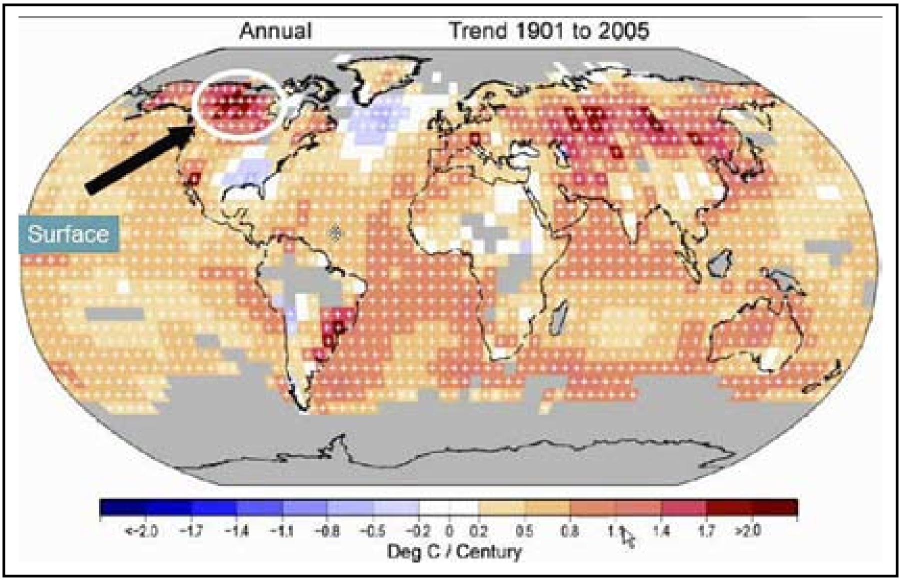

Figure 4. Spatial distribution of temperature increases.

Correlation of Stresses

Furthermore, stress factors are correlated. Without super sandbags stacked three high against last spring's flood, we would have lost Manitoba's second city, Brandon. And—unprecedented—a dyke on the banks of the Assiniboine River was deliberately breached and agricultural land inundated to minimize flooding in the city of Winnipeg. Also, increasing variability in climate is causing increasingly frequent hydrologic shock, and we know now that that this is correlated with nutrient level; the degree of flooding is exponentially correlated with the mass volume of nutrients that eventually flows downstream to Lake Winnipeg (Figure 7).

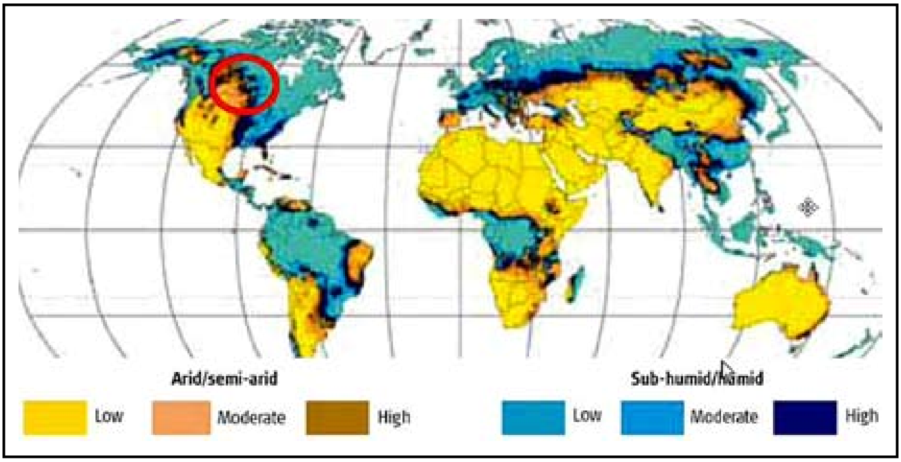

Figure 5. We'll get more extreme.

Figure 6. Landscape conversion for agriculture.

