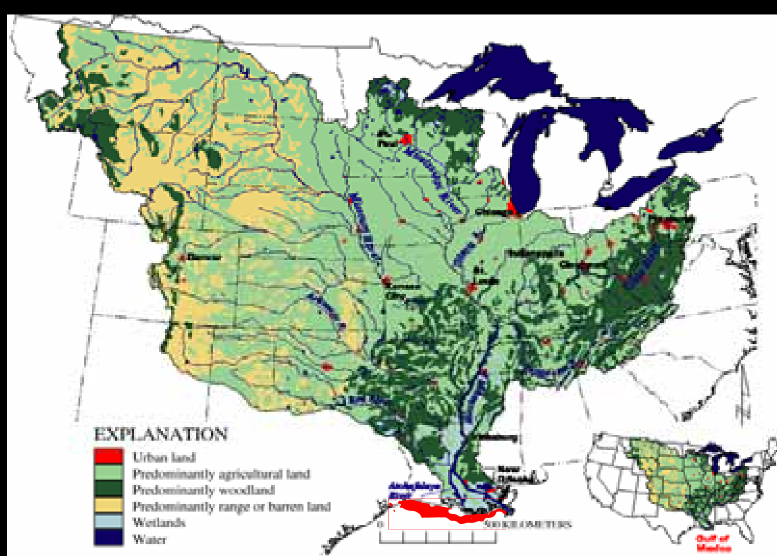
Landscapes from the Corn Belt to the Gulf: Implications for science, policy & action

"A landscape design perspective could improve the ability to understand and manage the complex system that is affecting hypoxia of the Gulf of Mexico."
EPA SAB Hypoxia Advisory Panel. 2008.

Joan Iverson Nassauer
School of Natural Resources and Environment, University of Michigan
http://www-personal.umich.edu/~nassauer



Map:
Don Scavia

A "dead zone" (lacking oxygen to support animal life) averaging 12700 sq. km. appears annually in the Gulf of Mexico

We know what causes the dead zone, but “actions to control hypoxia have lagged” behind science.

EPA SAB Hypoxia Advisory Panel. 2008.

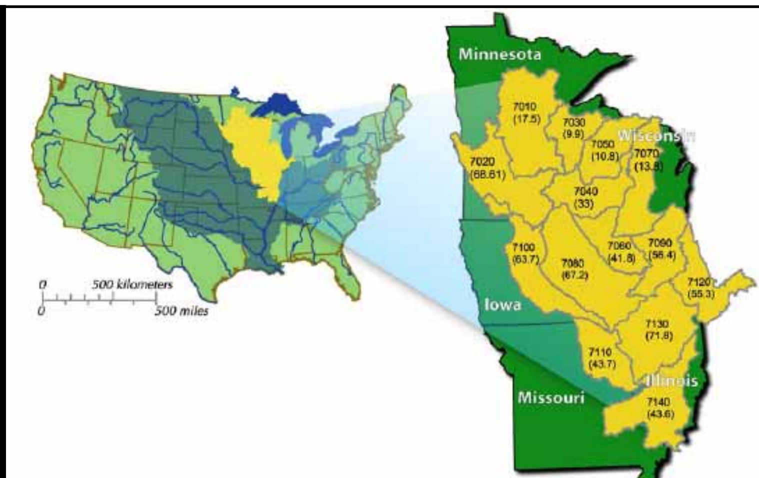


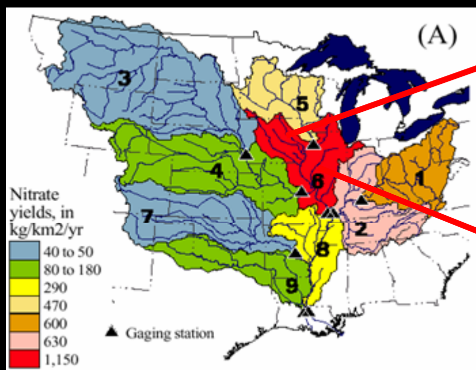
FIGURE 1. Upper Mississippi River Basin: 4-digit HUC and percentage of area under cropland

Feng et al. 2005

The most intensely cultivated watersheds of the Mississippi River Basin have been found to be sources of nutrients that create this dead zone and have numerous other detrimental environmental and societal effects.

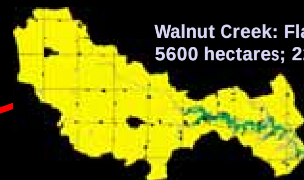
To consider how to alleviate hypoxia in the Gulf, improve local water quality and biodiversity, and support quality of life in the Corn Belt, we looked at how alternative policy scenarios could affect two small Iowa watersheds, each less than the size of a township. Santelmann, et al. EPA-NSF #R8253335-01-0.

How might looking at landscapes this *small* be effective in conducting science and supporting policy and action that could alleviate the continental scale cause and consequences of hypoxia?



Goolsby et al. 1999

Walnut Creek: Flat and 5600 hectares; 22 sq mi



Buck Creek: Rolling and 8800 hectares; 34 sq mi

"Efforts to remove or reduce nutrients through management scenarios generally are more effective at the source of nutrient loads in smaller streams…

National Research Council 2008

Small subwatersheds will provide a relevant scale for meaningful and interpretable results. "Demonstration of adaptive mgmt. within a small subwatershed may enhance practice adoption…"

EPA SAB Hypoxia Action Panel 2008

"For changes to be effectively implemented, they must be adopted by individual farmers at the local scale…

Doering et al. 2007

Science

Different disciplines investigating the same landscape pattern

Landscape Ecology

Pattern : process paradigm

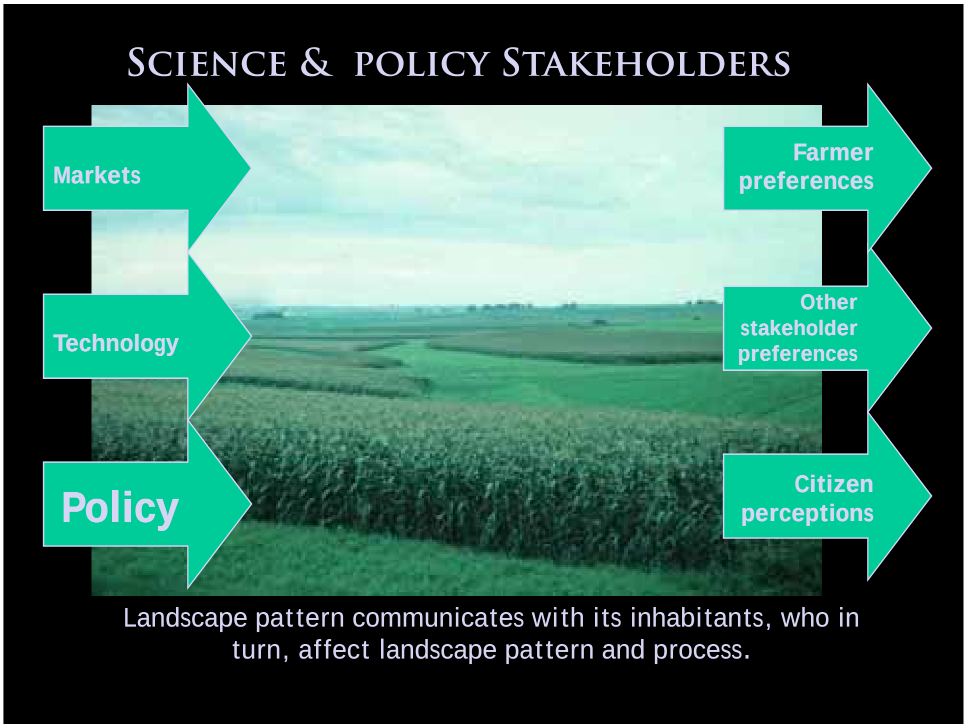
- Configuration
- Composition
- Environmental function

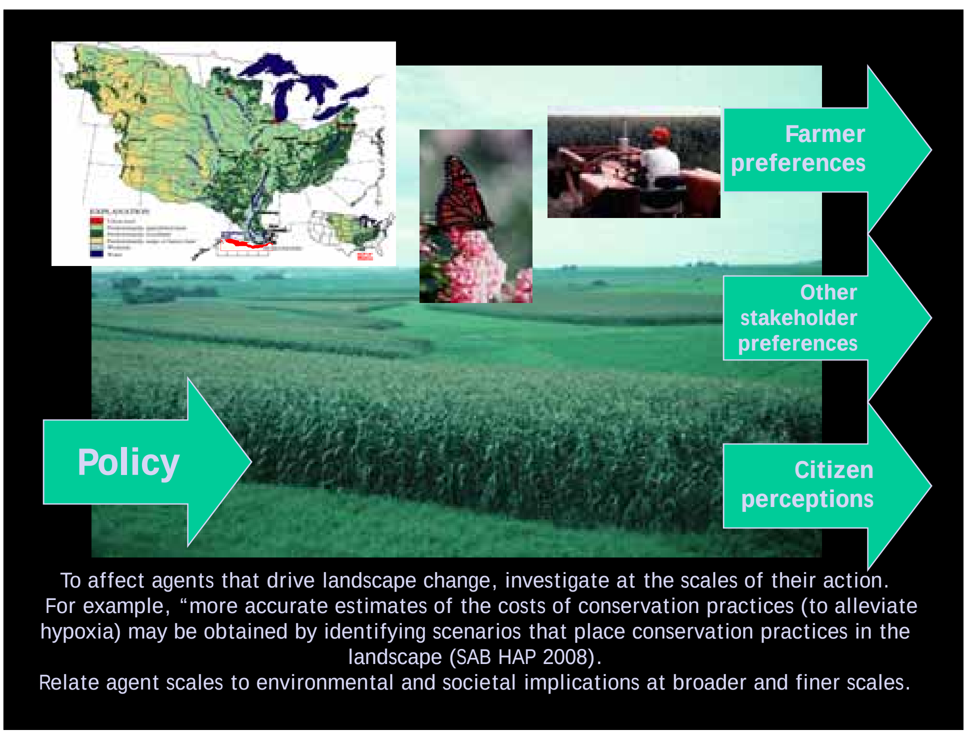
Agriculture

- Enterprise
- Conservation practices
- Management regime

Among disciplines

Faced with joint decisions or an integrated assessment about a particular landscape pattern, people in different disciplines *must* communicate effectively with each other.


