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A Methodology for the Preliminary Scoping of Future Changes in Ecosystem Services

With an Illustration from the Future Midwestern Landscapes Study

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With an Illustration from the Future Midwestern Landscapes Study

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EXECUTIVE SUMMARY

When designing studies of future environmental change, it is useful to have working hypotheses about drivers of change, stressors of concern, and potential ecological outcomes to guide the development of scenarios and the choice of models. Studies of ecosystem services must be concerned with multiple, simultaneous outcomes, because decision-makers are faced with the reality of making trade-offs among services. The extreme complexity presented by multiple ecosystem service endpoints can overwhelm typical approaches for hypothesis formation, such as the use of graphical conceptual models.

Therefore, we developed a new methodology for constructing hypotheses about the potential effects of future change scenarios on ecosystem services, which we call *scoping*. The scoping method is to first develop a hierarchy of relevant societal values, identify the ecosystem services that support those values, and then cross-link these services to a list of critical environmental elements that are sensitive to the drivers of change. Researchers then use best professional judgment (based on experience and supported by scientific literature) to rate these expected effects one by one in a large matrix. Ratings are then combined and graphically arrayed to create snapshots of the kinds of changes the researchers hypothesize to be most likely. These findings are then used to answer a set of scoping questions that can help ensure that studies focus on important changes, using appropriate models. This new methodology offers a well-defined procedure for managing ecological complexity and improving study design. Without this scoping methodology, ecosystem service assessments may suffer from lack of rigor in the design process, and therefore default to approaches of convenience.

We applied the scoping methodology in a proof of concept demonstration using the Future Midwestern Landscapes (FML) Study as an example of the extreme complexity presented when dealing with multiple ecosystem service endpoints. The FML Study will examine the effects of future scenarios of landscape change upon ecosystem services throughout the Midwestern United States. This scoping demonstration was conducted by a small group of researchers and was not intended to provide robust conclusions. Therefore, the following preliminary findings for FML Study design should be considered to be illustrative of the outcomes of the scoping method and not definitive recommendations:

(a) Studies of future changes in ecosystem services in response to current biofuel policies should give special attention to the potential impacts of corn stover removal on soil productivity and soil carbon sequestration.

(b) Agricultural conservation practices fall into two broad groups that differ in the patterns of changes in service production that are expected to result from their implementation. A distinction is found between practices that involve conversion of at least some cultivated land to non-crop cover, and those which only change agricultural management. This distinction should be addressed when developing future scenarios that focus on increased incentives for adoption of conservation practices. Studies of the differences between these two groups should include evaluation of pesticide impacts and evaluation of the potential for changes in human disease vectors.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

Human society depends on the services of nature (Daily, 1997, Millennium Ecosystem Assessment 2005). However, these services are rarely valued by current economic and social systems, and thus, degradation of resources threatens the provision of critical ecosystem services in many parts of the world. It is crucial that we develop methods to account for ecosystem services in societal decision-making processes (Daily et al. 2009). There are many scientific assessment methods and models developed to examine effects of one or more stressors on a single or a small set of closely related services. However, well-informed decisions require scientific assessment practices capable of evaluating many services at once. For example, a single action that preserves an intact ecosystem can protect many different kinds of services. In such a case, the assessment problem is to identify which services are at stake, estimate their magnitude, and determine their (direct or indirect) value to society. Such analyses can clarify benefits, damage, and trade-offs, and guide decisions that will provide greater benefits. More complex decisions may involve choosing among alternative land tracts to be preserved, improving the management of ecosystems (such as by changing agricultural, forestry, range, wildlife, fisheries or coastal management practices), or designing strategies for the rehabilitation of ecosystems. In addition to the assessment of many ecosystem services, these decisions require evaluation of trade-offs among services (Chan et al. 2006, Nelson et al. 2008). In any of these cases, the quality of the decisions may be compromised if assessment is limited to one or two well-recognized services (Kareiva et al. 2007, Nelson et al. 2009).

The evaluation of multiple services can quickly become extremely complex. A single policy change may induce many societal actions that vary over space and time and affect ecosystems in multiple ways. Conceptual models of ecosystems, or of linked socioeconomic and ecological systems, are useful tools for managing complexity when designing ecological research or assessment (USEPA 1998, Gentile et al. 2001). Conceptual models typically are a combination of visual and written depictions of causal relationships that are hypothesized to exist among system components. Conceptual models that guide large programs of research often depict only broad relationships between systems and services (e.g., Groffman et al. 2004). More focused models can offer detail on hypothesized interactions between system components and particular services (e.g., Kremen et al. 2007). Models developed as interactive tools can provide links to evidence supporting each hypothesized interaction (e.g., see, a conceptual model of stream impacts of phosphorus developed as part of EPA's Causal Analysis/Diagnosis Decision Information System, http://cfpub.epa.gov/caddis/icm/ICM.htm). In limited cases, Bayesian approaches have been used, in conjunction with expert opinion, to estimate functional values for these relationships (Borsuk et al. 2004, Marshall et al. 2007)

The extreme complexity presented by some assessment problems can overwhelm the capability of a graphical conceptual model to provide a useful depiction of hypothesized causal pathways of influence between systems and services. Therefore, we developed a new methodology for developing detailed, highly structured hypotheses of the expected effects of multiple influences on multiple ecosystem services, and using best professional judgment to rate the sign (direction), magnitude and certainty of those effects. We are applying this methodology as one phase of the Future Midwestern Landscapes (FML) Study, an ongoing study of the effects of future scenarios of landscape change on ecosystem services throughout the Midwestern United States.

The FML Study is a component of USEPA's Ecosystem Services Research Program, which seeks effective ways to bring information on ecosystem services into decision-making spheres (http://epa.gov/ecology). The FML Study is one of several place-based studies being carried out in locations where society faces critical choices. In the Midwest, a large-scale shift is now occurring from a historical focus on a single ecosystem service, food production, to addition of a new focus, energy production. For a 12-state area of the Midwest (Figure 1; Table 1), the FML Study is developing alternative future scenarios that will contrast a current trajectory of land-use change, emphasizing biofuels production, with an alternative path emphasizing increases in the uses of agricultural conservation practices. These future scenarios are termed *Biofuel Targets* (BT) and *Multiple Services* (MS), respectively. These scenarios will be examined in comparison to one another and each will also be compared to a *Base Year* (BY) scenario representing current conditions. The FML Study will develop detailed landscapes corresponding to each scenario and then use models of air quality, water quality and wildlife habitat suitability to estimate a myriad of environmental changes that are relevant to the provision of ecosystem services. We plan to use these results to estimate service changes, and to make this information available to a variety of decision-makers through an online, interactive 'Environmental Decision Toolkit' (via a process similar to that described in Mehaffey et al. 2008). The planned phases of the FML study (Table 2) were adapted from those of Liu et al. (2008) by adding a 'scoping analysis' as a distinct project phase.

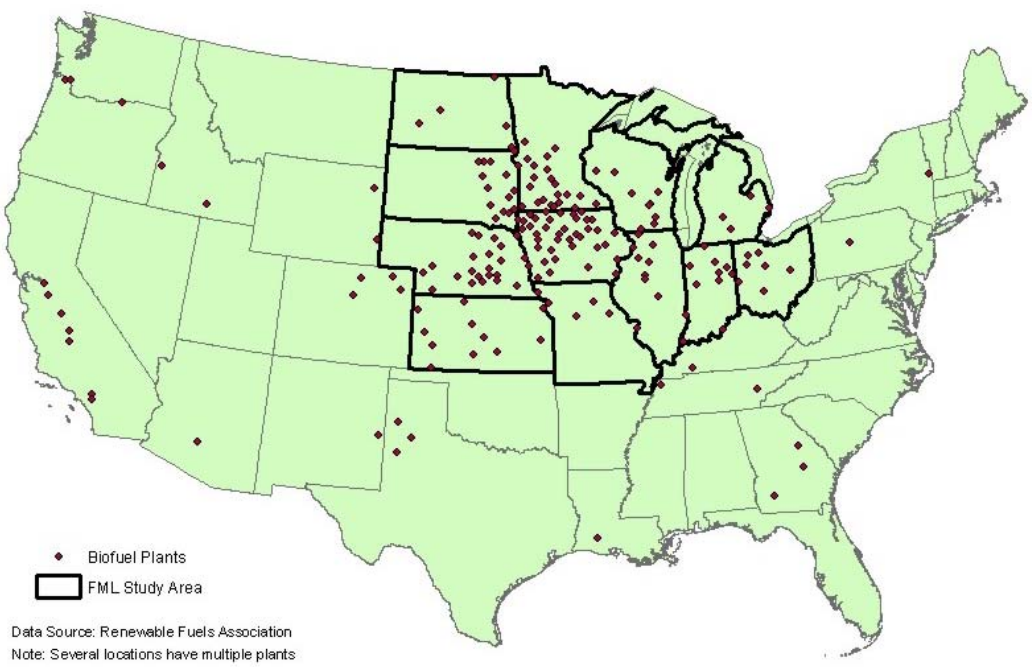


Figure 1. States included within the FML study area, shown in relation to the location of existing bioethanol refineries.

Table 1. Agricultural land use/land cover (plantings) for the 12-state FML region for the Base Year and Biofuel Targets (2022) scenarios.[1]

	2002 (BY)		2022 (BT)	
Land Use/Land Cover	**Total Area (10^6 acres)**	**Percent (%)**	**Total Area (10^6 acres)**	**Percent (%)**
Corn	66.5	28.2	90.4	38.6
Soybean	61.8	26.2	51.9	22.2
Wheat	37.3	15.8	33.4	14.2
All cultivated crops[2]	181.8	77.0	186.5	79.6
Hay	27.2	11.5	23.2	9.9
Conservation Reserve Program (CRP)	22.0	9.3	19.4	8.3
All Agriculture Uses[2]	235.9	100.0	234.0	100.0

[1]Source: Center for Agricultural and Rural Development, unpublished study
[2]Includes the 12 cultivated crops with highest production acreages

Table 2. Phases of the Future Midwestern Landscapes Study.

1. **Scenario definition**
   a. Define problem and change drivers of concern
   b. Define study area
   c. Identify stakeholder values and future concerns
   d. Identify base year for analysis
   e. Define key policy aspects associated with future scenarios
      i. Biofuel Targets (BT) Scenario (business-as-usual scenario based on future biofuel production targets contained in existing policy)
      ii. Multiple Services (MS) Scenario (hypothetical scenario having only generally defined goals at this stage in the process)
2. **Scoping analysis**
   See Table 4.
3. **Landscape construction**
   a. Develop spatially explicit baseline landscape
   b. Project economic conditions corresponding to each future scenario
   c. Create detailed landscape corresponding to each future scenario
4. **Landscape evaluation for ecosystem services**
   a. Biophysical modeling
      i. Select biophysical models (water quality, air quality, etc.)
      ii. Parameterize and run models for baseline and each scenario
   b. Ecosystem services evaluation
      i. Define ecosystem service indicators and production functions
      ii. Calculate ecosystem service changes in relation to interscenario comparisons
5. **Decision support**
   a. Develop online spatially-explicit decision support tool
   b. Load landscape and ecosystem service metrics
   c. Work with users to refine tool and conduct case studies

The scoping analysis phase was designed to develop detailed hypotheses about the sign and magnitude of expected changes in a number of different ecosystem services. There were three main goals for this phase of analysis. First, we wanted to assist the process of scenario design by identifying those environmental practices that appeared most likely to increase a wide range of ecosystem services and therefore were worthy of inclusion in the MS future scenario. Second, we wanted to ensure that project analytical resources are devoted toward analysis of the types of effects expected to be important. Third, we wanted to develop a comprehensive picture of effects of multiple causal pathways on multiple services, independently from the subsequent modeling phases of the study, to serve as a point of reference for evaluation of the modeling results.

This paper describes the methodology we have developed to address the scoping task. It also provides an illustrative demonstration, based on a small number of scorers, of how the process can produce ecosystem service hypotheses, which then can be used to adjust the design of subsequent phases of the FML study. In our future research, we plan to increase the number of scientists providing best professional judgment scores for a more robust demonstration, and apply this method in other ecosystem services studies.

II. SCOPING APPROACH

A. Overview of Scoping Methodology

The purpose of scoping is to develop a set of expected outcomes from each scenario. We use the term *ecosystem service change hypotheses* to describe these expectations. This is a borrowing from the language of ecological risk assessment, in which beliefs about the key relationships between ecological stressors (or their sources) and adverse effects on ecological receptors are termed *risk hypotheses* (USEPA 1998; Bruins et al. 2005). Risk hypotheses usually are too general to be statistically testable, but they can be used to develop testable hypotheses. Once the assessment participants and stakeholders agree that these hypotheses are correctly formulated, the computational phases of assessment are then aimed at substantiating or rejecting these hypotheses. In a similar vein, the hypotheses to be developed in scoping are general in form but can be used to develop testable statements. We avoid the term *risk* because we are concerned about scenario outcomes that include both increases and decreases in services.

Specific questions to be addressed by the FML scoping analysis are presented in Table 3. This analysis required development of a new methodology (Table 4**)**. The first step was to develop a values hierarchy, which helped us identify the services provided by ecosystems that are valued by stakeholders within the region. Next, we created both general and scenario-specific concept maps to help clarify the key drivers and factors potentially affecting ecosystem services. Using the values hierarchy and the concept maps, we created a matrix in which the elements in the values hierarchy, augmented by key environmental factors (*technical contributors*) identified from the concept maps, are arrayed against the primary changes defined by each scenario (*scenario-related changes*). We then made quantitative ratings of the expected effect of each change on each contributor, and of each contributor on each item in the hierarchy. We combined these ratings to develop ecosystem service change hypotheses (Figure 2).

Table 3. Questions which the scoping analysis is intended to answer and implications for study design. (MS – Multiple Services; BY – Base year; BT – Biofuel targets.)

Scenario comparison for which scoping question applies	**Scoping question**	**Implications of result for FML study design**
MS-BY comparison only	Which conservation practices appear to have the potential to strongly increase multiple services?	Use this information (together with feasibility of modeling each practice) in the selection of practices to include in the MS scenario
Both BT-BY and MS-BY comparisons	Which services appear likely to vary **strongly** in this scenario comparison (based on magnitude and certainty)?	Be sure these services are addressed in modeling; if they aren't, and we can't add them, be sure to make information users aware
	Which services appear likely to vary **little or none** in this scenario comparison (based on magnitude and certainty)?	If modeling these services demands significant resources, consider dropping them from the modeling plan
	For which services is the expected variation in this scenario comparison most **uncertain**?	In each case, if the service will be modeled, determine whether this is an uncertainty that is likely to be addressed by modeling, or is the source of the uncertainty outside the scope of modeling? If the latter, consider amending, dropping or caveatting the modeling result.

In the remainder of this section, we first provide necessary details about the two intended FML future scenarios and explain why they were treated differently in the scoping process. We then explain the scoping process in further detail.

Table 4. Outline of scoping methodology.

1. **Create value hierarchy to identify key ecosystem services**
    a. Create a structured hierarchy of the components of stakeholder well-being (a value tree)
    b. Identify ecosystem contributions to values-hierarchy components
    c. Define as ecosystem services the highest-level components which are aspects of ecosystems
2. **Create general concept map**
    a. Identify and diagram linkages between major ecological and social system components
    b. Identify, incorporate key drivers of socioeconomic or environmental change and stressors of concern
    c. Incorporate identified ecosystem services
3. **Create scenario-specific concept maps**
    a. Identify change drivers specific to each scenario (e.g., policy changes, extrinsic environmental changes)
    b. Determine scenario-related changes (i.e., expected primary effects) of each change driver
        i. land use, land cover, or land management changes
        ii. resource use changes
    c. Examine, qualitatively, how these primary changes will be causally propagated through the mapped system to influence each ecosystem service.
    d. Refine concept map as needed to reflect influences
4. **Create influence matrix (i.e., scoring spreadsheet)**
    a. For each ecosystem service identified in value hierarchy, use concept map to identify key technical contributors (i.e., environmental components potentially influenced by one or more scenario-related changes
    b. Add technical contributors to hierarchy
    c. Create matrix in which hierarchy elements are rows and scenario-related changes are columns
    d. Identify any appropriate weighting factors for scenario-related changes, such as:
        i. areas affected
        ii. costs or other feasibility considerations for management actions
5. **Score the influence matrix**
    a. Identify scorers with appropriate knowledge/experience
    b. Provide background information on scenarios, concept maps, and hierarchy
    c. Score sign/magnitude (-5 to +5) and uncertainty (1 to 5) of influences for each cell in matrix, specifically:
        i. influence of each scenario-related change on each technical contributor ("C score")
        ii. Influence of each technical contributor on element above it in the hierarchy ("H score")
    d. Discuss scores with differences in sign or large ranges among scores to check for differences in interpretation of matrix elements or scoring task
    e. Revise scores as appropriate
    f. Compute interscorer means and ranges for each matrix cell
    g. Compute product scores (HxC/5) for each technical contributor for each scorer
    h. Apply weights and within-scenario summations as appropriate
    i. Perform quality assurance checks
6. **Interpret results to create ecosystem service hypotheses**
    a. Plot means and ranges of product scores to visualize patterns of expected influence
    b. Identify services judged most and least likely to be affected by a given change
7. **Apply findings to subsequent phases of study**
    a. Adjust scenario specification to include scenario-related changes with potentially large influence
    b. Adjust modeling plans to ensure coverage of likely influences
    c. Examine model results; investigate reasons for discrepancies between hypotheses and model findings
    d. Include in decision support tools information about expected influences that were not modeled

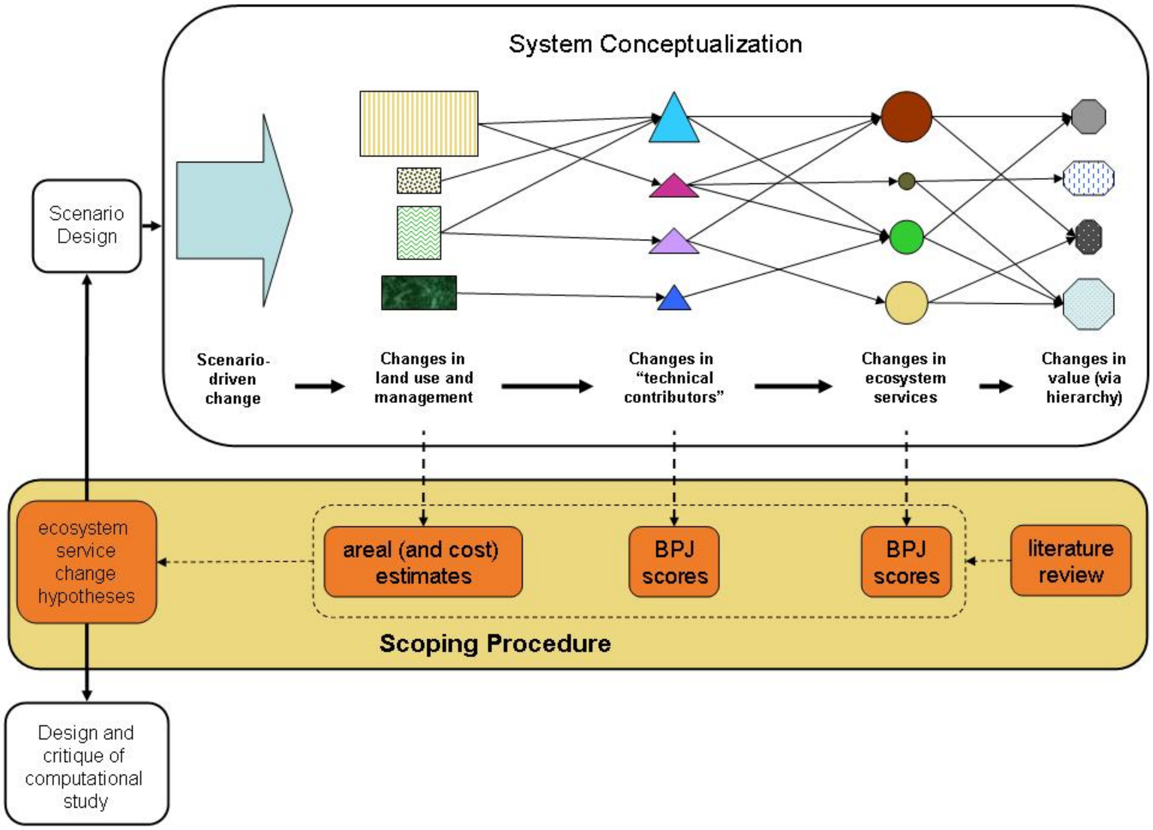


Figure 2. Overview of the scoping process and its relevance for the design of the FML Study and use of FML Study findings. (BPJ – best professional judgment.)

B. Future Scenarios

In this paper we use the term *scenario* to define a set of driving conditions that will cause change. While many kinds of factors could constitute driving conditions (e.g., climate change, oil price shocks), in the FML study our scenario drivers are existing or hypothetical policies, so the terms *scenario* and *policy* are used synonymously. We use the term *landscape* to describe the spatially explicit land cover, land use and land management practices that result from a given policy/scenario.

The BT scenario is a 'business-as-usual' scenario with respect to biofuel policy, and therefore its primary assumptions are already established based on existing policies. The BT landscape therefore is intended to approximate the land uses, crop rotations and land management practices that would be expected in the year 2022, if biofuel-related laws and policies remain in place as they currently exist. These include the renewable fuel standards established by the Energy Independence and Security Act of 2007 (EISA; Public Law 110-140) requiring, by 2022: 16 billion gallons (Bgal) cellulosic ethanol, 5 Bgal other advanced biofuel and 15 Bgal corn starch ethanol. Projections for the 12-state FML area indicate that net shifts will occur from soybeans

Table 5. Summary of projected changes in land use from the Base Year to the Biofuel Targets scenario.

Projected land use change	Total area of change (10^6 acres)	Change as percent of all agricultural lands (%)
CRP to corn	2.6	1.4
Other row crops to corn	19.1	10.3
Hay/pasture to corn	4.0	2.2
Utilization of corn stover	90.4	48.5

and other row crops to corn, from Conservation Reserve Program (CRP)-enrolled lands to corn and from hay/pasture to corn (Table 5). To meet the EISA mandate for cellulosic ethanol, this scenario also assumes that up to 30% by weight of corn stalk residues, which ordinarily would remain in the field, will be removed from all corn-growing fields for biofuel production. The BT scenario further assumes that adoption rates of conservation practices remain at current levels.

The MS scenario, which is currently being constructed, will define strategic shifts in agricultural practices that can enable agricultural landscapes to produce both conventional commodities and additional ecosystem services (Jordan et al. 2007). The MS landscape therefore is intended to approximate the land uses, crop rotations and land management practices that would be expected in the year 2022, in the absence of US biofuel incentives and in the presence of a hypothetical new program of incentives for agricultural conservation practices. The first step in constructing this scenario is the selection of a manageable set of conservation practices which, if increased through incentives, would collectively be capable of increasing the amount and variety of ecosystem services. The second step is the construction of a target landscape that would optimize ecosystem services and agricultural production through the placement of land uses and conservation practices, subject to a set of societal values and constraints. The final step entails modeling the process of land-manager adoption of these practices, given a set of incentive payments. This step would be iterated, with adjustments to the incentive payment structure, to achieve nearest approach to the target. A key aspect of designing this scenario, therefore, will be judging the ability of various practices to provide a range of ecosystem services. We have selected a set of candidate practices which correspond to, or are composites of, practices described by the USDA Natural Resources Conservation Service (Table 6). Since we need to be capable of modeling the uses of and outcomes from these conservation practices, individually and collectively, modeling feasibility, as well as service provision, is important in their selection. This scoping study did not address modeling feasibility, however.

For scenarios that reflect an existing or otherwise described policy, such as the BT scenario, the goal of a scoping analysis should be to determine which ecosystem services appear likely (or unlikely) to vary significantly relative to other scenarios. For scenarios to be designed, such as the MS policy, the goal of scoping can also include shorthand evaluation of alternative policy strategies to determine which ones are worth full development and evaluation.

Table 6. Candidate conservation practices considered for the Multiple Services scenario

Conservation practice (with applicable NRCS codes)[1]	**Description of Practice**[2]
Land retirement for conservation (327) and upland wildlife habitat management (645)	Establish and maintain perennial vegetative cover to protect soil and water resources and to establish natural areas and wildlife habitat on land retired from agricultural production.
Wetland restoration (644, 657)	A rehabilitation of a degraded wetland where the soils, hydrology, vegetative community, and biological habitat are returned to the original condition to the extent practicable for watershed protection and improvements to habitat for waterfowl, fur-bearers, or other wetland associated flora and fauna.
Wetland creation for water treatment	Creation of acreages that have wetland hydrology, hydrophytic plant communities, hydric soil conditions, and wetland functions and/or values.
Nutrient management	Application of best management practices for the amount, source, placement, form and timing of the application of plant nutrients and soil amendments.
Reduced tillage (includes no-till, 329; mulch till, 345; ridge till, 346)	Includes practices for managing the amount and orientation of year around crop residues on the field surfaces to limit soil-disturbances and/or the and utilization of alternating ridges and furrows to reduce water and wind erosion, improve soil organic matter, slow moisture losses, and provide food and cover for wildlife.
Winter ground cover (340)	Utilizes plant cover including grasses, legumes and forbs for seasonal cover to reduce wind and water erosion, increase soil organic matter content, capture/recycle soil nutrients, suppress weeds, manage soil moisture and promote other conservation purposes.
Contour farming (330), contour buffer strips (332), terracing (600)	Using ridges and furrows formed by tillage, planting and other farming operations to change the direction of runoff from directly downslope to around the hillslope. Cropped strips may be alternated with narrow strips of permanent, herbaceous vegetative cover; or an earth embankment, or a combination ridge and channel, may be constructed across the field slope.
Riparian forest buffer (391)	Use of trees, shrubs, and other vegetation adjacent and up-gradient from water bodies for reducing sediments, nutrients, pesticides and other pollutants in surface runoff and to create shade for lower water temperatures and provide a source of detritus and large woody debris for fish and other aquatic organisms, and to provide wildlife corridors.

Table 6 (continued).

Conservation practice (with applicable NRCS codes)[1]	**Description of Practice**[2]
Grassed waterways (412)	Utilization of natural or designed channels shaped and established with suitable vegetation to permit conveyance of runoff water from terraces, diversions, or other water concentrations without causing erosion or flooding, reduce gully erosion and to protect/improve water quality.
Drainage water management (554)	Control of water surface elevations and discharge from surface and subsurface drainage systems, to improve water quality, enable seasonal shallow flooding and prevent discharge of nutrient laden water carried through surface or subsurface drainage.
Flood plain grassland or forest serving for flood control (actively managed or passively)	Include conservation practices designed to restore floodplains, including wetlands, to condition and function that is as close to natural conditions as is practicable.

[1]Source: http://www.nrcs.usda.gov/technical/Standards/nhcp.html
[2]Adapted from NRCS descriptions.

We conducted scoping as a comparison of the base year to each future scenario separately (a BT-BY comparison and a MS-BY comparison), so that only interscenario differences had to be considered. In developing the BT and MS landscapes we hold constant all protected natural areas that existed in 2002 (i.e., not including temporary restrictions such as Conservation Reserve Program (CRP)), so these did not enter the scoping analysis. In both the BT and MS landscapes we make identical assumptions about the future locations of urban growth, based on a set of projections developed by USEPA (2008). Therefore, urban land use is changed compared to the BY, but this change is not large in the Midwest and was neglected for scoping purposes. Finally, although the BT-MS comparison is of interest in the FML Study, our scoping exercise did not undertake this comparison.

C. Values Hierarchy and Ecosystem Services

Adopting a definition put forward by Fisher et al. (2009), “ecosystem services are aspects of ecosystems utilized (actively or passively) to produce human well-being.” Any attempt to deal with ecosystem services in a rigorous fashion encounters difficulties of definition, because their definition is specific to the contexts of both ecological production and societal benefit (Fisher and Turner 2008, Fisher et al. 2009). Nor is there usually a fine line between ecological and social systems demarking a point at which the service is provided, especially when ecosystems are intensively managed.

We addressed this problem by constructing a hierarchy of values, and the ecosystem aspects contributing to those values, to provide a context within which ecosystem services could be identified. The hierarchy is shown in full in Appendix A; an illustrative portion is shown in Figure 3. In accordance with the above definition of ecosystem services, the highest level of the value hierarchy (not shown in Figure 3, but corresponding to level zero) is human or societal well-being. We then differentiated nine first-level values as primary components of well-being, as follows:

- Minimize health risks
- Maximize agricultural productivity/benefits
- Maximize forest productivity/benefits
- Maximize industrial productivity/benefits
- Maximize benefits from subsistence
- Maximize commercial fishery productivity/benefits
- Minimize nonindustrial property loss
- Maximize benefits from outdoor recreation
- Minimize broad-scale risks

These were chosen so as to represent, according to the judgment of the FML project team, a broad set of goals related to well-being of Midwestern residents and also potentially sensitive to the changes anticipated under our scenarios. Most are self explanatory but a few require further explanation. *Subsistence* refers to activities that derive food or sustenance from, e.g., hunting, fishing, collecting, rather than from agriculture. Commercial fishery benefits are differentiated from recreational fishery benefits (which are part of 'outdoor recreation'). Although several species (e.g., common carp, buffalo, catfish and freshwater drum) are harvested commercially in the upper and mid Mississippi River, for our study commercial fisheries were limited to those in the Great Lakes. Finally, broad-scale risks are effects whose primary impacts are felt outside the Midwest yet may still be considered important to Midwesterners and, to that extent, matter to their well-being as well. Certain effects overlap these categories. For example, Midwesterners can benefit directly from outdoor recreation (as participants or service providers) centered around the presence of migratory birds; they can also benefit from the knowledge that the Midwest provides critical habitat for internationally important avian biodiversity. Similarly, they can benefit directly from the production of agricultural commodities and also take satisfaction in the knowledge that their region contributes to international food security (as 'breadbasket to the world') or to national energy security.

Each first-level value was further subdivided – initially into constituent elements and later into contributing elements. For example, outdoor recreation was initially subdivided into component activities (hunting, fishing, hiking, boating and wildlife watching) as well as atmospheric visibility. One such component, fishing, was determined to depend on 'abundant aquatic habitat (recreational fishing species)' as a contributor, which depended in turn on 'water quality' and 'natural cover.' This section of the hierarchy was limited to general categories understandable to the public, so that it could be used later in public interactions. We used up to six levels to define these goals, their components and their contributors, and we defined as the ecosystem service the highest-level entity that could be considered, per the Fisher et al. 2009 definition, more as 'aspects of ecosystems' than of socioeconomic systems. In this fashion we identified 45 distinct services; they are denoted in bold and italic font in Figure 3 and Appendix A, and are summarized in Table 7.

Hier1	Hier2	Hier3	Hier4	Hier5	Hier6	Technical Contributor
Maximize benefits from outdoor recreation	Sustain/ improve Hunting opportunities	***Abundant wildlife habitat (recreational hunting species)***	Water quality			Wetland quantity
						Perennial riparian vegetation
						Water, sediment and chemical transport
						Pesticide applications
						Nutrient applications
			Natural cover			Wetland quantity & habitat quality
						Patch connectivity
						Upland resting habitat
						Foraging habitat
						Nesting habitat
			Landscape Mix			Landscape heterogeneity
	Sustain/ improve Fishing opportunities	***Abundant aquatic habitat (recreational fishing species)***	Water quality			Wetland quantity
						Perennial riparian vegetation
						Water, sediment and chemical transport
						Pesticide applications
						Nutrient applications
			Natural cover			Diverse channel structure (ditches, streams)
						Diverse floodplain habitats (rivers)
	Sustain/ improve Hiking opportunities	***Landscape conducive to hiking***	Natural cover			Woodland quantity/ quality
						Grassland quantity/ quality
						Perennial riparian vegetation
			Landscape mix			Landscape heterogeneity
	Sustain/ improve Boating opportunity	***Landscape conducive to boating***	Natural cover			Perennial riparian vegetation
			Landscape mix			Landscape heterogeneity
		Water quality conducive to boating	Water quality			Wetland quantity
						Perennial riparian vegetation
						Water, sediment and chemical transport
						Nutrient applications
		Water availability for boating	Surface water storage			Surface water withdrawals
			Flood moderation			Wetland quantity
						Water, sediment and chemical transport
						Diverse channel structure (ditches, streams)
						Floodplain flood storage capacity

Figure 3. A fragment of the FML hierarchy of values, ecosystem services and technical contributors. Ecosystem services are indicated in bold and italic font.

Table 7. List of ecosystem services to be considered in the FML Study, showing full name and corresponding short label. (See Appendix A for context of each service within the values hierarchy.) Double lines indicate groupings of similar services; this order of listing is the same as that used on data plots.

