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National Conservation Program
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CROPLAND CONSERVATION ANALYSIS #1
OPTIMIZATION: AN APPROACH TO TARGETING ACRES, ALLOCATING FUNDING, AND DETERMINING ALTERNATIVES

The Issue

Across the United States, there is variability in primary conservation needs and the appropriate conservation management strategies to best address those needs. There is no silver bullet: No single practice or single suite of practices is appropriate for all cropland acreage. This section explores using an optimization model to select conservation practices that maximize the ecological benefits of Federal investments under alternative assumptions about conservation priorities, funding levels, and regional funding distributions. Conservation treatments considered in the model are various combinations of planting cover crops, utilizing drainage water management, adopting sound nutrient management, and adding structural practices to reduce runoff and soil erosion. These practices are generally added to existing conservation measures and contribute to a comprehensive conservation plan.

Treatment Needs Classification

The Conservation Effects Assessment Project (CEAP) Cropland modeling team has classified all cultivated cropland acres into categories based on their inherent vulnerability and the current level of conservation treatment in place. Conservation treatment needs fall under three classifications, depending on the severity of the conservation need and the efficacy of current conservation practices on that acreage:

- **High Conservation Need (HCN):** Acres with the highest levels of imbalance between the inherent site vulnerability and the conservation treatments currently in place.
- **Moderate Conservation Need (MCN):** Acres with moderate levels of imbalance between the inherent site vulnerability and the conservation treatments currently in place. Field-level losses exceed acceptable limits.
- **Low Conservation Need (LCN)**: Acres with adequate conservation practices in place to manage current field-level soil and nutrient losses at or below acceptable limits. Management is appropriate to site vulnerability. Additional gains can be realized on these acres, but generally at a lower benefit-cost ratio.

Figure 1 shows the percent of total cultivated cropland in each conservation need category, by region. The USGS divides and subdivides the country into successively smaller hydrologic units based on surface features (USGS 2011). At the coarsest scale, the conterminous United States are classified into regions (2-digit hydrologic units,[1] or HUCs). For purposes of these analyses, data were compiled at the 2-digit HUC scale and the New England and Mid-Atlantic HUCs were considered as one 2-digit HUC.

In the optimization analyses presented below, HCN and MCN acres are aggregated and referred to as **Priority Conservation Need (PCN)** acres. Table 1 reports total cultivated cropland acres, HCN acres, and PCN acres for each region, and figure 2 shows the distribution of PCN acres at the 4-digit HUC level. The Upper Mississippi, Ohio, Lower Mississippi, and Missouri regions contain the highest number of PCN acres. The region with the greatest percentage of its acres identified as PCN acres is the Lower Mississippi (86.4 percent of the 18.8 million acres of cultivated cropland acres are PCN), followed in order by the South Atlantic Gulf, Tennessee, and New England – Mid-Atlantic regions.

Focused conservation investment strategies require that decisions be made about which acres should be treated first and which treatments are expected to return the most bene-

[1] A hydrologic unit can accept surface water directly from upstream drainages and indirectly from associated surface areas. A HUC may have single or multiple outlets.

Figure 1. Percentages of conservation need acreage by category for 13 HUC-2 regions or group of regions

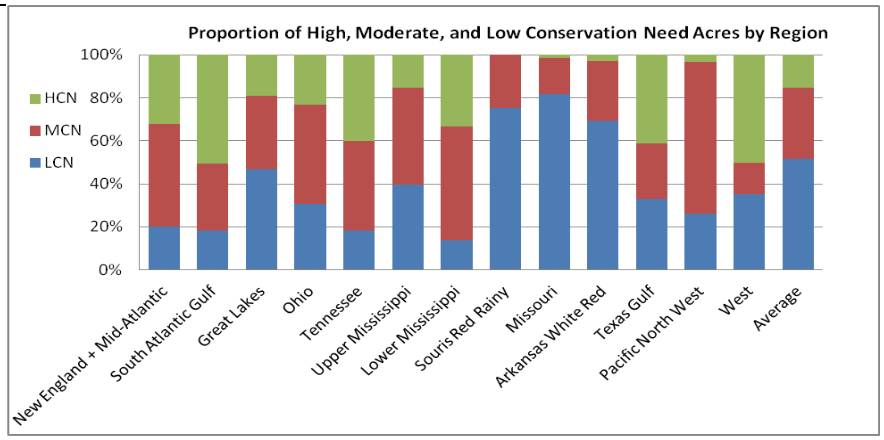
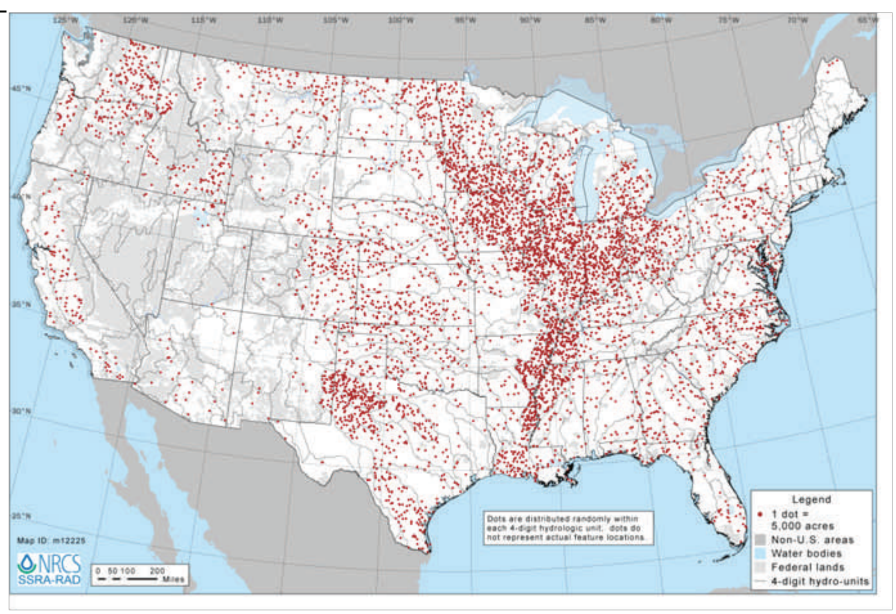


Table 1. High Conservation Need (HCN) and Priority Conservation Need (PCN) cultivated cropland acreage, by 2-digit HUC

Region	Total acres (thousands)	HCN acres (thousands)	Regional HCN percent	PCN acres (thousands)	Regional PCN percent
New England + Mid-Atlantic	5,989	1,926	32.2%	4,789	80.0%
South Atlantic Gulf	13,232	6,712	50.7%	10,838	81.9%
Great Lakes	14,804	2,842	19.2%	7,879	53.2%
Ohio	23,723	5,486	23.1%	16,445	69.3%
Tennessee	1,316	526	40.0%	1,073	81.6%
Upper Mississippi	58,154	8,980	15.4%	35,198	60.5%
Lower Mississippi	18,835	6,293	33.4%	16,273	86.4%
Souris Red Rainy	17,571	0	0.0%	4,343	24.7%
Missouri	83,615	1,127	1.3%	15,306	18.3%
Arkansas White Red	30,477	814	2.7%	9,375	30.8%
Texas Gulf	18,368	7,594	41.3%	12,329	67.1%
Pacific North West	11,650	388	3.3%	8,582	73.7%
West	6,610	3,327	50.3%	4,296	65.0%
Total or average	**304,342**	**46,015**	**15.1%**	**146,728**	**48.2%**

Figure 2. Cultivated cropland with priority conservation needs



fit per expenditure. These decisions will be influenced by a range of factors which may be simulated in the optimization model, including resource concern priorities, budget constraints, and considerations about equitable regional allocations of conservation funds. In actual application, the land manager's objectives are also a consideration.