Science & policy Stakeholders
Markets
Technology
Policy
Farmer preferences
Other stakeholder preferences
Citizen perceptions
Landscape pattern communicates with its inhabitants, who in turn, affect landscape pattern and process.


Policy
Farmer preferences
Other stakeholder preferences
Citizen perceptions
To affect agents that drive landscape change, investigate at the scales of their action.
For example, "more accurate estimates of the costs of conservation practices (to alleviate hypoxia) may be obtained by identifying scenarios that place conservation practices in the landscape (SAB HAP 2008).
Relate agent scales to environmental and societal implications at broader and finer scales.

Science and innovation

Process: pattern : design

Goal setting

Landscape process : Landscape pattern : Landscape design

Implementation

Assessment

Design means "any intentional change in landscape pattern".

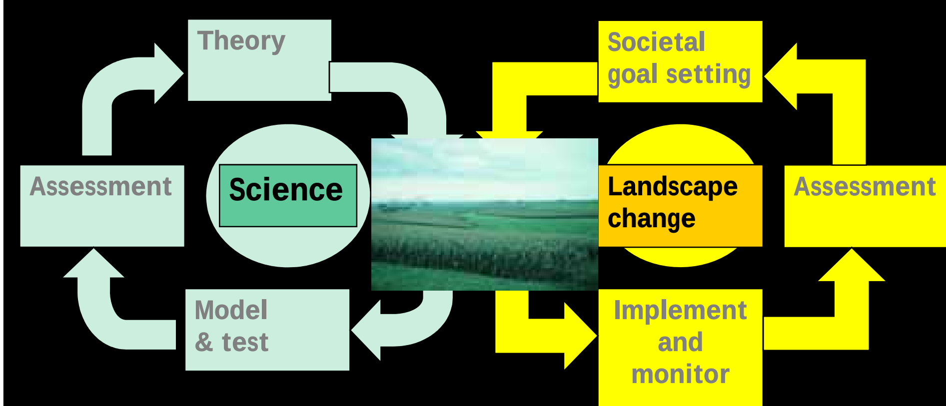
It invites innovation, where innovation is applied invention-

Either in policy or in management.

Nassauer and Opdam

Design in science: extending the landscape ecology paradigm

Landscape Ecol (2008) 23:633-644



Design is intentional change of landscape.

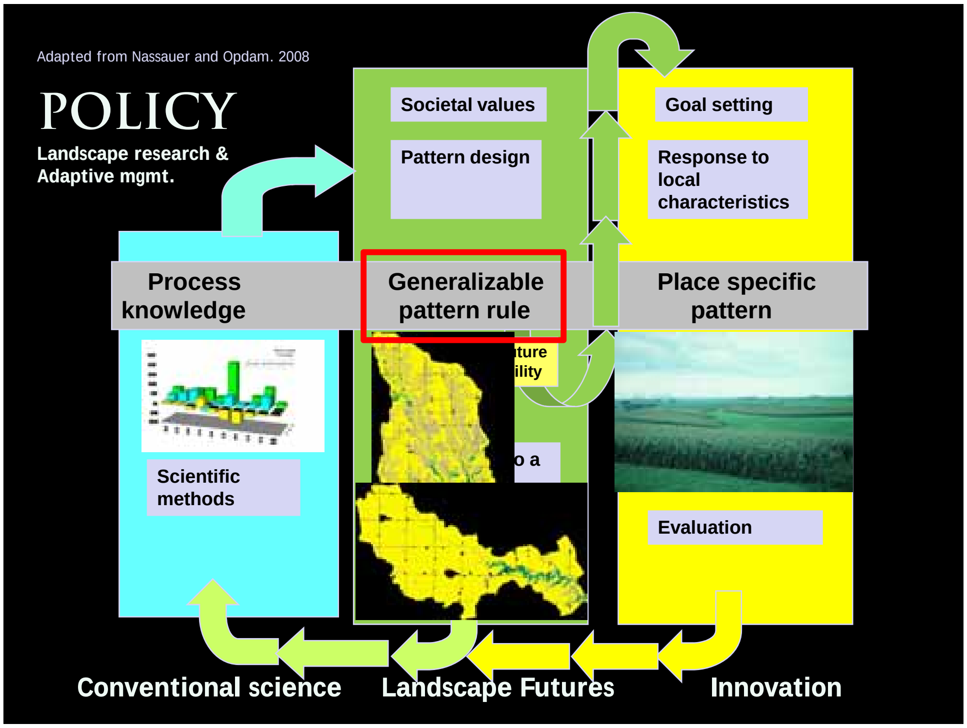
Design can make science more relevant.

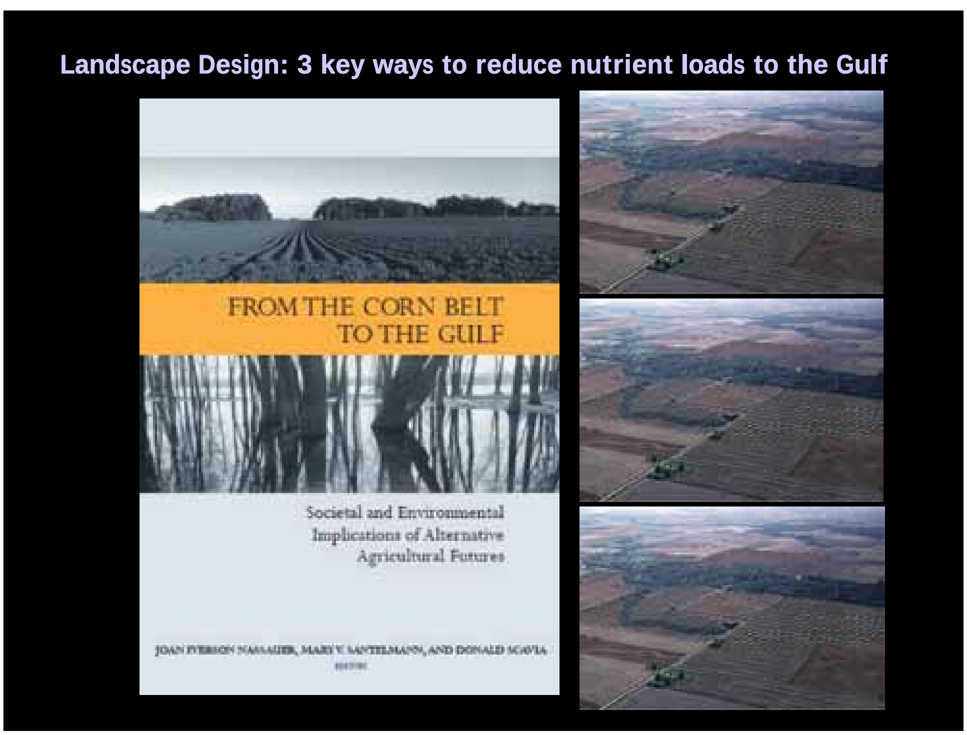
It can link science, policy, and action as a key phase of adaptive management.

Adapted from Nassauer and Opdam. 2008.

Design in science: extending the landscape ecology paradigm.

Landscape Ecology


Adapted from Nassauer and Opdam. 2008
POLICY
Landscape research & Adaptive mgmt.
Societal values
Pattern design
Goal setting
Response to local characteristics
Process knowledge
Generalizable pattern rule
Place specific pattern
Scientific methods
Evaluation
Conventional science
Landscape Futures
Innovation


Landscape Design: 3 key ways to reduce nutrient loads to the Gulf
FROM THE CORN BELT TO THE GULF
Societal and Environmental Implications of Alternative Agricultural Futures

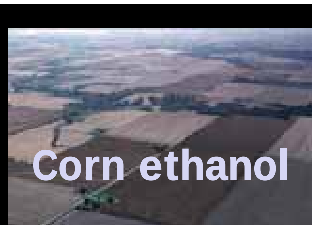
Could plausible future agricultural landscape patterns and management practices deliver more environmental and societal benefits by 2025?