Full name	Short label
Abundant agricultural land cover	Ag cover
Biofuel feedstock production	Biofuel prod
Food production	Food prod (gbl)
Abundant forest cover (forestry)	Forest cover
Land cover that minimizes vector-borne illness	Land cover (illness)
Air quality that maximizes agricultural production	AQ (ag)
Air quality (pollutant export)	AQ (export)
Air quality that maximizes forest production	AQ (forest)
Air quality that minimizes respiratory health risks	AQ (health)
Air quality conducive to visibility	AQ (visibility)
Abundant aquatic habitat (Great Lakes commercial fisheries)	Aqua hab (GL)
Abundant aquatic habitat (recreational fishing species)	Aqua hab (recr)
Abundant aquatic habitat (subsistence fishing)	Aqua hab (subs)
Water quality that maximizes agricultural production	WQ (ag)
Water quality conducive to boating	WQ (boat)
Water quality (pollutant export)	WQ (export)
Water quality that maximizes forest production	WQ (for)
Water quality that minimizes water-borne illness	WQ (illness)
Water quality that maximizes industry	WQ (ind)
Flood moderation that minimizes crop loss	Fld mod (crops)
Flood moderation that minimizes forest stand loss	Fld mod (for)
Flood moderation that minimizes risks to life and limb	Fld mod (health)
Flood moderation that minimizes industrial loss	Fld mod (ind)
Flood moderation that minimizes nonindustrial loss	Fld mod (non ind)
Water availability for agriculture	Water amt (ag)
Water availability for boating	Water amt (boat)
Water availability for forestry	Water amt (for)
Water availability for industry	Water amt (ind)
Carbon storage	Carbon storage
Productivity of agricultural soils	Soil prod (ag)
Productivity of forest soils	Soil prod (for)
Resistance of agricultural soils to erosion	Soil stability (ag)
Resistance of forest soils to erosion	Soil stability (for)
Abundance of insects beneficial to agriculture	Bene inscts (ag)
Abundance of insects beneficial to forestry	Bene inscts (for)
Abundant native species (subsistence)	Native spp (subs)
Biodiversity of vegetation communities	Veg diversity
Abundant wildlife habitat (recreational hunting species)	Wlf hab (hunt)
Abundant wildlife habitat (viewed spp)	Wlf hab (spp view)
Abundant wildlife habitat (globally important spp, e.g. T&E)	Wlf hab (spp gbl)
Abundant wildlife habitat (subsistence species)	Wlf hab (subs)
Diverse wildlife habitat (all native spp)	Wlf hab (com gbl)
Diverse wildlife habitat (all native spp)	Wlf hab (com view)
Landscape conducive to boating	Landscape (boat)
Landscape conducive to hiking	Landscape (hiking)

D. Concept Maps

We examined key drivers of change and impacts of concern for the FML Study region through the development of a comprehensive conceptual model (Figure 4). This model detailed causal pathways from global drivers and national policies to all possible services provided by the range of overlapping subsystems: agricultural production systems, industrial systems, aquatic and terrestrial ecosystems, energy systems, etc. At all stages of model development, however, we sought to focus on activities or processes that were likely to be affected by the future scenarios we are considering. (For example, water quality in many areas is dependent on reservoir management; but the latter is not affected by any of our scenarios and was omitted.)

We used the concept mapping tool, Cmap (http://cmap.ihmc.us/; Cañas et al. 2004), to perform this conceptual modeling task. Concept maps are an effective means of representing and communicating knowledge. Novak (1998) proposed that the primary elements of knowledge are concepts and the relationships between concepts are propositions. A concept map is a graphical, two-dimensional display of concepts connected by directional lines that are labeled to characterize the relationships between pairs of concepts.

In our models, ecosystem drivers, elements, processes and services became concepts. As can be seen in Figure 4, the general model for the FML study is an extremely complex web of interactions and linkages. We first developed a base model showing the connections between these concepts, and then additional models that compared two scenarios. In these comparative models, a policy change corresponding to the scenario comparison was introduced at a given location in the model, and then connections between other concepts were labeled as positive or negative according to the expected propagation of the influence of the policy change through the system: positive for influences that were increased and negative for those that were decreased. A search of the literature provided foundational documentation for the direction of the connections where it could be identified.

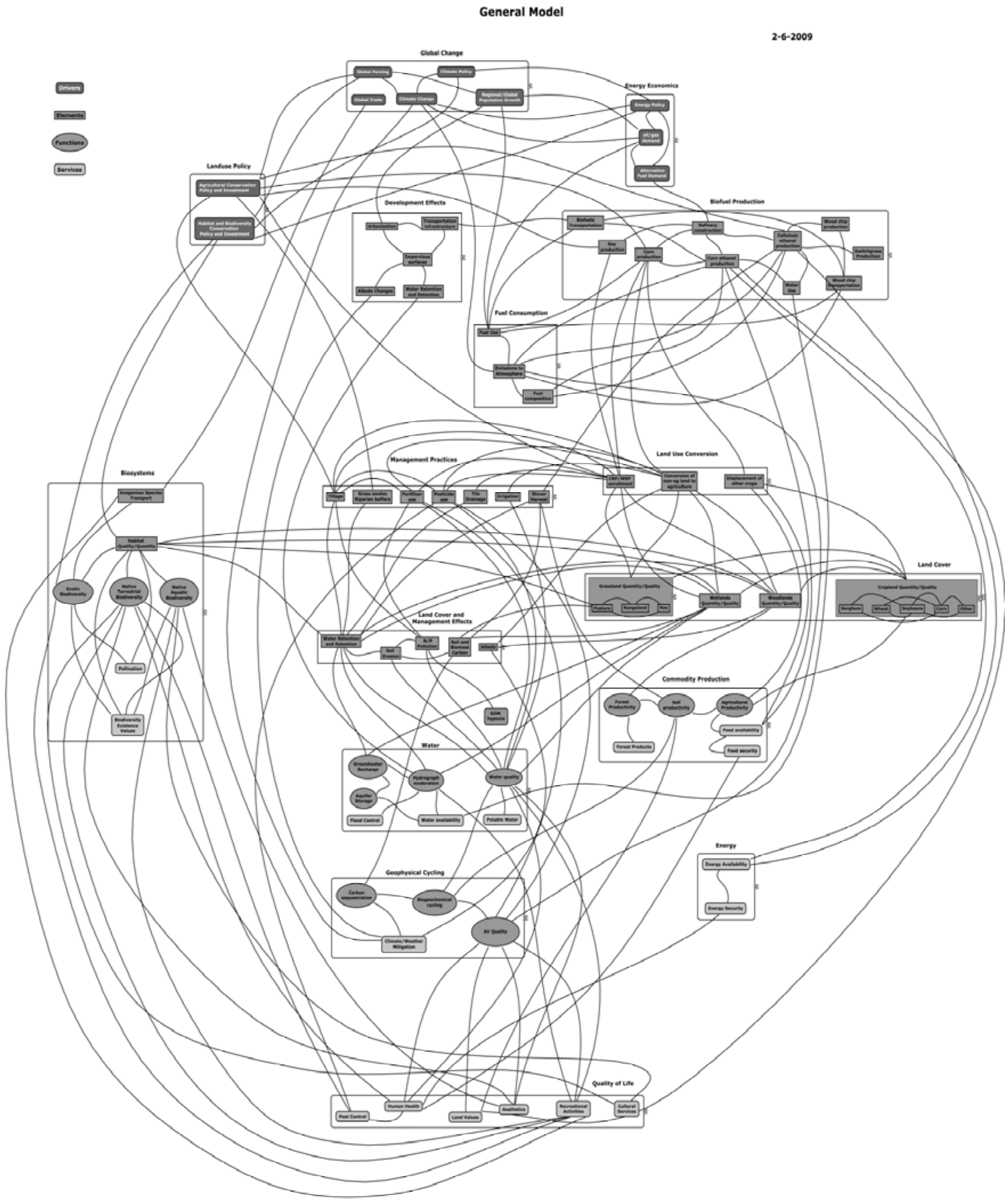


Figure 4. Illustration of the complexity of the base conceptual model diagram for the FML Study.

E. Creating an Influence Matrix

With the six-level values hierarchy as a point of departure, we used the concept maps to identify one additional level consisting of environmental elements, termed *technical contributors*, which we expected to be causally related to each of the lowest-level items in the hierarchy *and* likely to be affected by scenario-related changes (Appendix A). A total of 37 technical contributors (listed in Figure 5) were identified as potentially affecting one or more of the ecosystem services. For the example given above, technical contributors to water quality that could vary under our scenarios were determined to be:

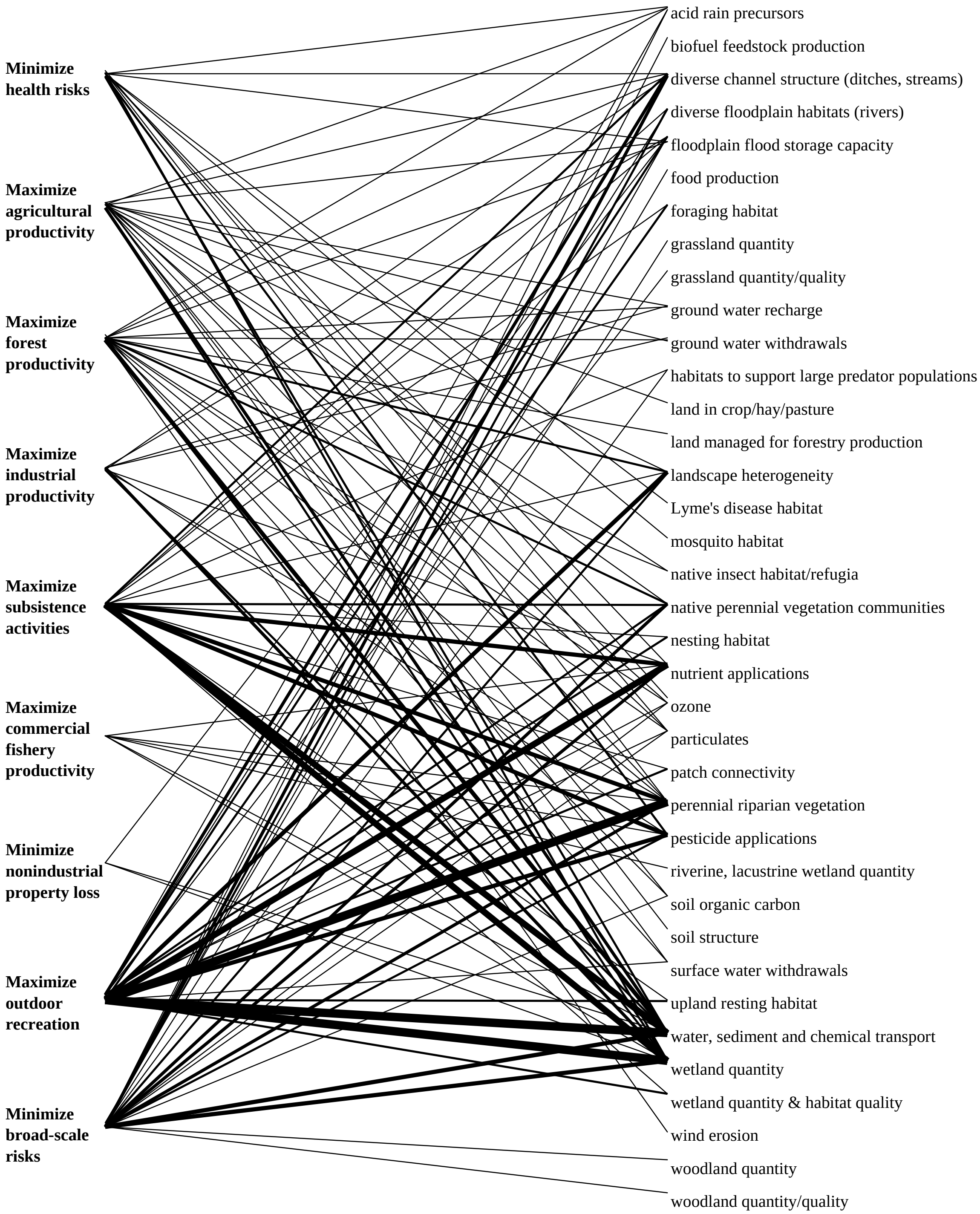
- wetland quantity
- perennial riparian vegetation
- water, sediment and chemical transport (i.e., field runoff)
- pesticide applications, and
- nutrient applications.

When repeated instances of the technical contributors were accounted for, the total number of rows in the hierarchy was 208. The degree to which a given technical contributor was repeated can be appreciated in Figure 5**.**

We examined the likely influence of a given scenario by examining separately the various changes that the scenario would directly cause. The BT-BY comparison entailed changes in both land use (due to demand for feedstocks) and biofuel production and use. We summarized the projected land use changes into four categories. Three of these were increases in corn plantings to meet projected increased demand (CRP to corn, other row crops to corn and hay/pasture to corn). The fourth was the expected harvesting of corn stover for use as cellulosic biofuel feedstock; we made a simple assumption of 30% stover removal from all land planted to corn (Table 5). We also summarized the projected changes in biofuel production and use into four categories (ethanol production; emissions from ethanol use; biodiesel production; emissions from biodiesel use) making a total of eight BT scenario-related changes. The MS scenario entails increases in the use of conservation practices; we are considering 11 candidate practices so each of these was separately considered a MS scenario-related change. At this stage we also identified various sets of weighting factors to reflect differences among the scenario-related changes in area and cost; these will be described below.

Using a Microsoft Excel spreadsheet, we created an influence matrix in which hierarchical elements were rows and scenario-related changes were columns.

Figure 5. Importance of technical contributors to ecosystem services in the FML Study. First-level hierarchy values (on left) are connected to all technical contributors (on right) that influence it; the thickness of the line indicates the number of times the technical contributor appears within that first-level hierarchy value. (See Appendix A for context of each technical contributor within the values hierarchy.)



F. Scoring the Influence Matrix

Scoring of the expected influences of agricultural changes on such a wide range of ecosystem services requires broad expertise spanning agricultural management practices, environmental science and ecology. Obtaining the judgment of 'experts' (i.e., leading authorities) for each of these topic areas would be extremely difficult. The goal of a scoping analysis is not to put forward scores that represent the best available knowledge, although we believe this method could be used for that purpose. Its purpose instead is to organize and concretize well-reasoned hypotheses about change to guide the design of a computational study. Therefore, the procedure we recommend is to rely on the judgment of scientists or practitioners with a broad knowledge of the pertinent subject area. For the illustrative demonstration presented in this paper, we used four environmental professionals on the FML project team, and each item was scored by at least three of the four scorers. Each scorer has more that 25 years professional experience in environmental science and at least three years addressing environmental issues related to agriculture. The scorers reviewed literature on biofuel feedstock production and agricultural conservation practices (including NRCS descriptions of these practices) in the process of conceptual model development.

Working independently from one another, the scorers scored the sign and magnitude (and scorer's level of certainty of the sign and magnitude) of the expected influence of each scenario-related change on each technical contributor. This included eight scenario-related changes for the BT scenario and 11 for the MS scenario, for a total of 19 scenario-related changes, multiplied by 37 technical contributors for a total of 703 influence scores. These were denoted 'C' scores, since they denoted expected influence on a 'contributor.' In a similar process, scorers also scored the influence of each technical contributor on the item immediately above it in the hierarchy (i.e., to its left in Appendix A); we called these hierarchy scores 'H' scores. H scores had to be assigned individually to each of the 208 rows in the hierarchy so that the hierarchical context could be taken into account.

Influence was scored with a positive integer if the change was expected to increase the contributor and a negative integer if the contributor would decrease. The magnitude of the influence value could range from zero to five; thus the overall potential range for any C or H score was -5 to +5, with zero indicating a lack of influence. For example, in the BT-BY comparison, one scenario-related change was conversion of Conservation Reserve Program (CRP) land to corn, and one technical contributor was 'channel structural diversity (ditches, streams).' For this case, the scorer considered the following question: "When a given area (size unspecified) is changed from CRP to corn, what is the effect on channel structural diversity of ditches or streams in or immediately adjacent to that particular area?" A score of +5 meant it would go from uniformly channelized to completely restored (e.g., natural meanders, floodplain, instream habitat diversity); -5 meant they would go from completely natural condition to all channelized.

Scorer certainty was rated from 1 to 5, as follows:

1. Both sign and magnitude are based more on intuition rather than professional knowledge.
2. Moderate certainty about the sign of the effect, but the magnitude is a best guess.

3. Moderate certainty about both sign and magnitude.
4. Certain about the sign and moderately certain of magnitude of the effect.
5. Certain about both the sign and the magnitude.

Cases of sign disagreement among scorers were examined through discussion to determine whether they were true disagreements or evidence of different interpretations of some part of the scoring task. Among the C scores there were 24 cases of sign disagreement of which 13 were resolved through discussion and 11 remained as disagreements. Of those resolved, 5 were found to be typographical errors, 4 involved different understandings about a conservation practice and were resolved through discussion and 4 involved different opinions about an influence where a change resulted from discussion. Among the H scores there were 4 instances of sign disagreement, all of which were resolved through discussion.

The final H and C scores from each of the individual scorers were compiled into one file for analysis. Calculations and plotting of results were carried out using SAS® software.

G. Scenario-Related Changes and Weighting Factors

In development of our hypotheses it was important to take into account potential differences in area or cost between certain of these changes. We decided to carefully separate these considerations as well. When scoring the influence of a land use change, we did so on an equal-area basis by assuming that the change occurred for the entirety of a given area (size not specified) and then we scored the effect of that change on a given technical contributor within or immediately adjacent to that area. Even when considering linear features such as grassed waterways or riparian buffers, we considered the area of the practice itself when scoring, not the areas through which the linear feature passed. We made an exception to this rule, however, in the case of wetlands constructed for treatment of drainage from higher-position crop land. In this case we considered the whole cropped area that the wetland was designed to address, and we assumed that the lowest 0.5 to 2% of the area was converted to wetland. This allowed us to score the expected effectiveness of the wetland for the contributing area.

In scoring, then, we could ignore whether the area of change expected in the scenario over the whole 12-state area was comparatively large or small. As a separate procedure we estimated the expected fraction of the total agricultural area of the FML expected to undergo that change. We were then able to make subsequent computations with or without the use of this fraction as a weighting factor. For the BT scenario, these area fractions were known based on available projections (Table 5). For the MS scenario (Table 8) these fractions were unknown because the FML research team has not determined which conservation practices to include and has not estimated their areas of increase. We created one set of weights by assuming a doubling of the area over which a practice is currently used (or a halving of the total potential use area in which it is *not* used, whichever was least). We created a second set of weights based on the reciprocal of the estimated per-acre cost. Potential areas, actual areas and costs were based on a review of the conservation practice literature; in our judgment, very rough estimates of central tendencies

Table 8. Weighting factors for conservation practices by area and cost, respectively. Rationales for the selection of these values are given in Appendix B**.**

Conservation Practice	Potential Area (ma)	Estimated BY use (%)	Estimated BY use (ma)	Assumed MS use (%)	Assumed MS use (ma)	Approx. annualized cost ($/acre/yr)	Weighting factors	
							BY - MS change as fraction of total ag area	Reciprocal of cost
Nutrient management	145	36	52	68	99	1	0.20	1.00
Reduced tillage	182	71	129	86	155	20	0.11	0.050
Winter cover	182	15	27	30	55	30	0.12	0.033
Drainage water management	40	1	0.40	2	0.80	12	0.0017	0.083
Land retirement for conservation	204	10	20	20	41	100	0.087	0.010
Wetland restoration	40	1	0.40	2	0.80	350	0.0017	0.0029
Wetland creation	145	1	1.45	2	2.91	80	0.0062	0.013
Contouring/ terracing	56	10	5.6	20	11	40	0.024	0.025
Riparian forest buffer	22	45	9.9	73	16	150	0.026	0.007
Grassed waterways	56	15	8.5	30	17	360	0.036	0.0028
Floodplain conservation easement	27	52	14.0	76	21	300	0.028	0.0033

of the available ranges were sufficient for the purposes of, and in keeping with the goals of, a scoping exercise. (Further information on potential and actual areas and costs of conservation practices is presented in Appendix B.) We used both weighted and unweighted values in the scoping process.

The costs of nutrient management require special explanation. The reported per-acre cost range for this practice in one analysis was from $-30 to $14, with a mean cost of $-1 (i.e., a mean savings). Since we could not use a zero or a negative cost as a weighting factor, we assigned a cost of $1 to this practice. Even this low cost caused this practice to dominate the other practices when expressed on a cost basis. Therefore certain comparative plots were generated with and without inclusion of nutrient management, so that the effects of other practices could be more easily examined.

H. Calculation and Plotting of HxC Values, Ranges and Uncertainties

Our overall scoping goal was to characterize the expected influence of a given scenario (for example, the BT scenario) upon each ecosystem service of interest. Our first computational step was to examine the influence of each scenario-related change on each service via a given contributor. We combined the influence of ‘Contributor’ or C scores and ‘Hierarchy’ or H scores through geometric aggregation; that is, by taking the product, H_m x C_m, where the subscript denotes mean across scorers. We judged geometric aggregation to be preferable to additive aggregation. First, it appropriately aggregates signs; i.e., if a technical contributor that negatively affects a service (H_m is negative) is reduced by a service-related change (C_m is also negative), the service is expected to increase (H_m x C_m is positive). Second, it ensures that a component (H or C) score of zero (no influence) yields an aggregate score of zero. We divided H_m x C_m by 5 so that the resulting combined value, like its constituent values, was within a -5 to +5 range; for convenience, however, we referred to these simply as HxC values. HxC values could be area-weighted (i.e., multiplied by the fraction of total FML agricultural area affected by the service-related change) or cost weighted (i.e., multiplied by the reciprocal of cost). Within a given row of the hierarchy, we practiced additive aggregation of cost- or area-weighted HxC values representing different scenario-related changes within the same scenario. Summed area-weighted values were used to indicate overall impact on that row of changes with differing respective areas of influence caused by that scenario. We did not, however, aggregate across rows since the relationship among different technical contributors to a given service is unclear; for example, the degree to which wetland quantity compensates for pesticide application in determining water quality is not obvious.

We examined the variability associated with the HxC values in two ways. First, we transformed the certainty scores assigned to each H and C score by the scorers themselves, to uncertainty scores, U_h and U_c, by subtracting from 5 (i.e., 5 – certainty = U). Uncertainty thus was a value from 0 to 4, with higher values indicating greater uncertainty. We then took the product of the interscorer mean uncertainty for H and C scores and divided the result by 5 (i.e., U_h x U_c/ 5) as we had done with the influence scores, to indicate the comparative uncertainty of each HxC value. Second, the range across scorers for each H and C score, R_h and R_c was used as a measure of interscorer agreement. The range value was a positive number, potentially as high as 10, with higher values indicating greater disagreement among scorers. As before, the product of the range for H and C divided by 5 (i.e., R_h x R_c /5) was computed to indicate the comparative interscorer agreement of each HxC value.

To characterize the expected influence of the various scenarios on ecosystem services, we first visually examined patterns in the weighted and unweighted HxC values and the associated variability. These patterns were explored by plotting values in a variety of combinations. Plots were of three primary types. Each of these is explained in detail here to orient the reader prior to the discussion of results.

In the first type, weighted or unweighted HxC score is on the y-axis, and the 208 HxC values (corresponding to the 208 hierarchy rows) are grouped along the x-axis according to ecosystem service (abbreviations are explained in Table 7). Figure 6 shows unweighted HxC values for one scenario-related change; in this case, the change of other row crops to corn. As indicated by the arrows on the figure**,** eleven HxC values pertain to the service *Abundant wildlife habitat (recreational hunting species)*, abbreviated *Wlf hab (hunt)*. The reason for this can be found in

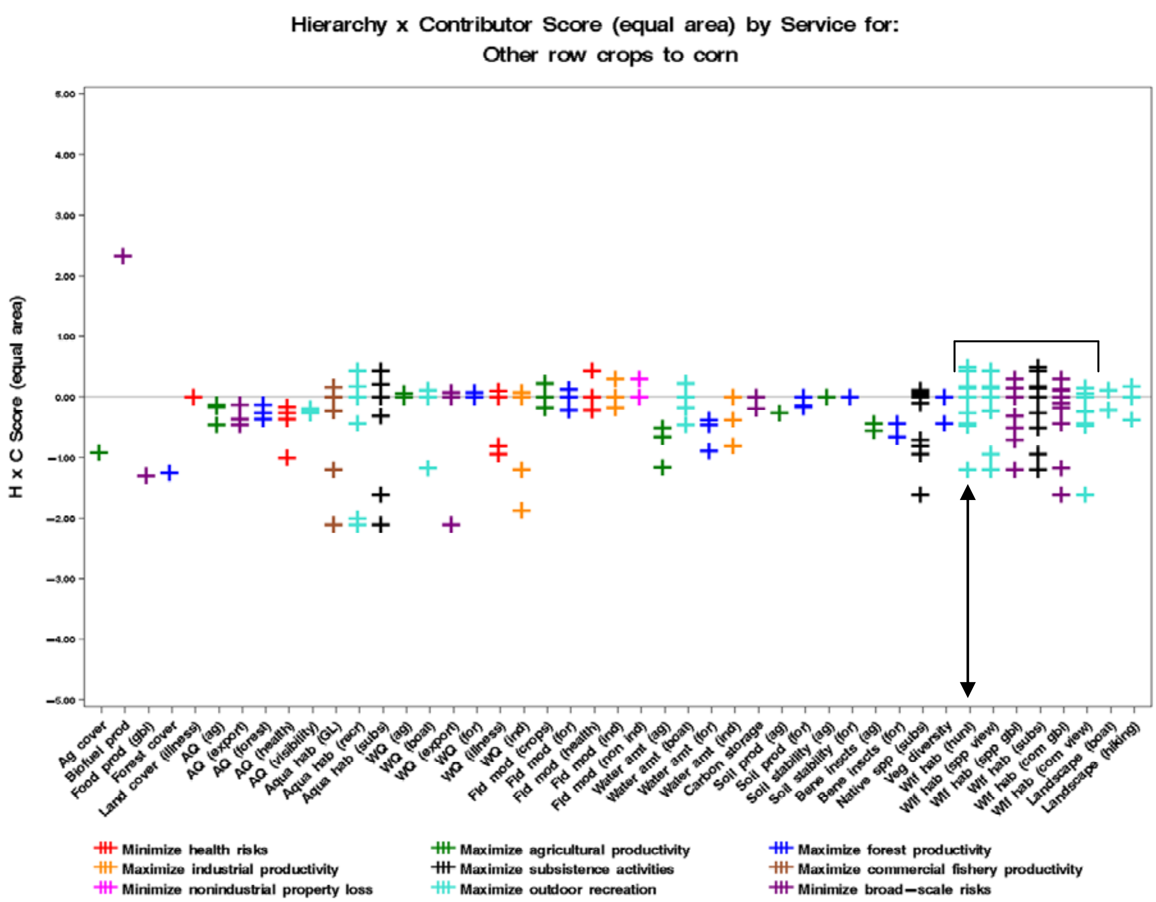


Figure 6**.** Example plot showing HxC values for one scenario-related change (other row crops to corn) grouped on the x-axis by ecosystem service. Symbol colors denote first-level hierarchy value to which each HxC value contributes influence.

Figure 3, where it is seen that 11 rows of the hierarchy pertain to this service. As explained above, we did not mathematically combine these values since one positive value does not necessarily counteract a negative value, and vice versa. A limitation of our displays is that they do not identify the specific technical contributor that corresponds to each plotted value.

The ordering of ecosystem services from left to right in Figure 6 (also as shown in Table 7) groups services that are similar in type, even though found in different sections of the hierarchy. For example, the six kinds of wildlife-habitat services (shown by bracket) are grouped for easy distinction. By contrast, symbol colors indicate the first-level value of the hierarchy to which the score pertains. All values in this plot that are under the first-level value *Maximize benefits from outdoor recreation* are in light blue.

The second type of plot is identical to the first except that symbols and colors now give an indication of the variability, either interscorer disagreement or uncertainty, associated with each HxC value plotted. Dots represent HxC values with no variability and larger circles indicate greater variability. For example, in Figure 7 where the symbol size represents interscorer disagreement, it is evident that scorers disagreed about the effect of this change on the overall amount of agricultural cover (range > 2.5).

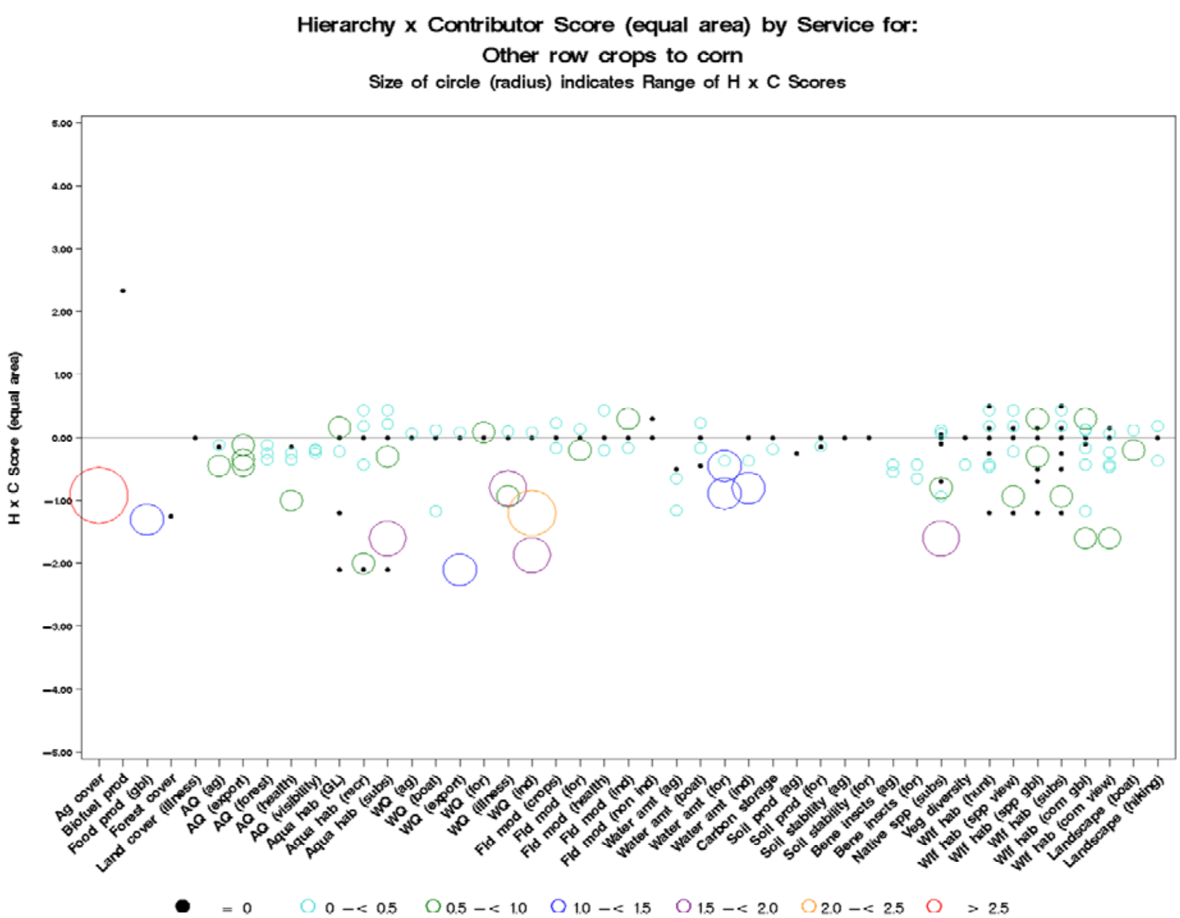


Figure 7. Example plot showing interscorer range of HxC values for one scenario-related change (other row crops to corn), grouped on the x-axis by ecosystem service. Symbol sizes and colors denote interscorer range.

In the third type of plot, HxC values are shown for one first-level value in the hierarchy, grouped according to the scenario-related changes which are now arrayed on the x-axis (Figure 8). From the left, the four BT changes related to land use are followed by the four related to biofuel production or combustion. Next, the four candidate conservation practices are shown that we have described as Conservation Practices Group I (i.e., involving only changes in management practice but not land cover) followed by Group II (those in which some land cover changes). Symbol colors now indicate the specific ecosystem services that contribute to that value in the hierarchy. Unweighted plots such as Figure 8 include HxC values for all of the scenario-related changes. Area-weighted plots omit the four changes related to biofuel production or combustion, since these cannot be area-weighted. Cost-weighted plots omit all BT scenario-related changes.

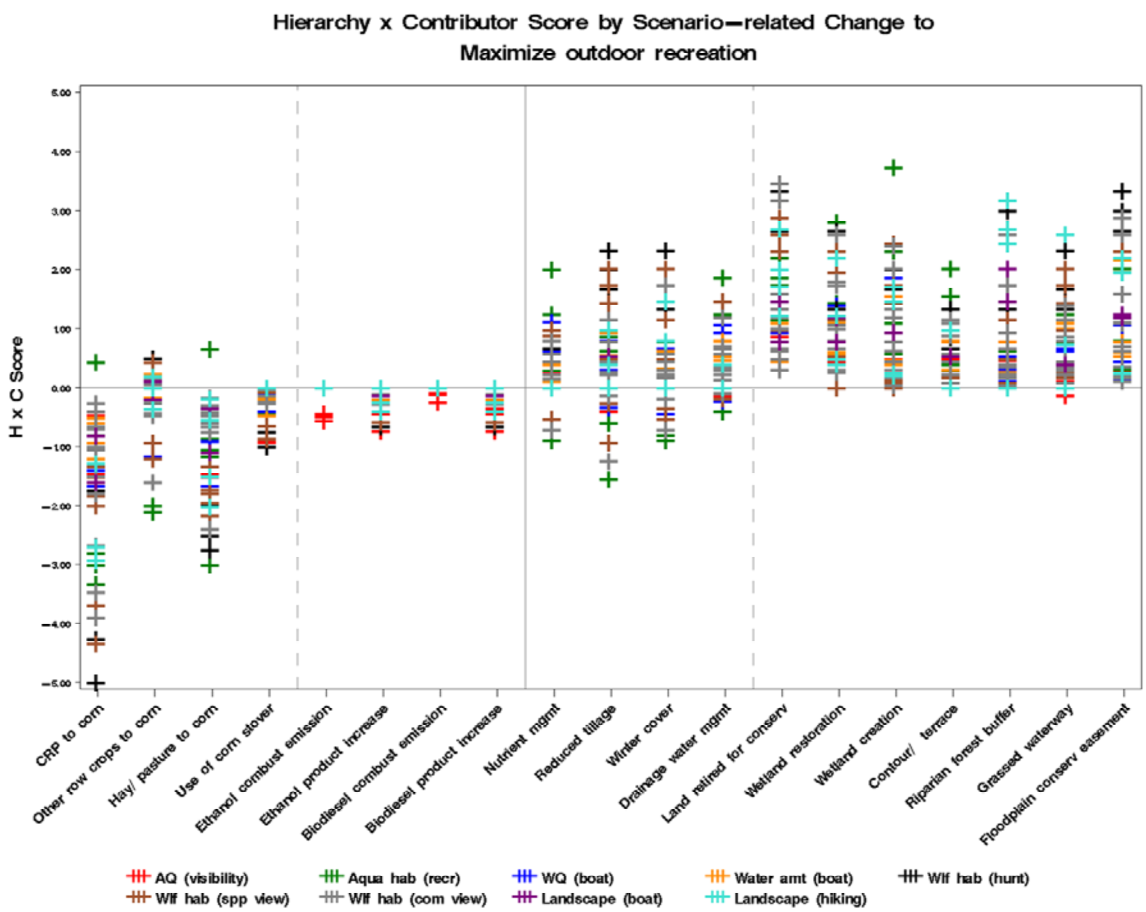


Figure 8. Example plot showing HxC values for one first-level hierarchy value (Maximize outdoor recreation), grouped on the x-axis by scenario-related change. Symbol colors denote ecosystem services to which each HxC score contributes influence.