In this document, the following optimization analyses are explored:

- **Optimization Analysis 1:** Maximize a single conservation benefit (nitrogen loss reduction) at different budget levels, with no restrictions on regional distribution of funds.
- **Optimization Analysis 2:** Maximize a single conservation benefit (nitrogen loss reduction) with a fixed budget and alternative assumptions about restrictions on the regional distribution of funds.
- **Optimization Analysis 3:** Maximize for alternative conservation benefits, with a fixed budget and no restrictions on regional distribution of funds.

Cover Crops in Select Regions

The South-Central, Southeastern, and Mid-Atlantic portions of the United States have critical needs for enhanced erosion reduction and nutrient loss prevention, and have the greatest potential to benefit from adding cover crops. These soils in general are inherently less fertile relative to those in the Midwest and Northern Plains and were some of the first soils to be intensively cultivated in the United States.

Adding cover crops to cropping systems in these regions typically costs between $48 and $69 per acre. If cover crops were added to all cultivated cropland acres needing treatment in these regions, estimated soil losses could potentially be reduced by 73 percent, nitrogen losses by 39 percent, and phosphorus losses by 44 percent; the current trend of soil carbon loss could be reversed and carbon could be sequestered. For a more detailed analysis of the benefits and costs of adding cover crops in these regions, please visit the RCA Web page, http://www.nrcs.usda.gov/technical/rca.

Conservation Treatment Options

Appropriate conservation treatment for any field depends on site-specific factors such as climate, soil type, slope and crop rotations. Conservation treatments considered in these analyses include cover crops, drainage water management, structural erosion control, and nutrient management. The optimization model selects the practice or combination of practices that should be implemented on a given acre, based on acreage needs in combination with costs and management goals, to maximize net benefits. Benefits calculated include net soil and nutrient edge-of-field loss reductions, reduced nutrient application levels, and carbon sequestration.

Cover Crops

Cover crops are grasses, legumes, or forbs grown when primary economic crops are not grown. Cover crop species are selected to be compatible with the components of the current cropping system and are terminated by harvest, frost, mowing, crimping, and/or herbicides in preparation for the following economic crop.

Cover crops serve many conservation functions. They provide soil surface cover, which reduces erosion and associated nutrient and contaminant losses. They sequester carbon and capture, recycle, and redistribute nutrients in the soil profile, thereby reducing nutrient leaching and soluble nutrient runoff. They also support biodiversity, provide supplemental forage, improve soil moisture, reduce soil compaction, and may promote biological nitrogen fixation. Cover crop biomass is often left on the field during the next growing season, providing a slow-release nutrient source and improving soils by increasing soil organic matter content. Cover crop adoption enhances soil's ability to retain nutrients, water, carbon, and contaminants, improving productivity and environmental quality. These benefits make cover crops an ideal practice for improving soil quality and water quality.

The presence or absence of cover crops was determined from farmer responses in the CEAP Cropland Survey conducted from 2003 to 2006 at selected National Resources Inventory (NRI) sample points, which provided the statistical basis for regional estimates. Simulated cover crops were inserted into baseline crop rotations according to the following rules:

- For every sample, in every crop year, if no crop was growing during the traditional winter period, a cover crop was planted the day after harvest or the day after the last major fall tillage operation. The crop's growth was simulated until the first spring tillage operation, or 2 weeks before the planting operation in the case of a no-till spring planting.
- Rye was used as the cover crop on all acreage.

- When simulation included cover crop adoption, there were no other changes to the baseline other than the addition of a broadcast seeder to plant the cover crop in the fall.

Drainage Water Management (DWM)
DWM practices manage water discharges from surface and/or subsurface agricultural drainage systems. A water-control structure is placed in a main, sub-main, or lateral drain as a means of varying the depth of the drainage outlet. These structures force the water table to rise above the enforced outlet depth before drainage can occur. When DWM was simulated, the outlet depth was raised after harvest to limit drainage outflow and reduce the losses of nitrate into ditches and streams; in early spring the outlet depth was lowered again to allow drainage prior to field operations.

The conservation benefits of DWM include reduction of nutrient, pathogen, and pesticide loading into drainage waters; improved productivity of plants due to extended water availability; reduced oxidation of organic matter in soils; reduced wind erosion; and improved wildlife habitat.

Erosion and Sediment Control (ESC)
The ESC treatment scenario adds structural practices (terraces, contouring, stripcropping, riparian buffers, and filter strips) where appropriate to control and trap runoff from the cropped area. These additional practices were applied in simulations using the following criteria:

- **In-field mitigation:**
  - ◊ Terraces were added in simulations to all sample points with slopes greater than 6 percent, and to points with slopes greater than 4 percent *and* a high potential for excessive runoff (hydrologic soil groups C or D). Although terraces may be too expensive or impractical to implement in all cases, they serve here as a surrogate for combinations of practices that control surface water runoff to an equivalent extent.
  - ◊ Contouring or stripcropping (overland flow practices) was simulated for all other fields with slopes greater than 2 percent that did not already have those practices and did not have terraces.
  - ◊ Concentrated flow practices were not applied in simulations since they occur on unique landscape situations within the field and are not geospatially definable with current CEAP technology.
- **Edge-of-field mitigation:**
  - ◊ Fields adjacent to water received a riparian buffer if one was not already present.
  - ◊ Fields not adjacent to water received a filter strip if one was not already present.

Erosion Control with Nutrient Management (ENM)
The conservation benefits of ENM include reduction of soil, nutrient, pathogen, and pesticide loadings associated with runoff and overapplication or inappropriate application of fertilizers, including manure. Appropriate nutrient management maximizes nutrient use efficiency; minimizes deleterious environmental impacts associated with nutrient losses; improves physical, chemical, and biological conditions in the soil; and reduces nitrogen emissions into the atmosphere. The 4 R's approach (see below) also typically enables land managers to apply less fertilizer each year.

The ENM scenario simulates:

- The ESC structural practices to control and trap runoff from the cropped area (see above), and
- **The "4 R's" approach:** Application of nutrients in an appropriate form, using an appropriate method of application, at an appropriate rate, and at an appropriate time to provide adequate nutrients for crop growth while minimizing losses to the environment.
  - ◊ **Right Source or Form:** In no-till systems, simulated commercial fertilizer form selected could be injected or knifed below the soil surface.
  - ◊ **Right Method:** If the current method of application did not include incorporation or injection, incorporation or injection was simulated. In no-till conditions slurried manures were simulated to be injected. Solid manures were simulated to be disked into the fields via mulch tillage.
  - ◊ **Right Rate:** Nutrient application rates were not changed if rates were lower than the limits discussed here. Reported nitrogen application rates above 1.2 times the crop removal rate were reduced to 1.2 times the crop removal rate for all crops except small grains and cotton. Small grain crop nitrogen application was reduced to 1.5 times the crop removal rate, and nitrogen application was reduced to 50 pounds per bale for cotton when necessary. Phosphorus application rates above 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation were adjusted to be equal to 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation. Application rates for all phosphorus applications in the rotation were reduced in equal proportions.