Because federal policy substantially affects farmers' enterprise and management choices, we assumed that several innovations as well as broader application of well-known conservation practices would be possible under **3 different federal policy scenarios.**

Santelmann, et al. EPA-NSF #R8253335-01-0.

Walnut Creek: Flat and 5600 hectares; 22 sq mi

Buck Creek: Rolling and 8800 hectares; 34 sq mi



3 alternative scenarios emphasized:

1 Commodity production

- Comprehensive use of precision agriculture
- Comprehensive BMP's including conservation tillage
- 6m (on each side) stream buffers
- Increased area in corn-bean rotation by 8-38%

2 Improved water quality

- Supports rotational grazing
- Targets pasture/alfalfa near fenced streams
- Widens stream buffers to 15 - 30 m
- Creates upland detention wetlands and off-channel wetland storage

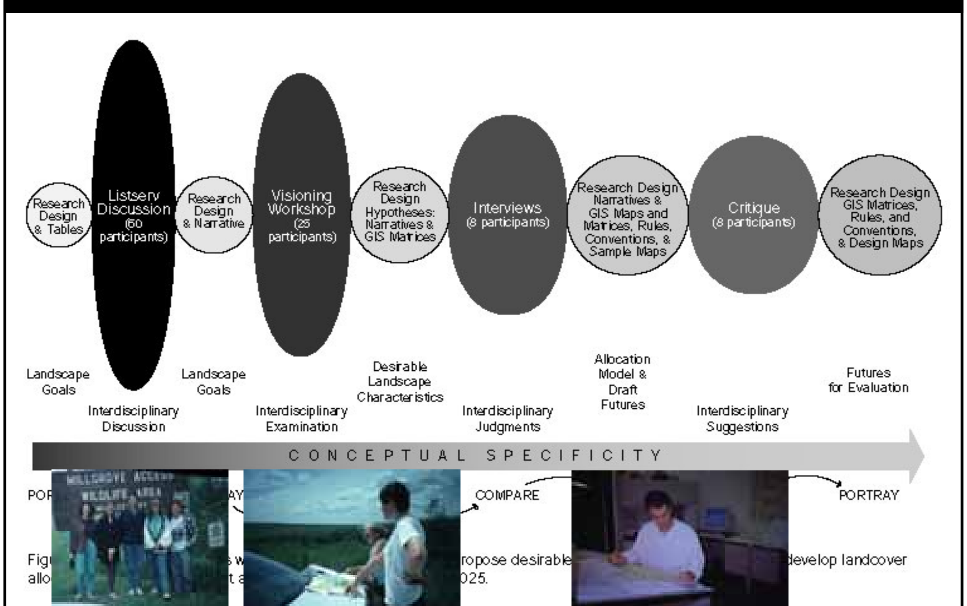
3 Enhanced biodiversity

- Targets increased area in perennial grasses to slopes and near streams.
- Supports organic production in target zone
- Introduces BMP cropping innovations, including perennial strip intercropping.
- Widens stream buffers to 30 - 90 m
- Creates large (>260 ha) long-term wetland and upland bioreserves that detain run-off

An iterative interdisciplinary process began in 1995, prompted by the first EPA/NSF Water and Watersheds Interagency grant competition

Policy scenarios led to landscape futures, which were used for our integrated assessment of 2 Iowa watersheds.

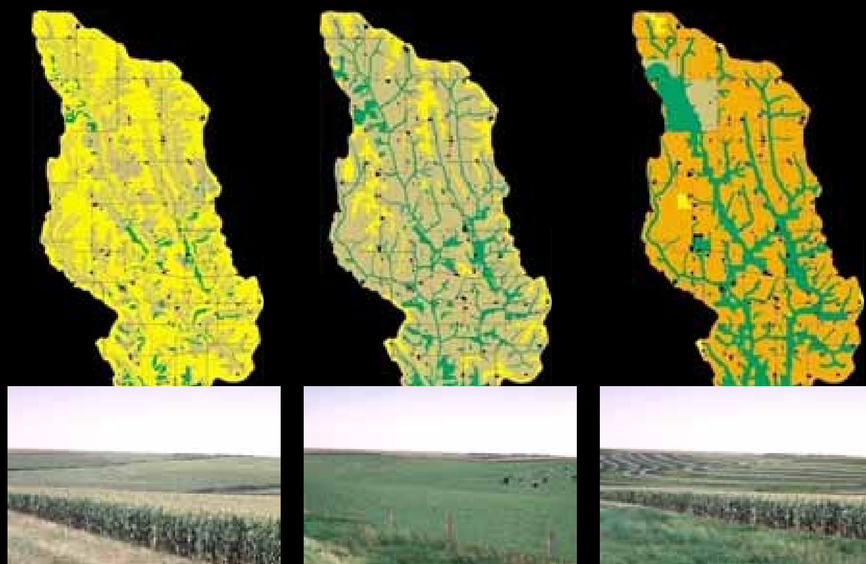
- Field inspections, Listserv, field workshop, web and phone conferencing, map integration
- Experts in sustainable agriculture, agronomy, animal husbandry, soil science, aquatic ecology, plant ecology, animal ecology, landscape ecology, forestry, hydrology, agricultural engineering, soil and water conservation, landscape architecture, agricultural and resource economics

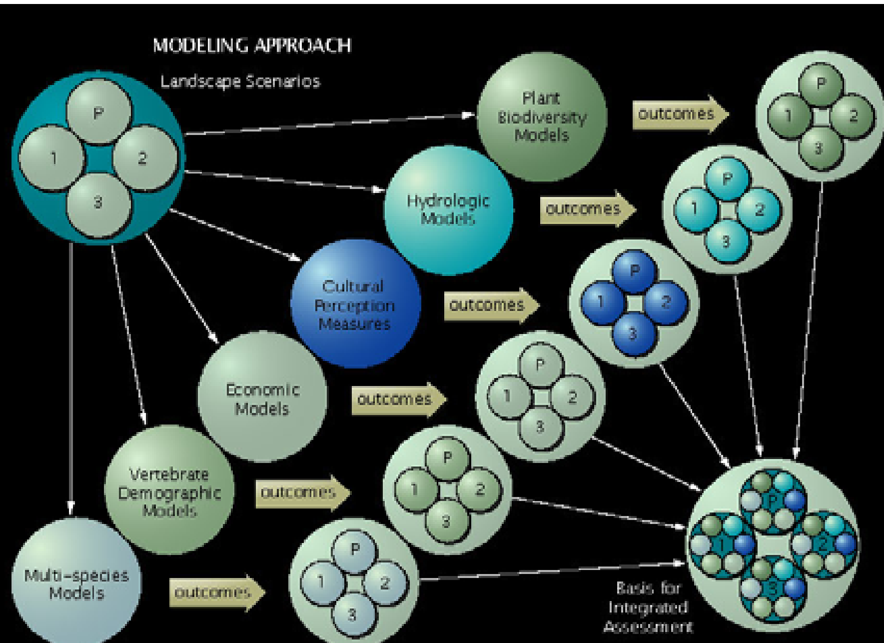


Landscape futures development process

Nassauer and Corry. 2004. Using Normative Scenarios in Landscape Ecology. Landscape Ecology.

For each GIS future, we developed numerous simulations of landscape appearance. Then we compared and integrated multiple measures and models of cultural, ecological and economic performance.





Policy, economic, and perception characteristics:

1.Commodity production as first priority

- profit is perceived as short term economic return under 1995-8 prices.
- high demand for Corn Belt grain crops by world markets, high use of fossil fuel, high use of chemical and technological inputs, and public support for large-scale, industrial agriculture.
- public trust in the quality of food produced by industrial agriculture is high
- public perceives the landscapes resulting from industrial agriculture to be environmentally acceptable
- public incentives for conservation at a level that encourages widespread adoption of the types of best management practices existing in 1995.

http://www-personal.umich.edu/~nassauer/RuralWatersheds/LandscapeScenariosDetails

Rules for allocating crop type and field size under Scenario I

- **High CSR field.** Existing and new corn and bean fields will be redesigned to increase their size up to 320 acres where the configuration would be accessible to a combine.
- **Low CSR field, more than 30 acres.** 1994 fields in corn or beans remain 2025 fields in corn or beans except where areas greater than 30 acres of low CSR are defined as separate fields to be planted to alfalfa for sale to concentrated animal feeding operations.
- **High CSR added to a field.** Unless a parcel is an occupied farmstead or non-farm home, 1994 parcels not in corn or beans become 2025 corn or beans where there are more than 3 contiguous, accessible acres of high CSR. For example, high CSR land in woodlands in 1994 will be cleared for crop production if it is > 3 acres and accessible by combine. Low CSR land will be included in the new field if there is less than 30 contiguous acres of low CSR, based on efficiency for planting and harvest.
- **Low CSR - not within a cultivated field.** Where there are not >3 contiguous, accessible acres of high CSR, 1994 landcover is 2025 landcover (allowing for changes in vegetation structure). The only exception is 1994 CRP and low CSR>30 acres, which becomes alfalfa in 2025.