III. RESULTS AND CONCLUSIONS

Prior to presenting any results and conclusions, we acknowledge several important caveats to the application of this scoping approach in general, and to the interpretation of the results of the scoping analysis of the FML Study reported here. Earlier we pointed out that scorers had extensive experience and pertinent knowledge but were not experts on every subject scored. Unless unusual efforts are made to assemble a large group of experts, this will always be a limitation of this scoping method. The particular results reported here are further limited by the fact that each item was scored by only three or four individuals; therefore the results obtained are only illustrative.

In adopting a matrix approach to hypothesis generation, we implicitly assume that influences of a given scenario-related change (column) upon a given element of the hierarchy (row) are all independent. We know that in any complex system there are interactions among elements. This simplification is necessary for a manageable process of hypothesis generation, but as a result we cannot examine potentially important interactions which could affect ecosystem service outcomes.

This scoping approach constitutes a supply-side examination of ecosystem service change hypotheses, in that it examines potential changes in the provision of services but ignores potentially large differences in demand for these services, which could change their relative importance. The latter could be examined by eliciting stakeholder weights for items within the hierarchy. Our demonstration did not involve such an elicitation process, though a scoping analysis could benefit from including such a step.

A. Biofuel Targets (BT) Scenario

Different ecosystem services are effective at different scales. Some services matter only over large scales. For example, although biofuel feedstock production can be measured at the farm scale, if processing only occurs at regional scales then service provision only occurs regionally and should be examined at that scale. Similarly, carbon storage (as related to climate regulation) ultimately matters only at global scales. All services defined in the FML hierarchy as contributing to the goal of ‘minimize broad-scale risks’ should, by definition, be examined at regional or larger scales. By contrast, services such as flood moderation may be important to landowners both at local scales (such as a watershed of a few thousand acres) and large-basin scales. We can examine the extremes of this range by examining both (a) unweighted service scores, which consider local service changes without regard for the likely regional extent of a given land use change, and (b) service scores that are weighted by expected total area of the practice.

If one thinks about services only in the immediate vicinity of a given land use change, without regard for how regionally widespread that change would be, all four types of land use changes in the BT scenario are associated with mostly negative impacts on a wide range of ecosystem service contributors (Appendix C.1, Figures C.1.1 – C.1.4). In general, the strongest negatives are related to change of perennials (hay/pasture or CRP) to corn. Impacts associated with conversion of other row crops to corn were not only lesser in magnitude but also more mixed in sign, with some positive as well as negative contributors, presumably due to the positive influences of corn on certain wildlife populations. Impacts attributed to stover removal were uniformly negative though generally of lesser magnitude. The only potential positive effects are reduced illness risks (Lyme disease and mosquito-borne illnesses) and increased agricultural cover.

Considering the relative proportions of areas projected for each land cover change, and summing all these impacts (Appendix C.5, Figures C.5.1), only a single improvement, increased biofuel production, appears likely to be important. Considering the four area-weighted changes individually (Appendix C.4, Figures C.4.1 – C.4.4), we see that this increase arises primarily from stover utilization and secondarily from changes from other row crops to corn, and includes comparatively small contributions from conversions of hay/pasture and CRP; no other improvements in services are expected.

The greatest expected reductions were found in productivity and carbon storage and were mainly attributable to stover utilization. Scorer agreement was high for these productivity scores and moderate for carbon storage (Appendix C.2, Figure C.2.4). Scorers rated their uncertainties for these services as low (Appendix C.3, Figure C.3.4). The scoping conclusion from these observations is that BT scenario-related changes in soil productivity and carbon storage should be modeled if possible. If it is not possible to do so, it will be important to conduct more detailed literature investigation of these concerns, and/or to advise users of FML Study findings that these effects were expected but could not be characterized.

Conversely, from inspection of Figure C.5.1, seven ecosystem services can be identified as relatively unaffected at this scale (arbitrarily, having no score > |0.15|):

- Abundant agricultural land cover
- Food production
- Land cover that minimizes vector-borne illness
- Abundant forest cover (forestry)
- Biodiversity of vegetation communities
- Landscape conducive to hiking
- Landscape conducive to boating

The scoping conclusion from this observation is that one might consider dropping these seven ecosystem services if their evaluation was resource-intensive; however, this would apply only if the same conclusion was reached at the local scale (i.e., using unweighted scores). We could not say this except for food production, since we include this only as a broad-scale concern (i.e., we have not concerned ourselves with food security within the Midwestern region).

B. Multiple Services (MS) Scenario

We compared the candidate conservation practices to one another to evaluate relative importance for inclusion in our Multiple Service scenario. Comparison of HxC values grouped by service (Appendix D.1, Figures D.1.1 – D.1.11) suggested the 11 practices comprise two groups. Although the distinction between these groups is not absolute, we have taken advantage of this difference by ordering the conservation practices accordingly in the presentation of some of the results, and separating the groups in the figures in Appendices C.5, D.5 and D.7 and Appendix E.

Group I practices, while positive on balance, tended to include a mix of positive and negative scores:

- Nutrient management
- Reduced tillage (includes no-till, mulch till, ridge till)
- Winter ground cover
- Drainage water management

Group II practices yielded scores that tended to be uniformly non-negative with exception of a few services (i.e., agricultural cover, food production and fuel production). Group II included the following practices:

- Land retirement for conservation and upland wildlife habitat management
- Wetland restoration
- Wetland creation for water treatment
- Contour farming, contour buffer strips and/or terracing
- Riparian forest buffer or grass filter strip
- Grassed waterway
- Floodplain conservation easement

The primary difference between these groups is that, with the partial exception of contour farming and terracing, the practices in the second group replace row crops with perennial vegetation, either in whole tracts (land retirement, wetland restoration or creation, floodplain easement) or in linear features (buffers and waterways). By contrast, the first group changes the management of row crops without reducing harvested area. A second difference, and a consequence of the first, is that the Group II practices are more expensive. Therefore, when services are examined on a cost basis (Appendix D.6, Figures D.6.1 – D.6.11; Appendix E.3, Figures E.3.1 – E.3.9; Appendix E.4, Figures E.4.1 – E.4.9), the Group I practices appear to have the potential to outperform Group II as service providers, although the mixing of positive and negative scores in Group I weakens this conclusion.

A slightly modified picture emerges if one assumes that success in increasing implementation of a given practice will be a function of its current adoption rate. When we assumed, as a simple example, that a doubling of the current rate of adoption is the most that could be hoped for any practice (Appendix D.4, Figures D.4.1 – D.4.11), then the first three of the Group I practices appear as important because they are already widely practiced, but since drainage water management is not widely practiced at present, it becomes less important in spite of its low cost.

By contrast, land retirement in Group II becomes important as well, due to its well-established use. Summing over these area-weighted changes (Appendix D.5, Figures D.5.1 and D.5.2), negative values are found to be related to health (air and water), aquatic habitat, and wildlife habitat. Inspection of the scoring data (not shown) reveals that in all cases these negatives are HxC values related to pesticide use. Scorers tended to show strong agreement (Appendix D.2, Figures D.2.1 - D.2.4), although they reported substantial uncertainty (Appendix D.3, Figures D.3.1 - D.3.4), about these negative Group I scores. Except for these pesticide-related negatives, there appears otherwise to be little difference between the Group I and Group II practices (when each is taken as a group), with two exceptions. The first exception is the obvious economic effects of removal of some land from crop production by the group II practices. A second exception is the presence of a weak concern about illness related to increased habitat for mosquitoes or the ticks that are vectors of Lyme disease.

An important scoping conclusion from these comparisons is that the FML computational study should give attention to quantifying changes in pesticide usage and impacts associated with Group I conservation practices. If this cannot be done, it will be important to conduct more detailed literature investigation of these concerns, and/or to advise users of FML findings that these effects were expected but could not be characterized. A secondary conclusion is the potential role of Group II conservation practices in the increase of habitat for human disease vectors. This concern also should be addressed via modeling, literature investigation and/or advice to FML information users.

Because the equal-area, area-weighted and cost-weighted results correspond to different goals for scenario creation, selection of practices for inclusion in a scenario will depend on whether the goal is to maximize services without regard to adoption-readiness or cost as a way to examine possibilities, or to focus on adoption-readiness or cost as a way to reflect feasibility. As pointed out earlier, selection will also depend on feasibility of modeling a practice which we have not evaluated in this exercise.

C. Summary and Hypotheses

In summary, we have developed and illustrated a highly structured method for gathering and displaying investigators' expectations about impacts of two alternative future scenarios for the Midwestern United States on a broad range of ecosystem services. This method, which we have termed *scoping*, depends on the development of hierarchically structured conceptual models of socioeconomic and environmental change, and the extensive use of best professional judgment (BPJ) scoring of elements within that hierarchy. Scoring is carried out using a Microsoft Excel spreadsheet; mathematically simple calculations of scores, interscorer ranges and scorer uncertainties are carried out and plotted using SAS® software. This new methodology offers an explicit procedure for managing ecological complexity and improving study design. Without such a scoping methodology, ecosystem service assessments may suffer from lack of rigor in the design process, and therefore default to approaches of convenience.

Although based on the best professional judgment of scorers with broad knowledge about the subject matter, these expectations or hypotheses should not be considered on par with the findings of experimental or computational studies or 'expert' determinations. Further, because each item in this demonstration was scored by only three or four individuals, these results are only illustrative and need to be confirmed through the use of additional scorers. Nonetheless, they have served to highlight several considerations for design of the Future Midwestern Landscapes (FML) Study, and/or use of the FML study results, that may not otherwise have been clear to our study team.

Based on this limited demonstration, we hypothesize that for the FML Biofuel Targets (BT) future scenario, the most widespread negative impacts will be on soil productivity and carbon storage. We also hypothesize that the FML BT scenario would have minimal impact on food production at the broad (e.g., global scale). The potential effects of increased biofuel production on global food security is a critically important issue, and we do not discourage the examination of this impact, but if resources for the FML Study are limited, investigating this issue might be given a lower priority.

Keeping in mind the limits of this demonstration, we hypothesize that for the FML Multiple Services (MS) scenario, the conservation practices under consideration for inclusion fall into two broad groupings: 'Group I practices' which involve agricultural management changes that do not decrease crop land cover, and 'Group II practices' which do change at least some land from crop to non-crop cover (and tend to be more expensive than Group I). A doubling of the current adoption level of both groups (where doubling is one way of thinking about the effects of incentives) would be hypothesized to result in generally similar increases of a broad range of ecosystem services. However, some negative influences due to pesticide use would be expected to result from the increase of Group I practices, and some concern would exist for increases in disease vectors from Group II practices.

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Appendix A: Hierarchy of values, ecosystem services and 'technical contributors' used for the FML scoping exercise.

Appendix A: Hierarchy of values, ecosystem services and 'technical contributors' used for the FML scoping exercise. Items in bold and italic font were defined as ecosystem services. Their complete names are listed here; complete and short-version names are given in Table 6.

Hier1	Hier2	Hier3	Hier4	Hier5	Hier6	Technical contributor
Minimize health risks	Minimize water-borne illness	***Water quality that minimizes water-borne illness***				Wetland quantity
						Perennial riparian vegetation
						Water, sediment and chemical transport
						Pesticide applications
						Nutrient applications
	Minimize vector-borne illness	***Land cover that minimizes vector-borne illness***				Mosquito habitat
						Lyme's disease habitat
	Minimize risks to life and limb	***Flood moderation that minimizes risks to life and limb***				Wetland quantity
						Water, sediment and chemical transport
						Diverse channel structure (ditches, streams)
						Floodplain flood storage capacity
	Minimize respiratory health risks	***Air quality that minimizes respiratory health risks***				Particulates
						Acid rain precursors
						Ozone
						Pesticide applications
Maximize agricultural productivity/ benefits	Maximize agricultural land	***Abundant agricultural land cover***				Land in crop/ hay/ pasture
	Minimize crop loss	Minimize flooding	***Flood moderation that minimizes crop loss***			Wetland quantity
						Water, sediment and chemical transport
						Diverse channel structure (ditches, streams)
						Floodplain flood storage capacity
		Maximize beneficial insects (predators, pollinators)	***Abundance of insects beneficial to agriculture***	Landscape Mix		Landscape heterogeneity
				Natural cover		Native insect habitat/ refugia
	Maximize/ Ensure Air Quality	***Air quality that maximizes agricultural production***				Particulates
						Acid rain precursors
						Ozone
	Maximize/ ensure Water Quality	***Water quality that maximizes agricultural production***				Wetland quantity
						Perennial riparian vegetation

					Water, sediment and chemical transport
	Ensure Water Availability	***Water availability for agriculture***	Groundwater storage		Ground water recharge
					Ground water withdrawals
			Surface water storage		Surface water withdrawals
	Minimize erosion	***Resistance of agricultural soils to erosion***	Flood moderation		Water, sediment and chemical transport
			Natural cover		Native perennial vegetation communities
	Maintain soil productivity	***Productivity of agricultural soils***			Soil organic carbon
					Soil structure
Maximize forest productivity/ benefits	Maximize managed forest cover	***Abundant forest cover (forestry)***			Land managed for forestry production
	Minimize crop loss	Minimize flooding	***Flood moderation that minimizes forest stand loss***		Wetland quantity
					Water, sediment and chemical transport
					Diverse channel structure (ditches, streams)
					Floodplain flood storage capacity
		Maximize beneficial insects (predators, pollinators)	***Abundance of insects beneficial to forestry***	Landscape Mix	Landscape heterogeneity
				Natural cover	Native insect habitat/ refugia
	Maximize/ Ensure Air Quality	***Air quality that maximizes forest production***			Particulates
					Acid rain precursors
					Ozone
	Maximize/ ensure Water Quality	***Water quality that maximizes forest production***			Wetland quantity
					Perennial riparian vegetation
					Water, sediment and chemical transport
	Ensure Water Availability	***Water availability for forestry***	Groundwater storage		Ground water recharge
					Ground water withdrawals
			Surface water storage		Surface water withdrawals
	Minimize erosion	***Resistance of forest soils to erosion***	Flood moderation		Water, sediment and chemical transport
			Natural cover		Native perennial vegetation communities
	Maintain soil productivity	***Productivity of forest soils***			Soil organic carbon
					Water, sediment and chemical transport
					Wind erosion

	Maintain genetic stocks for breeding	***Biodiversity of vegetation communities***	Biodiversity	Landscape heterogeneity
			Natural cover	Native perennial vegetation communities
Maximize industrial productivity/ benefits	Ensure Water Availability	***Water availability for industry***	Groundwater storage	Ground water recharge
				Ground water withdrawals
			Surface water storage	Wetland quantity
	Minimize loss to infrastructure & property	***Flood moderation that minimizes industrial loss***		Wetland quantity
				Water, sediment and chemical transport
				Diverse channel structure (ditches, streams)
				Floodplain flood storage capacity
	Ensure Water Quality	***Water quality that maximizes industry***		Wetland quantity
				Perennial riparian vegetation
				Water, sediment and chemical transport
				Pesticide applications
				Nutrient applications
Maximize benefits from subsistence activities	Sustain/ improve hunting opportunities	***Abundant wildlife habitat (subsistence species)***	Water quality	Wetland quantity
				Perennial riparian vegetation
				Water, sediment and chemical transport
				Pesticide applications
				Nutrient applications
			Natural cover	Wetland quantity & habitat quality
				Patch connectivity
				Upland resting habitat
				Foraging habitat
				Nesting habitat
			Landscape Mix	Landscape heterogeneity
	Sustain/ improve fishing opportunities	***Abundant aquatic habitat (subsistence fishing)***	Water quality	Wetland quantity
				Perennial riparian vegetation
				Water, sediment and chemical transport
				Pesticide applications
				Nutrient applications

			Natural cover		Diverse channel structure (ditches, streams)
					Diverse floodplain habitats (rivers)
	Sustain/ improve native species population viability	***Abundant native species (subsistence)***	Abundant native species habitat (subsistence)	Water quality	Wetland quantity
					Perennial riparian vegetation
					Water, sediment and chemical transport
					Pesticide applications
					Nutrient applications
				Natural cover	Native perennial vegetation communities
					Habitats to support large predator populations
			Reduce impacts from exotic species	Water quality	Wetland quantity
					Perennial riparian vegetation
					Water, sediment and chemical transport
					Pesticide applications
					Nutrient applications
				Natural cover	Native perennial vegetation communities
				Flood Moderation	Wetland quantity
					Water, sediment and chemical transport
					Diverse channel structure (ditches, streams)
					Floodplain flood storage capacity
Maximize commercial fishery productivity/ benefits	Sustain/ improve Great Lakes fish production	***Abundant aquatic habitat (Great Lakes commercial fisheries)***	Water quality		Wetland quantity
					Perennial riparian vegetation
					Water, sediment and chemical transport
					Pesticide applications
					Nutrient applications
			Natural cover		Riverine, lacustrine wetland quantity
Minimize nonindustrial property loss	Minimize flood hazard	***Flood moderation that minimizes nonindustrial loss***			Wetland quantity
					Water, sediment and chemical transport
					Floodplain flood storage capacity

Maximize benefits from outdoor recreation	Sustain/ improve Hunting opportunities	***Abundant wildlife habitat (recreational hunting species)***	Water quality	Wetland quantity
				Perennial riparian vegetation
				Water, sediment and chemical transport
				Pesticide applications
				Nutrient applications
			Natural cover	Wetland quantity & habitat quality
				Patch connectivity
				Upland resting habitat
				Foraging habitat
				Nesting habitat
			Landscape Mix	Landscape heterogeneity
	Sustain/ improve Fishing opportunities	***Abundant aquatic habitat (recreational fishing species)***	Water quality	Wetland quantity
				Perennial riparian vegetation
				Water, sediment and chemical transport
				Pesticide applications
				Nutrient applications
			Natural cover	Diverse channel structure (ditches, streams)
				Diverse floodplain habitats (rivers)
	Sustain/ improve Hiking opportunities	***Landscape conducive to hiking***	Natural cover	Woodland quantity/ quality
				Grassland quantity/ quality
				Perennial riparian vegetation
			Landscape mix	Landscape heterogeneity
	Sustain/ improve Boating opportunity	***Landscape conducive to boating***	Natural cover	Perennial riparian vegetation
			Landscape mix	Landscape heterogeneity
		Water quality conducive to boating	Water quality	Wetland quantity
				Perennial riparian vegetation
				Water, sediment and chemical transport
				Nutrient applications
		Water availability for boating	Surface water storage	Surface water withdrawals
			Flood moderation	Wetland quantity
				Water, sediment and chemical transport

						Diverse channel structure (ditches, streams)
						Floodplain flood storage capacity
	Sustain/ improve wildlife watching opportunities	Sustain/ improve wildlife population viability	***Abundant wildlife habitat (viewed spp)***	*Water Quality*		Wetland quantity
						Perennial riparian vegetation
						Water, sediment and chemical transport
						Pesticide applications
						Nutrient applications
				Natural cover		Wetland quantity & habitat quality
						Patch connectivity
						Upland resting habitat
						Foraging habitat
						Nesting habitat
			Diverse wildlife habitat (all native spp)	*Landscape Mix*		Landscape heterogeneity
				Water quality		Wetland quantity
						Perennial riparian vegetation
						Water, sediment and chemical transport
						Pesticide applications
						Nutrient applications
				Natural cover		Native perennial vegetation communities
				Minimize impacts from exotic species	*Flood Moderation*	Wetland quantity
						Water, sediment and chemical transport
						Diverse channel structure (ditches, streams)
						Floodplain flood storage capacity
					Natural cover	Native perennial vegetation communities
	Maximize visibility	***Air quality conducive to visibility***				Particulates
						Acid rain precursors
						Ozone
Minimize broad-scale risks	Minimize Climate Change	Mitigate Net GHG Additions	***Carbon storage***			Woodland quantity
						Grassland quantity
						Soil organic carbon

Minimize broad-scale risks	Sustain global biodiversity	Sustain/ improve target species (e.g., T&E)	***Abundant wildlife habitat (globally important spp, e.g. T&E)***	*Landscape mix*		Landscape heterogeneity
				Water quality		Wetland quantity
						Perennial riparian vegetation
						Water, sediment and chemical transport
						Pesticide applications
						Nutrient applications
				Natural cover		Native perennial vegetation communities
						Diverse channel structure (ditches, streams)
						Diverse floodplain habitats (rivers)
		Sustain/ improve diverse communities	***Diverse wildlife habitat (all native spp)***	*Landscape Mix*		Landscape heterogeneity
				Water quality		Wetland quantity
						Perennial riparian vegetation
						Water, sediment and chemical transport
						Pesticide applications
						Nutrient applications
				Natural cover		Native perennial vegetation communities
						Diverse channel structure (ditches, streams)
						Diverse floodplain habitats (rivers)
						Habitats to support large predator populations
				Minimize impacts from exotic species	*Flood Moderation*	Wetland quantity
						Water, sediment and chemical transport
						Diverse channel structure (ditches, streams)
						Floodplain flood storage capacity
					Natural cover	Native perennial vegetation communities
	Minimize export of pollutants	***Water quality (pollutant export)***				Wetland quantity
						Perennial riparian vegetation
						Water, sediment and chemical transport

			Nutrient applications
		Air quality (pollutant export)	Particulates
			Acid rain precursors
			Ozone
	Maximize US energy security	***Biofuel feedstock production***	Biofuel feedstock production
	Maximize global food security	***Food production***	Food production

Appendix B. Information used to develop area and cost weighting factors for conservation practices.

Table B-1. **Information used to develop area and cost weighting factors for conservation practices.**

Conservation Practice	**Area or Cost Factor**	**Value**	**Explanation**	**Sources**
Land retirement for conservation	Potential Area (Ma)	204	2002 total area of cultivated (12 main) crops plus CRP	CARD (unpublished); NRI (on-line report)
	Estimated BY use (%)	10	Computed.	
	Estimated BY use (Ma)	20	Estimates of 2002 total CRP acreage range from 14 - 22 Ma	CARD (unpublished); NRI (on-line report)
	Assumed MS use (%)	20	Computed.	
	Assumed MS use (Ma)	41	Assumes doubling of 2002	
	Annualized cost ($/acre/yr)	100	Published cost/benefits analysis from IA.	Feng, 2006
Wetland restoration	Potential Area (Ma)	40	Estimates of % FML cropland vary widely, value selected based on latest using GIS and hydric soils analysis.	WRI (on-line report); USDA, 1987
	Estimated BY use (%)	1	Unknown, but assumed small.	
	Estimated BY use (Ma)	0.4	Computed.	
	Assumed MS use (%)	2	Assumes doubling of 2002	
	Assumed MS use (Ma)	1	Computed.	
	Annualized cost ($/acre/yr)	350	Assumes costs spread over multiple year period	BNL (on-line report)
Wetland creation	Potential Area (Ma)	145	Based on estimate that 80% FML cropland is treated with nutrients in a given year.	CARD (unpublished); NRI (on-line report)
	Estimated BY use (%)	1	Unknown but assumed small.	
	Estimated BY use (Ma)	1.5	Computed	
	Assumed MS use (%)	2	Assumes doubling of 2002	
	Assumed MS use (Ma)	4	Computed	
	Annualized cost ($/acre/yr)	80	Assumes costs spread over multiple year period	BNL (on-line report)

Table B-1 (Continued).

Conservation Practice	**Area or Cost Factor**	**Value**	**Explanation**	**Sources**
Nutrient management	Potential Area (Ma)	145	Based on estimate that 80% FML cropland is treated with nutrients in a given year.	NRCS unpublished data
	Estimated BY use (%)	36	Based on farm surveys, approximately 36% of nutrient treatments fully meet BMP's	NRCS unpublished data
	Estimated BY use (Ma)	52	Computed	
	Assumed MS use (%)	68	Assumes nonuse rate is reduced by half	
	Assumed MS use (Ma)	99	Computed	
	Annualized cost ($/acre/yr)	1	Based on field data from IA and SD	ASCS, 1991; ISU, 1991
Reduced tillage	Potential Area (Ma)	182	Area of FML cultivated cropland in 2002 assumed potentially treated with nutrients.	CARD (unpublished); NRI (on-line report)
	Estimated BY use (%)	71	Based on farm surveys, approximately 71% of nutrient treatments fully meet BMP's	NRCS unpublished study, 2009
	Estimated BY use (Ma)	129	Computed	
	Assumed MS use (%)	86	Assumes nonuse rate is reduced by half	
	Assumed MS use (Ma)	156	Computed	
	Annualized cost ($/acre/yr)	20	Conservation tillage defined as leaving 30% crop cover on field.	Feng, 1991; USEPA, 2003
Winter cover	Potential Area (Ma)	182	Area of FML cultivated cropland in 2002 assumed potentially treated with nutrients.	
	Estimated BY use (%)	15	Based on published USDA production statistics for 2002	NASS (on-line report)
	Estimated BY use (Ma)	27	For 2002 18 Ma winter wheat planted, assumes an additional cover with other crops.	NASS (on-line report)
	Assumed MS use (%)	30	Assumes doubling of 2002	
	Assumed MS use (Ma)	55	Computed	
	Annualized cost ($/acre/yr)	30	Estimates from published studies. Costs dependent on operator options for use of cover crop	CTT on-line report; USEPA, 2003

Table B-1 (Continued).

Conservation Practice	Area or Cost Factor	Value	Explanation	Sources
Contouring/ terracing	Potential Area (Ma)	63	GIS analysis reveals 31% of FML cropland on >3% grade.	WF, 2009
	Estimated BY use (%)	10	Ohio and Iowa farm surveys suggest this practice utilized on 10% of applicable acres.	Sogren, 2004 (on-line report); Toigo, 2009
	Estimated BY use (Ma)	6	Computed	
	Assumed MS use (%)	20	Assumes doubling of 2002	
	Assumed MS use (Ma)	13	Computed	
	Annualized cost ($/acre/yr)	40	Estimated from published studies but may vary greatly depending on initial constuction required	Feng, 1991; IDALS, 2007 (on-line report)
Riparian forest buffer	Potential Area (Ma)	22	GIS computation and estimate of area within 30 m buffer of FML NHD reach file	WF, 2009
	Estimated BY use (%)	45	GIS land cover (updated NLD) computation indicates 45% of buffer area is permanent woody vegetation.	WF, 2009
	Estimated BY use (Ma)	9.9	Computed	
	Assumed MS use (%)	73	Assumes nonuse rate is reduced by half	
	Assumed MS use (Ma)	16	Computed	
	Annualized cost ($/acre/yr)	150	National average from NRCS database	CTT (on-line report)
Grassed waterways	Potential Area (Ma)	56	GIS analysis reveals 31% of FML cropland on >3% grade.	WF, 2009
	Estimated BY use (%)	15	Farm surveys (Ohio and Iowa) suggests grassed waterway practice utilized on 4 - 25% of applicable acreage.	Sogren, 2004 (on-line report); Toigo, 2009
	Estimated BY use (Ma)	9	Computed	
	Assumed MS use (%)	30	Assumes doubling of 2002	
	Assumed MS use (Ma)	19	Computed	
	Annualized cost ($/acre/yr)	360	Estimated from published studies but may vary greatly depending on initial constuction required	Feng, 1991; CTT (on-line report)

Table B-1 (Continued).

Conservation Practice	Area or Cost Factor	Value	Explanation	Sources
Drainage water management	Potential Area (Ma)	40	Base on published estiamates of acres fitted with sub-surface drainage systems.	WRI, 2007 (on-line report); USDA 1987, 2004 (on-line report)
	Estimated BY use (%)	1	Unknown but assumed small.	
	Estimated BY use (Ma)	0.4	Computed	
	Assumed MS use (%)	2	Assumes doubling of 2002	
	Assumed MS use (Ma)	1	Computed	
	Annualized cost ($/acre/yr)	12	Assumes 10-year life of structures and negligible maintainance costs	CTT (on-line report)
Floodplain conservation easement	Potential Area (Ma)	27	Flood plain computed as the area with a 500 m buffer of FML RF1 reach file	WF, 2009
	Estimated BY use (%)	52	GIS assessment of permanent vegetation (NLD) within the flood plain	WF, 2009
	Estimated BY use (Ma)	14	Computed	
	Assumed MS use (%)	76	Assumes nonuse rate is reduced by half	
	Assumed MS use (Ma)	21	Computed	
	Annualized cost ($/acre/yr)	300	Based cost estimates for easements and construction used by the Extension Service staff from OH, IA and MO.	Toigo, 2009

References for Appendix B

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Appendix C. Plots by Ecosystem Service for each BT Scenario-related Change

Appendix C.1 Unweighted HxC Values by Service for the BT Scenario
Appendix C.2 Unweighted HxC Values and Ranges by Service for the BT Scenario
Appendix C.3 Unweighted HxC Values and Uncertainties by Service for the BT Scenario
Appendix C.4 Area-weighted HxC Values by Service for the BT Scenario
Appendix C.5 Sum of Area-weighted HxC Values by Service for the BT Scenario

Appendix C.1 Unweighted HxC Values by Service for the BT Scenario.

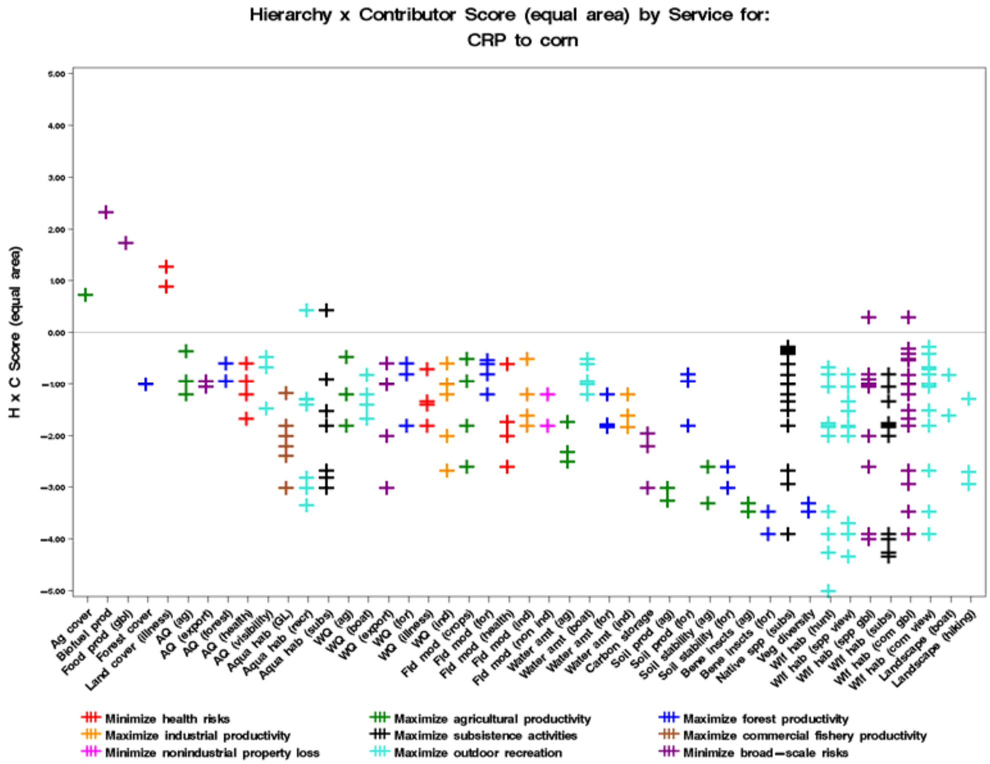

Figure C.1.1. CRP to corn.

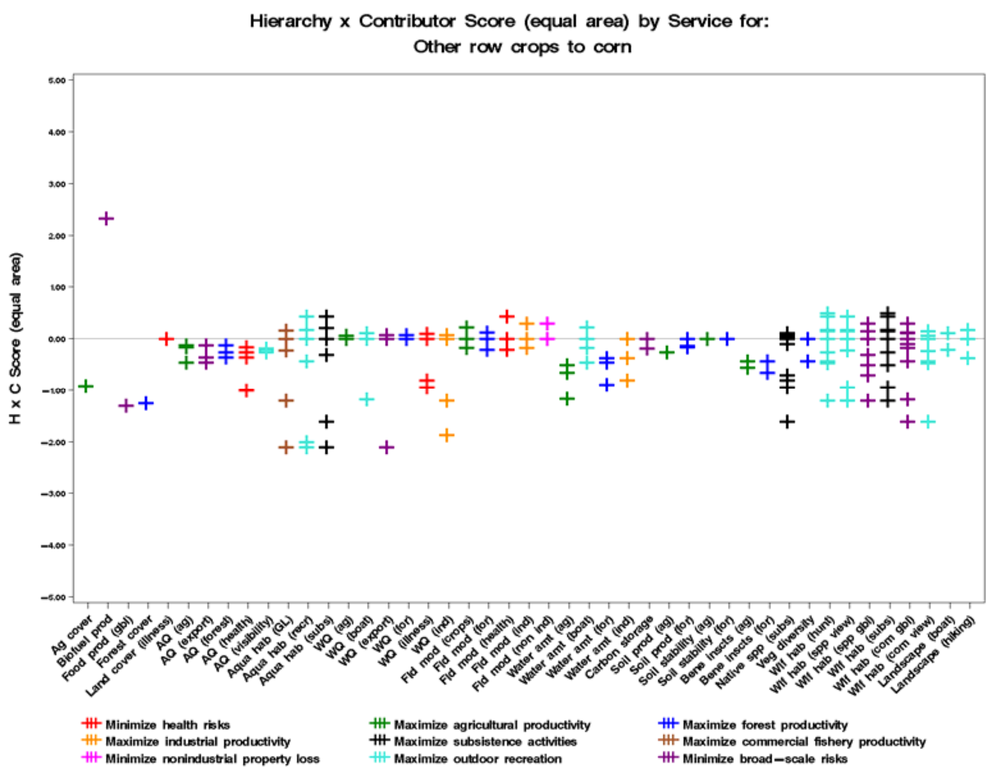

Figure C.1.2. Other row crops to corn.