◊ **Right Timing:** All commercial fertilizer applications were adjusted to occur 14 days prior to planting, except for those acres susceptible to leaching. In the case of lands with high potential for increased leaching, nitrogen was applied in split applications, with 25 percent of the total application 14 days prior to planting and 75 percent 30 days after planting.

Cover Crops or DWM with ENM

The optimization analyses also consider the impacts of combining ENM with either cover crops or drainage water management, which can maximize the benefits of both practices.

Conservation Treatment Costs

Costs of applying conservation practices vary by practice and by location. This analysis includes two types of costs: technical assistance (TA), and total landowner costs (referred to as non-TA). TA costs include the government staff time and equipment needed to assist with conservation planning, and costs incurred by Technical Service Providers who are reimbursed by the government. Landowner costs included the full implementation and maintenance costs of the selected conservation practices. In some cases, where included in the official NRCS conservation program payment schedules, these costs included foregone income (where land is removed from production) and risk costs (to compensate for yield changes). Total landowner costs of adopting conservation practices, which may be partially paid by government financial assistance programs, include both annual and periodic expenses. For this analysis, both TA and non-TA costs are amortized to annual values to calculate per acre costs of applying each conservation practice or treatment.

For each treatment scenario, TA and non-TA costs were calculated for each NRI-CEAP sample point, based on the unique system of practices required for treatment at that point. The NRI-CEAP sample point acreage expansion factors were used to estimate total costs by region. The total cost of treating all 46 million HCN acres with the ENM suite of practices would be $2.8 billion per year, or $60 per acre per year. The total cost of treating all 147 million PCN acres with ENM would be $8.1 billion, or $55 per acre per year. However, in the analyses presented below, we allow the model to optimize not only the appropriate acreage for treatment, but also the appropriate suite of treatments to apply. Other conservation treatments are more cost effective on some fields. For example, when optimizing for nitrogen loss reductions at an $8 billion annual funding level, ENM is the selected treatment for 60 percent of PCN acres, whereas other treatments provide greater net benefits on the remaining 40 percent.

Optimization Analysis 1: Impact of Budget Levels on Conservation Achievement

State, regional, or Federal management priorities sometimes focus on a single aspect of soil and water quality. In this section we assume that nitrogen conservation is the singular focus in the national strategy for protecting water quality and promoting soil conservation. The optimization identifies the cropland acres that maximize net nitrogen loss reductions subject to a series of budget constraints, ranging from $250 million to $8 billion dollars per year (which is approximately the annual budget required to treat all PCN acres identified in the CEAP analysis with ENM). No regional restrictions for fund distribution were considered in this scenario.

The focus on reducing total nitrogen losses was chosen because CEAP studies indicate that on the national scale, nitrogen loss is the primary conservation issue for cropland and must be addressed in order to alleviate impacts on water quality. Nitrogen is lost through multiple forms and pathways. In soluble form, nitrogen may be leached through the soil profile and/or lost with surface runoff. Nitrogen may bind to soil particles and be lost to water and wind erosion. Nitrogen may also be lost directly to the atmosphere in gaseous form. Conservation practices that minimize nitrogen loss tend to provide other conservation benefits concurrently (soil, phosphorus, and carbon retention) and therefore provide cumulative benefits for multiple resource concerns.

The optimization exercise simulates treating the PCN acres with the highest return per dollar investment first, and therefore shows diminishing returns on conservation treatments as budget levels increase. Subsequently treated acres have either more costly needs or lower treatment benefits. The optimization was run for incrementally larger budgets (table 2), with the initial investment of $250 million showing the lowest cost per acre and a 17-percent reduction of total PCN acreage nitrogen losses relative to current losses. A $1.25 billion budget is required to double the nitrogen loss reduction achievable with a $250 million budget.

Treating cropland for one conservation goal, in this case decreasing nitrogen loss rates, generates accompanying benefits related to nitrogen application rates, phosphorus application and loss rates, and soil and carbon conservation (table 3). These ancillary benefits also tend to show diminishing returns on investment, but there are exceptions. Carbon sequestration, for example, more than quintuples (from 93.2 to 515.9 million pounds per year) when funding is increased from $250 to $500 million; increasing funding to $750 million nearly doubles carbon sequestration again (990.7 million pounds per year).

Table 2. Percent of potential acres treated and nitrogen (N) reductions across alternative budget levels
M = million dollars, B = billion dollars

Budget ($)	250 M	500 M	750 M	1 B	1.25 B	1.5 B	2 B	4 B	8 B
N loss reduction (million lbs)	979	1,345	1,604	1,813	1,990	2,143	2,398	3,048	3,529
N loss reduction relative to current PCN N loss (%)	17	23	28	32	35	37	42	53	62
Acres treated (million)	11.2	19.3	27.0	33.3	39.5	45.2	56.0	91.0	134.1
PCN acres treated (%)	8	13	18	23	27	31	38	62	91
Cost per acre ($)	22.32	25.93	27.82	30.03	31.62	33.19	35.70	43.96	59.66

Table 3. Accompanying benefits of maximizing nitrogen reductions for alternative budget constraints
M = million dollars; B = billion dollars; N = nitrogen, C = carbon, P = phosphorus

Budget ($)	250 M	500 M	750 M	1 B	1.25 B	1.5 B	2 B	4 B	8 B
Budget (%)	3	6	9	13	16	19	25	50	100
PCN acres treated (%)	8	13	18	23	27	31	38	62	91
N loss reduction relative to current N loss (%)	17	23	28	32	35	37	42	53	62
C gains* relative to current losses (%)	2	10	18	26	35	43	58	99	130
Soil conserved relative to current losses (%)	6	12	17	21	24	27	33	50	63
P loss reduction relative to current P loss (%)	9	14	18	22	25	28	33	47	62
P application reduction (%)	6	7	9	10	10	11	12	16	23
N application reduction (%)	5	8	9	11	11	12	14	17	22

** Net carbon loss for the aggregate of all PCN acres is eliminated at about the $4B dollar funding level, and investments beyond that contribute to positive net carbon accumulation on PCN acres.*

Optimization Analysis 2: Exploring Constraints on the Regional Distribution of Funds

When conservation priorities are maximized on the national scale with no regard to regional distribution, some areas of the country receive less conservation funding than others, primarily due to an uneven distribution of conservation needs and potential conservation gains per dollar spent. Therefore, the optimization scenario discussed above does not assist policymakers in the difficult decisions related to regional distribution of Federal funds. As it is unlikely that Federal funds would be distributed based on national level analysis without regard to regional considerations, the following analysis explores five alternatives for optimizing funding distribution across the United States.