1. Future Landscape Characteristics:

- Cultivated land reduces woodlands.
- Landscape has been depopulated by 50% compared with 1994. Many farmsteads have been demolished and groves cut down.
- Farm size doubles; typical field size increases to 130 ha (320 acres).
- Crops are corn and soybeans.
- Livestock are raised almost exclusively in confinement feeding operations in a few counties of the state.
- Few people visit the rural landscape for recreation.

Policy, economic, and perception characteristics:

2. Water quality as first priority

- Federal agricultural and environmental policy enforce clear, measurable water quality performance standards for non-point sources.
- Public support for agriculture targets practices that efficiently reduce soil erosion, reduce sediment delivery to streams, prevent the movement of excess nutrients to streams, reduce the energy and flashiness of storm events, and improve aquatic habitat.
- Public environmental concerns focus on clean water.
- World markets for beef and pork increase Corn Belt interest in extensive animal grazing.

2. Landscape characteristics:

- Pasture and forage crops on rolling or erodible land.
- Hay and pasture along with selectively mown roadsides, and broader stream buffers create habitat.
- Network of upstream and off-channel detention wetlands.
- Woodlands have been maintained for grazing.
- Both urban and rural citizens appreciate the pastoral appearance of agricultural landscapes. Farm vacations and countryside second homes.
- To manage livestock operations and respond to rural recreation demand, 50% more farmers live in Corn Belt agricultural landscapes than under scenarios 1 or 3.

Policy, economic, and perception characteristics:

3. Biodiversity as first priority

- Public environmental concerns drive federal investment in agriculture, which is targeted to ecological results and long-term economic return.
- Public investment in new technologies that enhance biodiversity within farming systems.
- Public investment maintains and restores native flora and fauna through a system of government-purchased reserves.
- World grain market is robust but continues to produce a comfortable surplus.

3. Landscape Characteristics:

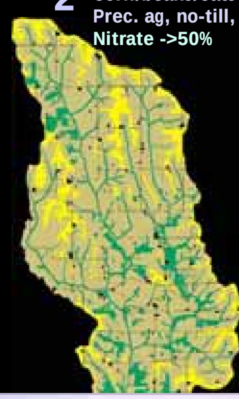
- Livestock enterprises are confinement feeding operations built according to rigorous standards for sewage treatment.
- Federal land purchases from willing buyers establish at least one indigenous ecosystem core reserve of at least 260 hectares (640 acres) in many Iowa watersheds.
- Federal support for innovative, biodiversity best management practices targets landscapes that connect and buffer the new reserves and riparian corridors.
- Ecological reserves and corridors invite public enjoyment of the rural landscape. Trail systems connect corridors and reserves.
- Farm size increases as in Scenario I, and the number of farms decreases to about 50% of the number present in 1994.
- Nearly all 1994 farmsteads remain inhabited in 2025. Many non-farmers and hobby farmers who enjoy the quality of life live on farmsteads.

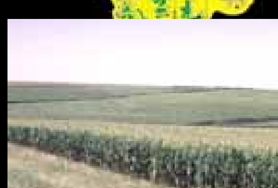

Our team of 25 scientists compared and integrated multiple measures and models of cultural, ecological and economic performance for each future - including water quality.

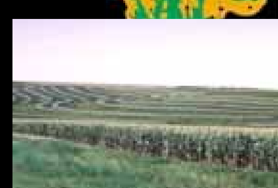
1 Corn/beans = 62%
Precision ag & no-till
Nitrate +19%

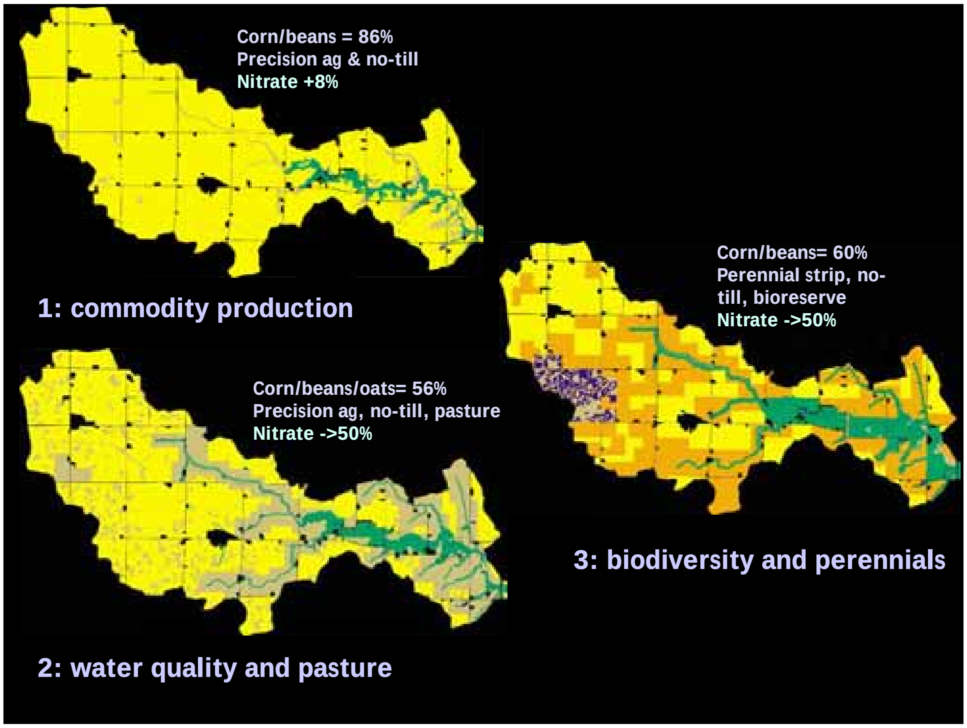
2 Corn/beans/oats= 12%
Prec. ag, no-till, pasture
Nitrate ->50%