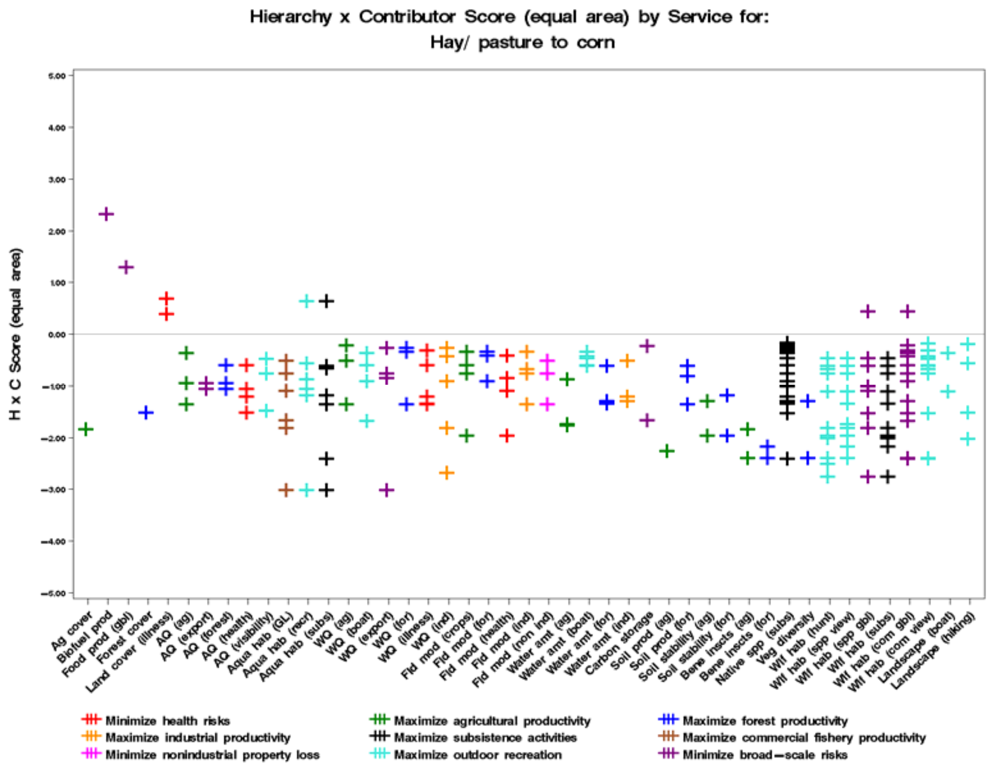

Figure C.1.3. Hay/ pasture to corn.

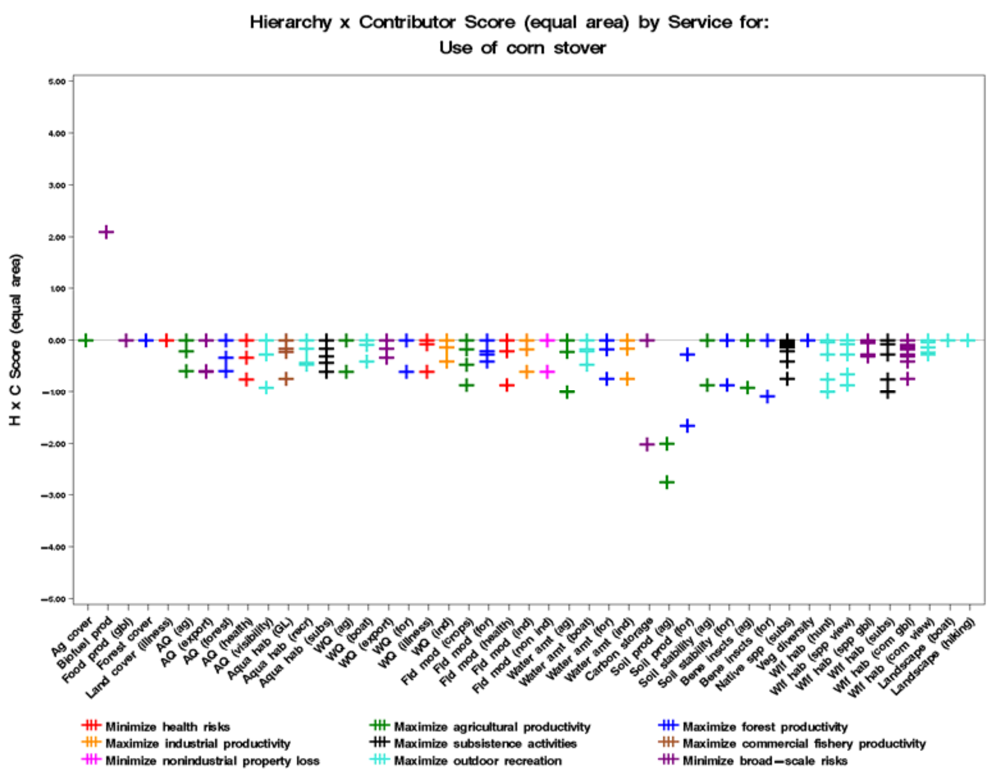

Figure C.1.4. Use of corn stover.

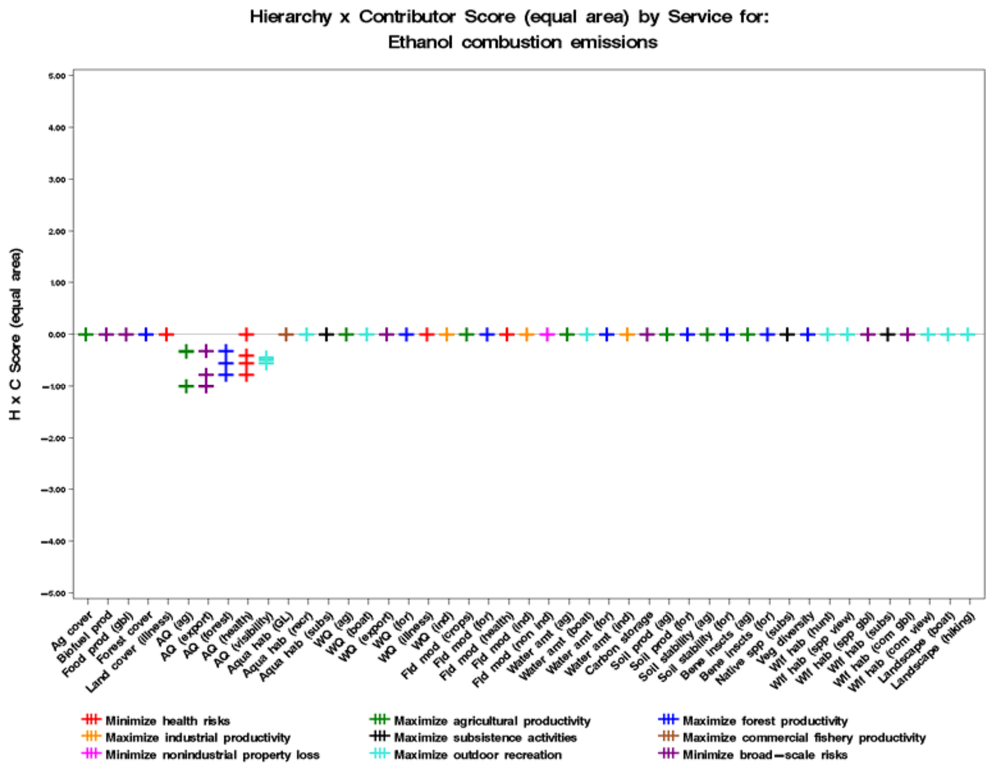

Figure C.1.5. Ethanol combustion emissions.

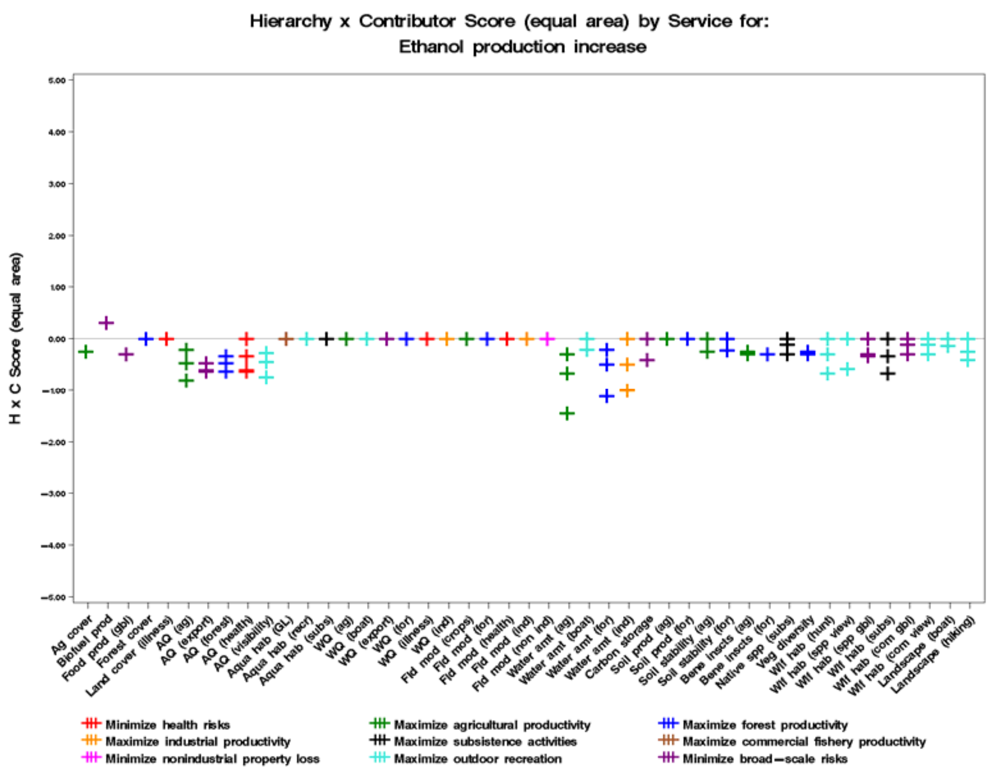

Figure C.1.6. Ethanol production increase.

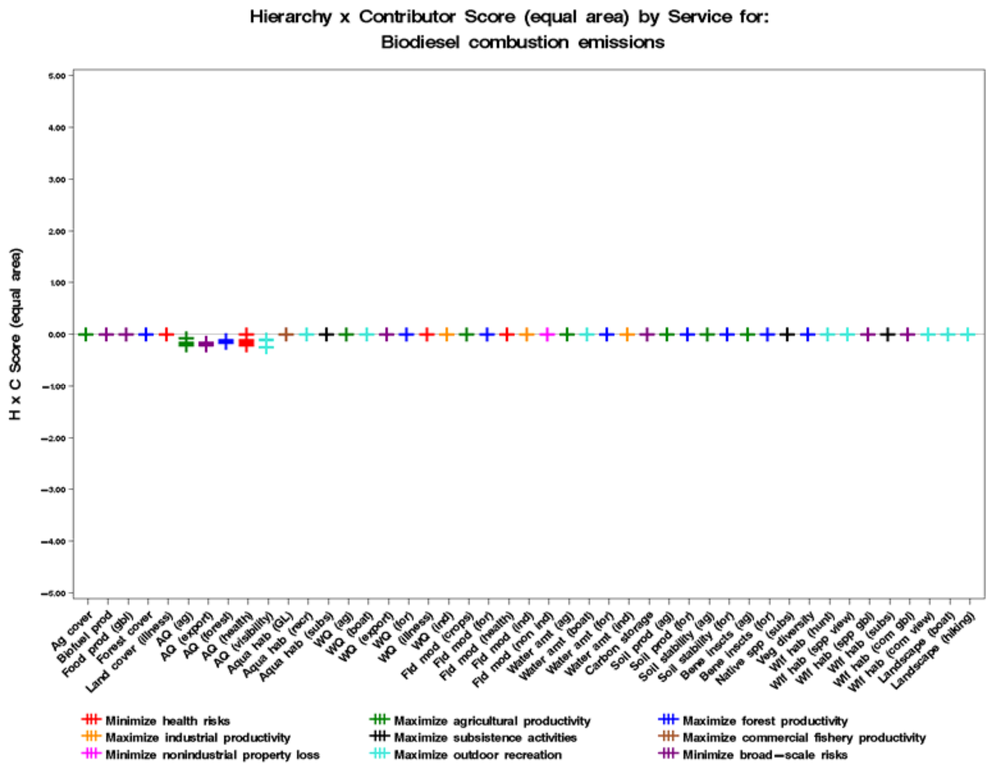

Figure C.1.7. Biodiesel combustion emissions.

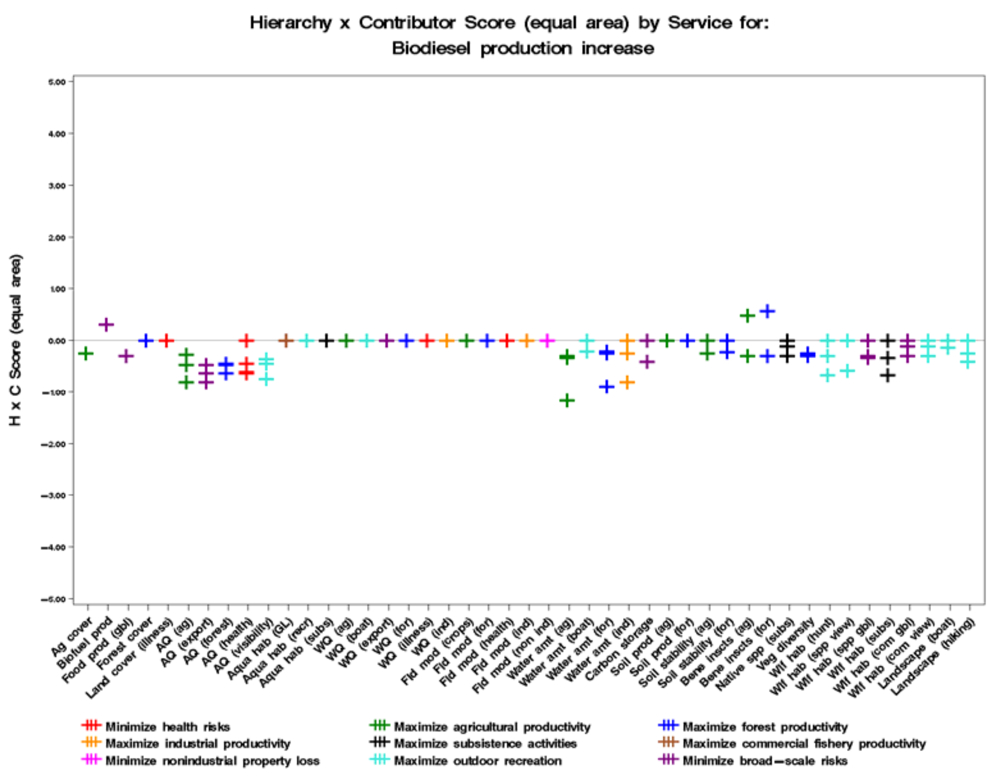

Figure C.1.8. Biodiesel production increase.

Appendix C.2 Unweighted HxC Values and Ranges by Service for the BT Scenario.

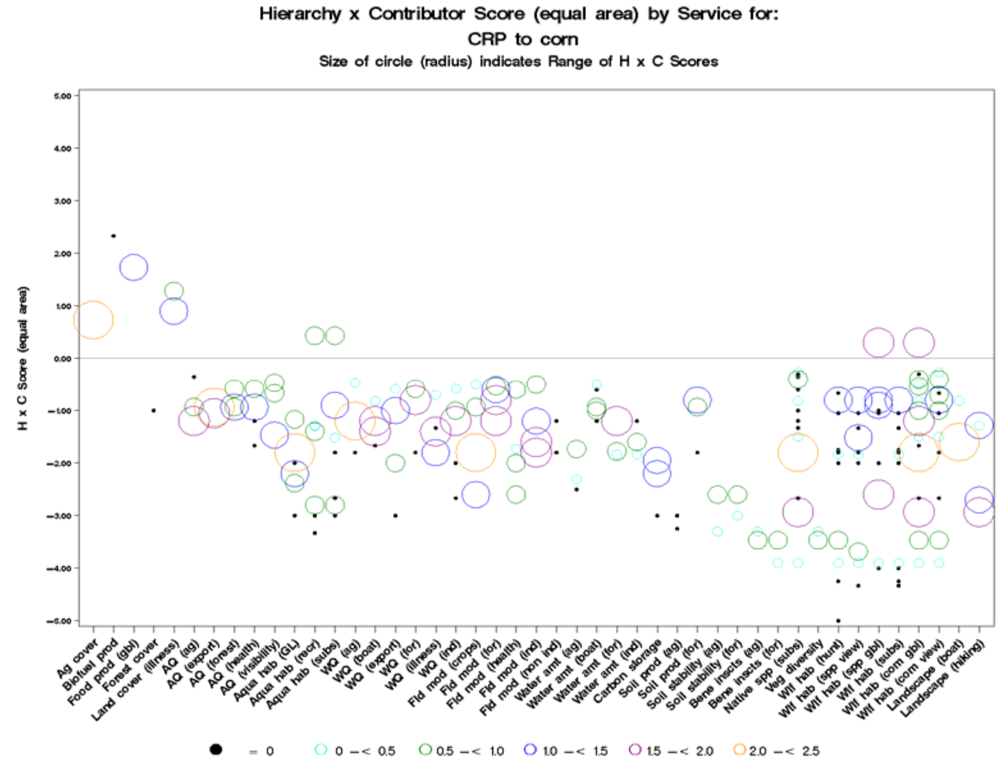

Figure C.2.1. CRP to corn.

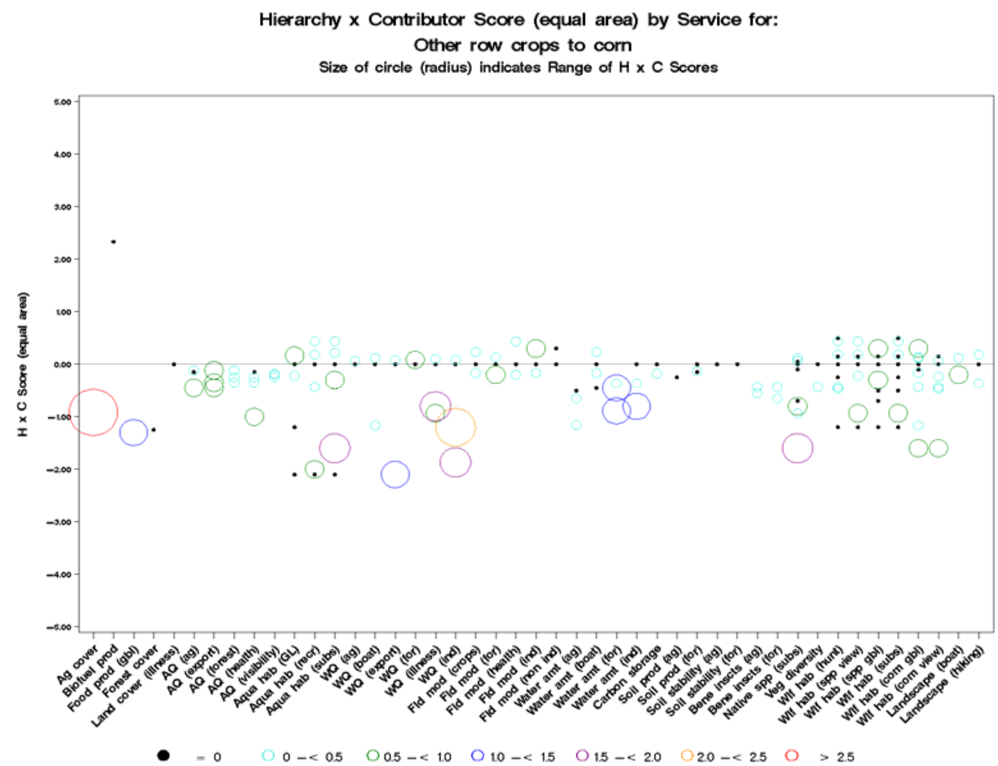

Figure C.2.2. Other row crops to corn.

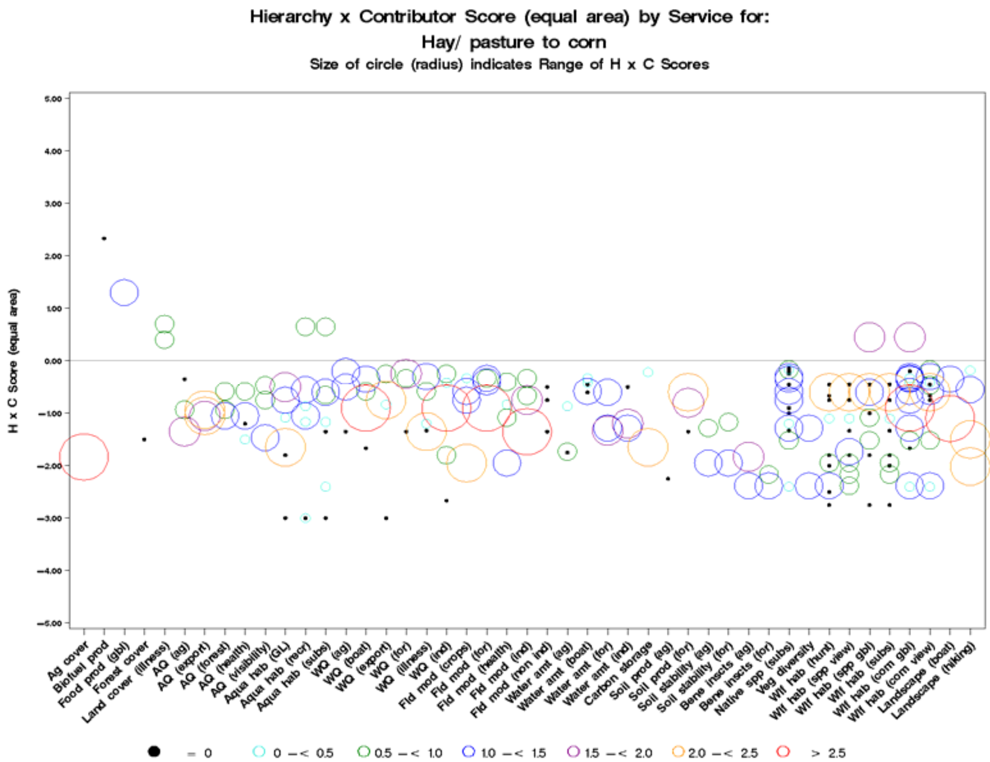

Figure C.2.3. Hay/ pasture to corn.

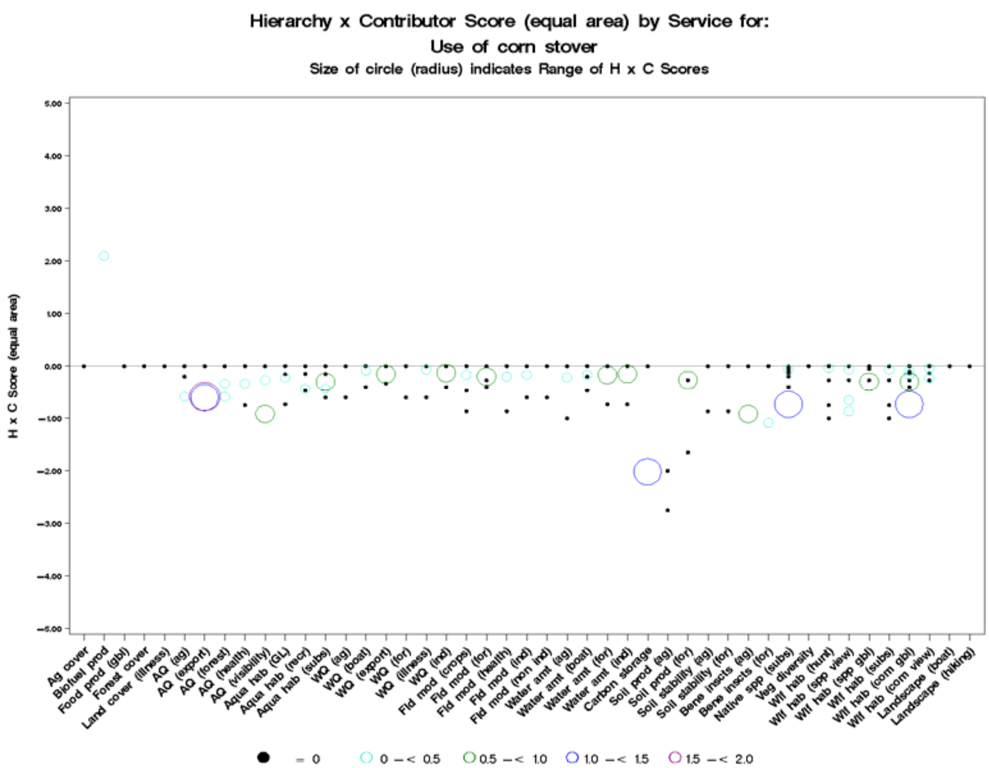

Figure C.2.4. Use of corn stover.

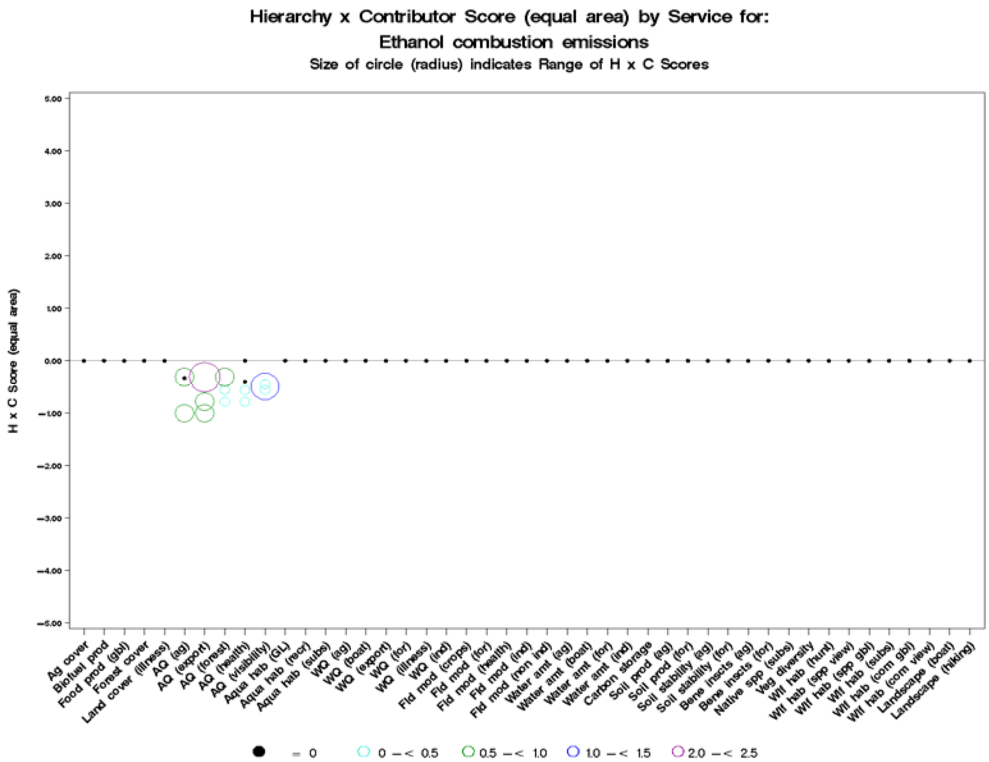

Figure C.2.5. Ethanol combustion emissions.

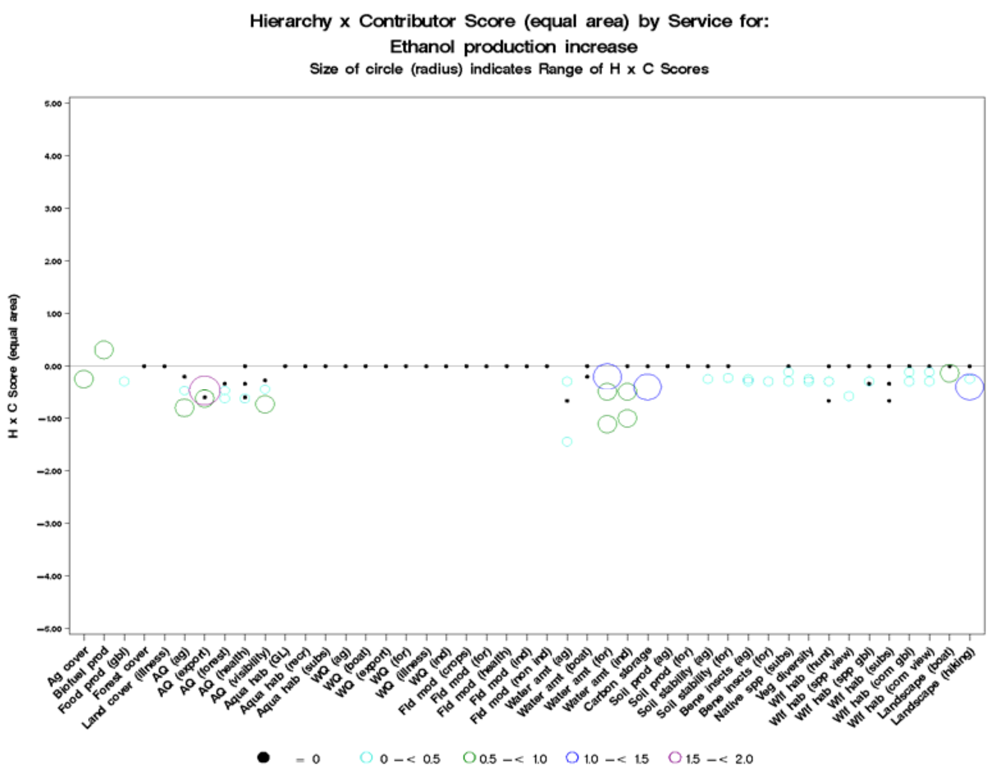

Figure C.2.6. Ethanol production increase.

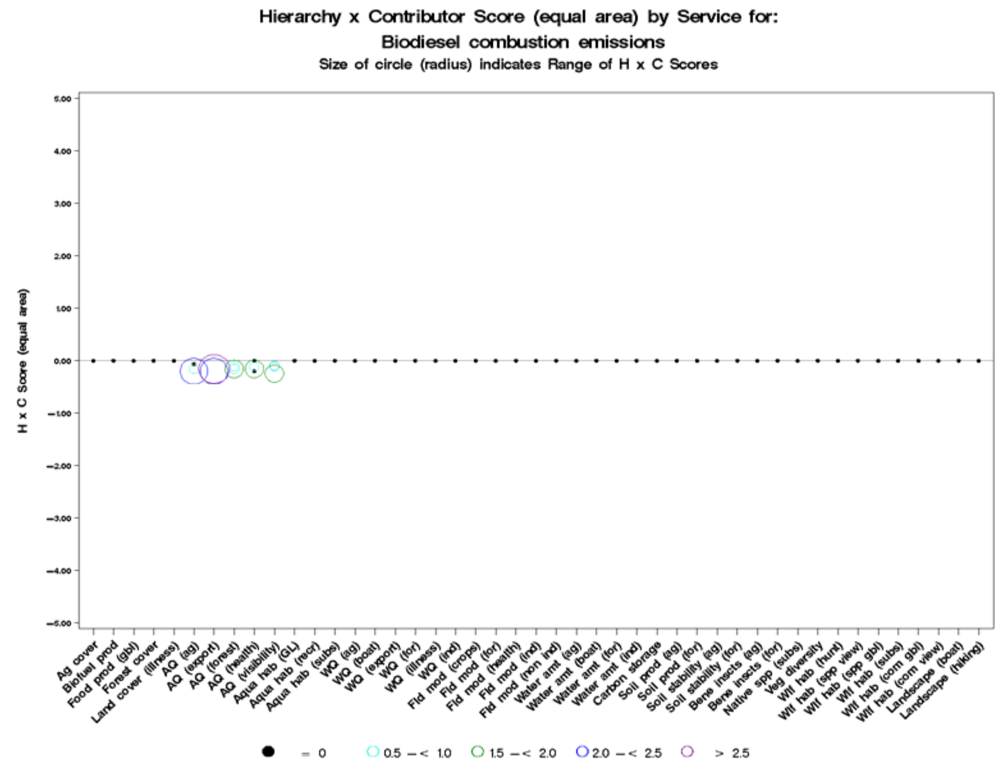

Figure C.2.7. Biodiesel combustion emissions.

