The Conservation Effects Assessment Project (CEAP): a national scale natural resources and conservation needs assessment and decision support tool

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Abstract. The Conservation Effects Assessment Project (CEAP) was initiated to quantify the impacts of agricultural conservation practices at the watershed, regional, and national scales across the United States. Representative cropland acres in all major U.S. watersheds were surveyed in 2003-2006 as part of the seminal CEAP Cropland National Assessment. Two process-based models, the Agricultural Policy Environmental eXtender (APEX) and the Soil Water Assessment Tool (SWAT), were applied to the survey data to provide a quantitative assessment of current conservation practice impacts, establish a benchmark against which future conservation trends and efforts could be measured, and identify outstanding conservation concerns. The flexibility of these models and the unprecedented amount of data on current conservation practices across the country enabled Cropland CEAP to meet its Congressional mandate of quantifying the value of current conservation practices. It also enabled scientifically grounded exploration of a variety of conservation scenarios, empowering CEAP to not only inform on past successes and additional needs, but to also provide a decision support tool to help guide future policy development and conservation practice decision making. The CEAP effort will repeat the national survey in 2015-2016, enabling CEAP to provide analyses of emergent conservation trends, outstanding needs, and potential costs and benefits of pursuing various treatment scenarios for all agricultural watersheds across the United States.

Additional Keywords: agriculture, APEX, CEAP, conservation impacts, resource assessment, simulation modelling, SWAT

1. Introduction

In the 2002 Farm Bill the United States Congress increased funding levels for conservation programs and initiatives by 80 percent compared to funding levels set in the previous Farm Bill. Administered through the United States Department of Agriculture (USDA), these funds support technical assistance and provide financial incentives to farmers and land managers to encourage voluntary conservation practice adoption on private lands. The commitment to an annual $3.5 billion dollar investment of Federal resources was accompanied by a Congressional request for greater accountability to ensure the magnitude of water quality and ecosystem service benefits achieved were commensurate with the American taxpayer investment [1]. This request exposed the need for a means of quantifying conservation practice benefits at regional and national scales. Although field-scale experiments generally supported the widespread assumption that conservation practices provide benefits, the extent to which conservation practices were achieving their intended functions of reducing edge-of-field losses of soil, nutrients, pesticides, and pathogens while supporting a sustainable and healthy agro-ecosystem was undocumented [2].

In 2003, in response to the imperative to quantify the watershed scale benefits of conservation investments, the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) launched the Conservation Effects Assessment Project (CEAP), a multi-agency effort. CEAP's goal was to apply scientific inquiry and analyses to quantify impacts of conservation dollar investments at the national and large watershed scales. With regional and state support, CEAP continues to strengthen collaborations across academia and the interagency within five component areas: Cropland, Grazing lands, Wetlands, Wildlife, and Watersheds [3]. CEAP's Cropland National Assessment, or Cropland CEAP, focuses on quantifying impacts of cultivated cropland management and conservation practices on soil health and water quality at local, regional, and national scales. The Grazing lands component focuses on the impacts of conservation practice implementation on rangeland, pastureland, and grazed forests. The Wetlands and Wildlife components consider conservation practice impacts associated with their respective themes. The Watershed component complements all other components by providing detailed and landscape-specific assessments of a variety of benefits provided by conservation practices. These studies within the Watershed component provide scientific support for more detailed modelling of agricultural production and watershed hydrologic processes at a fine scale of resolution for selected watersheds, which contributes to improvement of regional and national scale modelling efforts [4]. Numerous academic and federal researchers are involved with CEAP related research and serve as peer reviewers for CEAP related products.

The remainder of this manuscript describes the structure and utility of the Cropland CEAP effort. Through application of a sound statistical approach to data collection and a well-validated modelling approach to estimating impacts of agricultural land management and conservation practices on natural resource concerns, Cropland CEAP has produced regional-scale reports on ten major river basins in the U.S., with reports on four additional large watersheds in development [5]. These publicly available reports provide detailed information on current (2003-2006) agricultural and conservation management and the resultant fate and transport of water, sediment, soil, nutrients, and pesticides, at the edge-of-field and landscape scales. These reports quantify the range of benefits provided by conservation practice adoption in the context of conservation concerns and ecosystem services, including water quality and soil health [6]. By informing Congress and other governmental entities of agricultural conservation successes and outstanding opportunities, these reports inform policy and improve development and implementation of future conservation programs and initiatives.

2. Data Collection for the CEAP Cropland National Assessment (2003-2006)

This section describes the data collection efforts that informed Cropland CEAP's benchmark reports. Large-scale monitoring efforts similar to some of the U.S. national effort informing CEAP are underway across the globe, and include efforts by the Australian Soil Resource Information Service (ASRIS), the Indian Bureau of Soil Survey and Land Use Planning (ICAR), the United Nation's

Office of Outer Space Affairs' Natural Resources Management and Environmental Monitoring Program (NRM&EM), and others.

The Conservation Effects Assessment Project's task was daunting in scope and complexity. In the United States in 2007 approximately 304.9 million acres were maintained in cultivated cropland and an additional 31.5 million acres of agricultural land were enrolled in the Conservation Reserve Program (CRP). Initiated in 1985, the CRP is a Federal conservation program in which enrolled farmers enter long-term contracts to remove highly erodible land from agricultural production and maintain it in continuous perennial or woody cover [7]. U.S. cultivated cropland acres support a broad variety of crops, cropping systems, and conservation practices. Field office records show over 1.6 million *new* unique combinations of conservation practices were applied to over 62.8 million cropland acres between 2003 and 2006. Estimating benefits from conservation practice adoption is further complicated by the fact that in many cases the new conservation practices were adopted on land with conservation practices already in place. Further, regional variability in soils, topography, and climate across the country contribute to variability in conservation needs and impact the magnitude of benefits derived by specific practices and suites of practices.