3 Corn/beans= 42%
Perennial strip, no-till, bioreserve
Nitrate ->50%

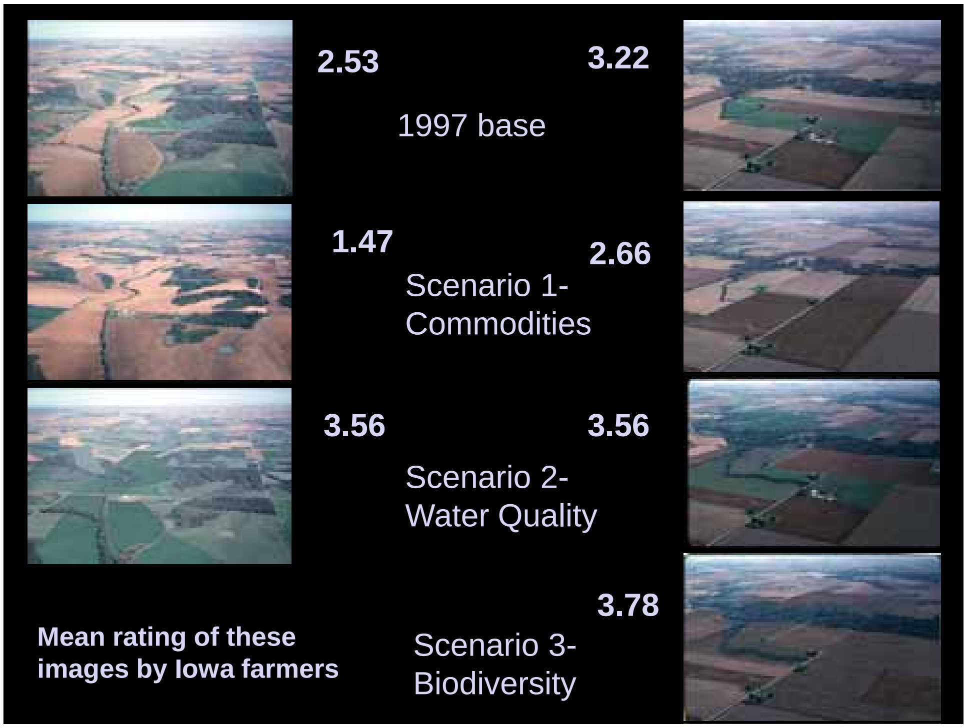



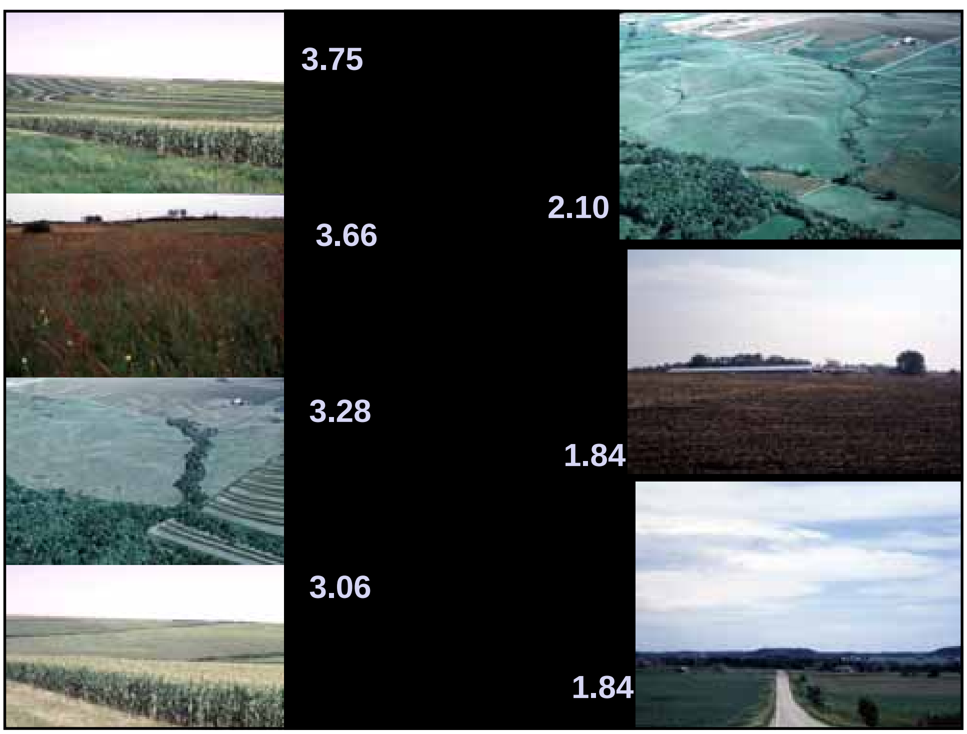


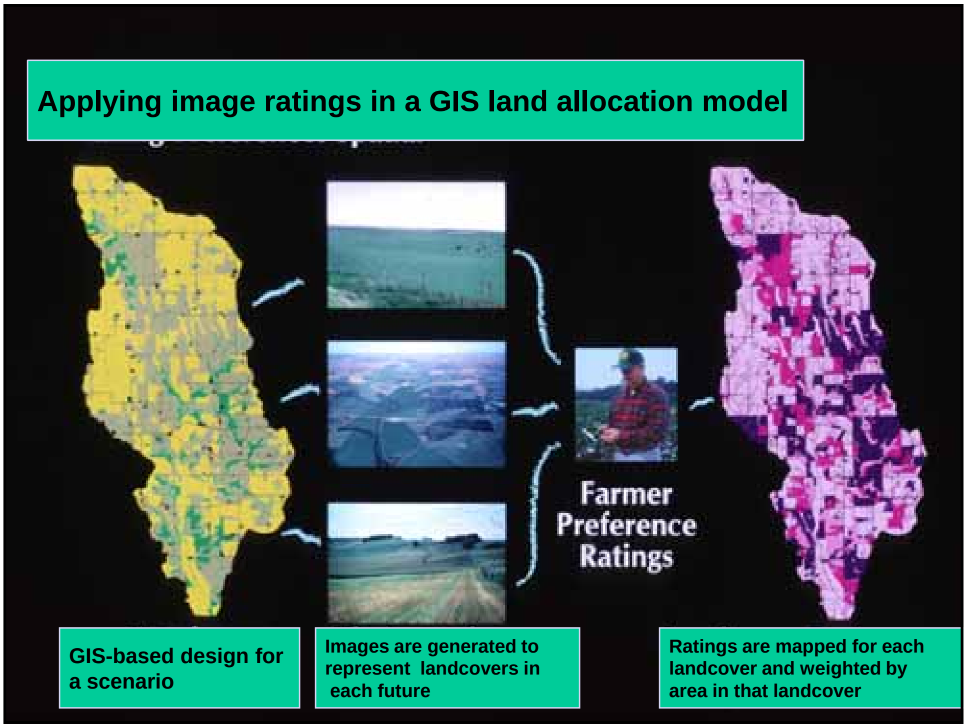


We conducted in-depth on-farm interviews with 32 Iowa farmers in 1998. As part of the interview, we used a Q-sort technique to derive farmer's ratings (1-5) of 20 images. They sorted images according to what would be "best for the future of the people of Iowa" in 2025.

Nassauer, Corry, and Dowdell. 2007. Farmers Perceptions.
In **From the Corn Belt to the Gulf.** RFF Press.


2.53
3.22
1997 base
1.47
2.66
Scenario 1-
Commodities
3.56
3.56
Scenario 2-
Water Quality
3.78
Mean rating of these
images by Iowa farmers
Scenario 3-
Biodiversity

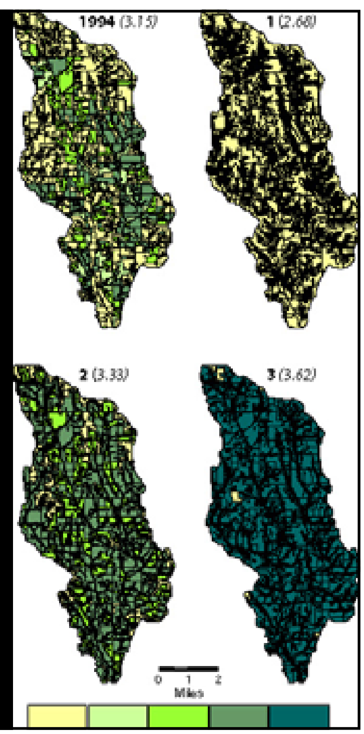

3.75
2.10
3.66
3.28
1.84
3.06
1.84



We linked perception data with GIS spatial data by applying farmers' ratings to landcovers, and weighting landcover rates by area within each watershed.

For both watersheds, the order of farmer preference was:

Scenario 3 – Biodiversity
Scenario 2 – Water Quality
Present landscape
Scenario 1 - Production

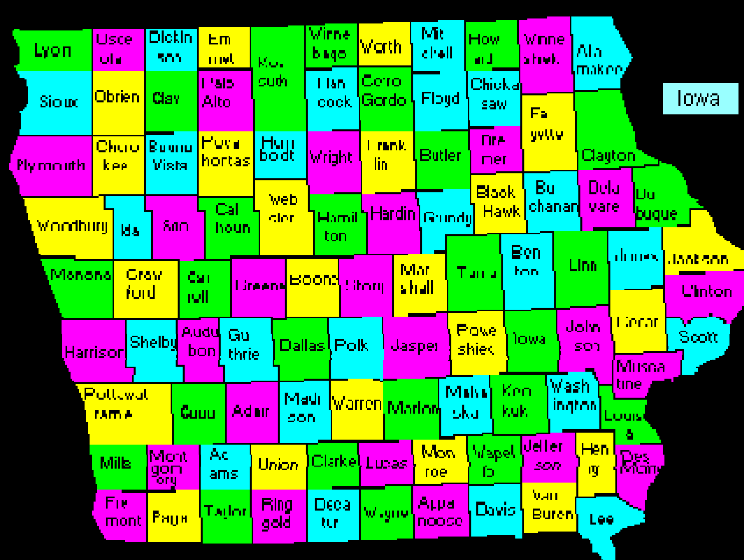


Farmer photos: NRCS

What about a more representative sample of farmers?

Image-based web survey of 549 Iowa farmers from Nov. 2006 – Sept. 2007

Responses were evenly distributed across Iowa's 99 counties.



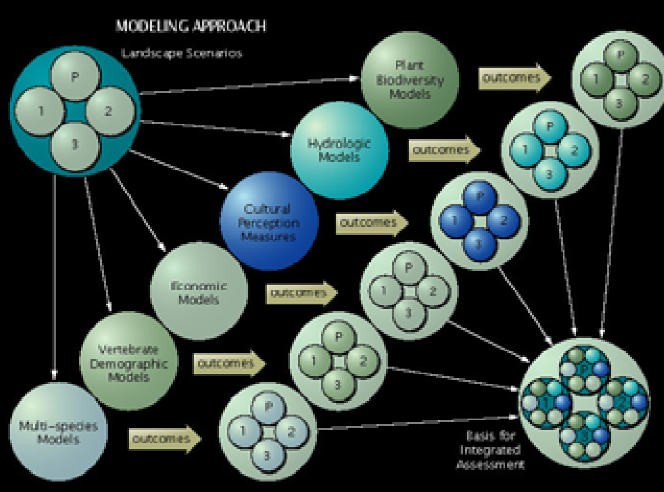
Farmer photos: NRCS

When we surveyed 549 Iowa farmers in 2007, they told us that they belonged to these organizations:

Conservation International, American Tree Farm Association, Arbor Day, Conservation Conservancy, Center for Rural Affairs, Practical Farmers of Iowa, Ducks Unlimited, Pheasants Forever, Environmental Working Group, Cornucopia, Organic Crop Improvement Association (OCIA), Hartman Reserve, Prairie Rapids Audubon, Iowa Natural Heritage Foundation/Association, Iowa Trails, ICC , Nature Conservancy, Ikes, Iowa Drainages District Association, Iowa Farm Bureau, Iowa Woodland Owners Association, Iowa Association of County Conservation Boards, Trees Forever, Isaac Walton League, Jefferson County Farmers and Neighbors (NFAN), Lake McBride Watershed Committee, Land Institute, Sierra Club, INHF, League of Conservation Voters, Union of Concerned Scientists, National Resource Defense Council, Seed Savers Exchange, COPIRG, Land Institute, Denver Botanic Gardens, National Arbor Foundation, Audubon Club, Farm Land Trust, Missouri Prairie Foundation, World Wildlife Fund, National Wild Turkey Foundation/Federation, National Parks Association, Quail Forever, American Farmland Trust, Turkey Federation, Tree Farm, Sustainable Woodland Cooperative, Whitetails Unlimited, Animal Welfare Institution, CCI, RCALF-USA, Soil and Water Commissioner Marshall County, Soil and Water Conservation Society (SWCS), Environmental Defense Fund

Assessing Alternative Futures for Agriculture in Iowa, USA. Landscape Ecology 19: 357-374. 2004.