1. No regional restriction on fund distribution (as in optimization analysis 1).
2. Treated acreage distribution is proportional to distribution of PCN acres at the HUC-2 scale (if a HUC contains 5 percent of the Nation's PCN acres, it receives funding adequate to address 5 percent of the Nation's treated acres).
3. Funding distribution is proportional to distribution of PCN acres at HUC-2 scale (if a HUC has 5 percent of the Nation's PCN acres, it receives 5 percent of national funding).
4. Funding distribution is proportional to distribution of total cropland at HUC-2 scale (if a HUC contains 5 percent of the Nation's cropland, it receives 5 percent of national funding).
5. Funding distribution is proportional to total baseline nitrogen losses at HUC-2 scale (if a HUC accounts for 5 percent of Nation's total baseline nitrogen loss, it receives 5 percent of national funding).

All of the analyses in this section assume an annual budget of $500 million, with the continued singular objective of maximizing reduction of nitrogen loss. Table 4 and figure 3 show how treatment distributions vary by scenario.

With no regional distribution restrictions in place, the Lower Mississippi, South Atlantic Gulf, New England + Mid-Atlantic, and Tennessee regions would receive more funding than they would under the other distribution scenarios. Figure 4 shows the distribution of PCN acres treated under the no regional restrictions scenario, in terms of percent of total acres treated. For this funding scenario, an additional 1.3 billion pounds of nitrogen loadings could be prevented annually. Figure 5 shows the optimal distribution of PCN acres treated when funding is restricted to be proportional to baseline cropland acreage. Distributing funds in proportion to the amount of U.S. cropland in each region would send 29 percent of total funding to the Missouri region, even though a much smaller proportion of the cropland in this region is PCN (see table 4).

By imposing regional constraints on funding distributions, achievable nitrogen reduction benefits decrease because the geographic constraints may require treating acres with lower benefits per dollar in one region rather than higher priority acres in another region that has already used all of

Table 4. Percent of treated acres distributed to each 2- digit HUC under various funding distribution scenarios

HUC-2	No regional restrictions	Acreage proportional to PCN acreage	Funding proportional to PCN acreage	Funding proportional to cropland	Funding proportional to nitrogen loss
	- - - - - - - - Percent of nationally treated acres in each HUC - - - - - - - -				
New England + Mid-Atlantic	4.2	3.3	2.4	1.7	3.1
South Atlantic - Gulf	11.5	7.4	5.4	3.3	7.1
Great Lakes	7.3	5.4	6.3	5.5	7.5
Ohio	7.3	11.2	9.7	6.8	9.4
Tennessee	1.7	0.7	0.6	0.3	0.7
Upper Mississippi	14.8	24.0	17.9	14.4	17.5
Lower Mississippi	19.0	11.1	14.4	8.9	15.9
Souris - Red - Rainy	0.8	3.0	2.8	4.8	1.9
Missouri	9.1	10.4	15.3	29.4	10.7
Arkansas - White - Red	5.0	6.4	6.3	10.5	5.0
Texas Gulf	3.4	8.4	7.0	4.9	5.6
Pacific Northwest	6.1	5.8	5.3	3.6	5.3
West	10.0	2.9	6.6	5.9	10.3
Acres treated (1,000s)	**19,275.5**	**21,576.1**	**20,583.8**	**21,217.1**	**20,215.4**

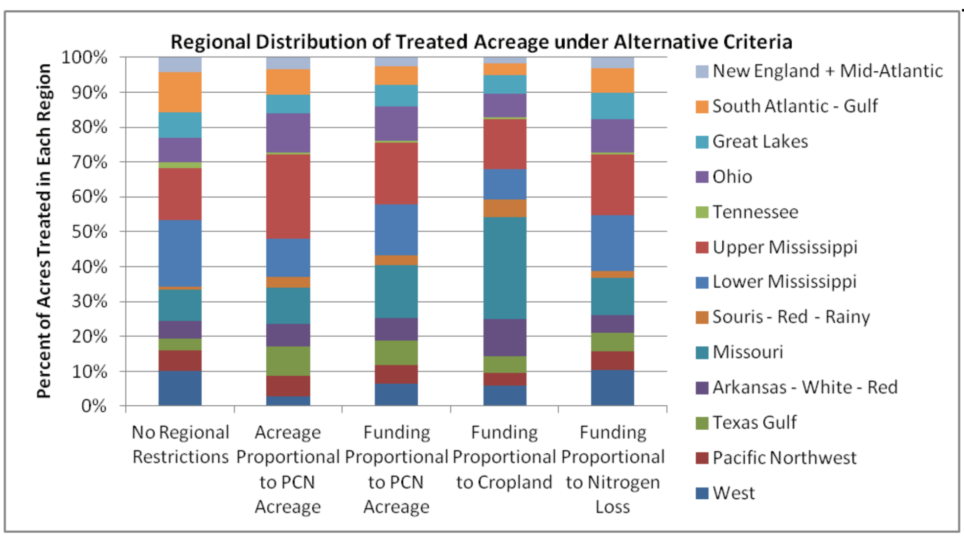


Figure 3. Proportion of total treated acres within each HUC-2 region or group of regions under alternative funding distribution scenarios