In the development of the Cropland CEAP benchmark reports, four data sources supported the modelling effort: the 2003 National Resource Inventory (NRI), the NRI Cropland CEAP Survey, NRCS field office records, and USDA Farm Service Agency (FAS) data [8]. CEAP was able to respond to the Congressional request for accountability so quickly because of its reliance on the successes of past monitoring efforts, including the NRI. Since 1977 the NRCS has used the NRI to provide scientific assessments of the status, conditions, and trends of natural resources across the United States in order to support agricultural and environmental policy development and program implementation. The NRI consists of a statistically designed longitudinal survey of over 200 attributes related to spatial and temporal trends in soil, water, and related natural resources on non-Federal lands in the U.S. [9]. Each NRI sampling point is linked to NRCS Soil Survey databases, which include associated soil characteristics and climate data. The well-tested, well-designed, and ever improving framework of the NRI has consistently proven to be a valuable source of nationally consistent and scientifically credible data for analysing agro-ecological impacts, economic impacts, and policy implications of land-use change [10]. Cropland CEAP's adaptation of the NRI's sampling design was logical, as it allowed CEAP to quickly establish a statistically sound national sampling protocol. A similar sampling approach could be adapted to any geographical setting.

The NRI's design supports a valid means of collecting important model inputs and a statistically sound means of assimilating and interpreting modelled results at large spatial scales [11]. A sub-sample of 31,189 NRI cropland points included in the 2002 and 2003 annual NRI surveys provided data for the national Cropland CEAP reports (Figure 1). This subsample represented about 98 percent of the diversity of cultivated cropland across the United States. However, early Cropland CEAP modelling efforts based on these NRI site specific data suggested that more information was needed to meet CEAP's goals of providing a scientifically credible assessment of agricultural conservation practice adoption impacts on the nation's natural resources [12].

To meet this need, NRCS partnered with the National Agricultural Statistics Service (NASS) to develop the NRI-CEAP Farmer Survey in order to collect more detailed information on land use and conservation practice implementation at each NRI point [13]. From 2003 to 2006 NASS-trained non-Federal enumerators administered the survey to farmers and land managers responsible for management on agricultural land at each of the 31,189 NRI cropland points. Participation in the survey was *voluntary*, with no penalties imposed on those who opted not to participate and no incentives provided to those who did participate. All proprietary information included in the survey, such as information on land management (crops grown, planting and harvesting dates, nutrient and pesticide applications, tillage applications, and conservation practice use, etc.), is held in the strictest confidence.

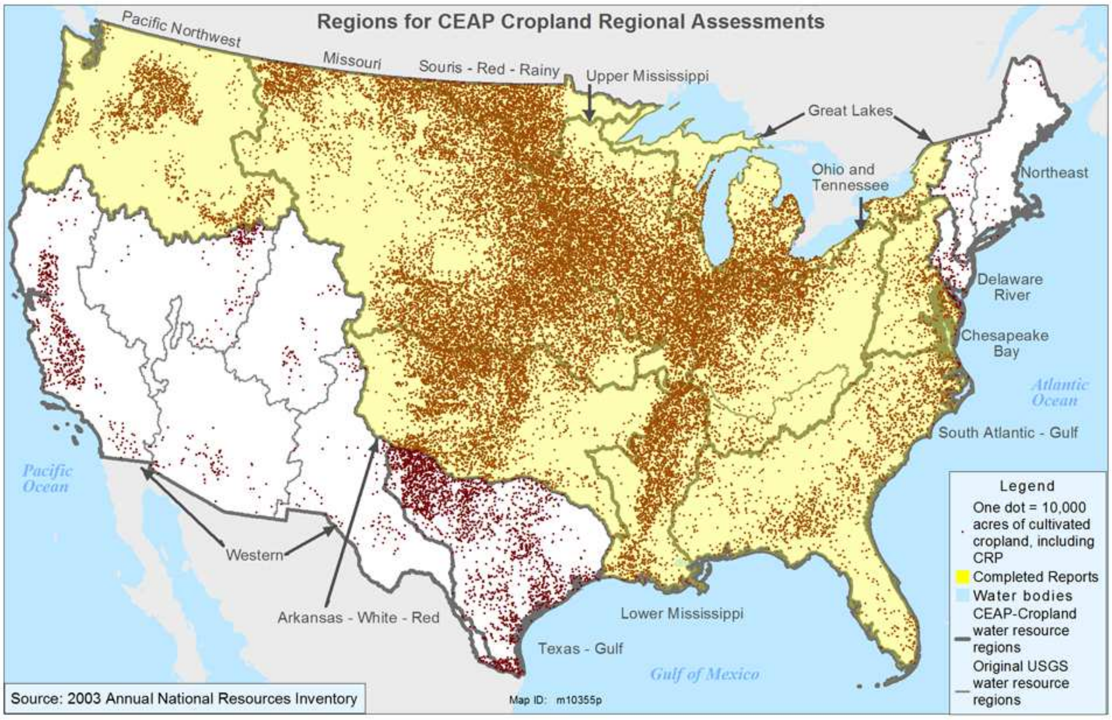

Figure 1. National Resource Inventory (NRI) points are part of a statistically sound sampling framework that allows expansion factors to be applied to data collected at each point. The NRI-CEAP points shown here are the subsample (31,189) of NRI cropland points (300,000) used to inform the benchmark CEAP reports. Cropland points include agricultural land currently enrolled in the Conservation Reserve Program (CRP), through which these acres are temporarily removed from production agriculture and maintained in perennial or woody cover. The 31,189 NRI points were sampled over the period of 2003 to 2006 and have informed all of the benchmark regional watershed scale CEAP Cropland National Assessments. Reports have been published for watersheds represented in yellow.