Santelmann, M.V., White, D., Freemark, K., Nassauer, J. I., Eilers, J. M., Vache, K B., Danielson, B.J., Corry, R.C., Clark, M. E., Polasky, S., Cruse, R.M., Sinfeos, J. Rustigan, H., Coiner, C. Wu, J., Debinski, D.



Assessment measures and models

Water quality: SWAT (Soil and Water Assessment Tool (Arnold et al. 1997) was used to evaluate scenarios for water quality response (Vaché et al. 2002).

Profitability and Water Quality: EPIC model (Erosion Productivity Index Calculator (Williams et al. 1988) was used to calculate return to crop yields.

Public perception: spatially explicit method for determining landscape preference rating for alternative future scenarios (Nassauer, Corry, and Dowdell 2007).

Biodiversity 1: statistical estimate of change in habitat area, weighted by habitat quality (White et al. 1997), for all butterfly and non-fish vertebrate species that occur in central Iowa, or
by estimated abundance in that habitat (Eilers and Roosa 1994) for all plant species that occur in central Iowa (White et al. 1999).

Biodiversity 2: spatially explicit population models (SEPMs) to assess the impact of changes in land use and management on species of interest (

Water quality response endpoints 1-3:

1) annual flow in m^3/year
2) annual export of sediment in tonnes/year
3) annual export of nitrate-nitrogen in kg/year

Economic endpoint 4:

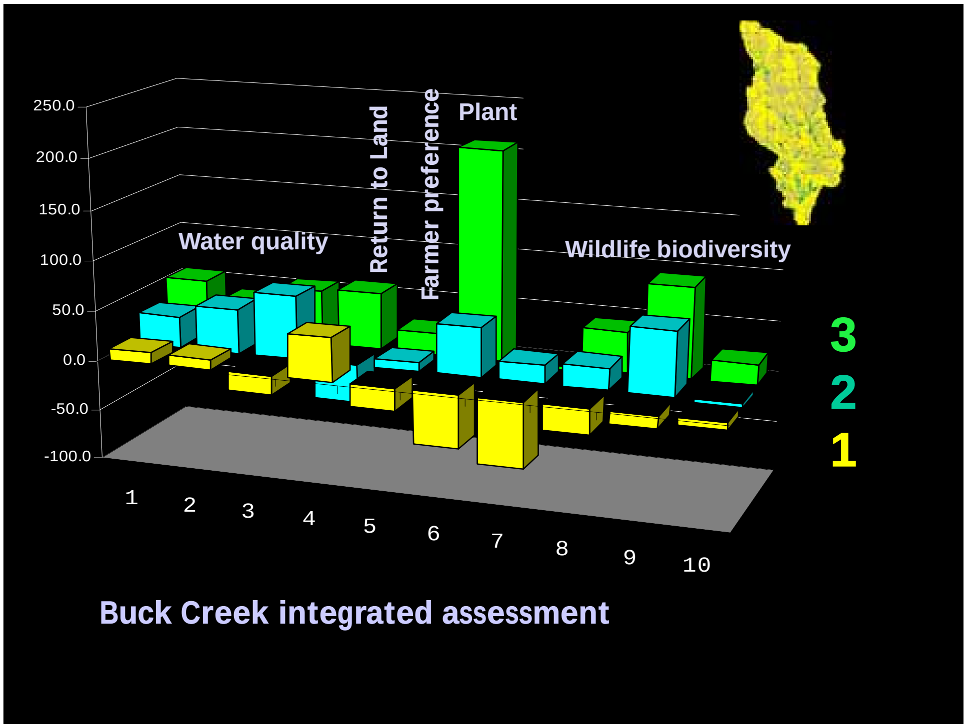
4) annual return to land summed for watershed (dollars)

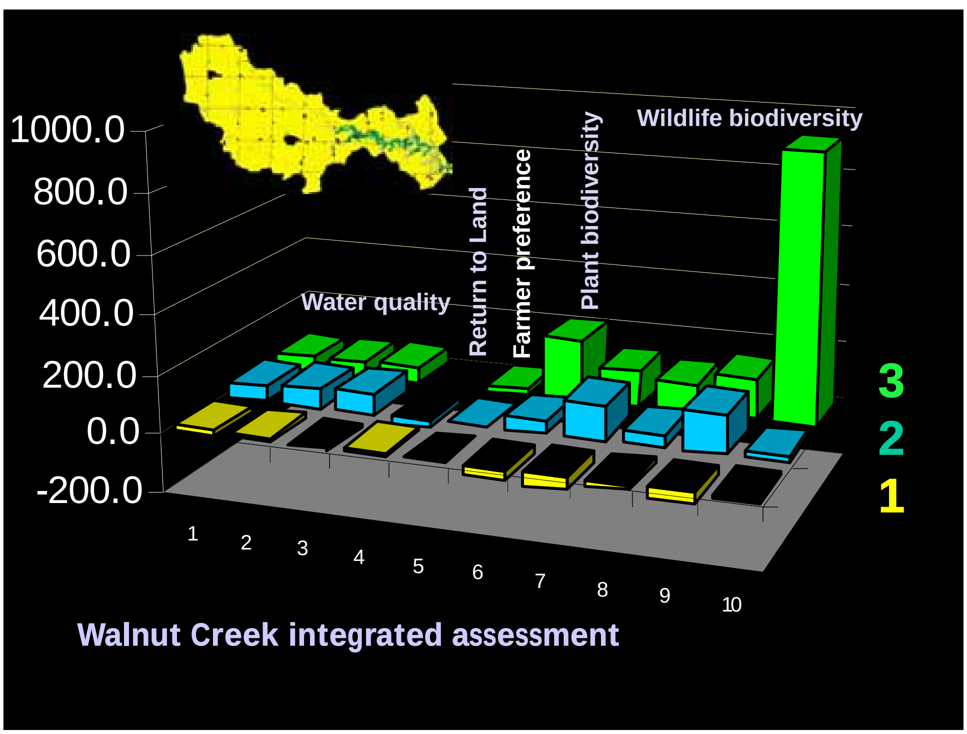
Public preference endpoint 5:

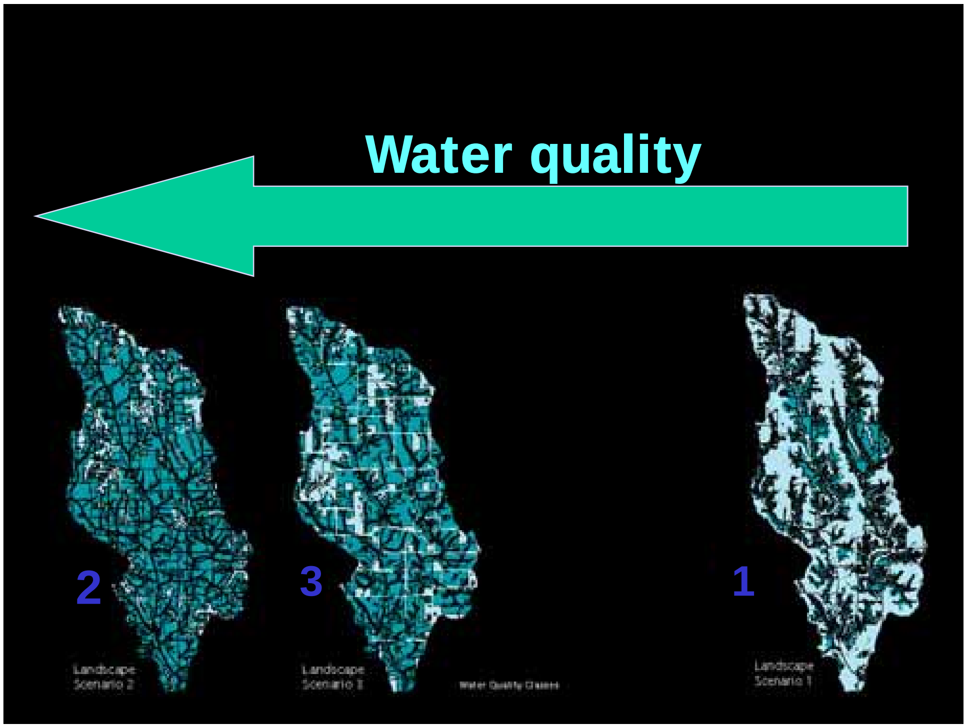
5) Preference rating for scenario based on farmer interviews