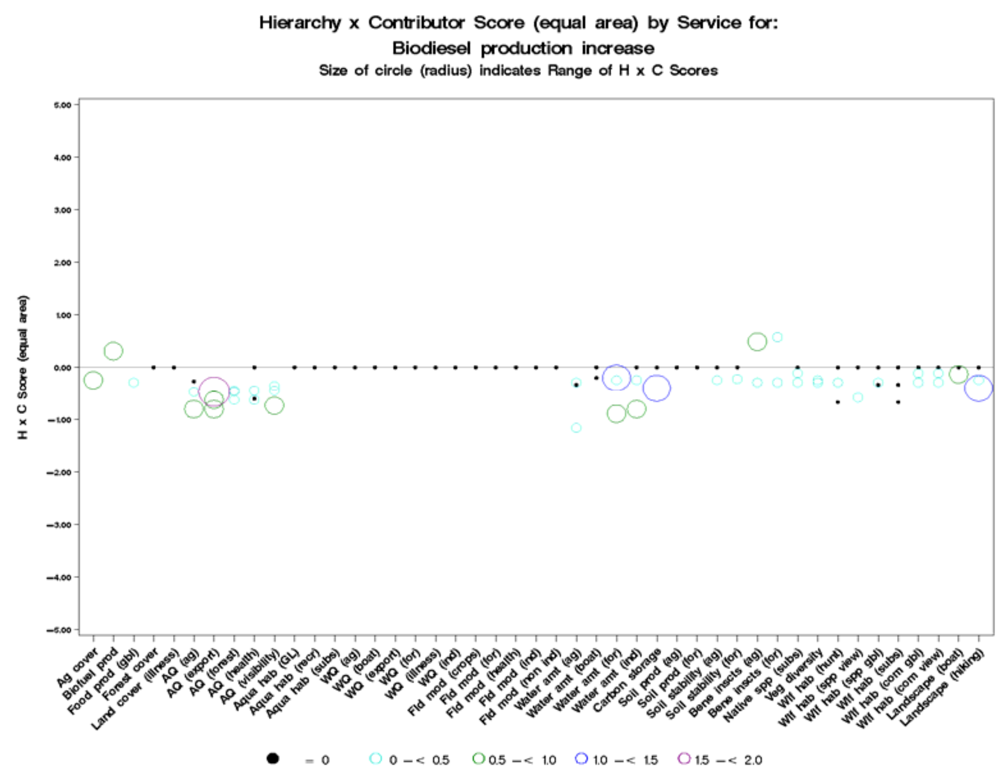

Figure C.2.8. Biodiesel production increase.

Appendix C.3 Unweighted HxC Values and Uncertainties by Service for the BT Scenario.

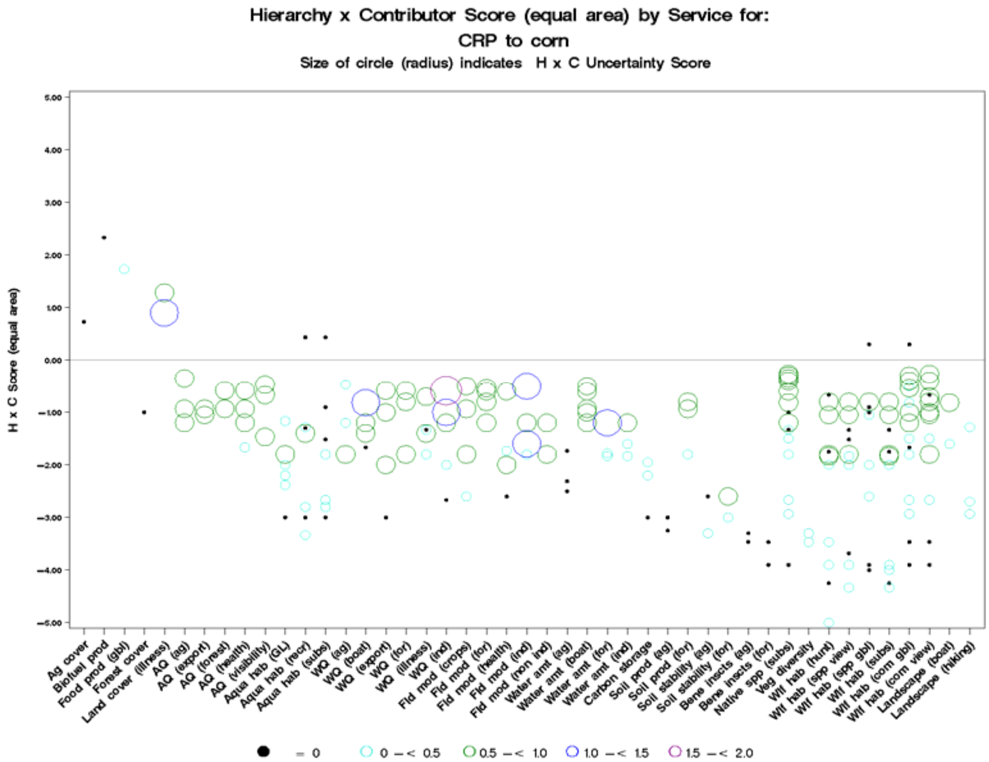

Figure C.3.1. CRP to corn.

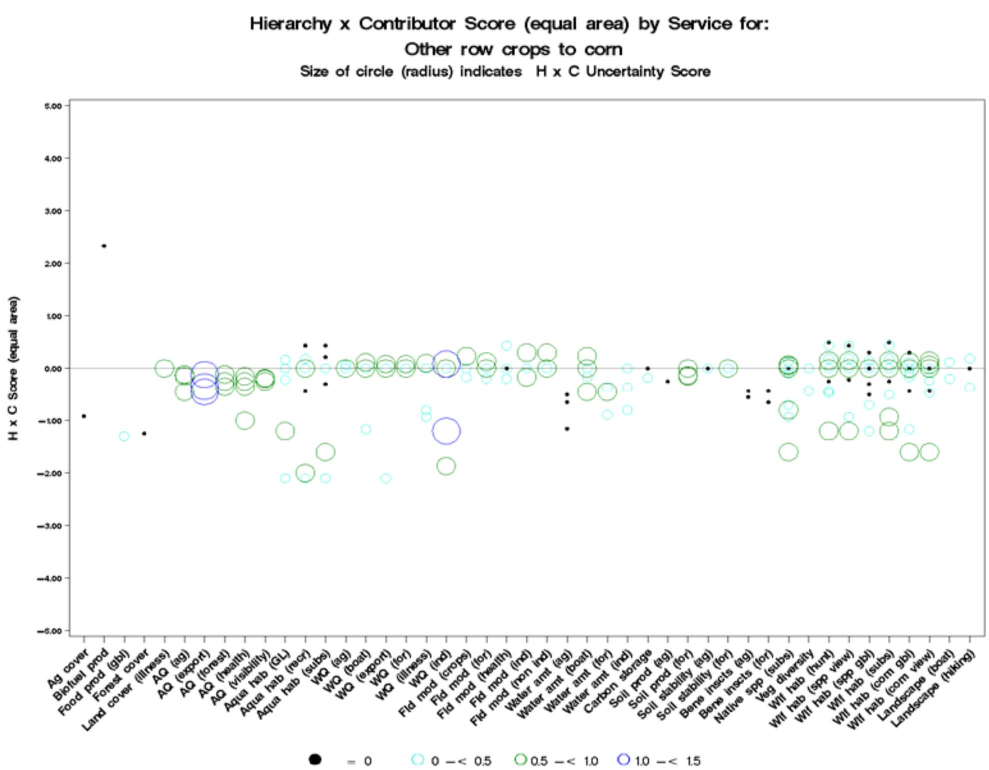

Figure C.3.2. Other row crops to corn.

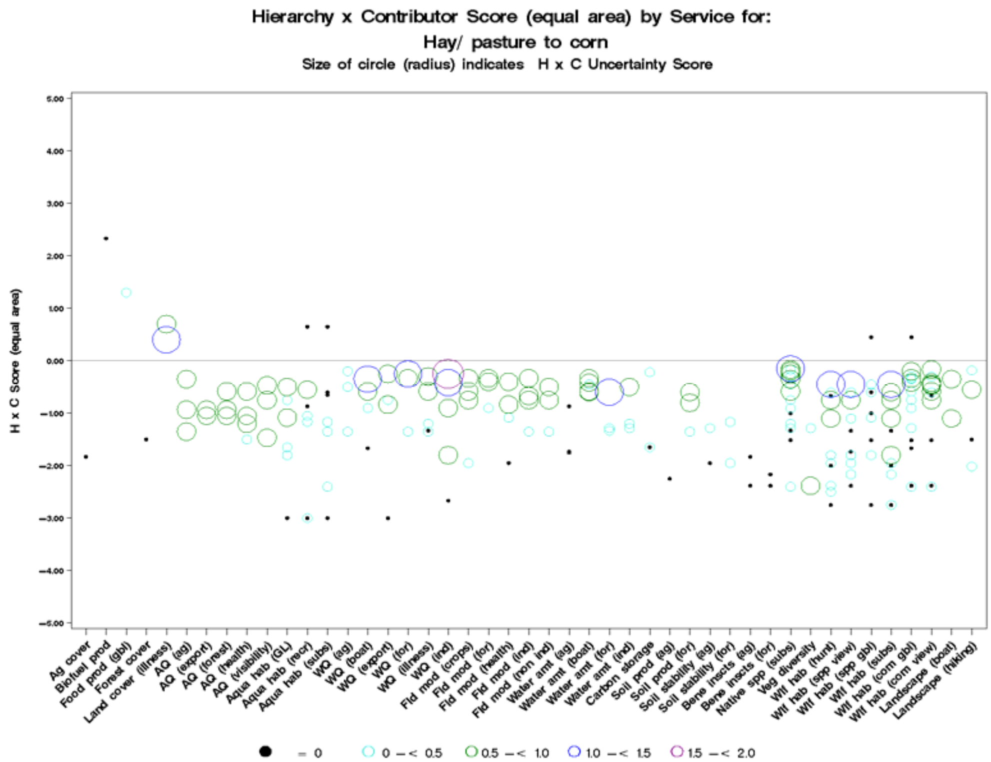

Figure C.3.3. Hay/ pasture to corn.

Figure C.3.4. Use of corn stover.

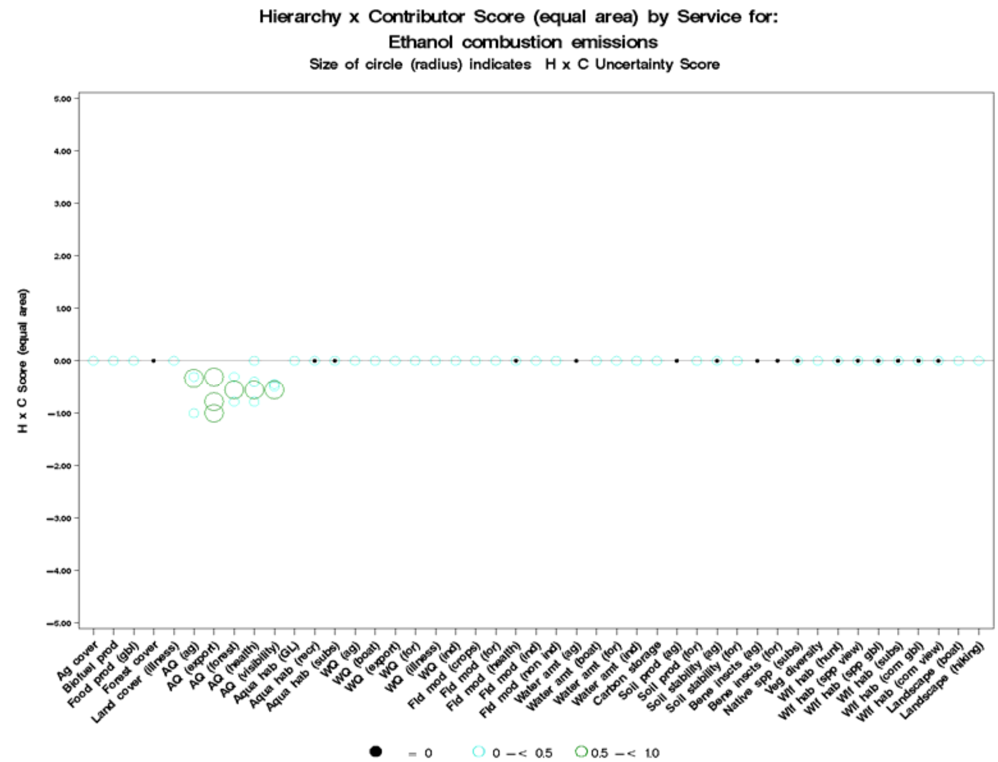

Figure C.3.5. Ethanol combustion emissions.

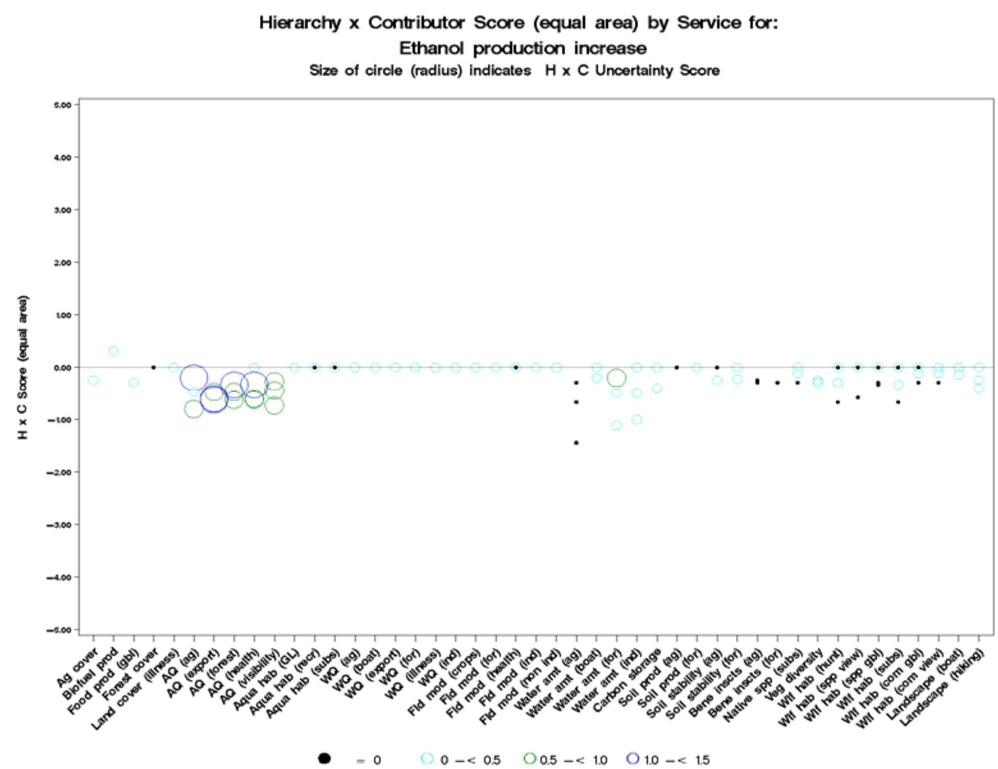

Figure C.3.6. Ethanol production increase.

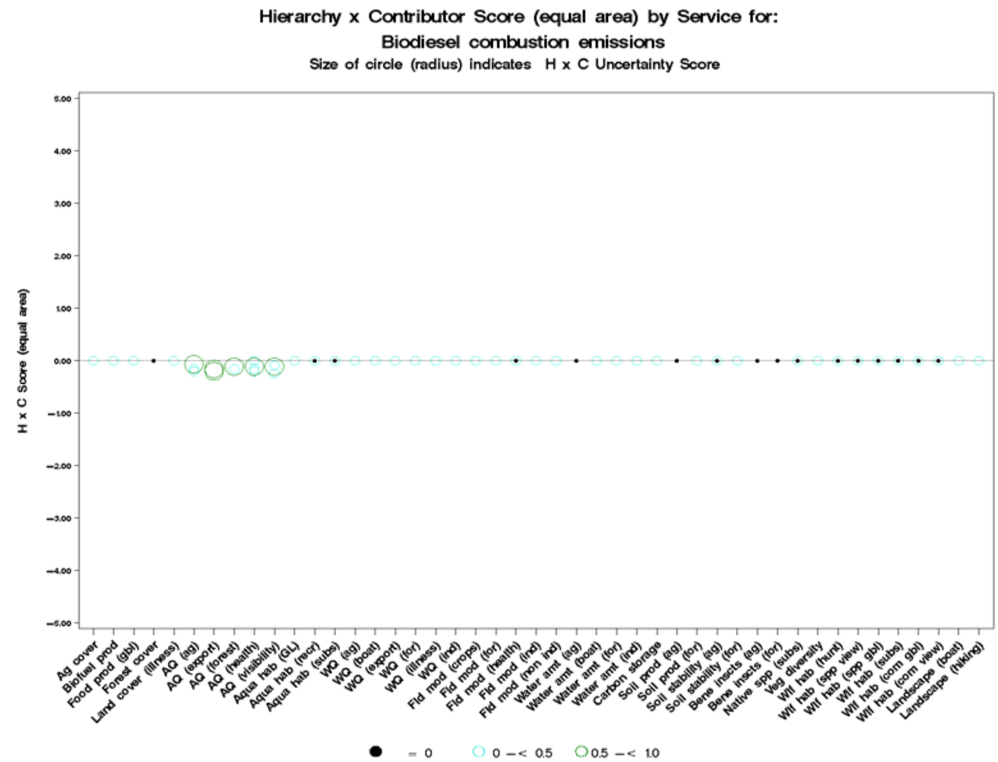

Figure C.3.7. Biodiesel combustion emissions.

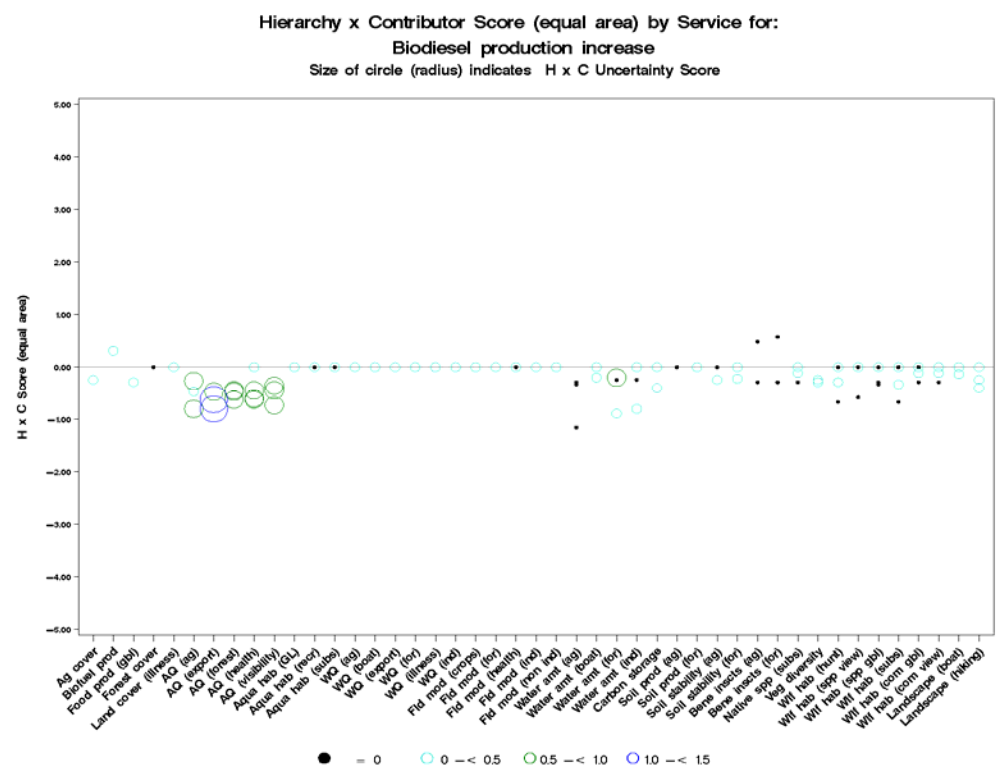

Figure C.3.8. Biodiesel production increase.

Appendix C.4 Area-weighted HxC Values by Service for the BT Scenario.

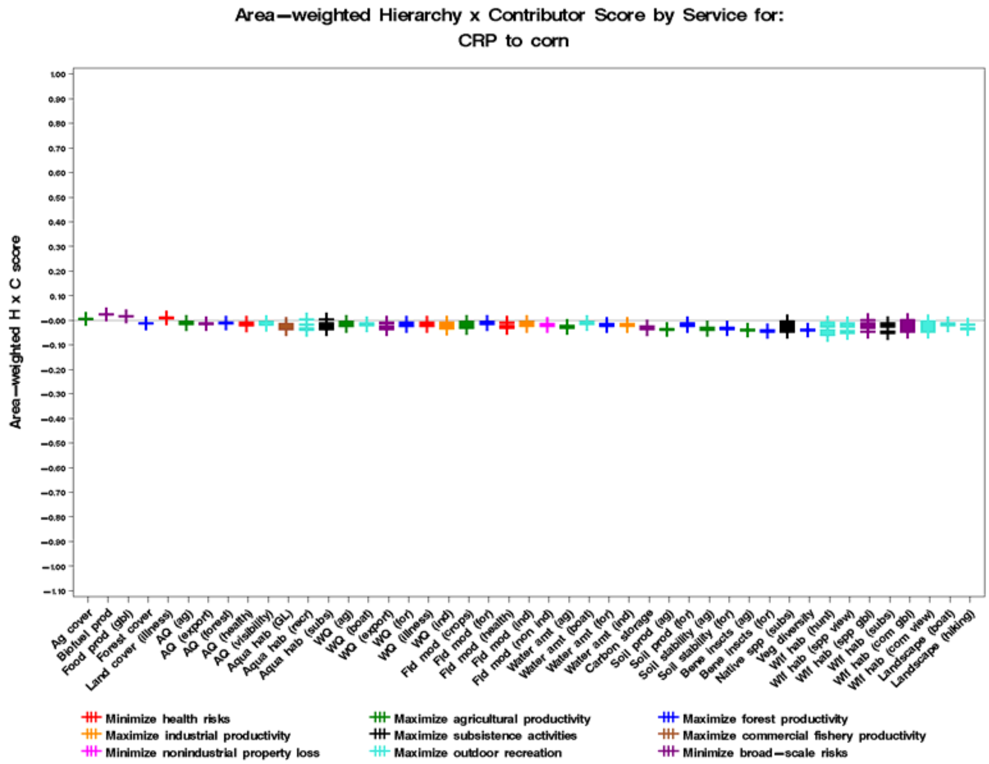

Figure C.4.1. CRP to corn.

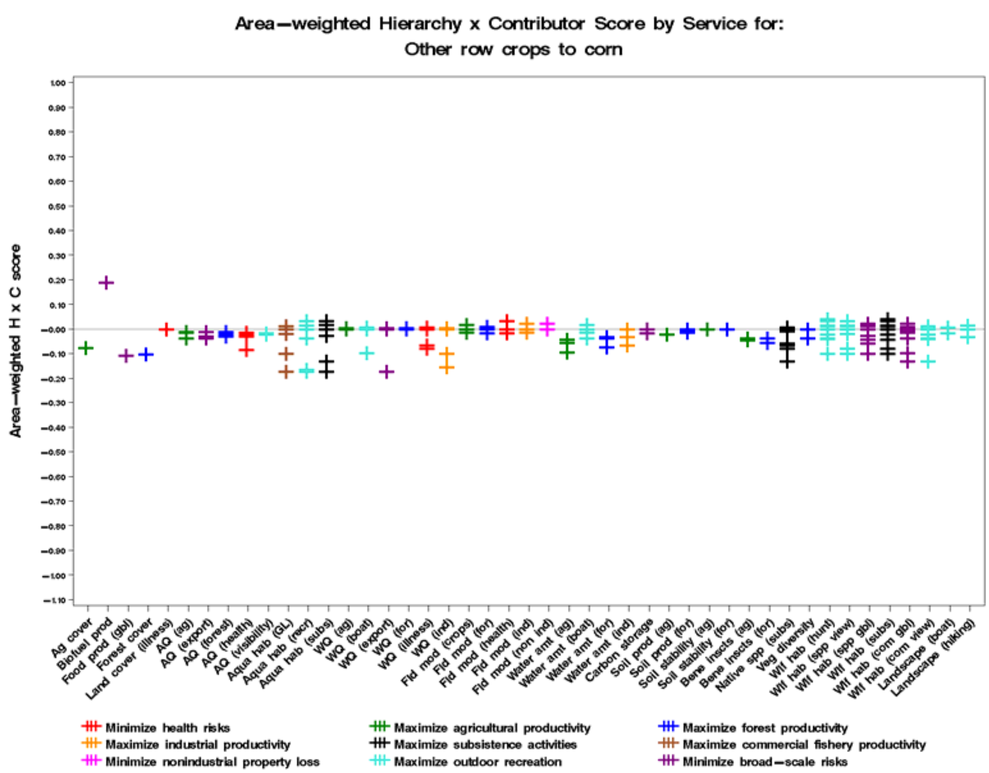

Figure C.4.2. Other row crops to corn.

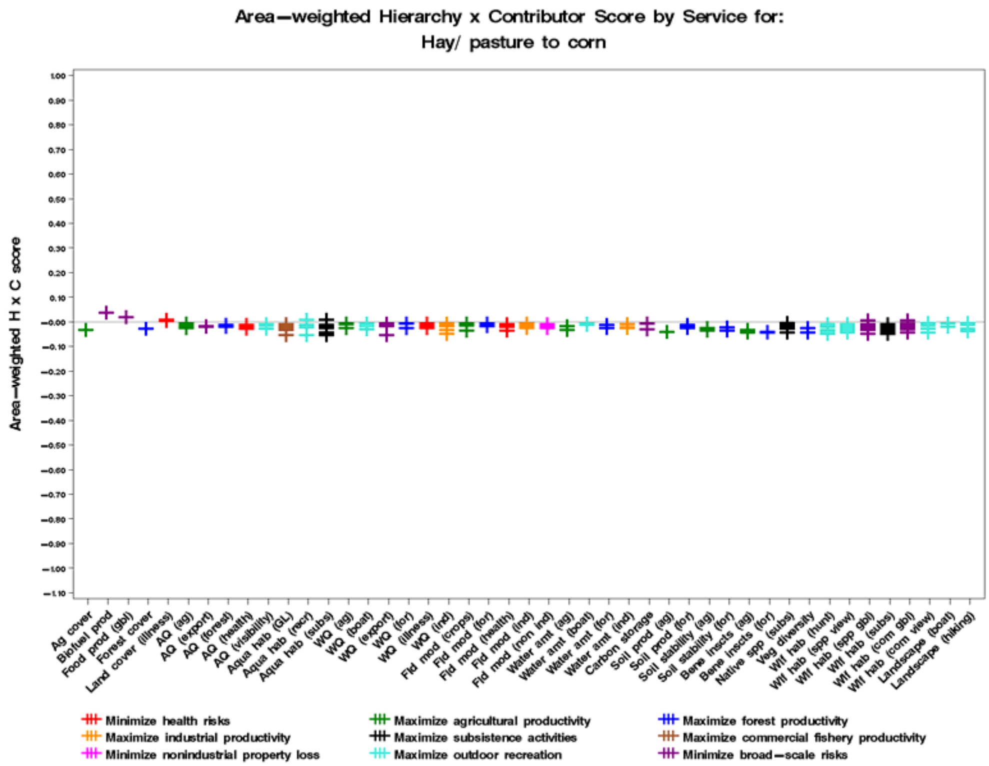

Figure C.4.3. Hay/ pasture to corn.

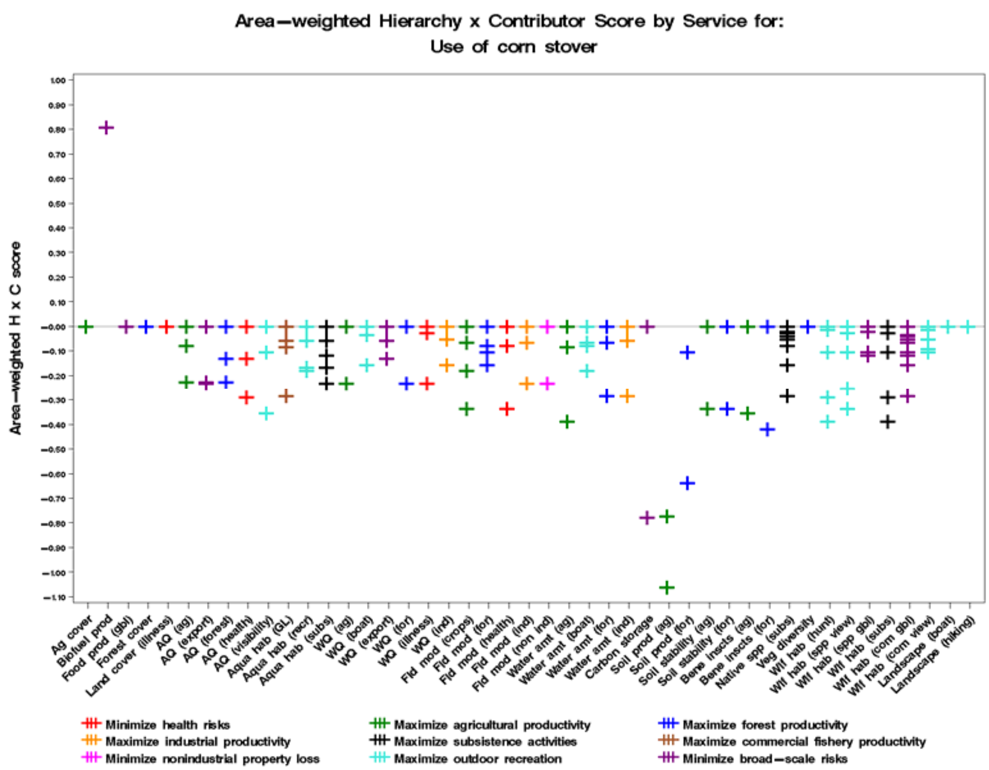

Figure C.4.4. Use of corn stover.

Appendix C.5 Sum of Area-weighted HxC Values by Service for the BT Scenario.

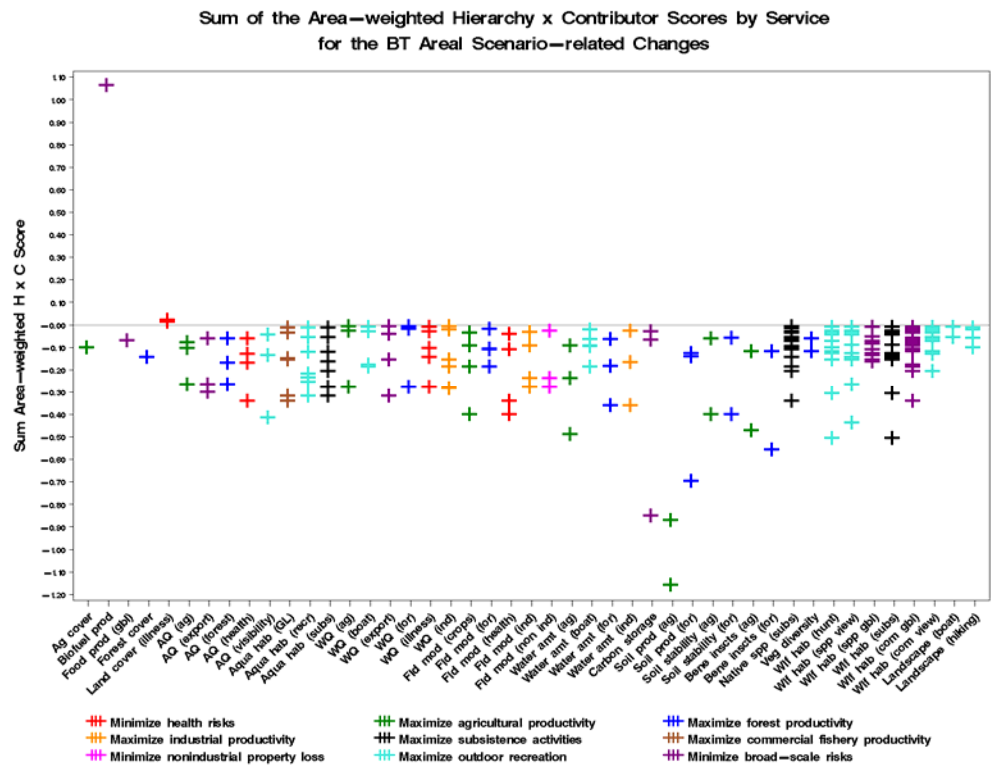

Figure C.5.1. Areal BT scenario-related changes.

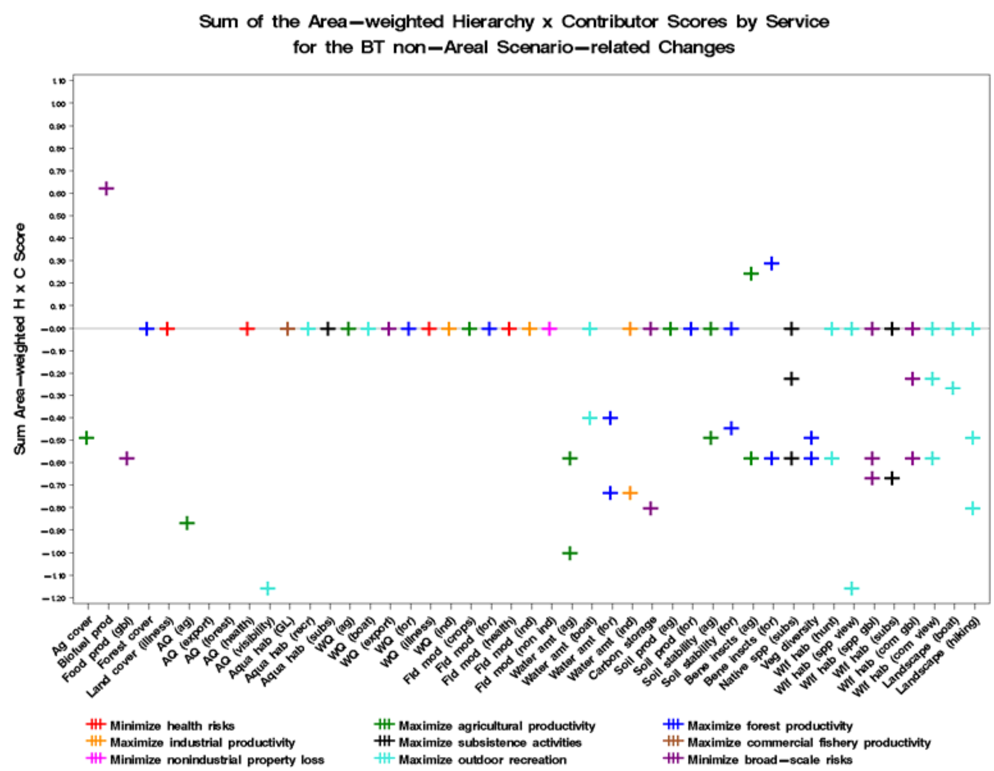

Figure C.5.2. non-Areal BT scenario-related changes. The sum is of the Unweighted scores.