Across the United States NRCS field office specialists work directly with land-owners and land-managers to provide technical assistance and develop comprehensive conservation plans that are soil, climate, and land-use appropriate. These land management data, recorded by NRCS field office personnel, complemented the NRI and supplementary NASS survey data. The final source of management related model input data came from the USDA – Farm Service Agency (USDA-FSA), which provided information on agricultural lands enrolled in various conservation programs [14]. In addition to detailed land management data collected from these four sources, site specific data was required to inform the daily-time step, process based models used in CEAP analyses for simulating impacts of land management and conservation practices at each point [15].

3. The Modelling Methods in the CEAP Cropland National Assessment

The USDA-NRCS leads the Cropland CEAP modelling effort, with technical support provided by USDA-ARS and Texas A&M AgriLife. The models used in Cropland CEAP analyses for the benchmark surveys are free to the public and are readily adaptable to any geographic area. These models could be applied to CEAP-like efforts in other countries and regions.

The CEAP modelling process involves application of two daily time-step models, the Agricultural Policy Environmental eXtender (APEX) model and the Soil and Water Assessment Tool (SWAT) [16] (Figure 2). APEX and SWAT operate at different spatial scales, but interface easily. Both models operate on similar theoretical principles and are able to simulate run-off, sediment loss, leaching, plant growth, and nutrient cycling (nitrogen (N), phosphorus (P), and carbon (C) dynamics). APEX was developed to assess field-scale effects of land management and provide estimates of edge-of-field sediment, nutrient, and pesticide losses by loss pathway. APEX is a flexible model that can simulate the interactions between agricultural management and various conservation practices, including combinations of nutrient, tillage, and physical conservation management strategies. The SWAT model is a hydrologic model that considers the inputs from agricultural lands in conjunction with other land uses (*i.e.* forests, hay lands, wetlands and urban development) to assess water quality at a watershed scale. SWAT captures instream processes that occur in streams, rivers, reservoirs, and lakes, impacting the fate and transport of sediment, nutrients, and pesticides in the watershed systems [17]. Coupling APEX and SWAT provides insights into how cultivated cropland conservation practices and other land uses interact to impact the nation's waters. Both APEX and SWAT have been widely applied in studies predicting sediment, nutrient, and pollutant fate in the landscape at various spatial and temporal scales [18]. Previous work on APEX and SWAT integration provided the foundation for integration of the models used in Cropland CEAP's national effort [19].

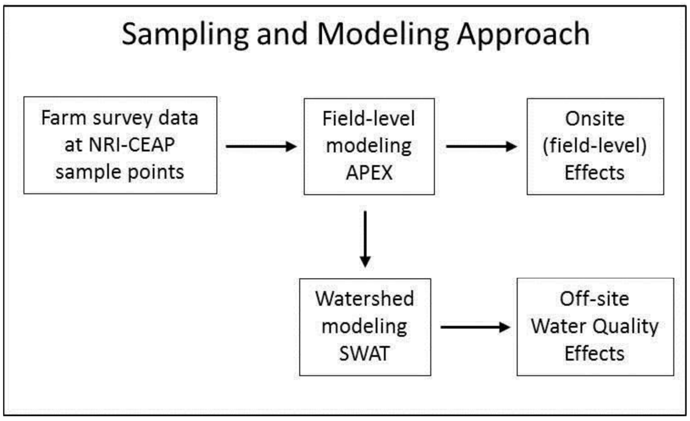

Figure 2. The CEAP Cropland National Assessment sampling and modelling framework.

In the Cropland CEAP modelling framework, the APEX model is used to estimate the impacts of reported land management and conservation practice adoption on factors that impact soil health and water quality, including soil water holding capacity, C sequestration and water and nutrient retention on farmed fields. The majority of scientific research on conservation practice effects has been conducted at the field scale upon which APEX operates, enabling modellers to develop well calibrated and validated simulations. The watershed component of CEAP continues to provide scientific data to improve field scale modelling efforts [20]. APEX simulates structural conservation practices, including in-field overland flow controls, in-field concentrated flow controls, and edge-of-field filter and buffering controls. APEX also simulates residue and tillage management, including conservation tillage, mulch tillage, and conventional tillage. N and P management methods are also simulated, including simulation of rate of application, method of application, nutrient source, and timing of application. APEX accommodates changes in crop rotations, including cover crop and winter cover adoption. Specifically, APEX simulates the interactions between these management approaches and conservation practices to predict plant growth and water, nutrient, and pesticide dynamics to estimate yield stability and water, N, P, C, sediment, and pesticide losses at the edge-of-field, including below the root-zone [21].