Figure 4. PCN acres treated with no regional funding restrictions

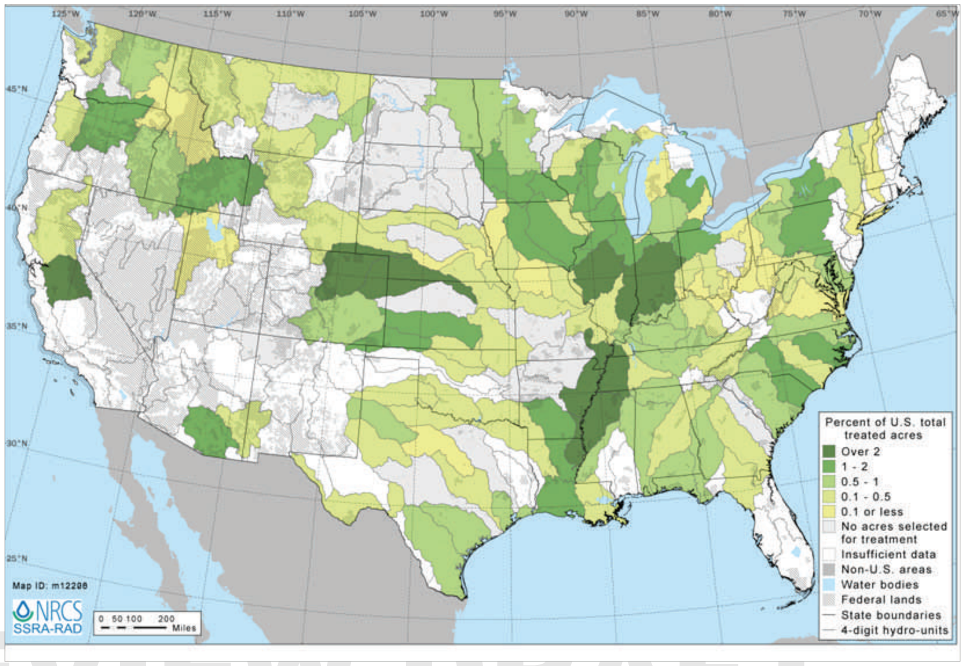
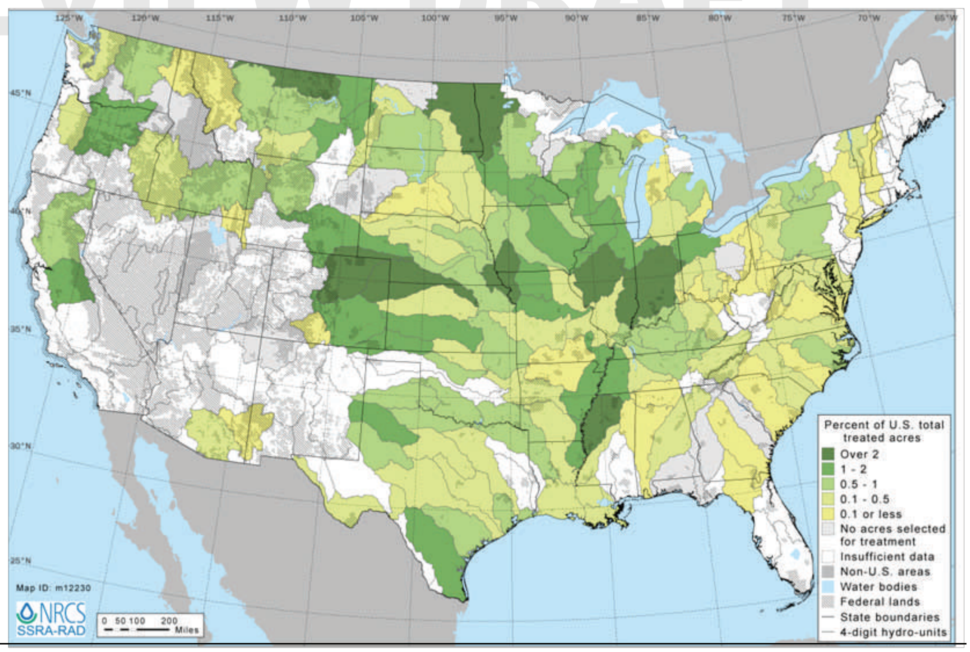


Figure 5. PCN acres treated with funding proportional to distribution of cropland acreage



SOURCE: NRCS

its simulated funds. Among the constrained scenarios considered, the highest nitrogen reduction gains are associated with distributing funding proportional to current nitrogen losses, which would achieve 98 percent of the nitrogen loss benefits of the geographically unconstrained distribution, and would treat more acres at a lower average cost per acre (table 5, fig. 6). When compared to the geographically unconstrained distribution, this funding distribution would shift funds to the Upper Mississippi, Ohio, Missouri, and Texas Gulf regions, and away from the South Atlantic-Gulf, Lower Mississippi, New England + Mid-Atlantic, and Tennessee regions. Just as primary objective gains (nitrogen loss reduction) vary by funding distribution, so too are ancillary benefits affected. For example, distributing funding in proportion to regional cropland acreage would return only 85 percent of the nitrogen loss conservation gains that could be achieved if no regional restrictions were placed on funding allocations, but this scenario maximizes both soil and carbon retention as compared to the other scenarios.

Table 5. Comparison of gains under alternative funding distribution scenarios

	No regional restrictions	Acreage proportional to PCN acreage	Funding proportional to PCN acreage	Funding proportional to cropland acreage	Funding proportional to nitrogen loss
Acres treated (millions)	19.3	21.6	20.6	21.2	20.2
Nitrogen loss reduction (million pounds)	1,344.9	1,286.1	1,254.2	1,139.6	1,317.1
Phosphorus loss reduction	87.2	85.3	85.3	79.3	87.2
Soil savings (million tons)	59.3	56.4	65.8	66.3	62.0
Carbon sequestration (million pounds)	516.0	691.5	849.3	986.3	647.2
Nitrogen application reduction (million pounds)	1,411.4	1,347.9	1,275.9	1,143.2	1,375.6
Phosphorus application reduction (million pounds)	227.0	214.9	189.0	158.3	216.8

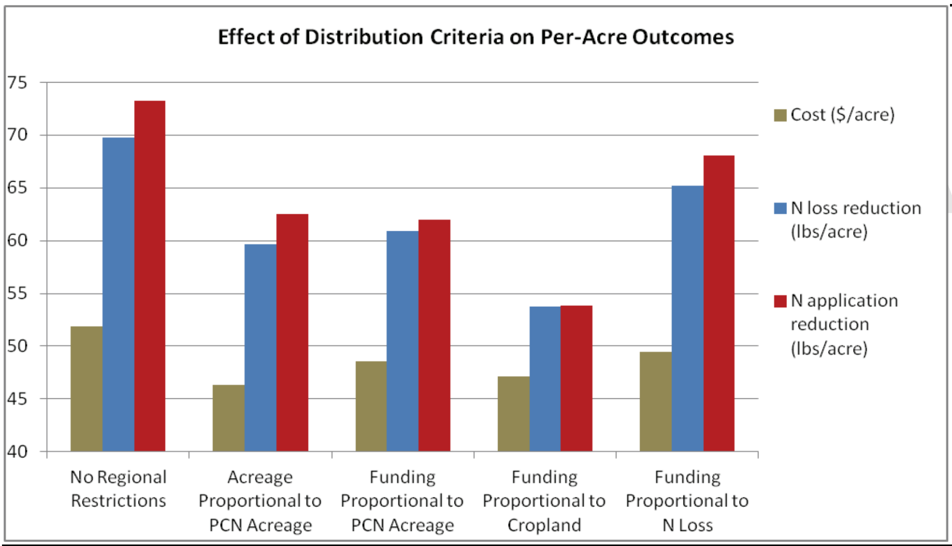


Figure 6. Cost per acre and nitrogen loss and fertilizer reductions per acre under various funding distributions

Optimization Analysis 3: Maximize for Multiple Conservation Benefits

Conservation practices often impact multiple resource concerns, and suites of practices will have interdependent impacts. Focusing solely on a single conservation goal will achieve ancillary benefits, as shown above, but may also have undesirable consequences for other conservation goals. For example, managing nitrogen loss by controlling surface runoff often results an increase in the percolation of soluble nutrients. No one conservation practice or suite of practices is the best option for all cultivated cropland.

Using a multi-criteria optimization model allows policymakers and landowners to maximize multiple interacting conservation goals. For example, nitrogen loss reductions could be maximized subject to concurrently achieving other environmental benefits, such as soil retention, reduction of nutrient inputs, reduction of phosphorus losses, or sequestration of carbon. The optimization model could be increased in complexity to allow weighting of various conservation goals. Determining the best set of weights for various conservation goals is beyond the scope of this analysis, but the analysis below does include one scenario that optimizes a specific combination of nitrogen reduction and carbon accumulation benefits.