Phosphate Conundrum

As bleak as this is, I'm going to compound it with messages from the United Nations Environment Program (UNEP) yearbook for 2011, *Emerging Issues in our Global Environment*. They picked up not only on the impact of punishing agroecological systems, but they picked up on the stewardship issue of the depletion of rock phosphate.

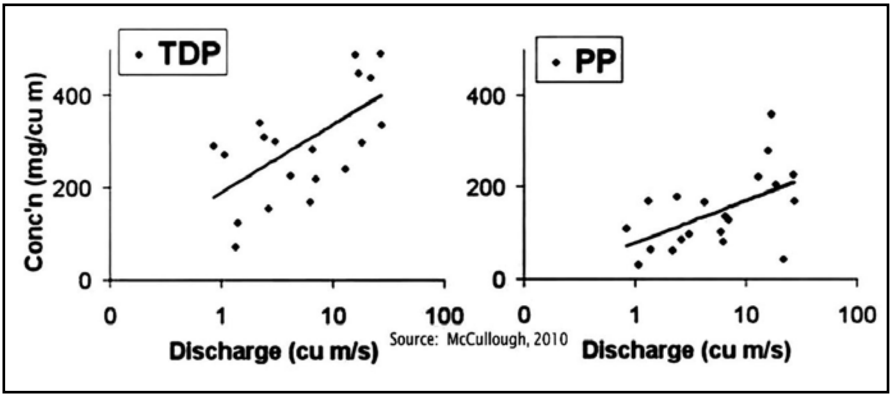

Figure 7. Correlations of concentrations of total dissolved phosphate and particulate phosphate with discharge rate in river water.

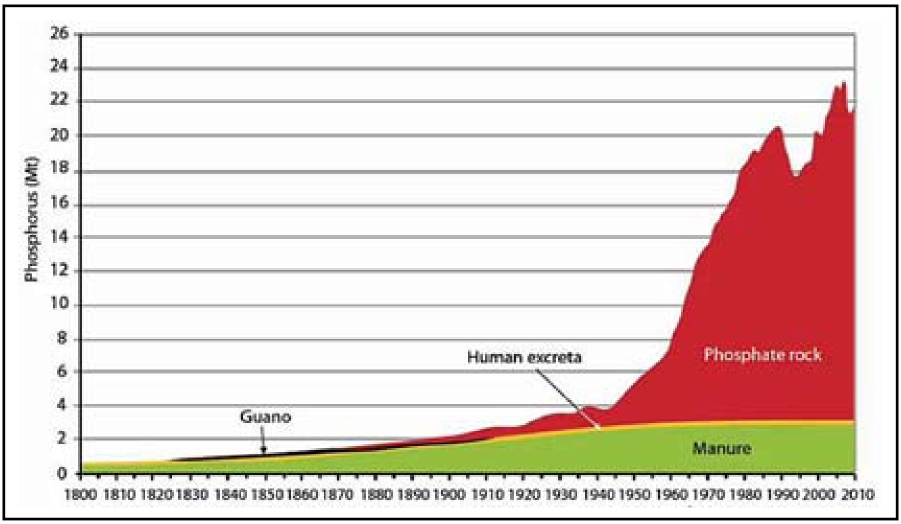

Figure 8. Sources and global consumption and fertilizer P.

A duality exists; phosphorus is at once a noxious pollutant that fouls ecosystems and a scarce strategic asset. Figure 8 shows the hugely increased use of phosphate rock since World War II. Prior to mining of rock phosphate, in the 1800s and early 1900s, the Guano Islands of the South Pacific were major sources of phosphorus that had accumulated as excreta of seabirds. The concern is that rock phosphate is a limited resource. The UNEP yearbook includes a photograph of an algal bloom in Lake Winnipeg as an example of a dysfunctional agroecosystem and, in particular, mismanagement of rock phosphate. We are consuming a scarce mineral resource by continuously reapplying it to agroecosystems—negatively impacting aquatic and other ecosystems downstream—when it could be recycled. It's a precious resource that we are squandering by feeding it to algae.