SWAT uses aggregated APEX output as input representing cultivated cropland contributions to instream loads of runoff, nutrients, pesticides, and sediments. SWAT is able to accommodate other land use inputs as well, including point and non-point source discharge to simulate the interaction between all land use types in the upstream watersheds. SWAT then routes the cumulative flows and loads through each downstream watershed and eventually routes the water, sediment, and nutrients through the river basin outlet. As the water, nutrients, and sediments move through the system, SWAT applies in-stream and reservoir routing submodels to simulate instream load dynamics and delivery from one watershed to the next. This enables modellers to estimate the impacts of cultivated cropland conservation practice adoption on sediment and nutrient fate and transport across various regional scales [22]. Appropriate delivery ratios are applied to account for the fact that nutrient and sediment deposition may contribute to legacy loads, which may later become re-suspended or dissolved back into the water column [23]. Instream processes simulated by SWAT include sediment degradation, streambed deposition, nutrient cycling and transformation, and other in-stream kinetic processes [24]. Details on APEX and SWAT modelling processes, assumptions, validation, and calibration techniques applied within Cropland CEAP simulations are available in the literature [25].

By using APEX outputs to inform the SWAT simulations, Cropland CEAP is able to answer larger scale policy relevant questions, including assessment of conservation practice impacts at the watershed scale. The APEX outputs may be aggregated and scaled up to the eight-digit watershed scale with the same expansion factors developed for expansion of other NRI data [26]. The eight-digit hydrologic watersheds (HUCs) delineated by the United States Geological Service (USGS) are the scale at which current Cropland CEAP sampling and modelling protocol produce statistically sound reports. From a statistical perspective, performing the weighted aggregation of data after the APEX model runs is preferable to data aggregation prior to model simulation, as the latter practice may mask the actual statistical distribution of data [27].

4. The Benchmark CEAP Cropland National Assessment Reports

Cropland CEAP has generated a series of regional reports that provide a baseline estimate of conservation practice adoption and resources status across the United States, based on analyses of the 2003-2006 NASS NRI survey and associated data [28]. The scientifically defensible design of the NRI, upon which the CEAP survey was based, allows the APEX and SWAT models to simulate the anticipated impacts that long-term adoption of current (2003-2006) conservation practices at a regional scale. Process based models were setup to simulate reported land use, land management, and conservation practices at a national scale, in order to determine the edge-of-field and watershed impacts of agricultural production on water quality, water quantity, erosion rates, and nutrient and carbon dynamics. Current conservation treatments and outstanding treatment needs could be compared across the nation's cropland to help inform current and future policy and practice implementation. Cropland CEAP developed a classification system of treatment needs for cropland acres based on inherent site vulnerability and the current level of conservation treatment in place (Figure 3). "Adequately treated" or "low needs" acres had annual average per acre loss rates of less than 2 tons of sediment per year, 15 pounds of N through runoff losses, 25 pounds of N through leaching, and 3 pounds of P to runoff. When model simulations showed that an acre's level of vulnerability exceeded the current conservation effort on that field, causing loss rates to exceed those just listed, the acre was classified as having outstanding conservation treatment needs, with high needs acres showing the highest levels of imbalance between inherent vulnerability and current conservation. A discussion of the development of this classification structure is beyond the scope of this manuscript, which intends to demonstrate the benefits to conservation planning that may be derived from a CEAP or CEAP-like assessment of cultivated cropland within any geographical setting. Further information on the system of classification used to determine conservation need levels is available in the regional CEAP reports [29].

The CEAP classification system was applied to cultivated cropland represented by each NRI-CEAP point. Analyses of the acreage included in each of the nine published reports demonstrate great variability in conservation treatment needs across the nation's river basins (Figures 1 and 3). On average, 54 percent of the cropland acres in these nine basins were adequately treated as of 2003-2006, but acres with outstanding conservation treatment need were not uniformly distributed across the landscape. For example, per this classification system, over 80 percent of acres in the Missouri Basin were adequately treated, but fewer than 14 percent of the acres in the Lower Mississippi Basin were adequately treated. Because the Basins were selected based on drainage rather than size, they varied in size from 83.6 million acres (Missouri Basin) to 4.3 million acres (Chesapeake Bay Region). Although within the Upper Mississippi Basin only 15 percent of the acres have high treatment needs, because of the large size of the basin, these acres account for 27 percent of the United States' high needs acres (Figure 4).