Here we report on simpler techniques used to explore the feasible range of outcomes related to prioritizing conservation goals. Estimated outcomes for the following six conservation goals were obtained, again for a set annual budget of $500 million and with no restrictions on regional funding distributions:

1. Maximize reduction of total nitrogen loss
2. Maximize reduction of total phosphorus loss
3. Maximize reduction of total waterborne soil loss

4. Maximize reduction of total windborne soil loss

5. Maximize accumulation of total soil carbon

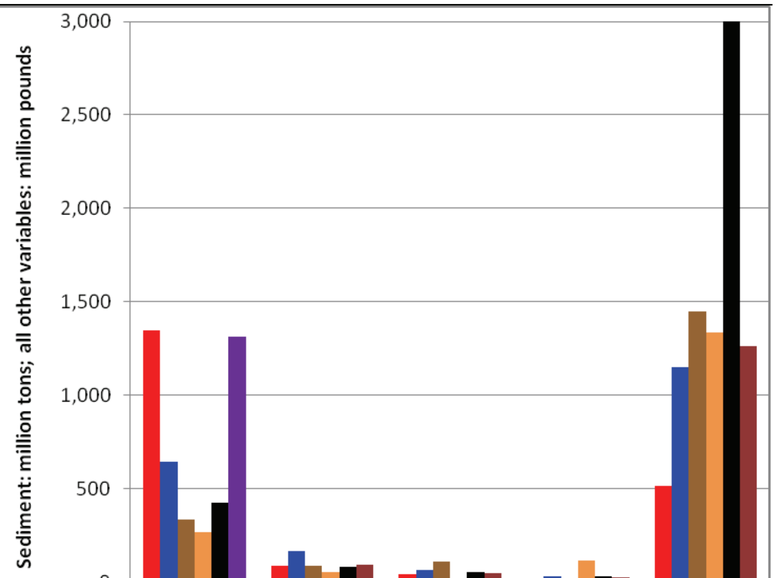
6. Maximize the sum of ten times the nitrogen loss reduction *plus* soil carbon accumulation

The impacts of these six alternative management scenarios can be compared in a loss reduction matrix (fig. 7). The values found at the intersection of each goal and its outcome show the potential “best case scenario” outcome, which results when that goal is optimized in isolation from the other goals. For example, if reduction of nitrogen loss were the only management goal, 1,345 million pounds of nitrogen and 87 million pounds of phosphorus could be conserved. If phosphorus loss were the only management goal, 167 million pounds of phosphorus could be conserved, but nitrogen loss would be reduced by only 644 million pounds.

When management focuses on a singular priority, ancillary impacts would vary considerably across benefits categories. For example, nitrogen loss reductions range from 1,345 million pounds when nitrogen is the management priority, to 269 million pounds when reducing wind erosion is the priority. Similarly, carbon accumulation ranges from 3,001 million tons when soil carbon is the management priority, to 516 million tons when nitrogen loss reduction is the priority.

The sixth management scenario, a dual nitrogen-carbon optimization scenario, demonstrates an important capability of optimization: managing systems for more than one conservation goal. In this case, the optimization criteria chosen maximized important aspects of soil health (carbon) and water quality conservation (nitrogen). Any weights can be chosen for the factors, depending on conservation priorities. Here, the weights of 10 for nitrogen and 1 for carbon are used because nitrogen loss reduction was the primary concern of interest, so treatments were heavily weighted for nitrogen loss reduction while still considering means to optimize carbon loss reduction. The outcome of this dual-goal scenario demonstrates substantial conservation achievements for both criteria. The gains in nitrogen loss reduction are 98 percent of the gains achieved under the less robust scenario where nitrogen loss reduction alone is optimized, while soil carbon accumulation is 144 percent larger than it is in the optimization scenario with the sole goal of nitrogen loss reduction.

Figure 7. Optimal conservation outcomes and accompanying benefits for various management priorities



	N	P	Soil (water)	Soil (wind)	Soil C
Reduce N loss	1,345	87	42	18	516
Reduce P loss	644	167	66	31	1,148
Reduce soil loss (water)	337	87	109	3	1,447
Reduce soil loss (wind)	269	52	3	115	1,334
Increase soil C	425	79	53	33	3,001
Weighted: 10N+1C	1,314	94	48	24	1,261

In this exercise no controls were placed on acreage or funding distributions across regions. Because different parts of the country have different conservation needs, prioritizing one conservation concern over another at the national scale will skew acres treated to the parts of the country most severely in need of conservation measures to address that particular concern (fig. 8). Total acreage treated under the six scenarios ranged from a maximum of 21.6 million acres when the goal was a reduction in water erosion impacts on soil losses to a minimum of 19 million acres treated when the goal was a reduction in wind erosion impacts on soil losses (table 6).

The optimization results clearly demonstrate that adopting a universal conservation management practice is not the best approach for either conservation gains or per-dollar returns (fig. 9). The optimization model determined which practices should be implemented on a given acre based on acreage needs in combination with costs and management goals. Alternative optimization criteria have a large impact on treatments chosen, but characteristics of individual acreage needs also determine appropriate management choices. Under no optimization scenario did the model treat all acres with the same conservation practice.

Figure 8. Proportion of total treated acres within each HUC-2 region under six different treatment scenarios