Appendix D. Plots by Service for each MS Conservation Practice

Appendix D.1. Unweighted HxC Values by Service for the MS Scenario.

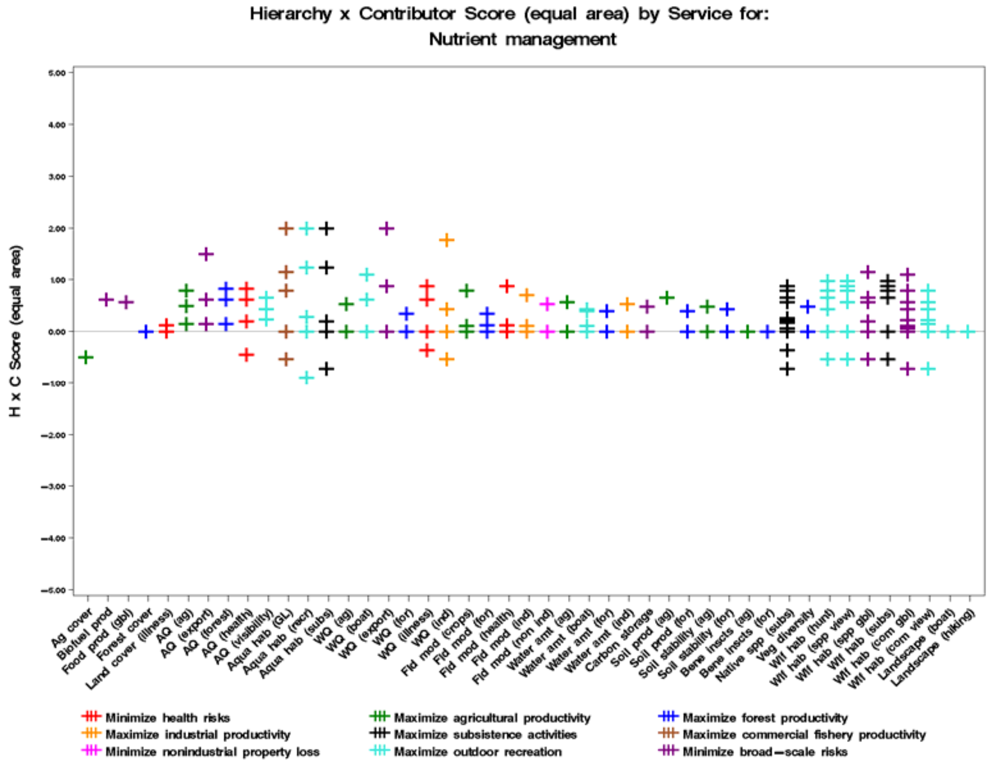

Figure D.1.1. Nutrient management.

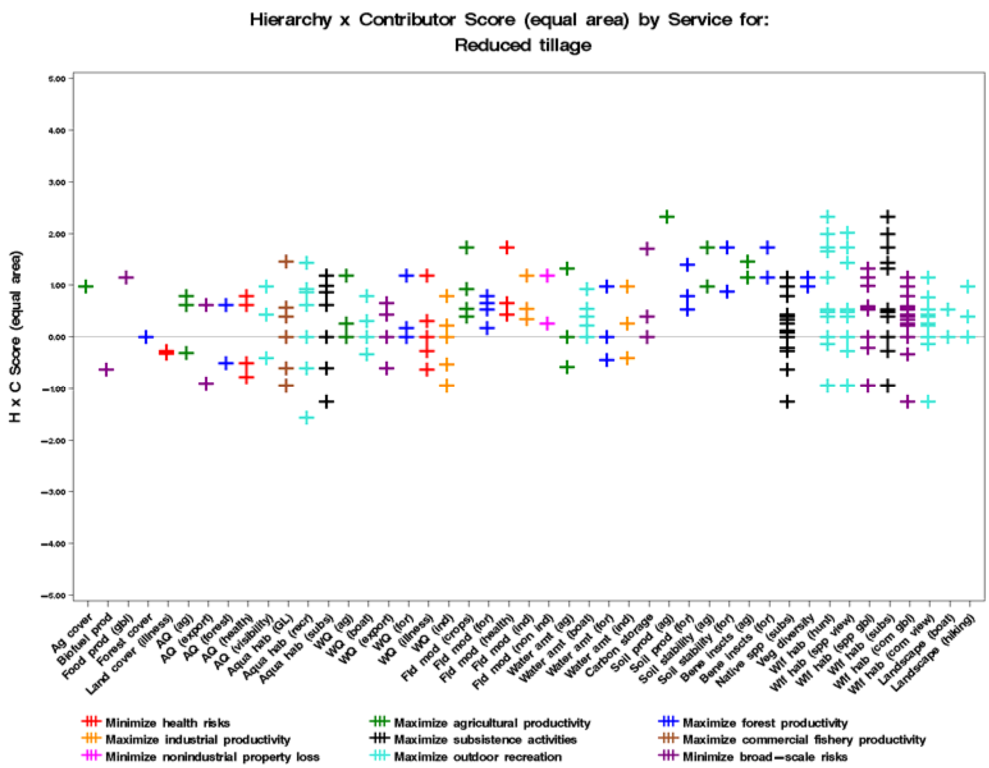

Figure D.1.2. Reduced tillage.

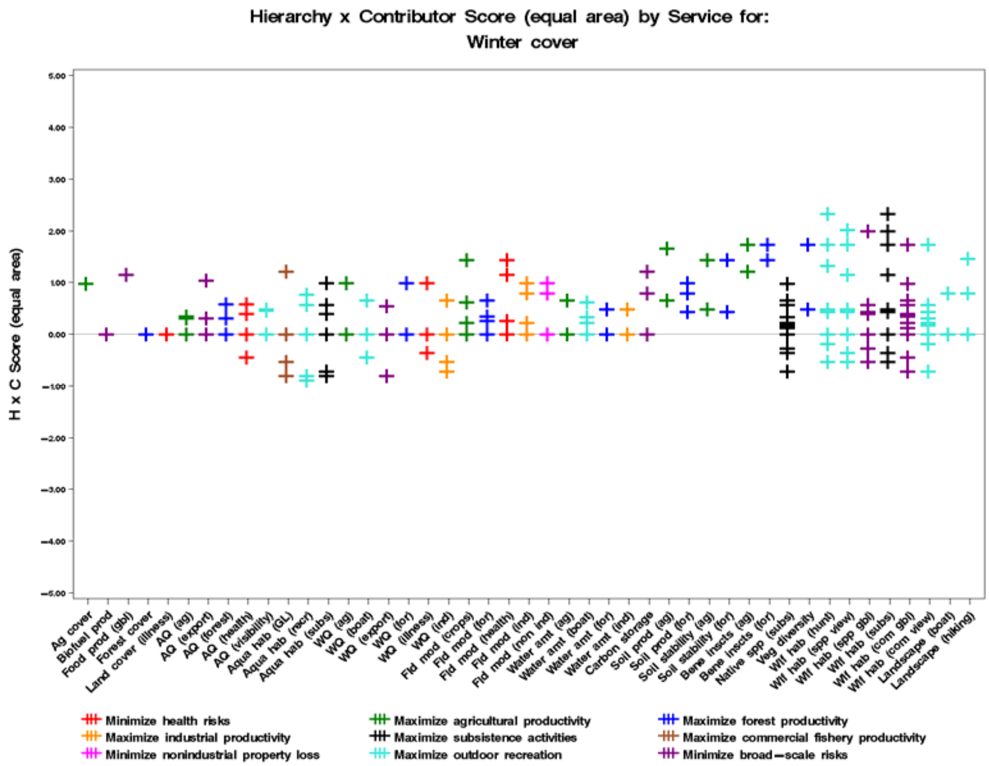

Figure D.1.3. Winter cover.

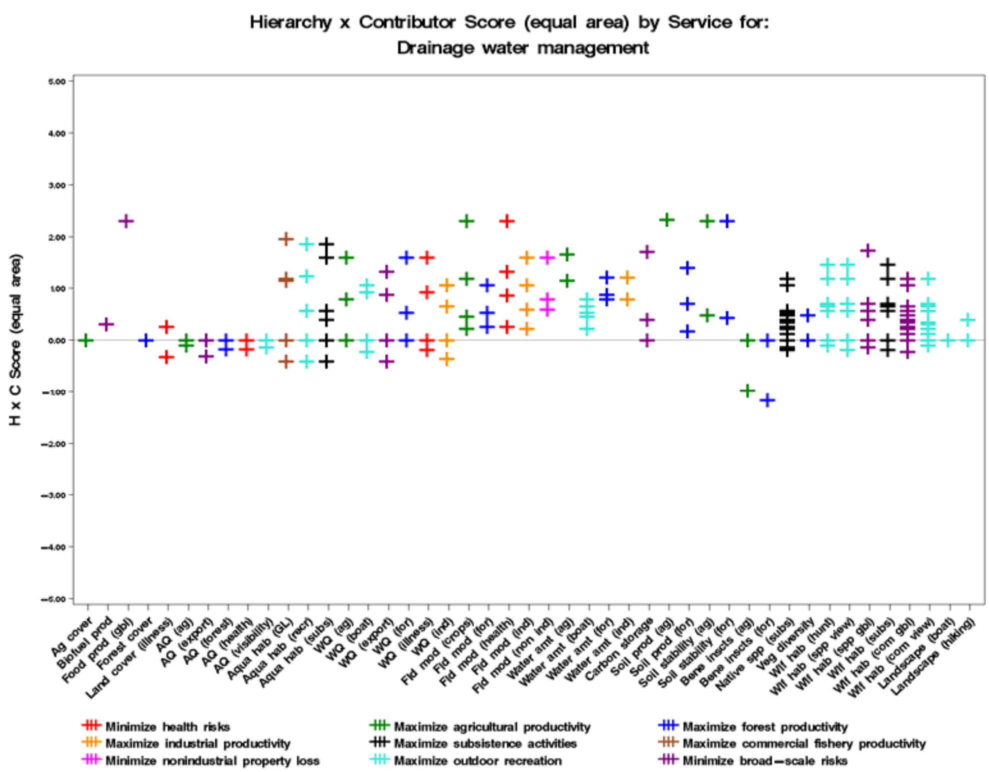

Figure D.1.4. Drainage water management.

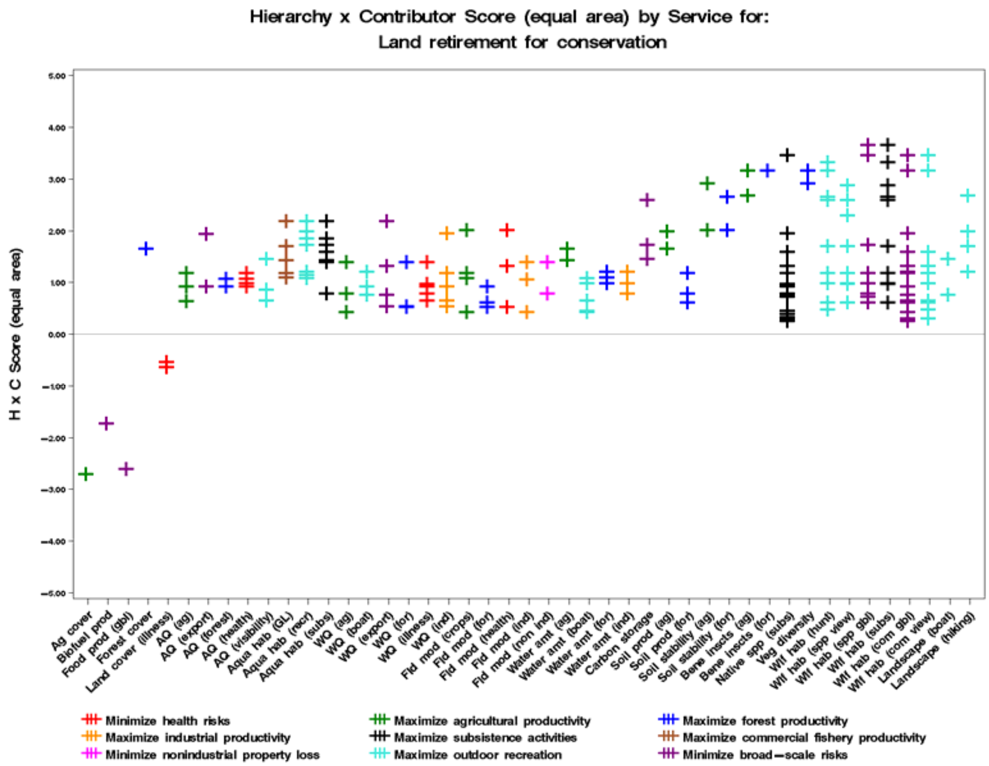

Figure D.1.5. Land retirement for conservation.

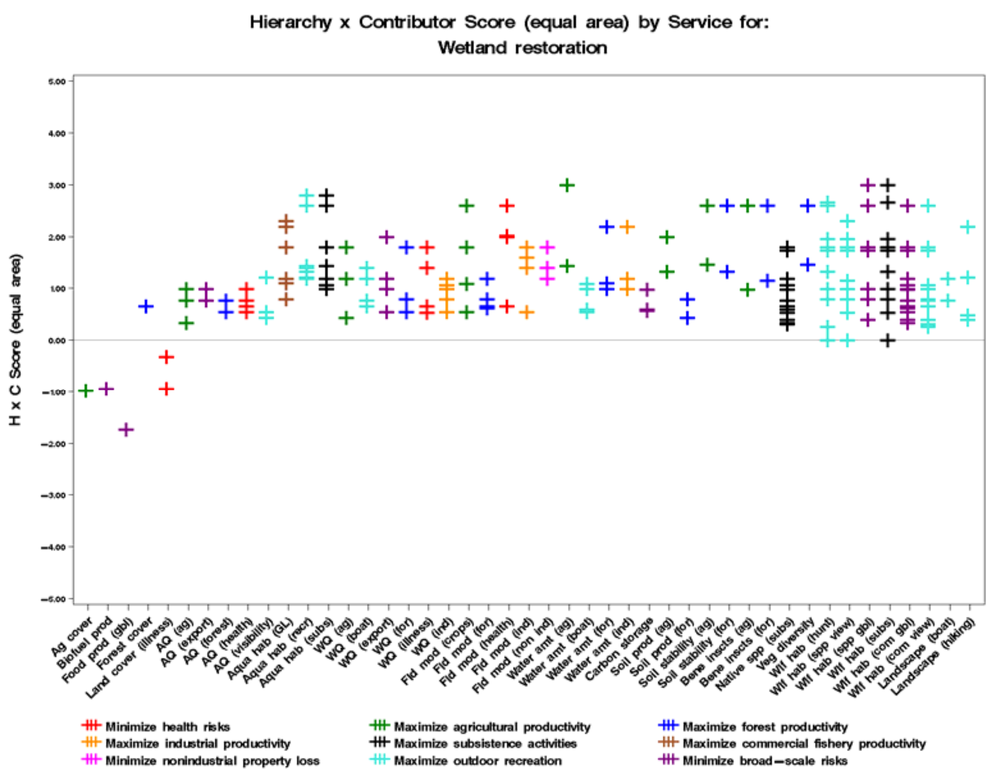

Figure D.1.6. Wetland restoration.

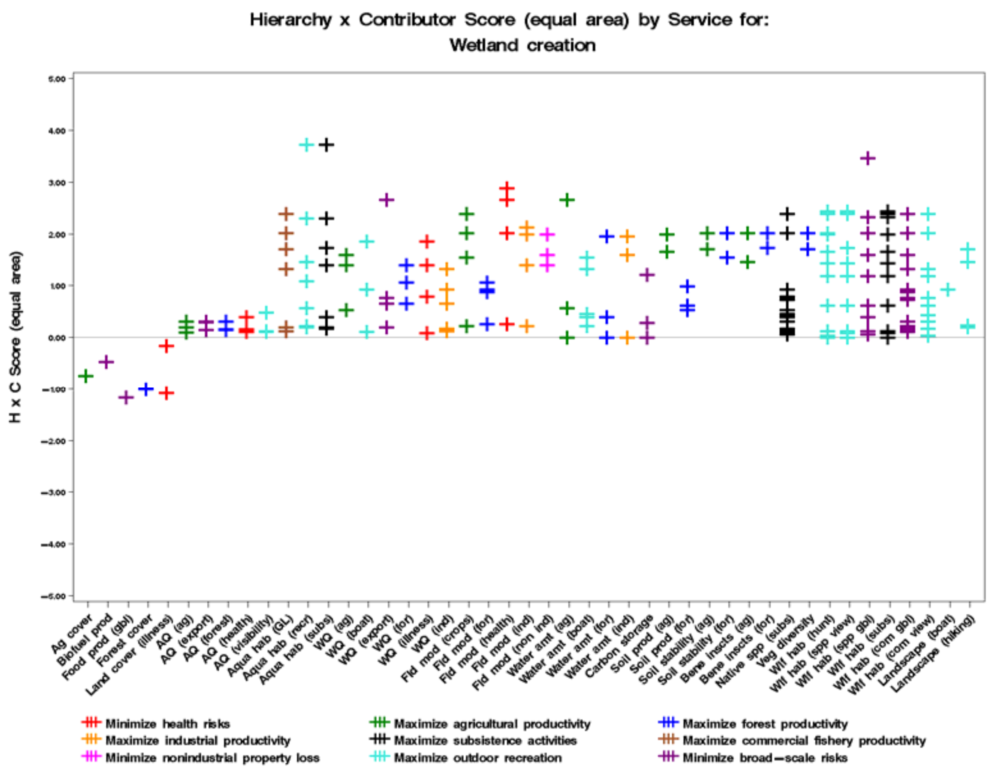

Figure D.1.7. Wetland creation.

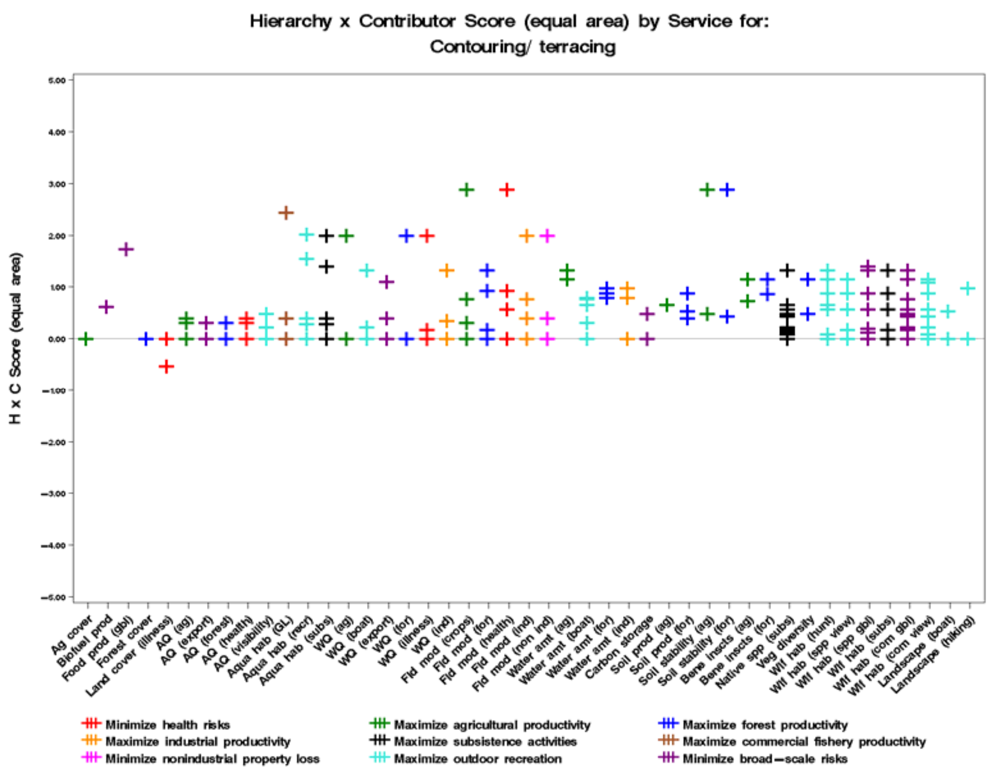

Figure D.1.8. Contouring/ terracing.

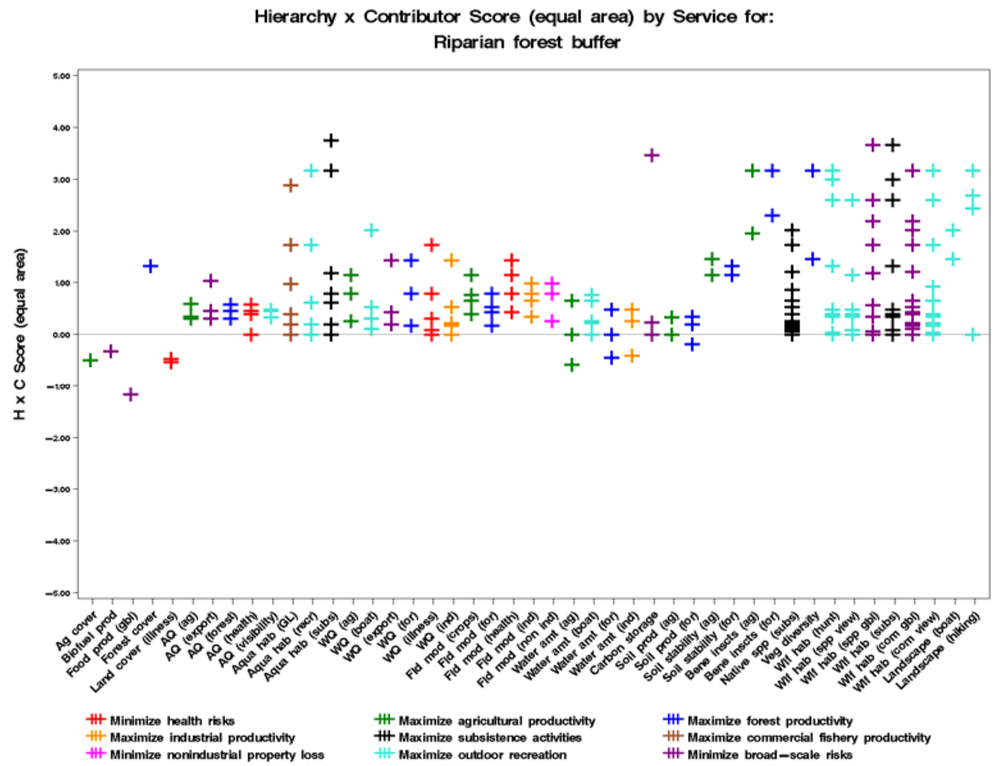

Figure D.1.9. Riparian forest buffer.

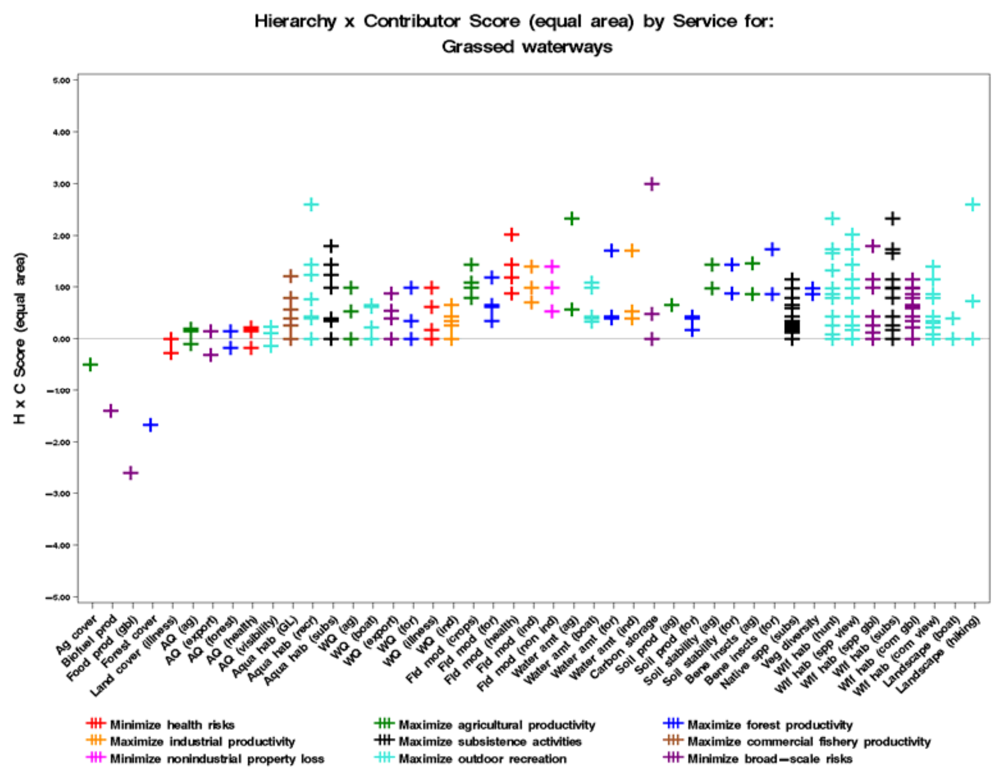

Figure D.1.10. Grassed waterways.

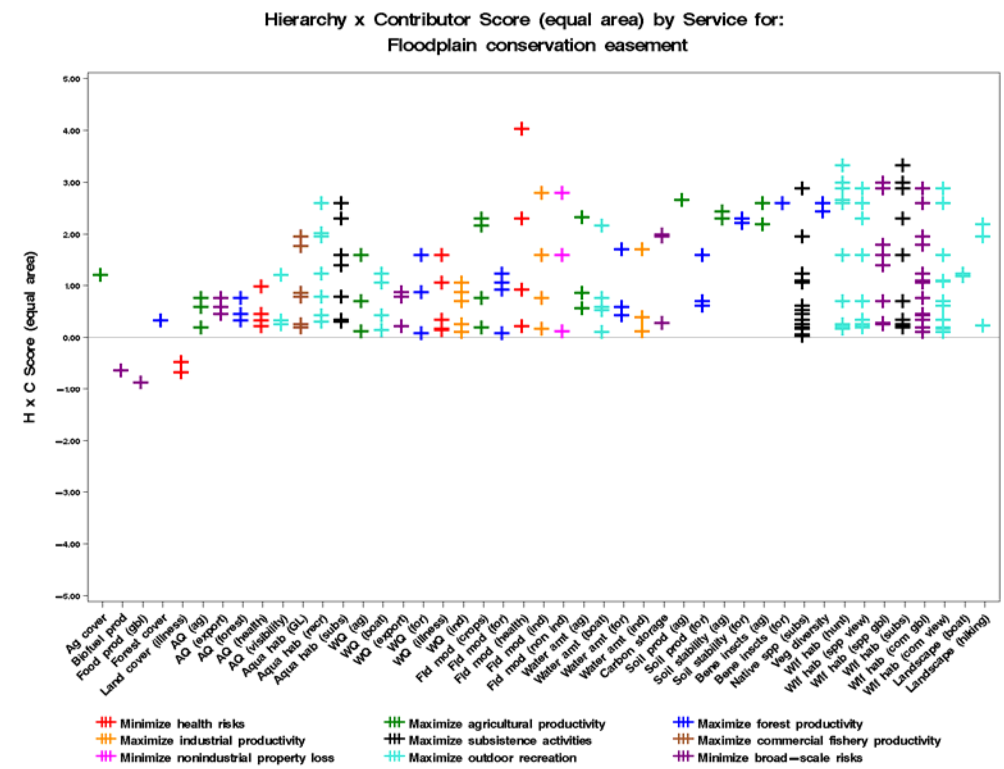

Figure D.1.11. Floodplain conservation easement.

Appendix D.2. Unweighted HxC Values and Ranges by Service for the MS Scenario.

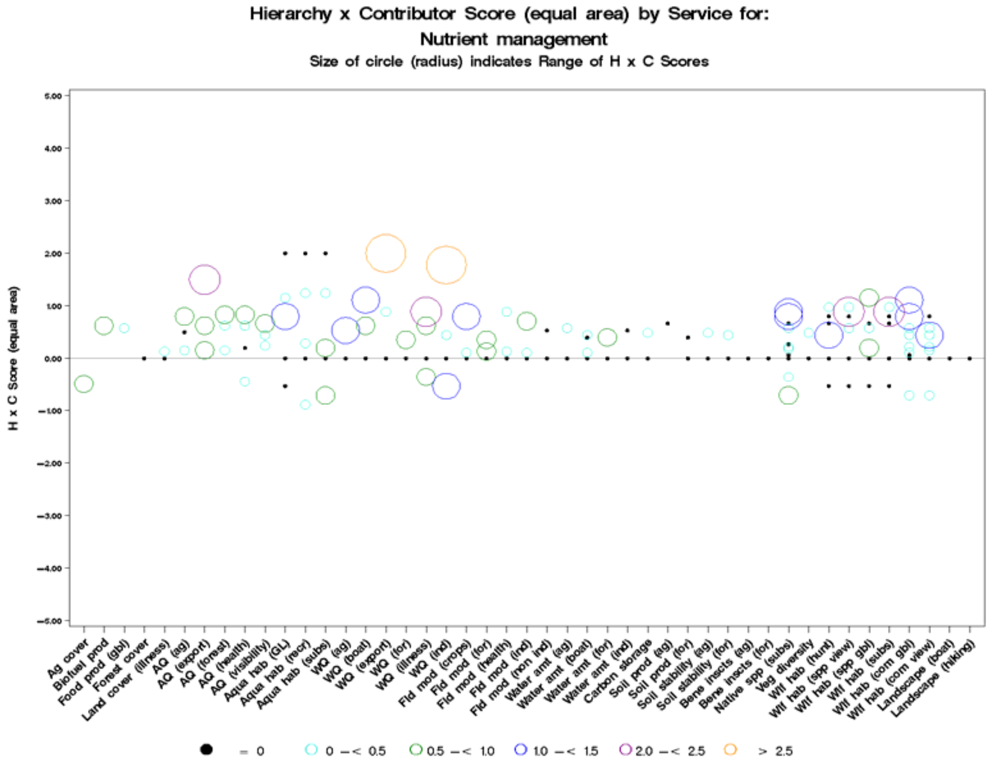

Figure D.2.1. Nutrient management.

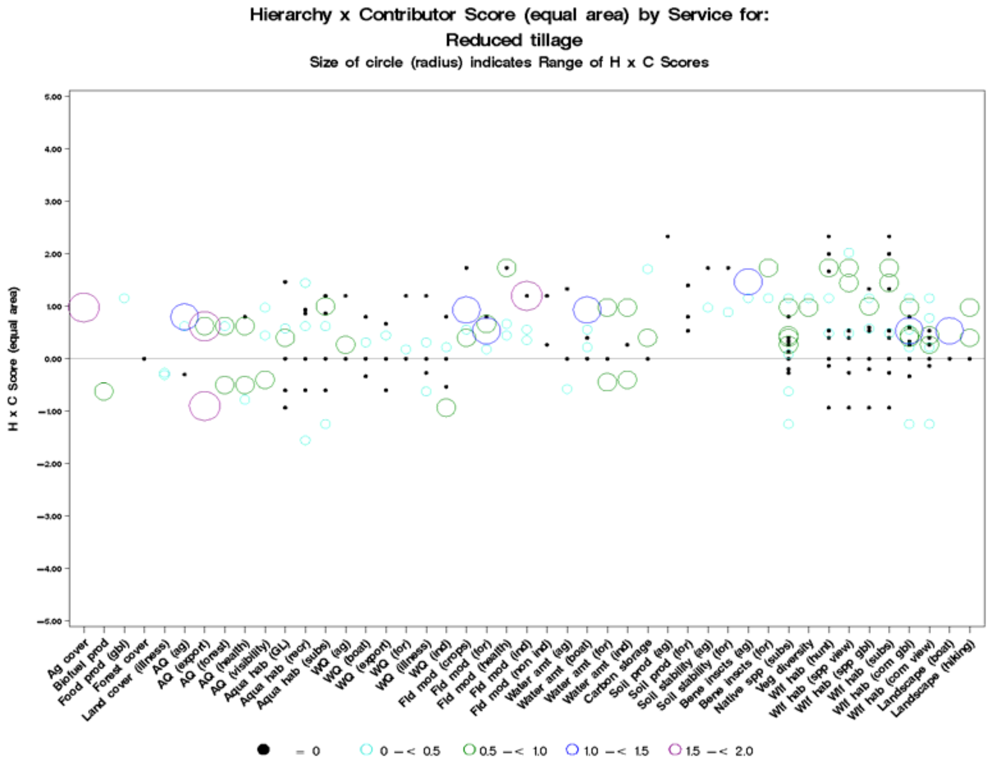

Figure D.2.2. Reduced tillage.

Figure D.2.3. Winter cover.