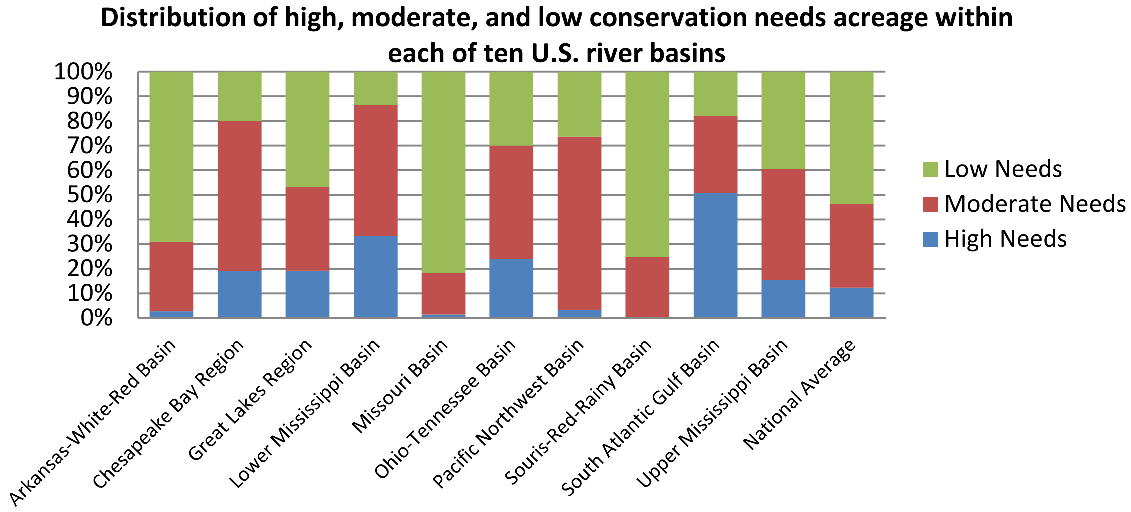

Figure 3. The percentage of cultivated cropland acreage in each basin identified as having High, Moderate, or Low need for additional conservation treatment to address one or more conservation concern based on inherent site vulnerability and current conservation practices.

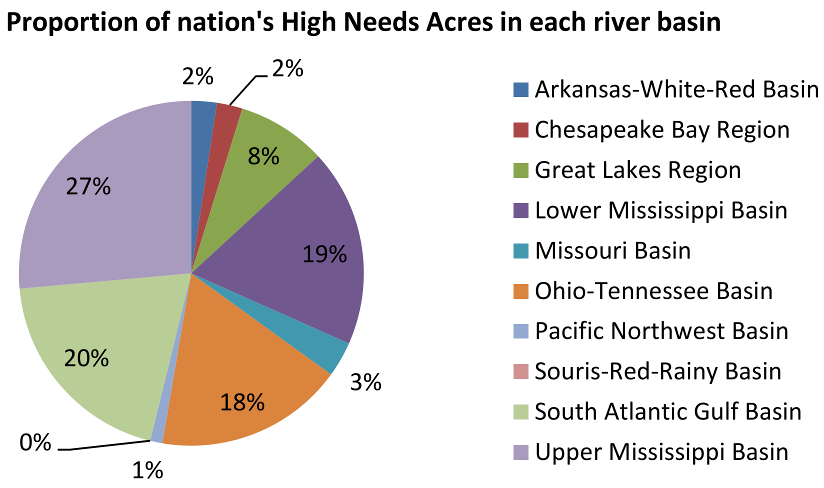

Figure 4. The percentage of the United States' cultivated cropland acreage classified in the CEAP classification system as having high outstanding needs for additional conservation practices, as distributed in each of ten river basins analyzed in CEAP's Cropland National Assessment.

In the seminal CEAP Cropland National Assessment regional reports the Cropland CEAP national survey provided information for only one point in time, the 2003-2006 sample period. These data provide an important baseline against which future conservation may be compared. However, in order to provide Congress with an estimation of current conservation practice benefits, the CEAP effort constructed a hypothetical "no practice" scenario in which all reported agricultural conservation practices were removed and replaced with reasonable conventional management. Choices in management in the no-practice scenario were made with care to guard against overestimation of current practice benefits. For example, a reported no-till system would be simulated as two tandem disking operations 3 days prior to spring planting as opposed to intense fall tillage with a mouldboard plow. More information on construction of the no-practice scenario may be found in the regional reports [30]. All other model inputs and parameters were maintained between the two scenarios, allowing the modellers to attribute the differences between the 2003-2006 baseline condition simulation and the no practice condition simulation to cultivated cropland conservation practices [31]. The APEX model enabled per-acre quantification of conservation practice impacts on surface water run-off rates and percolation volumes, water and wind erosion rates, nutrient dynamics and loss pathways, and carbon dynamics. The SWAT model interpreted cultivated cropland conservation practice impacts on these same dynamics at the watershed scale, providing insights into the role of agricultural conservation impacts in context with other land use impacts at the watershed scale. The APEX and SWAT models are extremely flexible and can accommodate additional alternative management scenarios. In fact, various CEAP reports explored simulations of targeting all high needs or all high and moderate needs acres (per the CEAP needs classification system previously discussed) [32].

5. Beyond the CEAP's Original Intent: a Decision Support Tool Emerges

The regional Cropland CEAP reports address the original driver of CEAP development: they assess the benefits derived by conservation practices in place during the 2003-2006 survey. However, the iterative CEAP process has also improved the modelling capacities of APEX and SWAT to act as powerful decision support tools within the CEAP context [33]. The versatility of these models and their ability to provide information on impacts of changing conservation practices enables the identification of conservation gains and remaining conservation needs at multiple spatial scales. Within a given spatial scale, the models may be used to explore anticipated impacts of various schemes of prioritizing conservation treatment.

Budget disbursement decisions are complicated and take a number of factors into consideration, including political and economic realities. The simplest means of allocating funds, equally among all basins is likely not the most efficient for achieving conservation gains. Each basin varies in terms of size, current level of treatment, and outstanding conservation needs. If funds were disbursed on the basis of acreage in cropland, the Upper Mississippi and Missouri would be allocated 21 and 30 percent of all funding (Figure 5). A more informed means of prioritizing acreage for treatment could include selecting to treat acreage with the most significant outstanding needs first. Here we used the CEAP needs classification system discussed above, which was developed solely for use in CEAP reporting, to enable comparison across basins. In this scheme the Upper Mississippi basin's allocation would increase to 27 percent of the budget and the Missouri basin's allocation would decline to only 3 percent (Figure 4). Simulated outcomes for treating all high needs acreage or all high and moderate needs acreage are included in each of the regional reports [34].