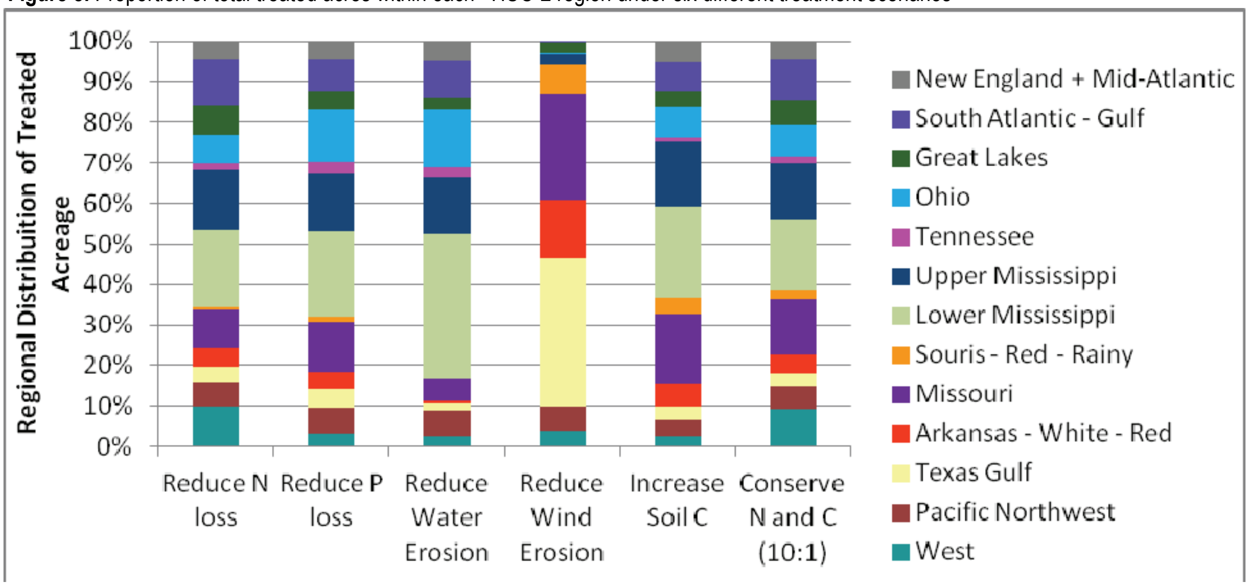
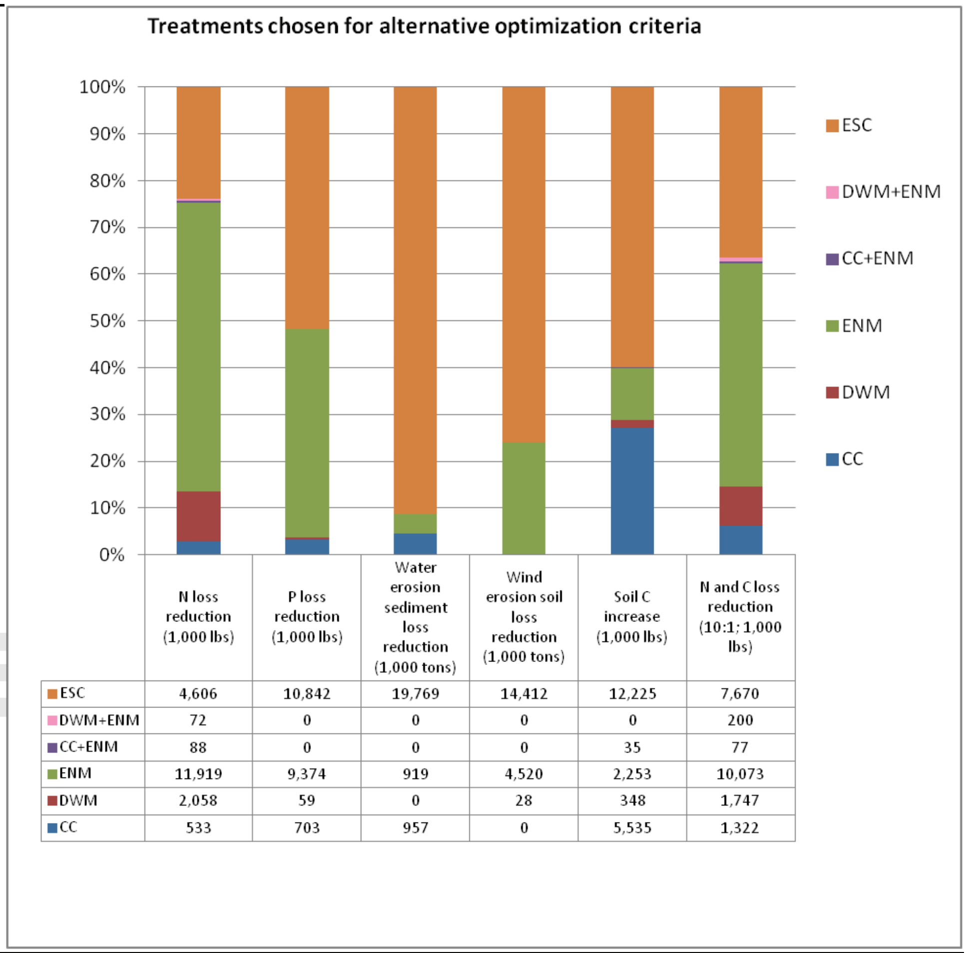


Table 6. Total treated acres (thousands) within each HUC-2 region under six different treatment priority scenarios

HUC	Reduce N loss	Reduce P loss	Reduce soil loss (water)	Reduce soil loss (wind)	Increase soil C	Conserve N and C (10:1)
			Treated Acres (thousands)			
New England + Mid-Atlantic	810	900	981	9	1,009	892
South Atlantic - Gulf	2,207	1,698	2,039	32	1,492	2,231
Great Lakes	1,400	903	618	550	791	1,261
Ohio	1,404	2,780	3,063	19	1,566	1,617
Tennessee	323	560	535	6	207	340
Upper Mississippi	2,850	3,001	3,059	448	3,254	2,891
Lower Mississippi	3,668	4,394	7,731	31	4,578	3,688
Souris - Red - Rainy	147	280	0	1,354	824	510
Missouri	1,750	2,645	1,202	4,953	3,513	2,851
Arkansas - White - Red	959	796	115	2,745	1,113	1,001
Texas Gulf	650	1,044	365	6,911	732	683
Pacific Northwest	1,177	1,284	1,416	1,158	812	1,203
West	1,930	693	523	744	505	1,921
National Total	19,276	20,979	21,645	18,960	20,396	21,089



	N loss reduction (1,000 lbs)	P loss reduction (1,000 lbs)	Water erosion sediment loss reduction (1,000 tons)	Wind erosion soil loss reduction (1,000 tons)	Soil C increase (1,000 lbs)	N and C loss reduction (10:1; 1,000 lbs)
ESC	4,606	10,842	19,769	14,412	12,225	7,670
DWM+ENM	72	0	0	0	0	200
CC+ENM	88	0	0	0	35	77
ENM	11,919	9,374	919	4,520	2,253	10,073
DWM	2,058	59	0	28	348	1,747
CC	533	703	957	0	5,535	1,322

Figure 9. Treatment instances by management priority

ESC = Erosion and Sediment Control; ENM = Erosion Control with Nutrient Management; DWM = Drainage Water Management, CC = Cover Crops.

Conclusions

American agriculture is faced with increasing demands for food, feed, fiber, and fuel production concurrent with increasing pressures to institute environmentally responsible and sustainable production systems. These demands are occurring at a time when Federal budgets for conservation face significant funding reductions. Difficult decisions must be made to ensure that conservation investments return maximum conservation benefits. Optimization models supported by CEAP estimates provide policymakers with a powerful tool to develop insights into how to maximize conservation gains under various combinations of conservation priorities, funding levels, and regional funding distributions.

CEAP has classified all cultivated cropland acres into High, Moderate, or Low Conservation Need acreage. Targeting all High Conservation Need (HCN) acreage with the same treatment is an easy solution, but would not make the best use of limited conservation dollars (fig. 10). For example, treating all HCN acres with ENM would require a $2.8-billion investment and could reduce nitrogen losses by an estimated 27 percent (1.5 billion pounds). Estimated ancillary benefits include the reduction of soil losses to wind and water erosion by 35 percent, phosphorus losses by 31 percent, and carbon losses by 52 percent.

However, the CEAP optimization model used here demonstrates what conservation experts already know—no single suite of practices works best on all cropland. With an optimization approach that considers a variety of possible conservation treatments—including expanded use of cover crops and drainage water management in combination with erosion control and nutrient management—and that allows treatment of Moderate Conservation Need (MCN) acreage or HCN acreage based on per-acre benefit per dollar invested, the same $2.8 billion investment could reduce nitrogen losses by 47 percent (2.7 billion pounds), reduce soil losses to wind and water erosion by 45 percent, reduce phosphorus losses by 39 percent, and reduce carbon losses by 77 percent. Instead of treating only the 46 million HCN acres, the $2.8 billion would treat 28.2 million acres of HCN and 43.2 million acres of MCN cropland. As shown in Optimization Analysis 1, an optimized $500 million investment could reduce nitrogen loss by an estimated 23 percent (1.3 billion pounds).