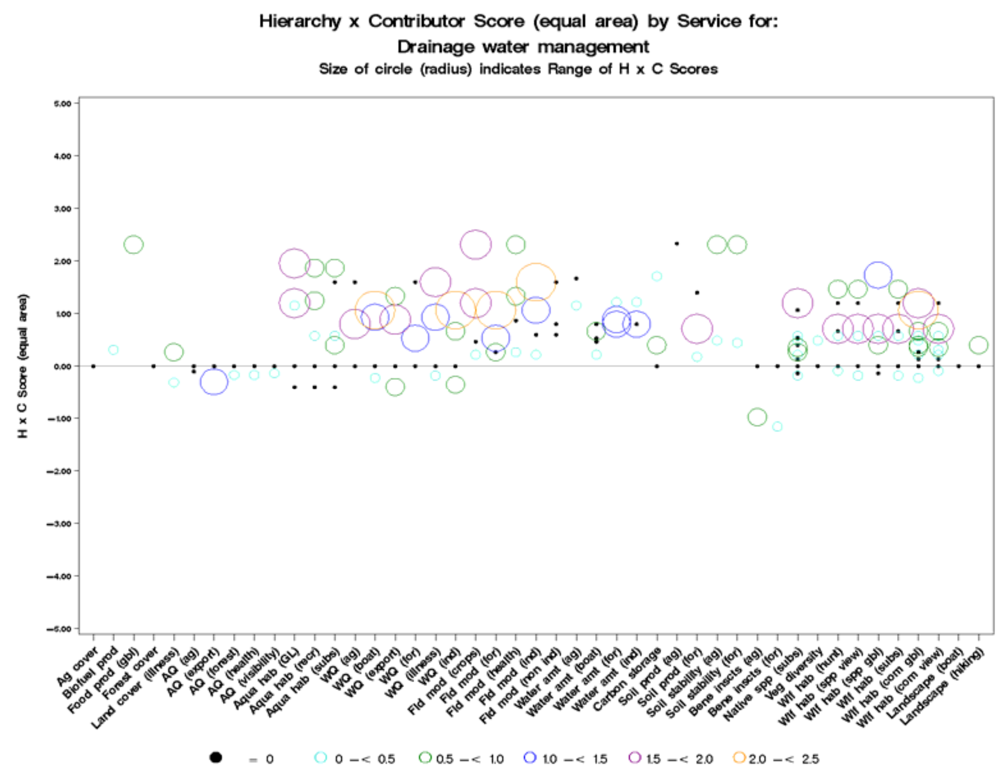

Figure D.2.4. Drainage water management.

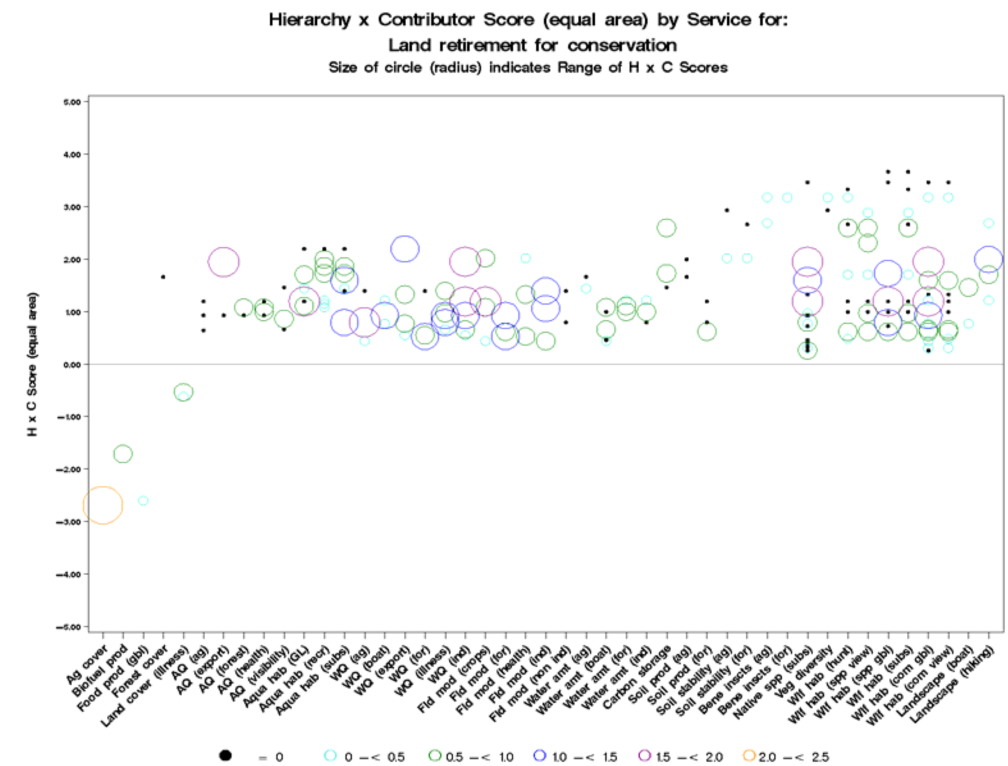

Figure D.2.5. Land retirement for conservation.

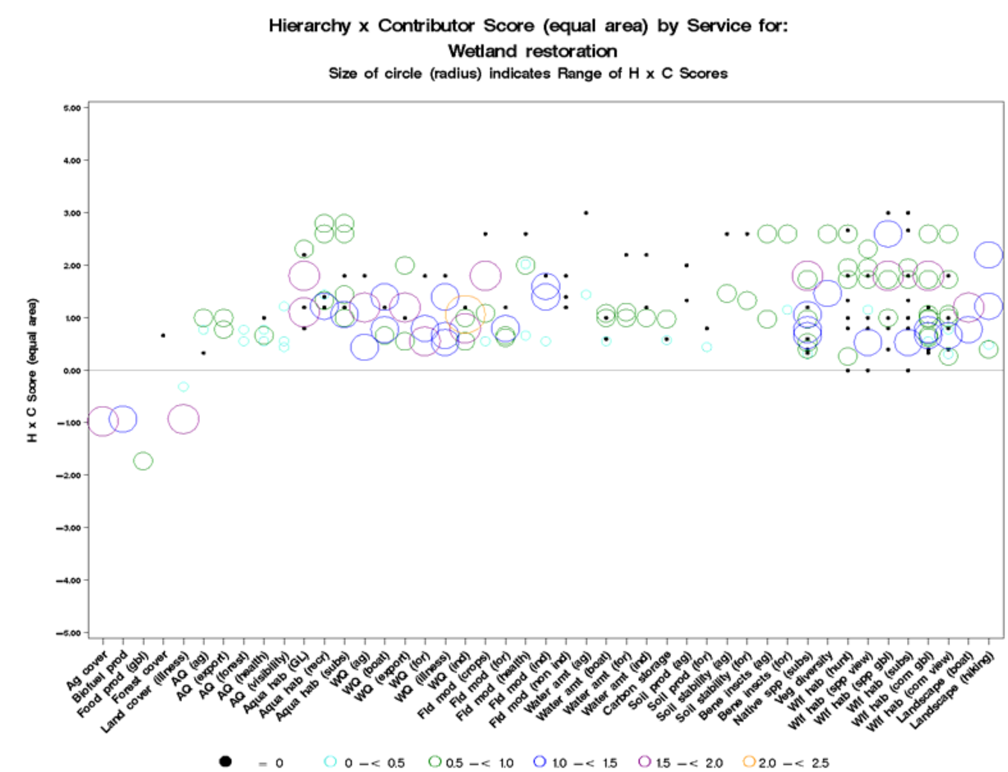

Figure D.2.6. Wetland restoration.

Figure D.2.7. Wetland creation.

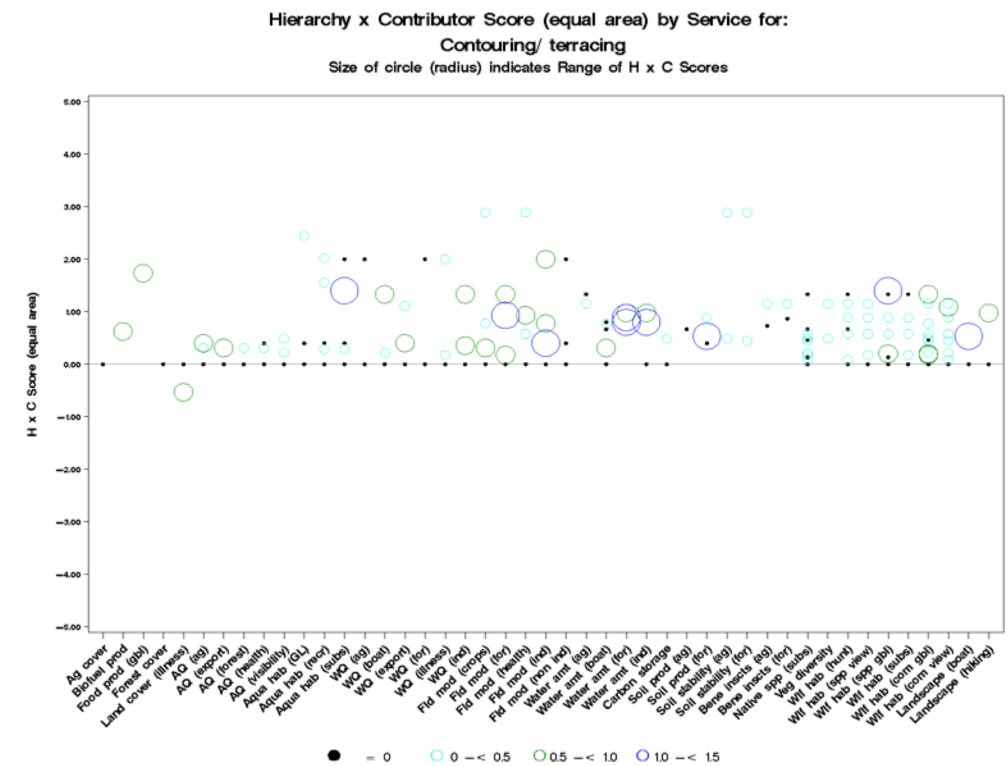

Figure D.2.8. Contouring/ terracing.

Figure D.2.9. Riparian forest buffer.

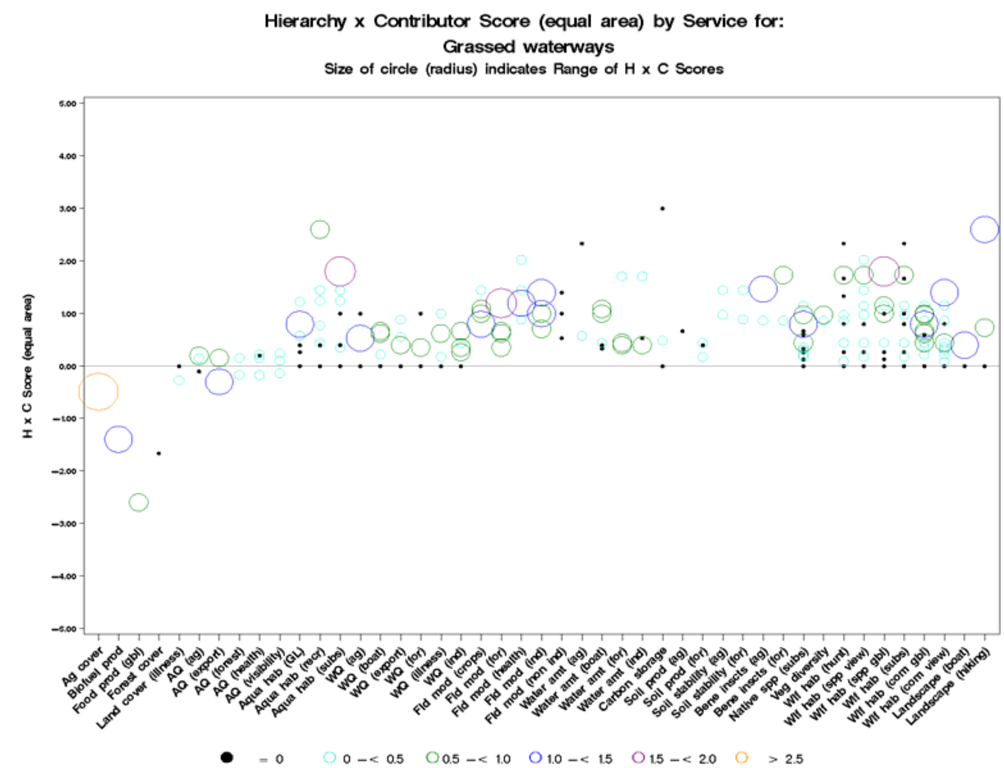

Figure D.2.10. Grassed waterways.

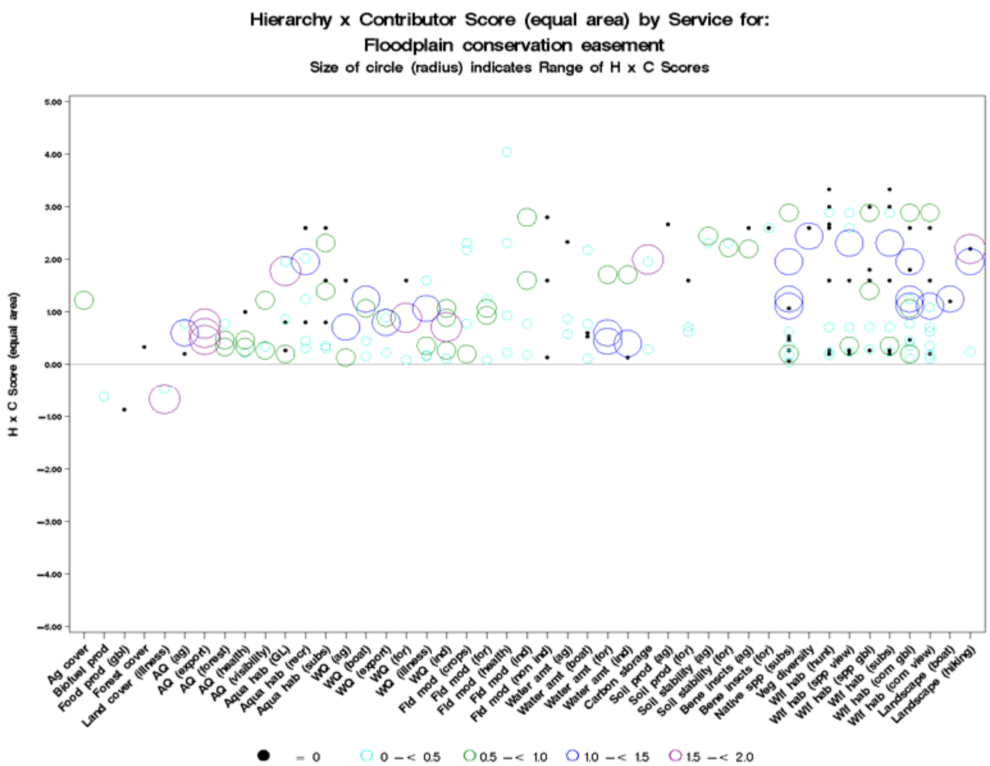

Figure D.2.11. Floodplain conservation easement.

Appendix D.3. Unweighted HxC Values and Uncertainty by Service for the MS Scenario.

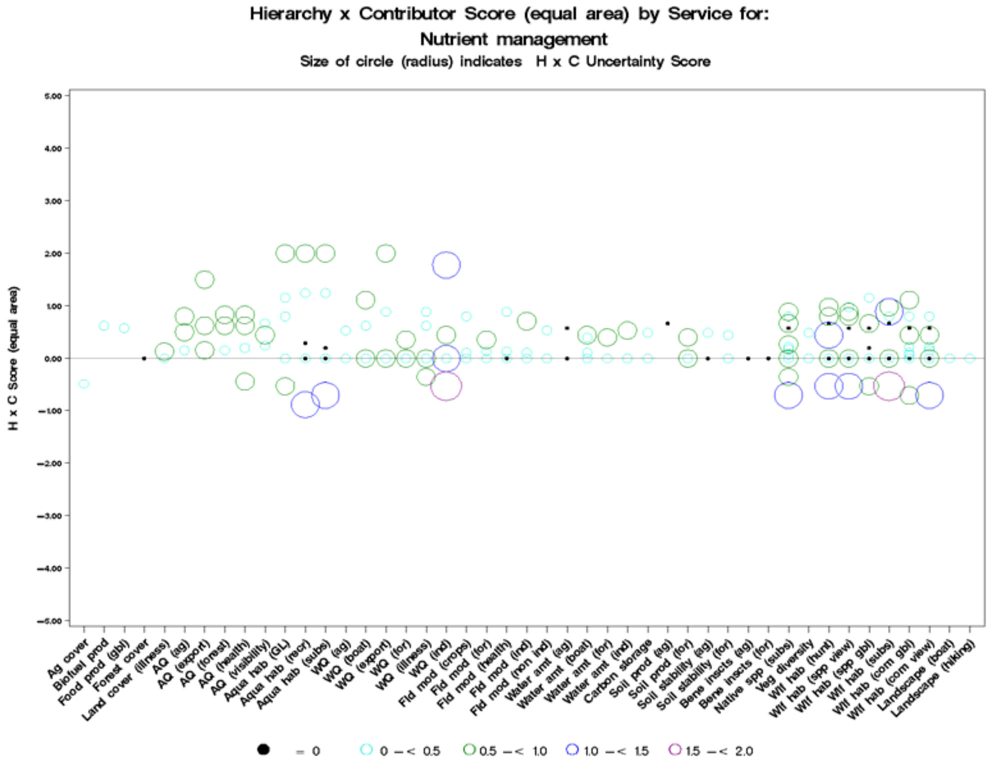

Figure D.3.1. Nutrient management.

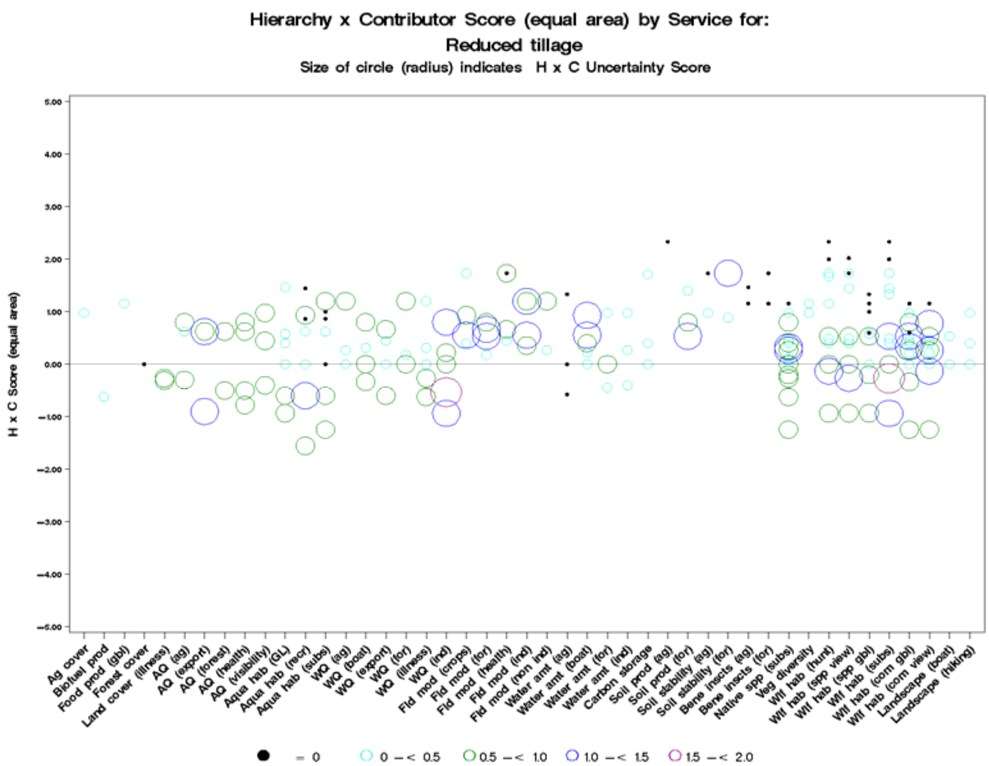

Figure D.3.2. Reduced tillage.

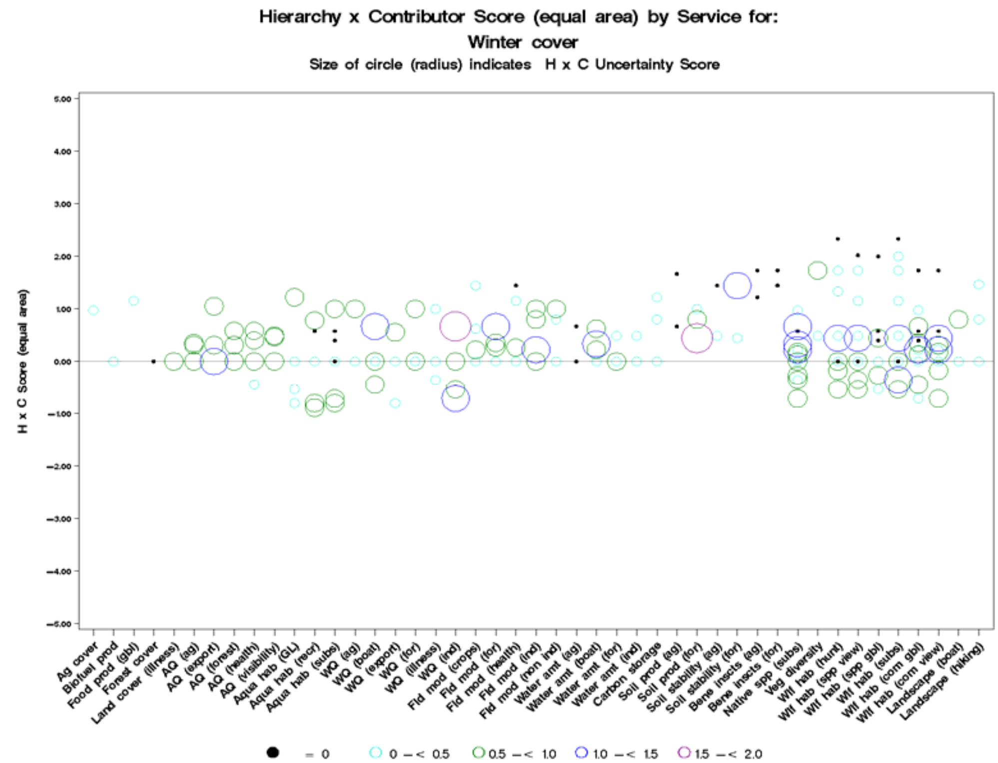

Figure D.3.3. Winter cover.

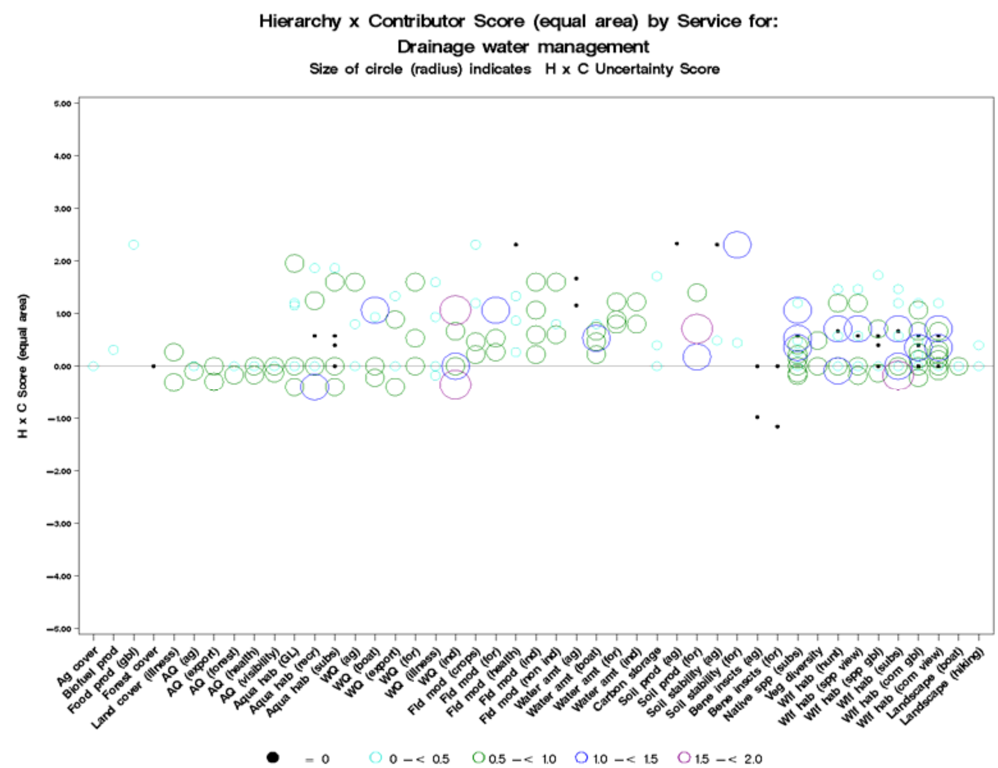

Figure D.3.4. Drainage water management.

Figure D.3.5. Land retirement for conservation.

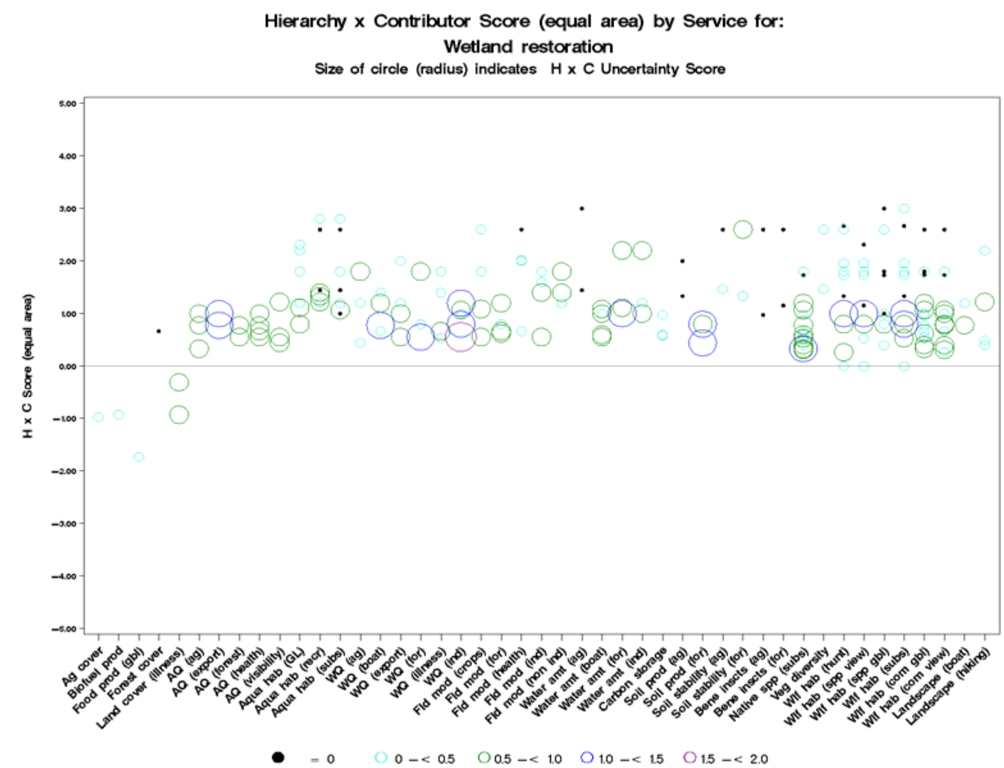

Figure D.3.6. Wetland restoration.

Figure D.3.7. Wetland creation.

Figure D.3.8. Contouring/ terracing.

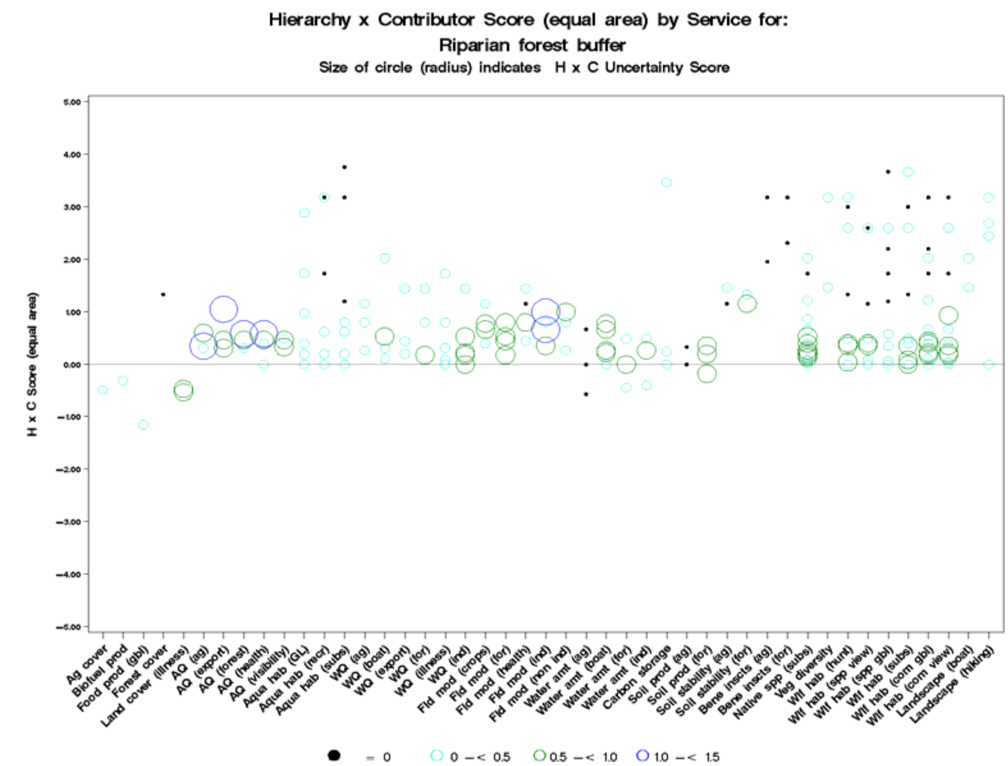

Figure D.3.9. Riparian forest buffer.

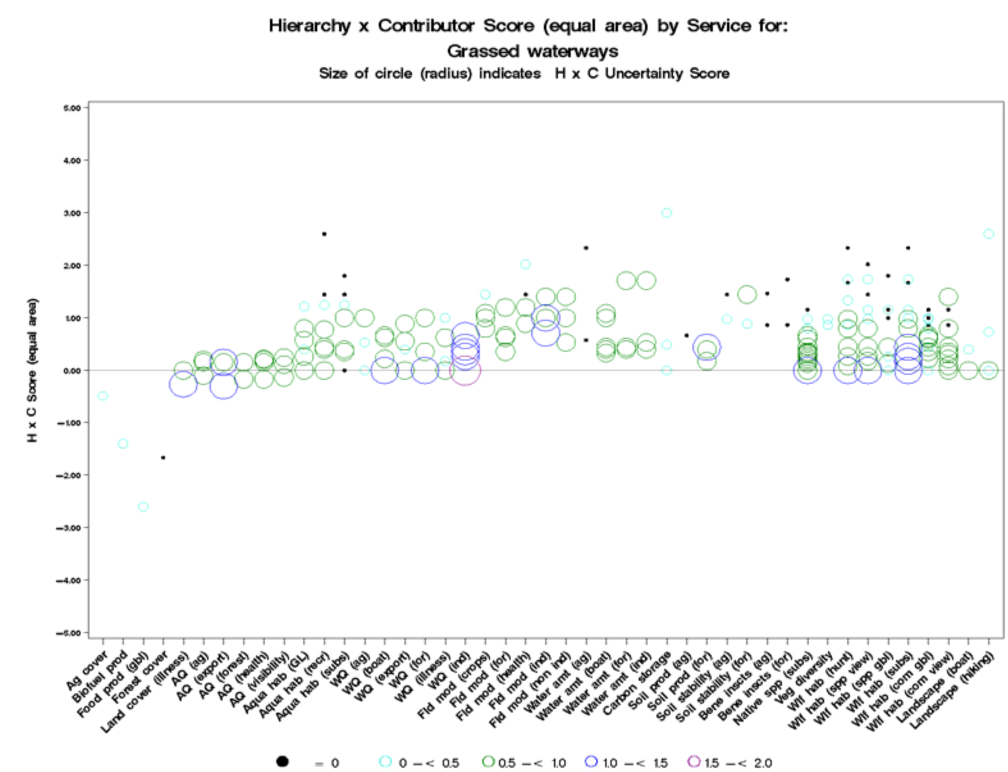

Figure D.3.10. Grassed waterways.