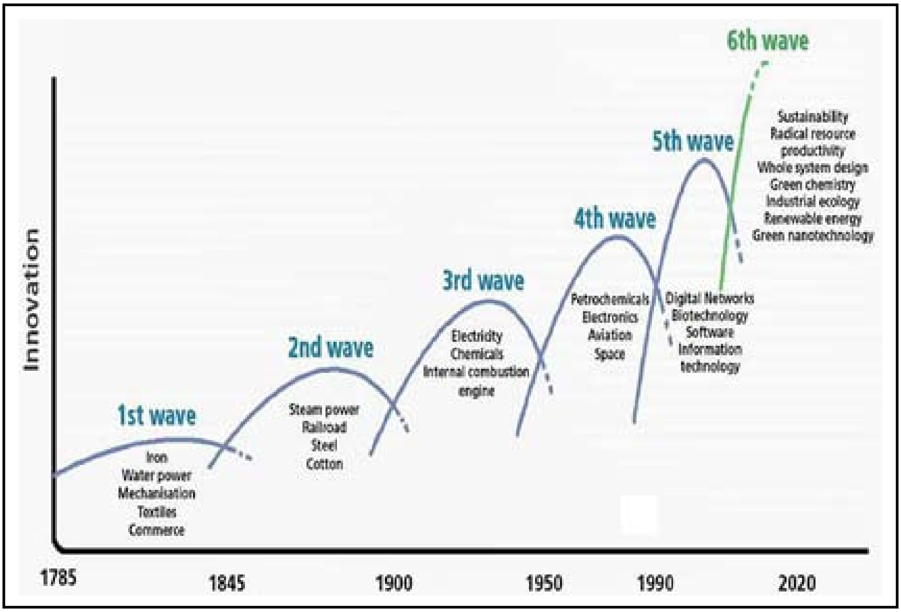

Figure 9. Waves of innovation.

The King of Morocco owns 40% of the world's rock-phosphate assets. China is also a major producer of rock phosphate and, in 2011, they imposed an export tariff as they recognize the strategic value of this resource and its necessity for domestic food production. And UNEP pointed out that:

> *Optimizing agricultural practices while exploring innovative approaches to sustainable use can reduce environmental pressures and enhance the long-term supply of this important plant nutrient.*

Sixth Wave of Innovation

Futurists may have seen the diagram in Figure 9 before. The speculation is that we are at the take-off point for the sixth wave of innovation. The first wave coincided with the industrial revolution and the harnessing of water-power and development of mechanization, *etc*. The second wave was the development of steam power and railroads, *etc.* And so on. Some say we are witnessing the sixth wave of innovation, characterized by sustainability, rapid resource productivity, whole systems design, green chemistry, industrial ecology, renewable energy and green nanotechnology; in short, this is the bioeconomy. In April, 2012, the White House released a *National Bioeconomy Blueprint* that we are examining carefully in Canada. In February, the European Commission released a communication titled *Innovating for Sustainable Growth: A Bioeconomy for Europe*. The European strategy refers to:

> *…adapt[ing] to and mitigating the adverse impacts of climate change, such as droughts and floods.*