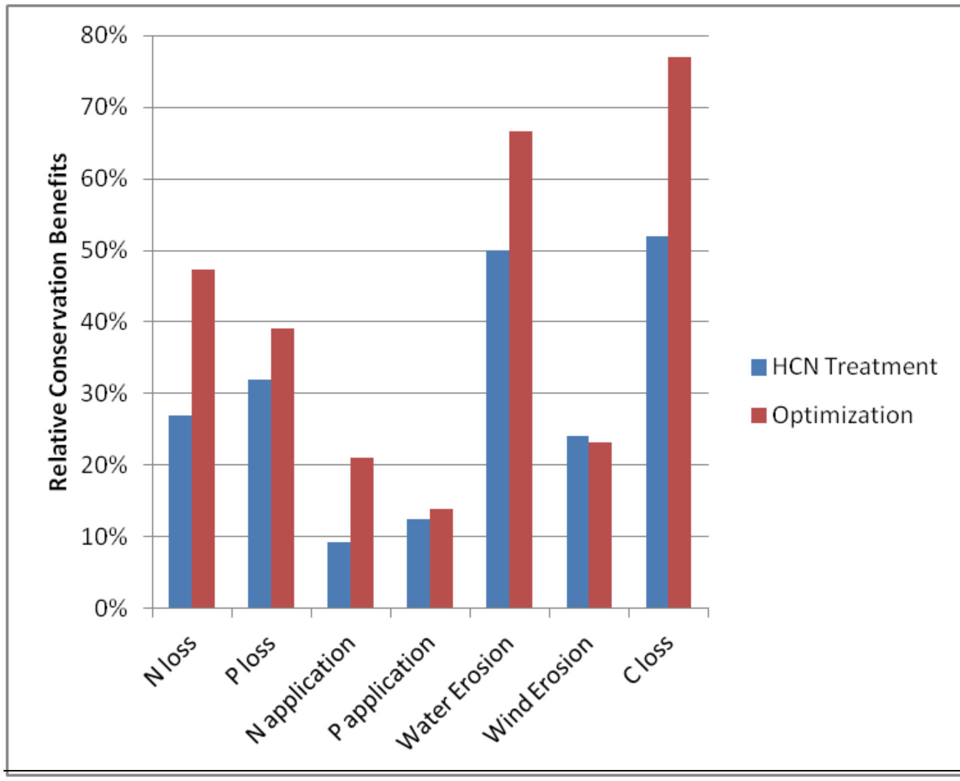


Figure 10. Relative benefits of treating HCN acres for Erosion Control with Nutrient Management (ENM) compared to applying an Optimization strategy targeting nitrogen loss with no regional restrictions

Primary conservation needs and appropriate conservation management strategies to address those needs vary across the United States. The optimizations presented here show the range of possible outcomes for alternative conservation priorities and demonstrate the advantages of taking current conservation efforts into account and selecting different treatments for different locations. These optimizations each assumed a particular management priority at the national scale. However, since conservation needs vary across the country, it may be more beneficial to prioritize conservation objectives at the 2- or 4-digit HUC scale rather than at the national scale.

The optimizations presented here focused on reducing nitrogen losses because CEAP studies indicate that on the national scale, nitrogen loss is the primary conservation issue for cropland and must be addressed in order to alleviate impacts on water quality. It was also shown that optimizing for more than one resource concern can substantially increase the overall effectiveness of treatment by providing an improved suite of benefits. The example used was a 10:1 nitrogen to carbon scenario, which achieved 98 percent of the nitrogen loss reduction and 144 percent more carbon conservation as compared to a scenario focused on nitrogen loss reductions alone.

Another option that optimizations allow is the ability to examine the actual load reduction estimates and focus efforts on the geographic regions supplying the greatest environmental benefits. Figure 11 shows estimated nitrogen load reductions for a scenario that combines the 10:1 nitrogen to carbon optimization with a $500 million dollar investment and with funding proportional to baseline Priority Conservation Need (PCN) acres. The greatest load reductions would occur in the Upper and Lower Mississippi River regions and in the northern portions of the Ohio River region.

This section shows the power and versatility of optimization techniques when used with the CEAP estimates of conservation treatment needs. The ability to visualize conservation problems, potential benefits, and various funding distribution mechanisms empowers policy makers to explore the best solutions for addressing both national problems, and pointed issues, such as Gulf hypoxia.

Reference

USGS. 2011. Federal standards and procedures for the National Watershed Boundary Dataset (WBD). Chapter 3 of Section A, Federal Standards. Book 11, Collection and delineation of spatial data. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_021581.pdf Accessed 9 February 2012

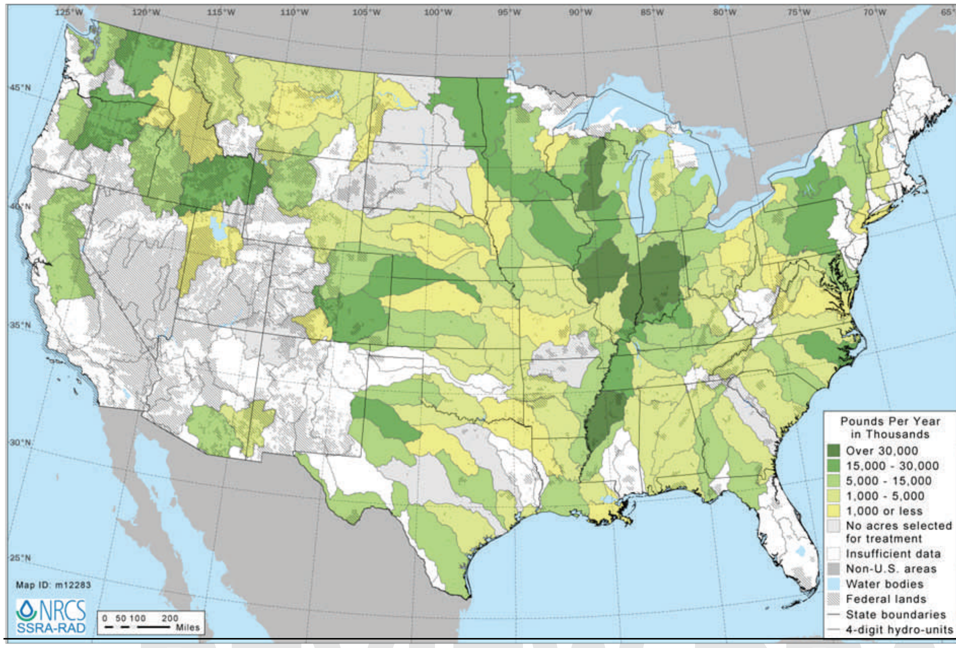


Figure 11. Nitrogen loss reductions on PCN acres, $500 million optimization for 10:1 nitrogen to carbon ratio, with funding proportional to baseline PCN acres (pounds per year)