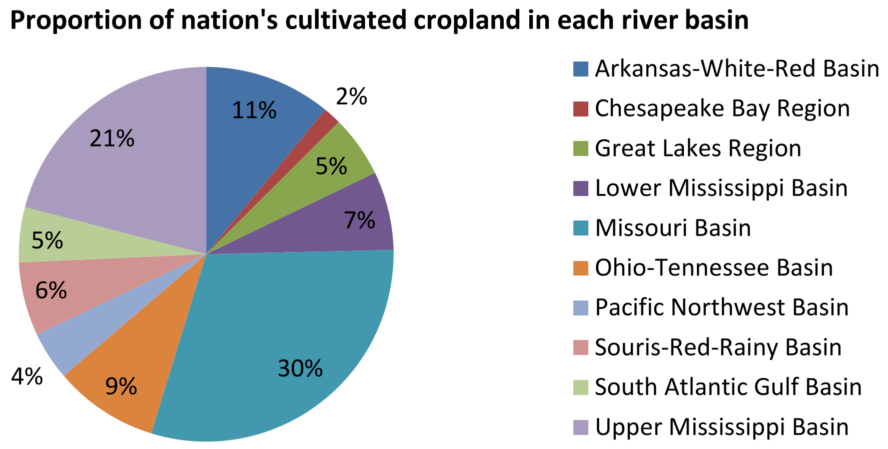

Figure 5. The percentage of the United States' cultivated cropland acreage, as distributed in each of ten river basins analyzed in in CEAP's Cropland National Assessment.

Another means of selecting acreage for treatment is choosing to address particular conservation concerns. Conservation concerns vary by region across the United States, with some areas more prone to water or wind driven erosional losses, while others are more prone to leaching losses. This means some areas tend to lose soil and nutrients through runoff loss pathways (water, N, P, C, and sediment), while others have more significant problems with leaching losses (water and N). Conservation programming in the United States has traditionally focused on controlling erosion, but in the 1990's the focus began to shift to be more inclusive of all natural resources related to the agroecosystem. By coupling the APEX model with mathematical programming to enable optimization of conservation treatment application, Cropland CEAP outputs allow modelers to explore the potential impacts of shifting the focus of conservation practice adoption across a broad spectrum of conservation concerns, including combinations of two or more conservation concerns (Figure 6). Here we demonstrate that N loss reductions could be maximized subject to also achieving other environmental benefits, such as sequestration of C; the results of this analyses suggest focusing on the dual conservation concerns of N loss reduction and C sequestration would provide 98 percent of the N loss reduction benefits and more than double the C sequestration benefits as would focusing solely on N loss reduction (Figure 6). Using a multi-criteria optimization model allows maximization of multiple interacting conservation goals. An optimization approach is flexible and could be designed to accommodate a variety of restrictions and concerns, including limiting acreage selection, limiting budget disbursements, focusing on particular loss pathways, selecting for particular conservation treatments, etc. 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.

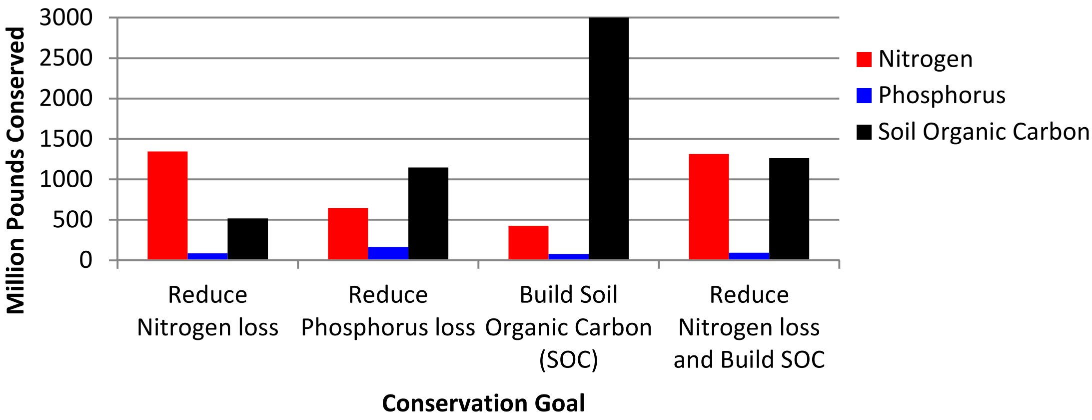

Figure 6. Potential national level impacts of shifting conservation goals between various conservation concerns, assuming a fixed budget and full participation by land owners on acres selected for treatment. Each conservation approach provides ancillary benefits to conservation concerns other than the primary concern on which the conservation goal is focused.

The ability of the models to represent watersheds within the national context also enables exploration of conservation needs as they vary geographically. In this modelling exercise no controls were placed on acreage or funding distributions across basins. Because different parts of the country have different conservation needs, prioritizing one conservation concern over another at the national scale skews funding and acres treated to the parts of the country most severely in need of increased conservation efforts to address that particular concern (Figure 7). This figure demonstrates the fact that different regions of the country have different conservation concerns and changing conservation priorities will change fund distribution patterns. Policy makers considering efforts to address nutrient and soil losses are necessarily concerned with both the conservation outcomes and the distribution of funds in a geopolitical context.