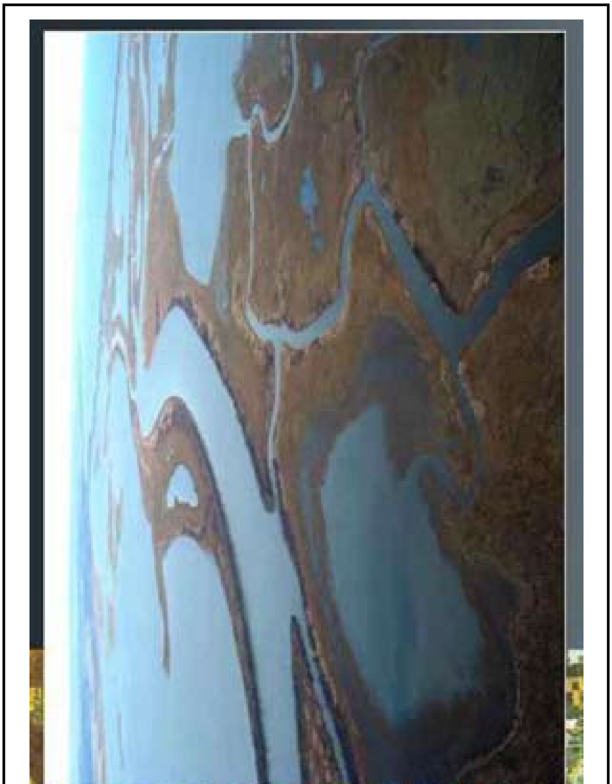

Figure 10. The Netley-Libau Marsh, a freshwater coastal wetland complex on Lake Winnipeg.

Clearly, they are grasping the connection that biotechnology is instrumental to a larger vision of the bioeconomy and, when deployed at ecosystem scale, it can contribute both to climate-change mitigation and adaptation. It's an interesting evolution of the narrative.

That sounds positive, and I'll provide a concrete example. Lake Winnipeg is characterized by two connected oblong basins. At the south end of the south basin, the Red River of the North drains through the Netley-Libau Marsh, a freshwater coastal wetland complex of about 25,000 square kilometers where 60% of the nutrient flow into Lake Winnipeg occurs (Figure 10). This is the river that flooded catastrophically in 1997 when the city of Grand Forks, North Dakota, was inundated and many buildings burned to the ground. The marsh is characterized by an invasive species of cattail.

Problem Converted to an Oppportunity

We are employing a form of passive ecological engineering. Water flows into and out of the wetlands complex, mixing constantly and creating a hypertrophic system that fosters vigorous growth of the invasive macrophyte, which can be harvested and even baled. It can be densified as a pellet and used as a biofuel to displace coal, for example, with recovery of 90% of the phosphorus in the ash, even without combustion optimization (Figure 11). In short, we are taking a downstream environmental management problem and creating a biomass benefit, a carbon-credit benefit and a habitat benefit for wildlife, and we are stimulating regrowth of the macrophyte by cutting it and allowing better light penetration, and, of course, we are recycling phosphorus. We are transforming a vexing and intractable non-point-source problem into a biomaterials-production opportunity.

We are working with colleagues at the University of Manitoba and the Composites Innovation Center in Winnipeg on higher-value products and alternative uses for the biomass including cellulosic liquid fuels, biocomposites and bioplastics. And we are cooperating with Manitoba Hydro on a biochar demonstration and production of a carbonized coal substitute.

Figure 11. Innovative technology: recapture of phosphorus from harvested cattails.

Watershed of the Future

We are synthesizing these insights into something we are calling the *Watershed of the Future* (Figure 12). We are integrating hydrologic functions, water-management functions and non-point-source-pollution benefits. Our vision is that, on a watershed basis, well designed distribution of biomass will produce higher levels of ecological *and* economic function. Biomass is the key carrier for diverting nutrients to the biorefinery where we anticipate production of all manner of high-value products ranging from liquid fuels to bioplastics. The key proviso is that we recycle the nutrients because it's a world food-security issue, as well as a source of income.

We have determined that such redesigned watersheds across our landscape, with the biomass-interception function, would enable removal of the phosphorus load on Lake Winnipeg. Furthermore, by producing solid fuels to generate heat, we would have a value chain of several hundred million dollars. If we could deploy bioeconomy technologies on a large scale and produce bioplastics, for example, the potential value chain increases to tens of billions of dollars.