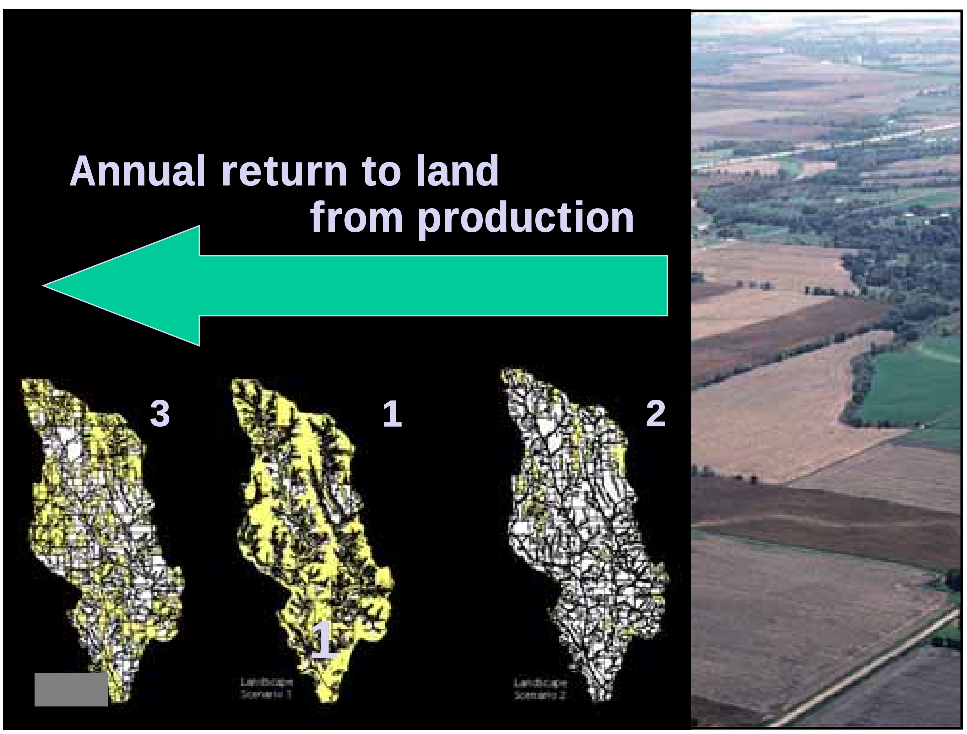
Biodiversity response endpoints 6-10:

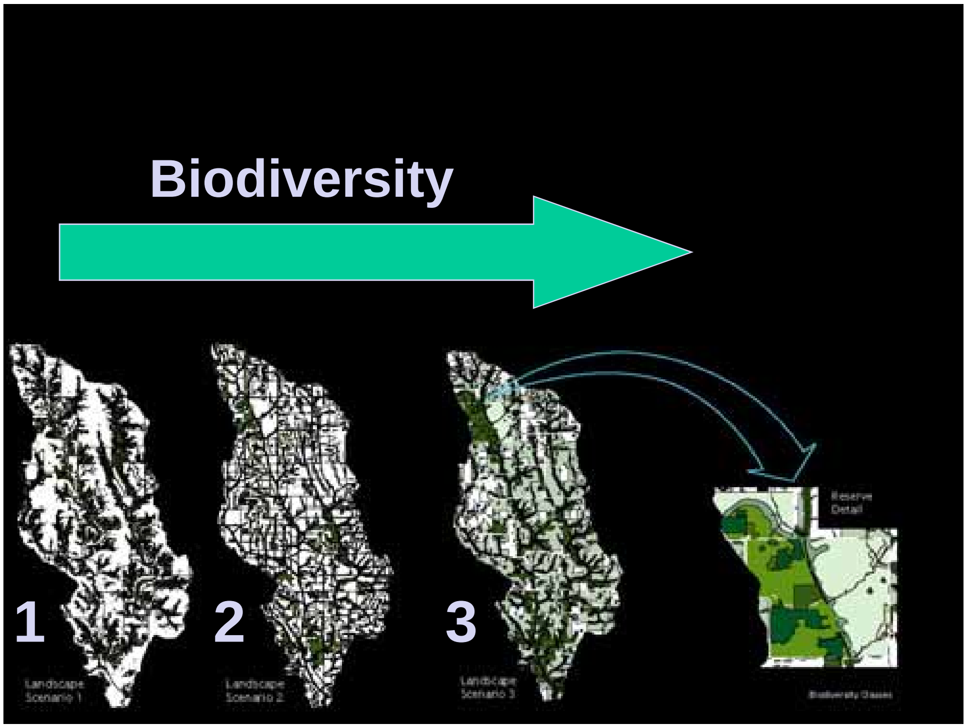
6) index of native plant biodiversity
(median percent change for all native plant species (n = 932) of index of abundance in each land cover, weighted by area of that land cover)
7) index of butterfly biodiversity
(median percent change for all butterfly species (n = 117) in habitat area in each land cover weighted by suitability of that land cover for the species)
8) index of native vertebrate biodiversity
(median percent change for all bird, mammal, reptile, and amphibian species (n = 239) in habitat area in each land cover weighted by suitability for the species)
9) SEPM population viability index for mammal species
(median percent change for all mammal species (n = 52) of relative density in simulation year 100 of species persisting in the watershed).
10) Index of response for 4 amphibian species

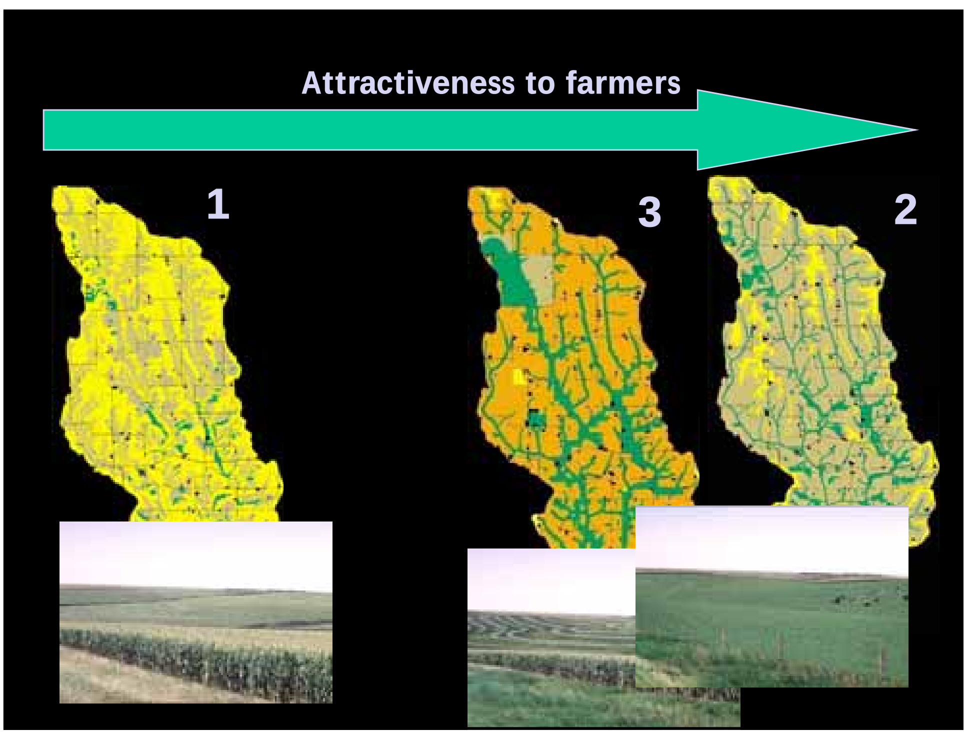

250.0
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
Water quality
Return to Land
Farmer preference
Plant
Wildlife biodiversity
1
2
3
4
5
6
7
8
9
10
3
2
1
Buck Creek integrated assessment


1000.0
800.0
600.0
400.0
200.0
0.0
-200.0
Water quality
Return to Land
Farmer preference
Plant biodiversity
Wildlife biodiversity
1
2
3
4
5
6
7
8
9
10
3
2
1
Walnut Creek integrated assessment


Water quality
2
3
1
Landscape Scenario 2
Landscape Scenario 1


Annual return to land
from production
3
1
2
1


Biodiversity
1
2
3
Landscape Scenario 1
Landscape Scenario 2
Landscape Scenario 3
Reserve Detail
Biodiversity Classes


Attractiveness to farmers
1
3
2

Summary of integrated assessment rank

1 Corn/beans = 62%
Precision ag & no-till
Nitrate +19%

2 Corn/beans/oats= 12%
Prec. ag, no-till, pasture
Nitrate ->50%

3 Corn/beans= 42%
Perennial strip, no-till, bioreserve
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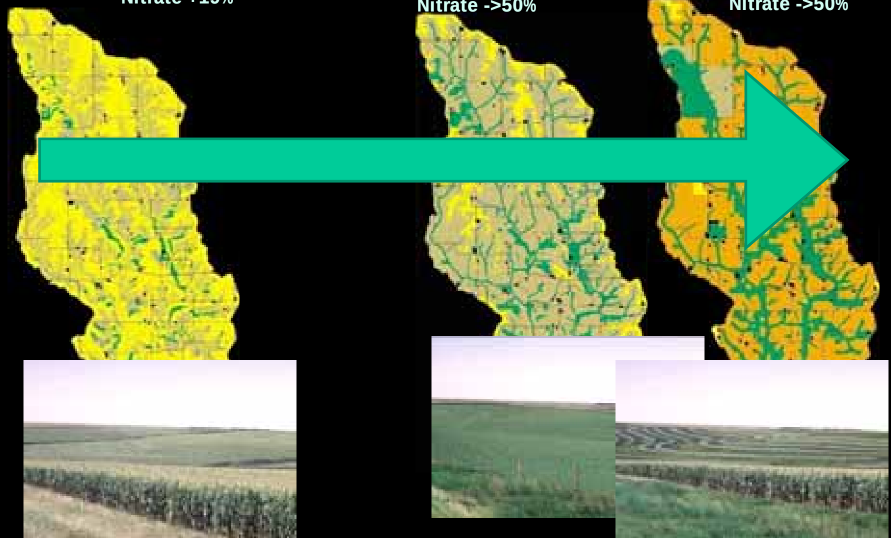


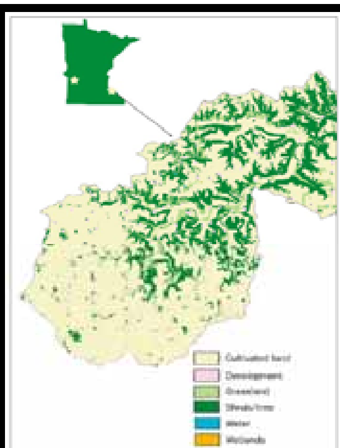


Figure 1. Wells Creek study area (baseline conditions in 1999), located in Goodhue County in southeast Minnesota.