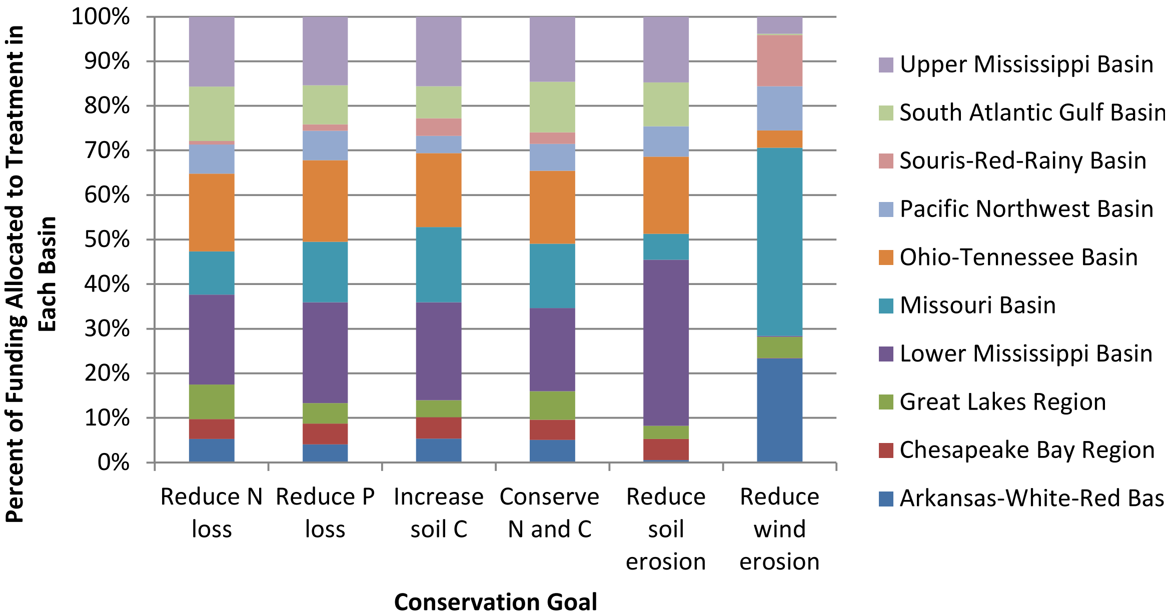

Figure 7. Shifting priorities from one conservation concern to another shifts funding and treated acreage from one basin to another, as different parts of the country have different severities of need to address each conservation concern. This figure demonstrates how conservation treatment would shift

between basins depending on whether the emphasis was on nitrogen loss reduction, phosphorus loss reduction, building soil organic carbon, adopting the dual focus of nitrogen loss reduction in conjunction with building soil organic carbon, reducing soil erosion, or reducing wind erosion.

6. Conclusion

The benchmark Cropland CEAP reports provide a baseline against which all impacts of all current and future conservation practices and programming may be assessed. Although the farm survey data used to generate the Cropland CEAP assessments is not publicly available, the benchmark Cropland CEAP assessments are all available online [35]. These reports continue to contribute to development of improved decision support tools, refined sampling protocols, revisions to national databases, and modelling improvements. A recent resurvey of the Chesapeake Bay watershed emphasizes the tremendous value of the quantified benchmark reports, against which conservation successes may be measured [36].

In addition to addressing the Congressional request for quantification of conservation practice impacts, Cropland CEAP has explored myriad hypothetical conservation practice scenarios, all of which would have cascading impacts on funding disbursements, geographical distribution of conservation practices and programming, and selection of suites of appropriate conservation practices to meet conservation goals. It is not the purpose of this manuscript to select the best conservation treatments for U.S. cultivated cropland acreage, nor to choose the best conservation goal, or means of selecting that goal. Here we demonstrate how these models and data may be used to construct and explore conservation scenarios that provide land managers and policy makers with information they need to make decisions about future conservation efforts at multiple scales in order to meet the concerns of the farmer, the local community, the environment, the state, and the American taxpayer.

Cropland CEAP provides a powerful decision support tool for United States policy makers, enabling efficient application of the American taxpayer's conservation dollar. The resurvey of the country slated to occur in 2015 and 2016 will further improve this powerful tool. Reanalysis of the benchmark data (2003-2006) alongside the resurvey will improve our scientific understanding of the impacts of and trends in conservation practices at the local and watershed scales. Further, Cropland CEAP's second survey and analyses of the nation's state of conservation will increase the scientific knowledge base helping policy makers implement appropriate programs and helping land managers and farmers apply appropriate practices to best meet conservation goals. Thus Cropland CEAP has evolved from its original goal of assigning metrics to past conservation efforts to become a dynamic and promising tool informing current and future conservation decision making in the United States.