Bioeconomy Pixel

A disadvantage of the atomized landscape across the Great Plains, discussed above, is that we live with flood episodes and drought episodes because all we do is manage landscape

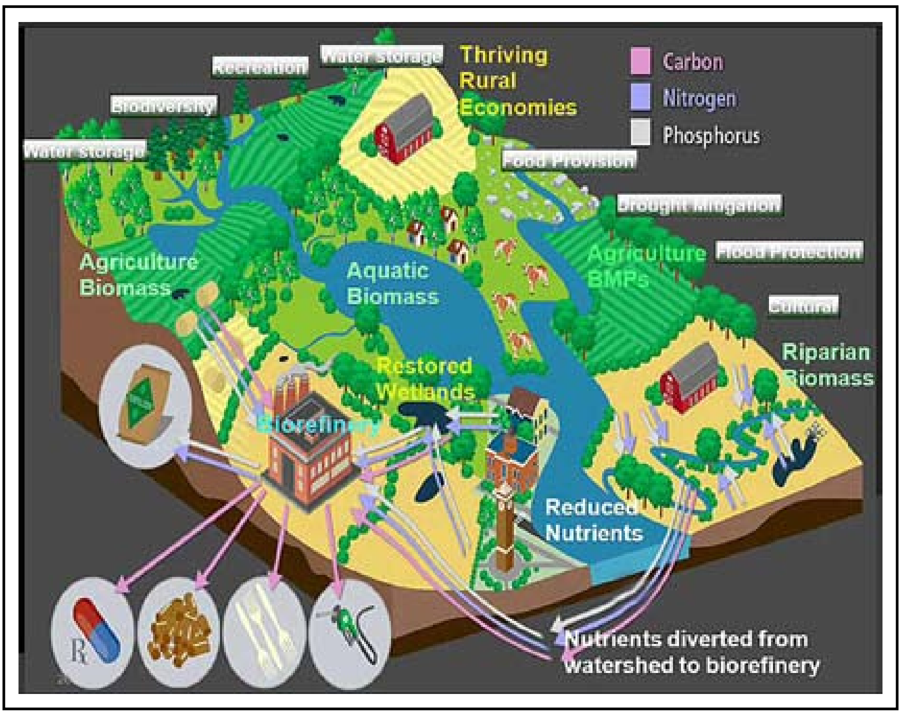

Figure 12. Watershed of the future.