Figure 2. Chippewa River study area (baseline conditions in 1999), located in Chippewa and Swift Counties in southwest Minnesota.

Table 1. Demographic and physical characteristics of the Wells Creek and Chippewa River study areas.

	Population							
Study area	Farm	Rural (nonfarm)	Incorporated	Total	Average slope (%)	Rainfall (cm/yr)	Area (ha)	Soil
Wells Creek	810	450	240	1500	6.5	75	16,264	Silty-loam to silt-loam
Chippewa River	150	525	5682	6357	2.2	64	17,994	Silt-clay to silt-loam

Boody et al. 2005. Multifunctional Agriculture in the United States. **BioScience.**

% Change in Environmental Damage Compared to Baseline Data

	Wells Creek Study Area					Chippewa Study Area			
Scenario	. A	B	C	D		A	B	C	D
Sediment	+4%	-31%	-56%	-84%		-9%	-25%	-35%	-49%
Nitrogen	-7%	-37%	-63%	-74%		+1%	-17%	-51%	-62%
Lethal fish events/year	+10%	-57%	-72%	-98%		+2%	0	0	-10%
Water runoff	+1%	-3%	-24%	-35%		0	-1%	-21%	-34%
Downstream cleanup costs from sediment	+4%	-31%	-56%	-84%		-9%	-25%	-35%	-49%

The Multiple Benefits of Agriculture Project Executive Summary 3

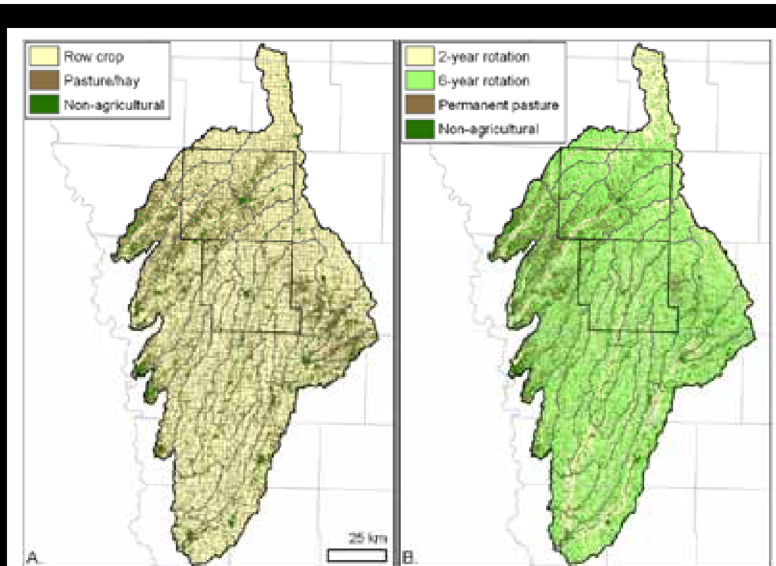


Figure 2. Spatial distribution of major land uses: (a) current conditions and (b) alternative land use pattern.

Burkhart , James, Liebman, Herndl. 2005. **Impacts of integrated crop-livestock systems on nitrogen dynamics and soil erosion in western Iowa watersheds . Journal of Geophysical Research.**

Table 1. Crop and Livestock Summary for Current and Alternative Land Uses

	Current	Alternative 1	Alternative 2
Maize, ha	499,131	379,535	379,535
Soybean, ha	461,070	268,592	268,592
Oat/alfalfa hay, ha	13,602	33,296	33,296
Oat/grass hay, ha	39,369	99,888	99,888
Pasture, ha	83,198	262,226	262,226
Permanent cover, ha	156,522	221,148	221,148
Cow/calf, pair	90,992	259,189	259,189
Stockers, head	204,623	196,983	196,983
Finished hogs, head	970,479	1,000,000	7,566,400

Burkhart et al. 2005

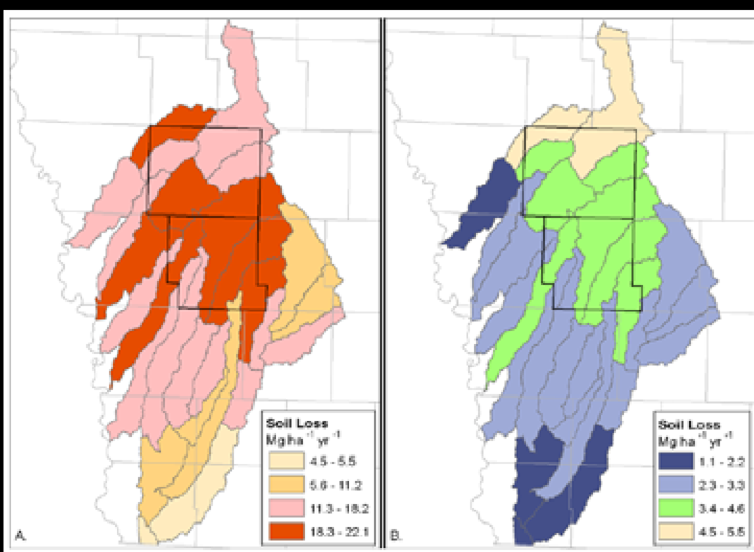


Figure 5. Soil erosion rates in watersheds of western Iowa: (a) current land use and (b) vegetation cover under alternative land uses.

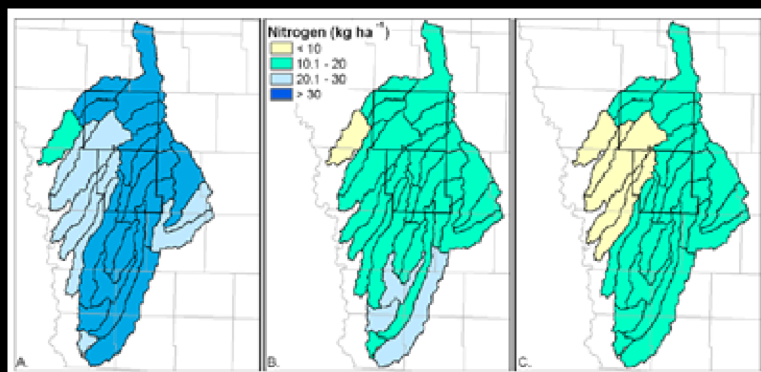
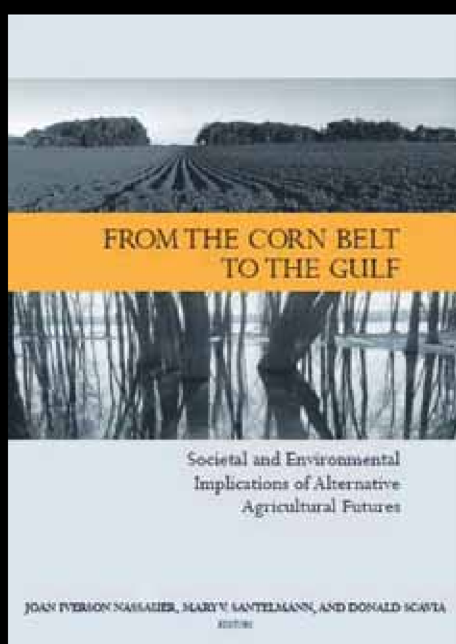


Figure 9. Leachable nitrogen in watersheds of western Iowa: (a) current land use, (b) alternative land use pattern with current swine production (Alternative 1), and (c) alternative land use pattern with increased swine production (Alternative 2).



AGRICULTURAL POLICY could help to reduce the "dead zone" by prompting farmers to:

- More completely adopt traditional and innovative conservation practices, including residue management
- More efficiently apply fertilizer inputs
- Participate in upland and wetland habitat restoration
- Employ perennial crops – properly managed for conservation value

Landscape research

can improve understanding and management of
complex agricultural systems and
contribute to **science, policy & action.**