Acknowledgements

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References

[1] Tomer M D and Locke M A 2011 *Water Sci Technol* **64** 300-10
[2] Mausbach M J and Dedrick A R 2004 *J Soil Water Conserv* **59** 96A-103A
[3] Maresch W, Walbridge M R and Kugler D 2008 *J Soil Water Conserv* **63** 198A-203A
[4] Richardson C W, Bucks D A and Sadler E J 2008 *J Soil Water Conserv* **63** 590-604
[5] United States Department of Agriculture, National Resources Conservation Service, Conservation Effects Assessment Project, Cropland National Assessment webpage (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014144)
[6] United States Department of Agriculture, Natural Resources Conservation Service, Soil and Water Resources Conservation Act Report 2011 (United States Department of Agriculture:

Washington, DC) p 164 (http://agwaterconservation.colostate.edu/PDFs/2011_RCA_Appraisal_Pre_Publication_Copy.pdf)
[7] United States Department of Agriculture, Natural Resources Conservation Service, National Resources Inventory 2009 *Summary Report: 2007 National resources inventory*, (Washington, DC and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa) p 123 (http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1041379.pdf)
[8] United States Department of Agriculture, Natural Resources Conservation Service, National Resources Inventory webpage (http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/results/)
[9] Nusser S M and Goebel J J 1997 *Environ Ecol Stat* **4** 181-204
[10] Goebel J J and Kellogg R L 2002 Using survey data and modelling to assist the development of agri-environmental policy *Conf. on Agricultural and Environmental Statistical Applications in Rome* (Rome, Italy: National Statistical Institute of Italy) pp 695-704
[11] Goebel J J 2009 *Statistical methodology for the NRI-CEAP Cropland Survey* p 28 (http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_013402.pdf)
[12] Potter S, Andrews S, Atwood J D, Kellogg R L, Lemunyon J, Norfleet L and Oman D 2006 *Model simulation of soil loss, nutrient loss, and change in soil organic carbon associated with crop production* United States Department of Agriculture, Natural Resources Conservation Service, Washington, DC p 245 (http://babel.hathitrust.org/cgi/pt?id=umn.31951d027280886;view=1up;seq=1)
[13] United States Department of Agriculture, Natural Resources Conservation Service, 2006 CEAP Farmer Surveys. (United States Department of Agriculture, Natural Resources Conservation Service: Washington, DC) (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014163)
[14] Allen A W and M W Vandever, eds 2005 *The Conservation Reserve Program - Planting for the future* (Reston, Virginia: United States Geological Survey, Biological Resources Discipline, Scientific Investigations Report) p 268 (http://www.fsa.usda.gov/Internet/FSA_File/21490.pdf)
[15] Gianessi L P and Peskin H M 1984 *An overview of the RFF environmental inventory: methods, sources, and preliminary results v. 1* (Renewable Resources Division, Resources for the Future: Washington, DC) p 111
[16] Arnold J G, Srinivasan R, Muttiah R S and Williams J R 1998 *J Am Water Resour As* **34** 73-89
[17] White M J, *et al.* 2014 *J Soil Water Conserv* **69** 26-40
[18] Gassman P W, Reyes M R, Green C H and Arnold J G 2007 *T ASABE* **50** 1211-50
[19] Saleh A and Gallego O 2007 *T ASABE* **50** 1177-87
[20] Duriancik L F, *et al.* 2008 *J Soil Water Conserv* **63** 185A-197A
[21] Wang X, Kannan N, Santhi C, Potter S R, Williams J R and Arnold J G 2011 *T ASABE* **54** 1281-98
[22] Arnold J G, Williams J R and Maidment D R 1995 *J Hydraul Eng-ASCE* **121** 171-183
[23] Wang X, Kannan N, Santhi C, Potter S R, Williams J R and Arnold J G 2011 *T ASABE* **54** 1281-98
[24] Neitsch S L, Arnold J G, Kiniry J R, Williams J R and King K W 2002 *Soil and Water Assessment Toll (Version 2000). Theoretical documentation* GSWRL 02-01, BRC 02-05, TR 191. (Texas Water Resources Institute: College Station, Texas)
[25] Santhi C, Kannan M, White M, DiLuzio M, Arnold J G, Wang X and Williams J R 2014 *J Environ Qual* ***43*** 177-98
[26] Goebel J J 2009 *Statistical methodology for the NRI-CEAP Cropland Survey* pp 28 (http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_013402.pdf)

[27] Goebel J J and Kellogg R L 2002 Using survey data and modelling to assist the development of agri-environmental policy *Conf. on Agricultural and Environmental Statistical Applications in Rome* (Rome, Italy: National Statistical Institute of Italy) pp 695-704
[28] United States Department of Agriculture, National Resources Conservation Service, Conservation Effects Assessment Project, Cropland National Assessment webpage (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014144)
[29] United States Department of Agriculture, National Resources Conservation Service, Conservation Effects Assessment Project, Cropland National Assessment webpage (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014144)
[30] United States Department of Agriculture, National Resources Conservation Service, Conservation Effects Assessment Project, Cropland National Assessment webpage (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014144)
[31] Duriancik L F, *et al.* 2008 *J Soil Water* Conserv **63** 185A-197A
[32] United States Department of Agriculture, National Resources Conservation Service, Conservation Effects Assessment Project, Cropland National Assessment webpage (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014144)
[33] Arnold J G, Harmel R D, Johnson M V V, Bingner R, Strickland T C, Walbridge M, Santhi C, DiLuzio M and Wang X 2014 *J Soil Water Conserv* **69** 137A-44A
[34] United States Department of Agriculture, National Resources Conservation Service, Conservation Effects Assessment Project, Cropland National Assessment webpage (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014144)
[35] United States Department of Agriculture, National Resources Conservation Service, Conservation Effects Assessment Project, Cropland National Assessment webpage (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014144)
[36] United States Department of Agriculture, Natural Resources Conservation Service 2013 Impacts of Conservation Adoption on Cultivated Cropland in the Chesapeake Bay Region, 2003-06 to 2011 Pp 113 (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=stelprdb1240074)