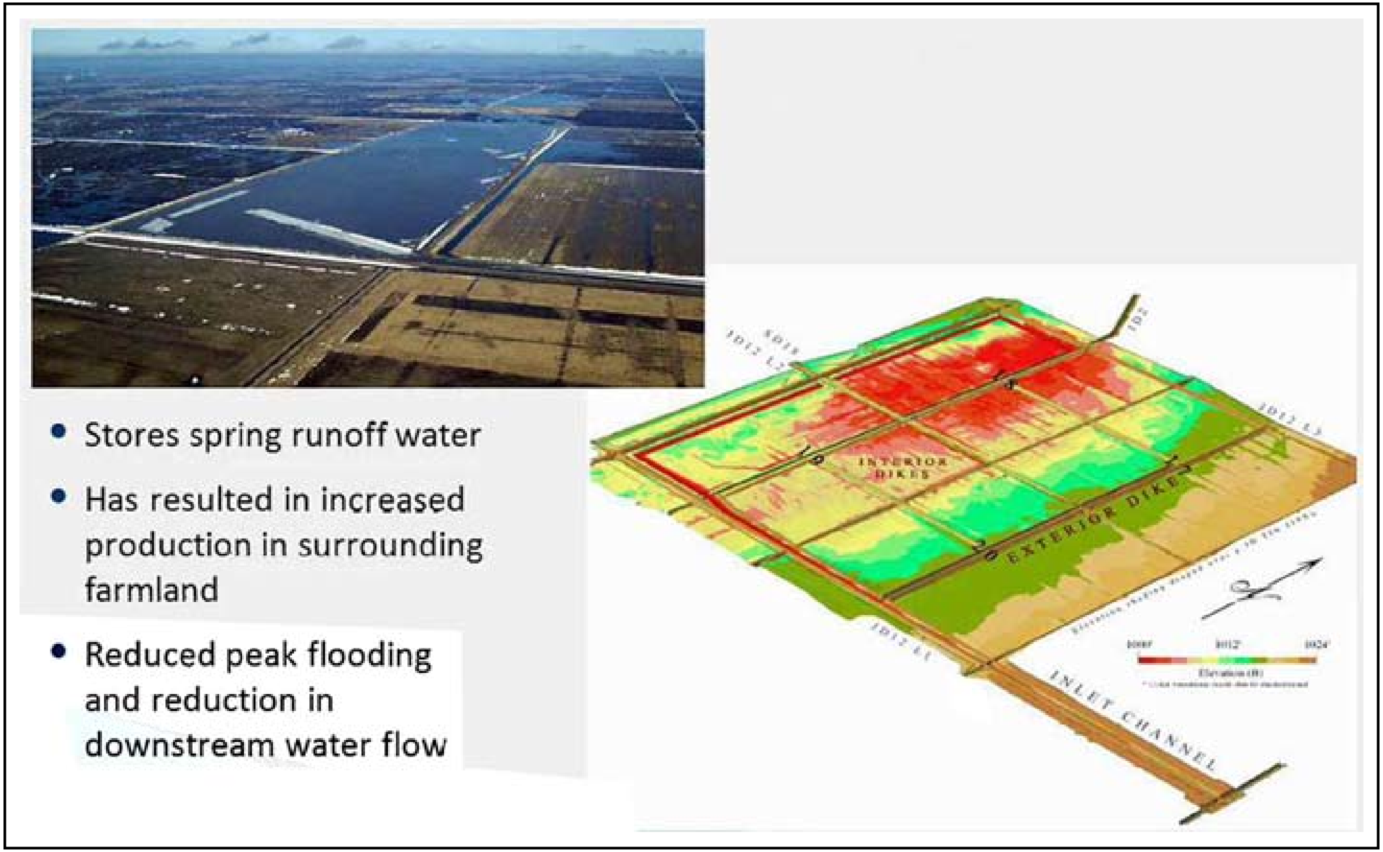

Figure 13. A bioeconomy pixel: the North Ottawa Project, Minnesota.

rather than water, and we have to move past that. Figure 13 shows a possible prototype for consideration: the North Ottawa Project in Minnesota, constructed in the basin of the Red River of the North. It is in an area that is chronically wet. Farms upstream are frequently dysfunctional and farms downstream are frequently flooded. Three sections of land were impounded for the purpose of storing water; it took 20 years for the watershed agency to obtain necessary permits because taking possession of land for seasonal storage was so radical. But now, everyone loves the Project and it is being replicated elsewhere. When I visited in March of 2012, what did I see growing near the twelve corner sections? Cattails. We are working with them to develop biomass/bioenergy capability. We believe that this landscape approach is a practical option for amelioration, adaptation and production of bio-economy value chains.

HENRY DAVID (Hank) Venema directs the Water Innovation Centre and Natural and Social Capital Program at the International Institute for Sustainable Development (IISD). He is an engineer with a diverse background. Since 2004, he has led IISD's research on water and agricultural issues in pioneering the application of Natural Capital principles to water-management challenges in Western Canada. In 2009, he led the creation of IISD's Water Innovation Centre with an initial mandate to build a strategic vision for managemen of the Lake Winnipeg Basin based on leading-edge policy, management and technological concepts. The Water Innovation Centre builds upon Lake Winnipeg Basin research work that he has directed at IISD, including ecological goods and service valuation, payments for ecosystem services, decision-support systems for ecosystem investments, water-quality trading, large-scale nutrient capture through ecosystem restoration and watershed management, and innovative governance models for basin management. In 2010, Dr. Venema launched the Lake Winnipeg Bioeconomy Project reframing the issue of lake eutrophication as a regional innovation and economic development opportunity based on the insight that phosphorus—the element regarded as the noxious pollutant responsible for fouling Lake Winnipeg—is, in fact, a scarce and strategic resource that can be captured, recycled and transformed into high-value biomaterial.