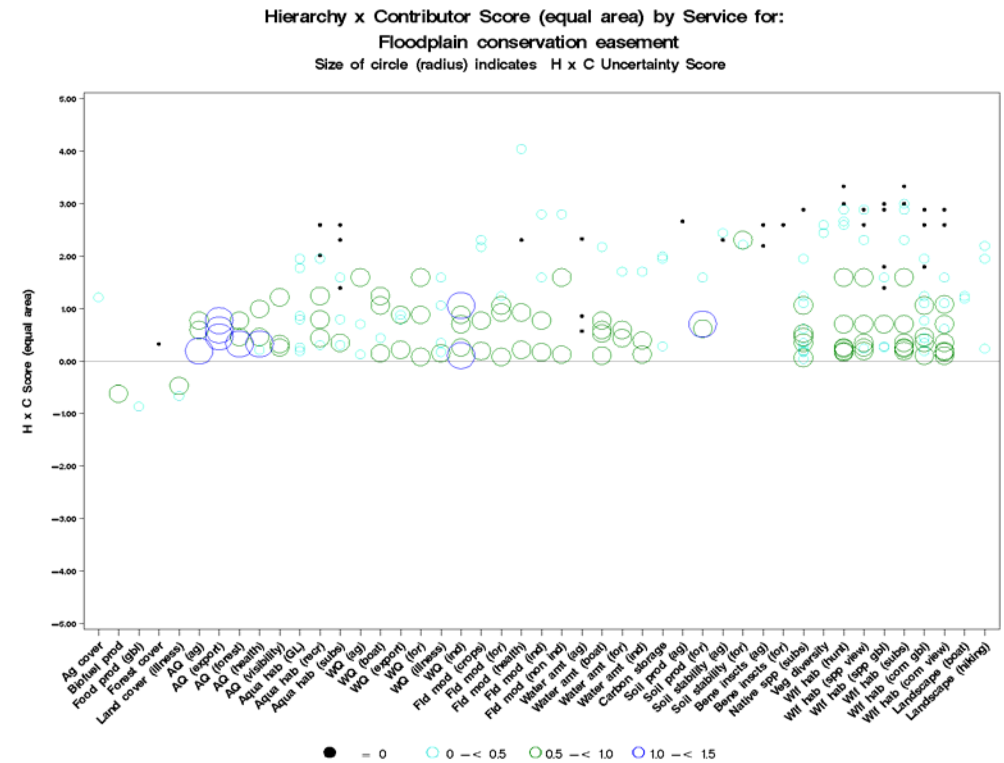

Figure D.3.11. Floodplain conservation easement.

Appendix D.4. Area-weighted HxC Values by Service for the MS Scenario.

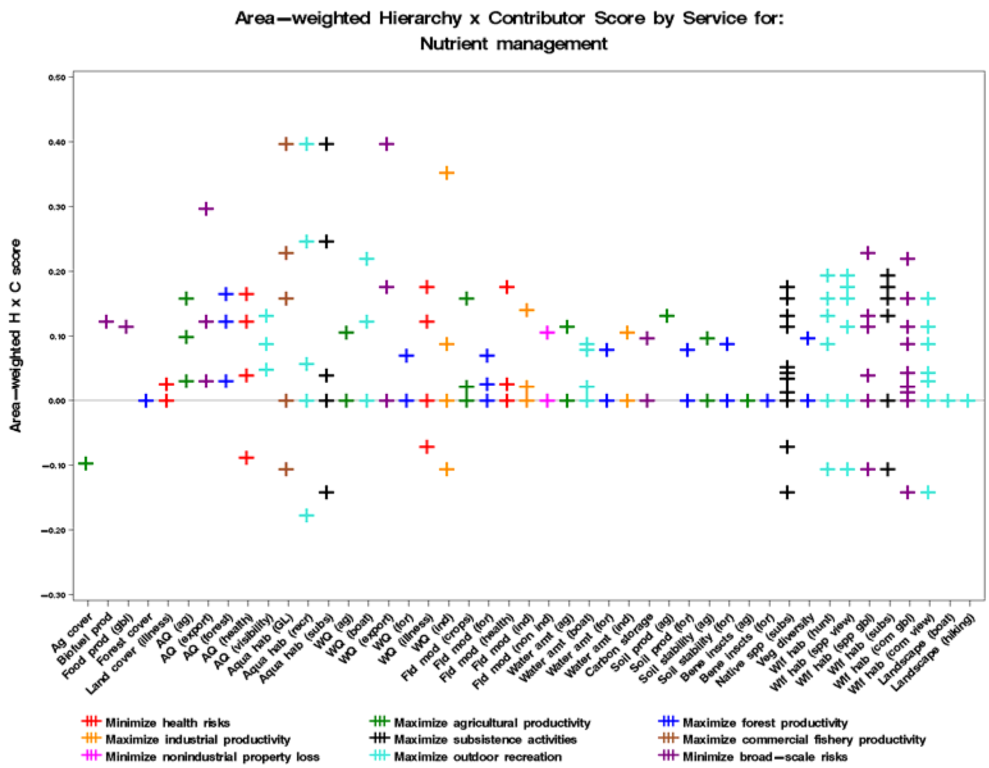

Figure D.4.1. Nutrient management.

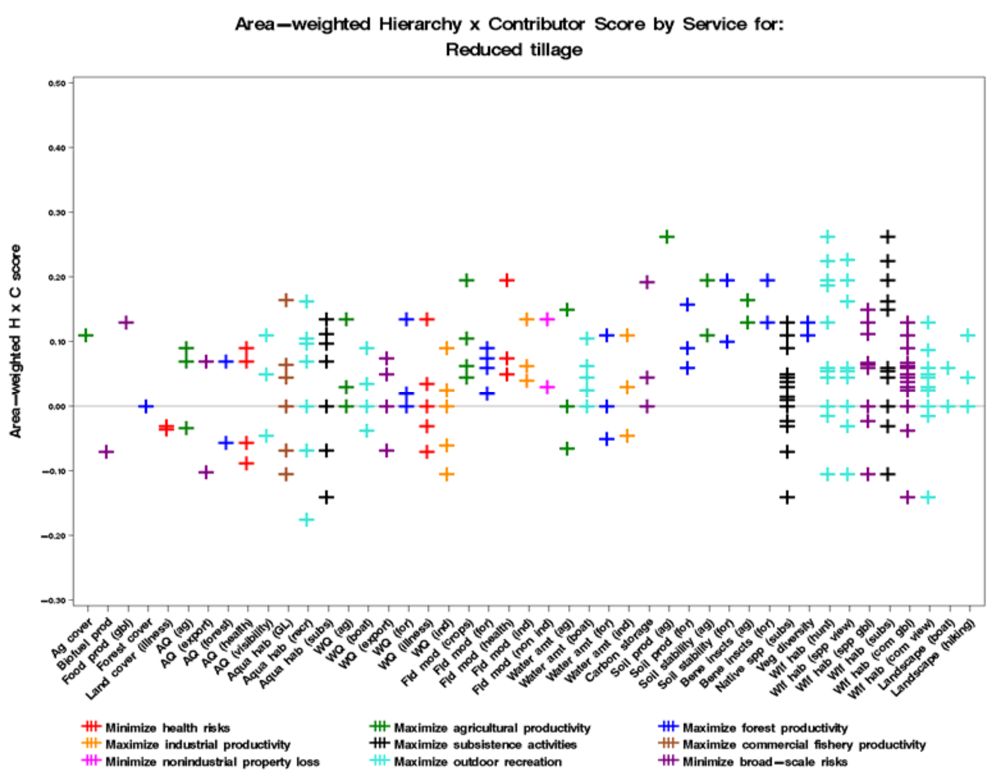

Figure D.4.2. Reduced tillage.

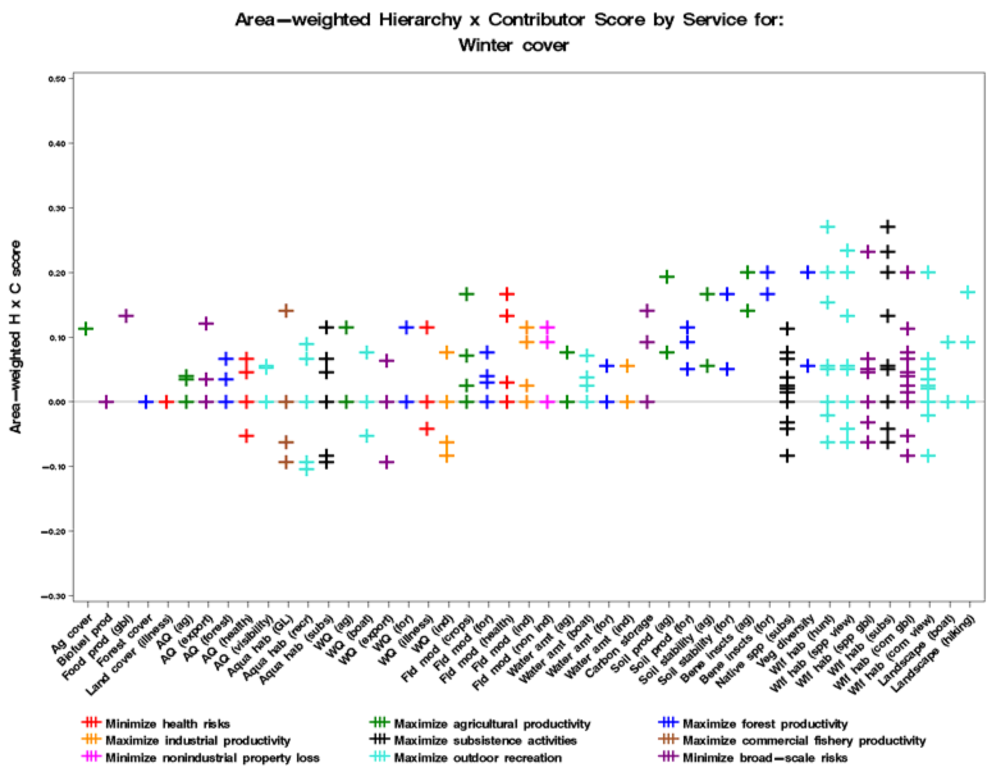

Figure D.4.3. Winter cover.

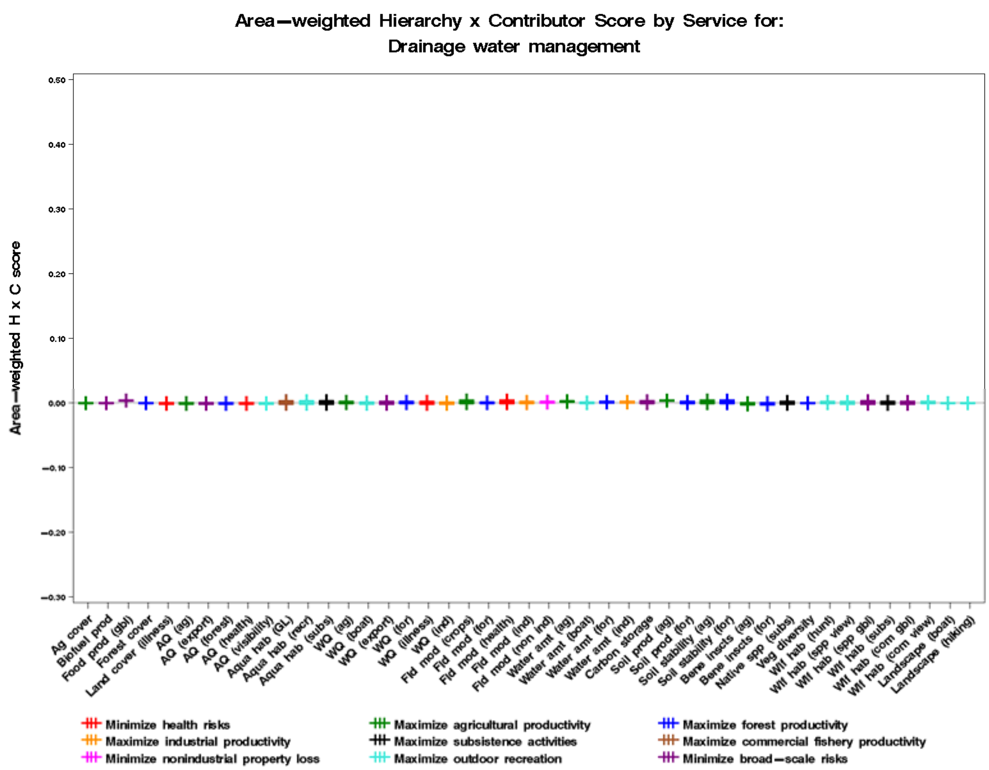

Figure D.4.4. Drainage water management

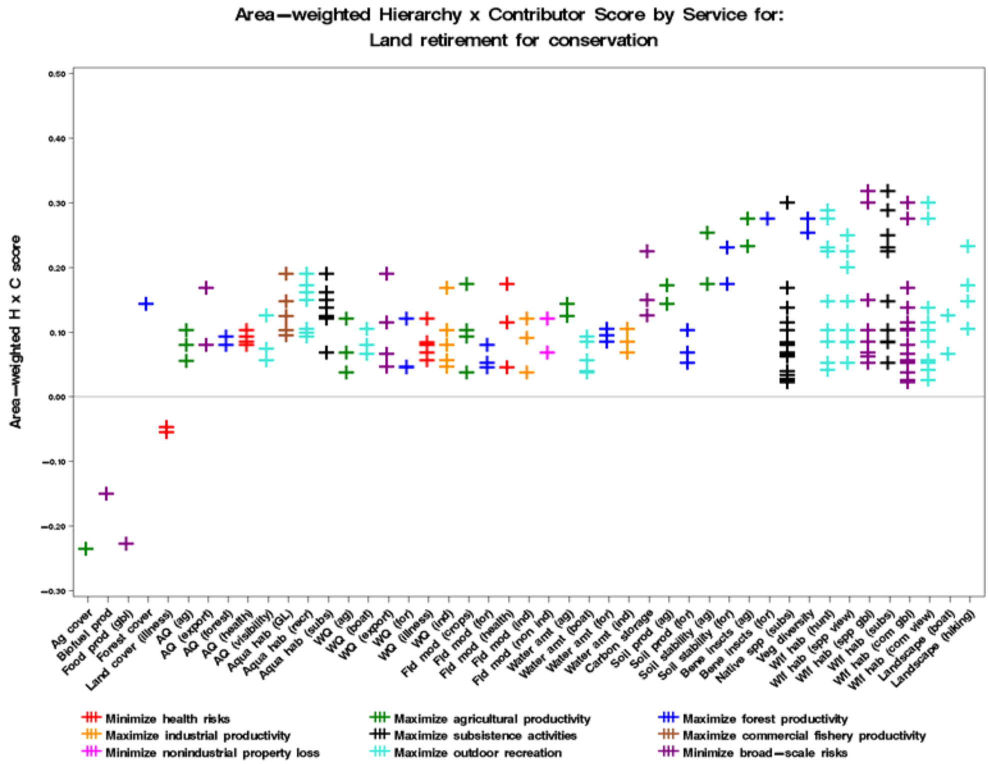

Figure D.4.5. Land retirement for conservation.

Figure D.4.6. Wetland restoration.

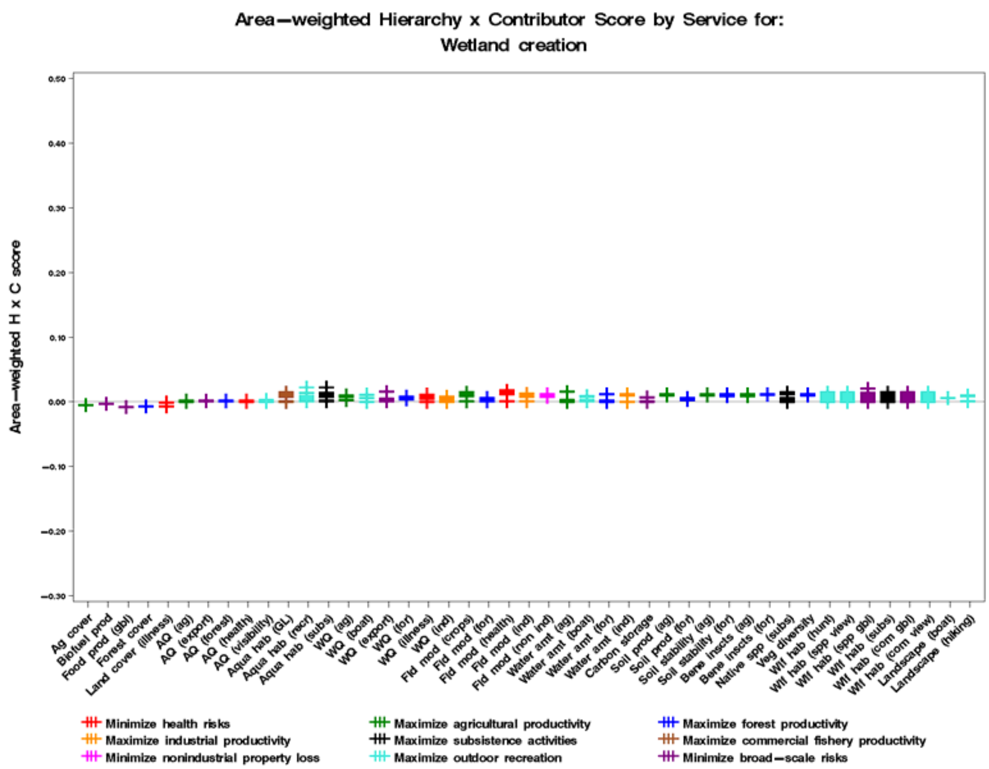

Figure D.4.7. Wetland creation.

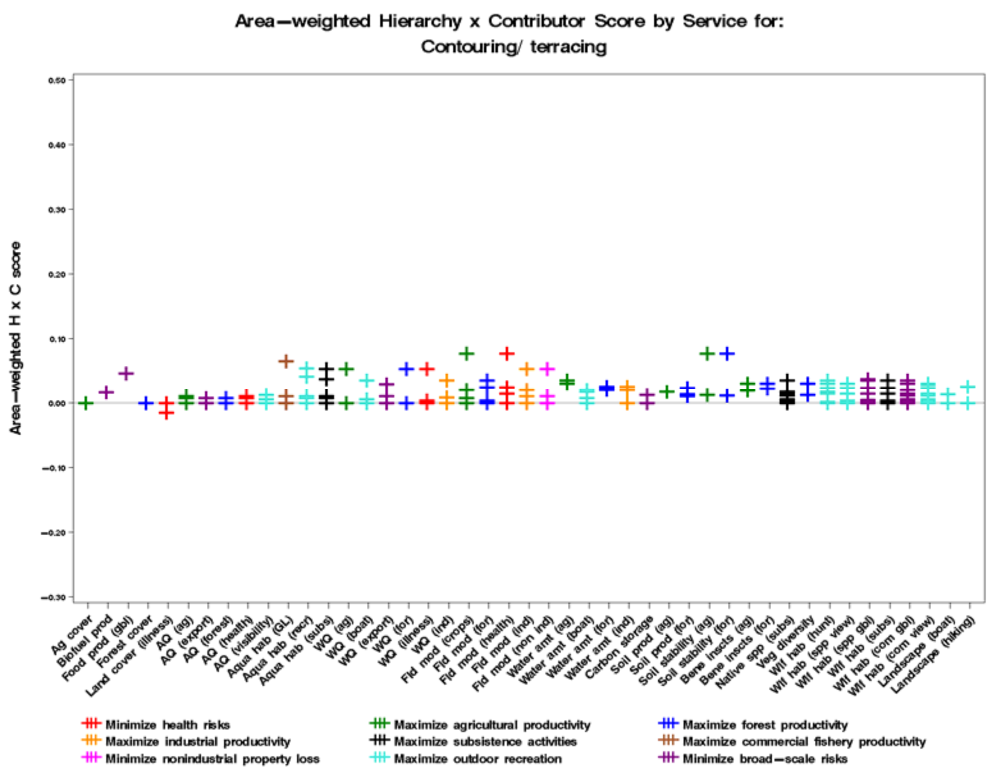

Figure D.4.8. Contouring/ terracing.

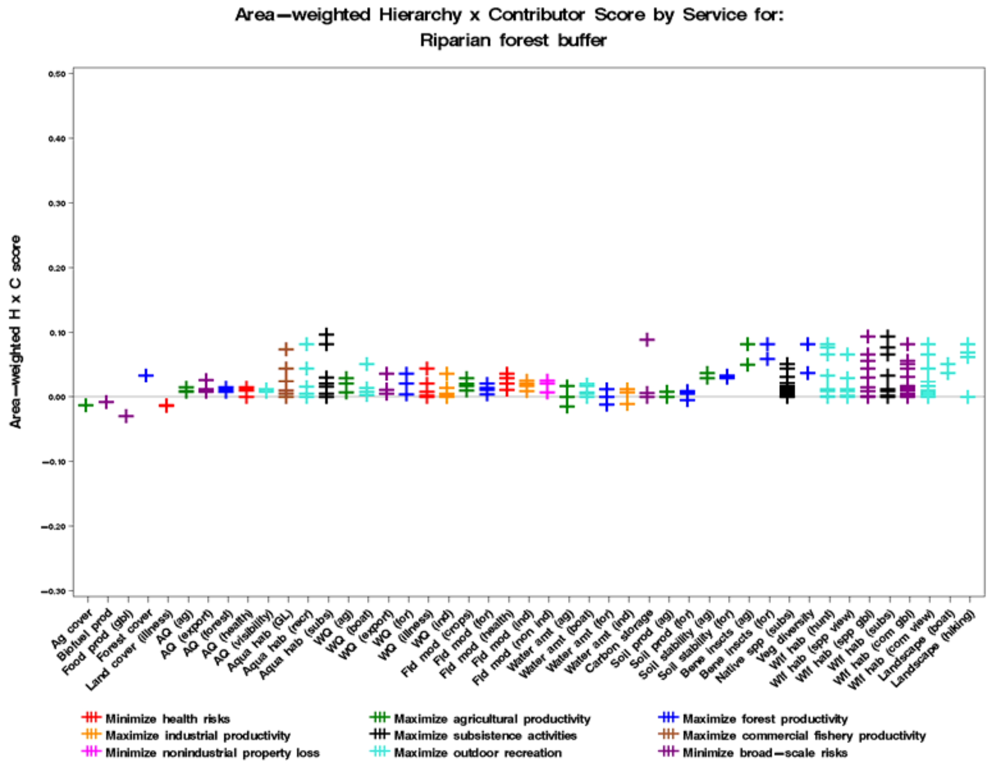

Figure D.4.9. Riparian forest buffer.

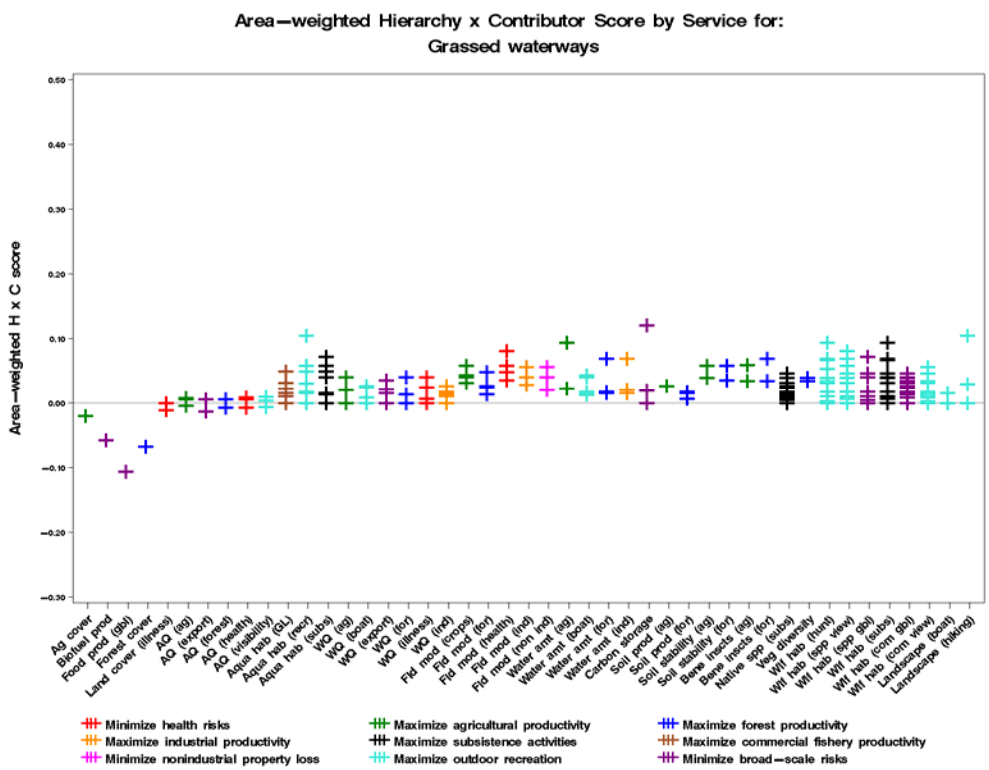

Figure D.4.10. Grassed waterways.

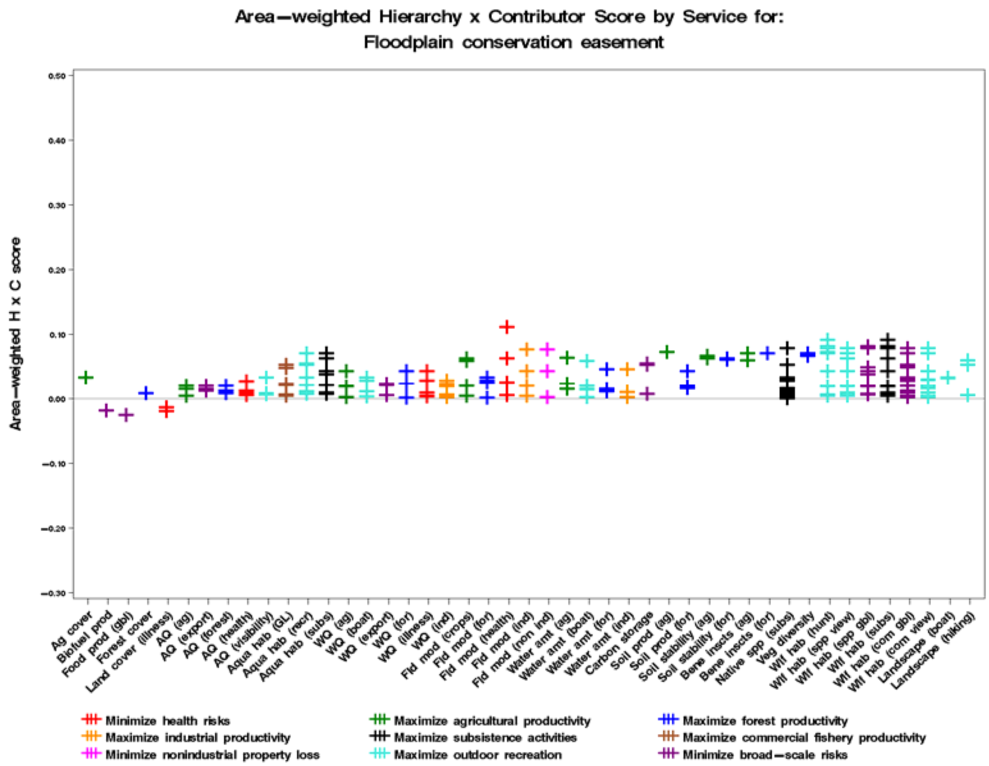

Figure D.4.11. Floodplain conservation easement.

Appendix D.5. Sum of Area-weighted HxC Values by Service for the MS Scenario.

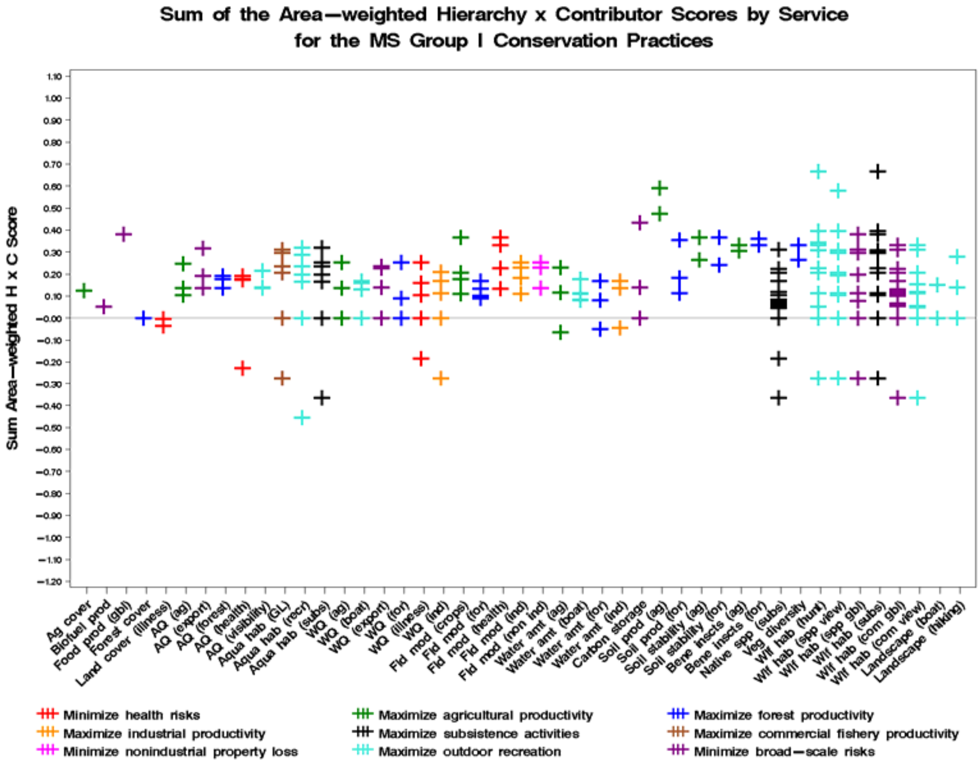

Figure D.5.1. MS Group I conservation practices.

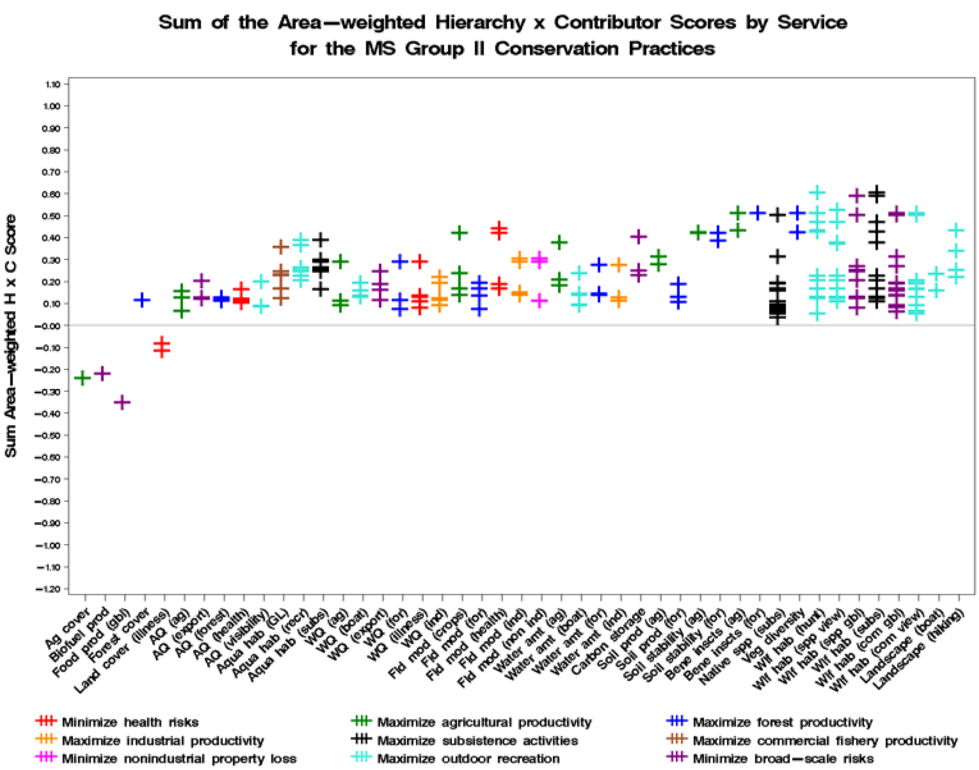

Figure D.5.2. MS Group II conservation practices.

Appendix D.6. Cost-weighted HxC Values by Service for the MS Scenario.

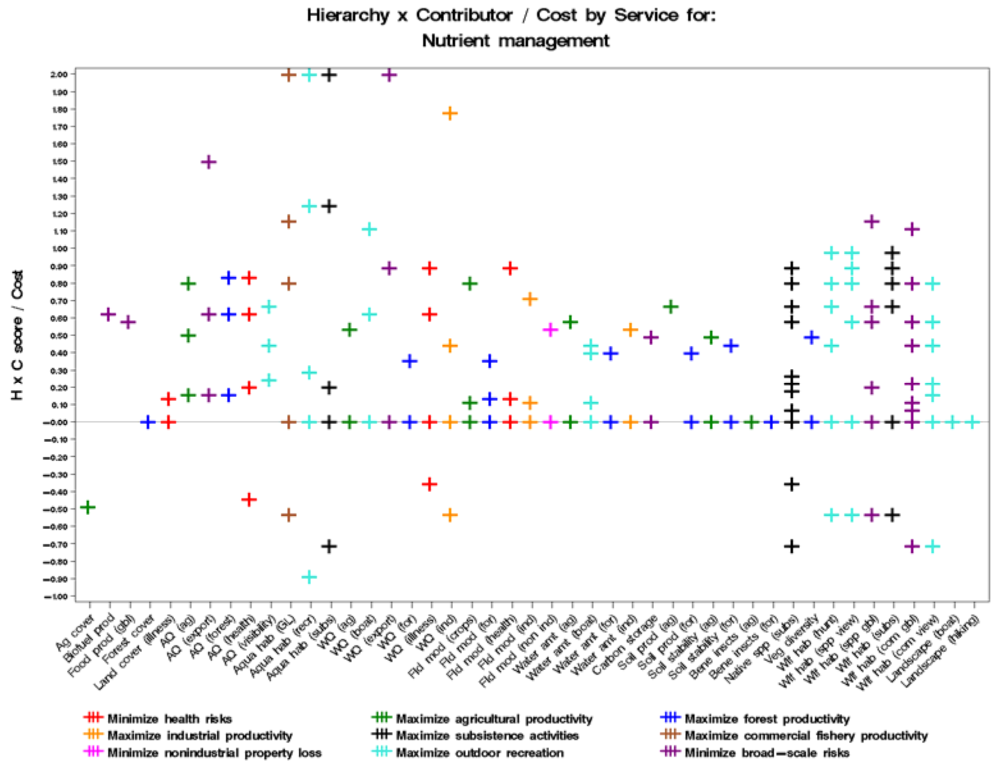

Figure D.6.1. Nutrient management.

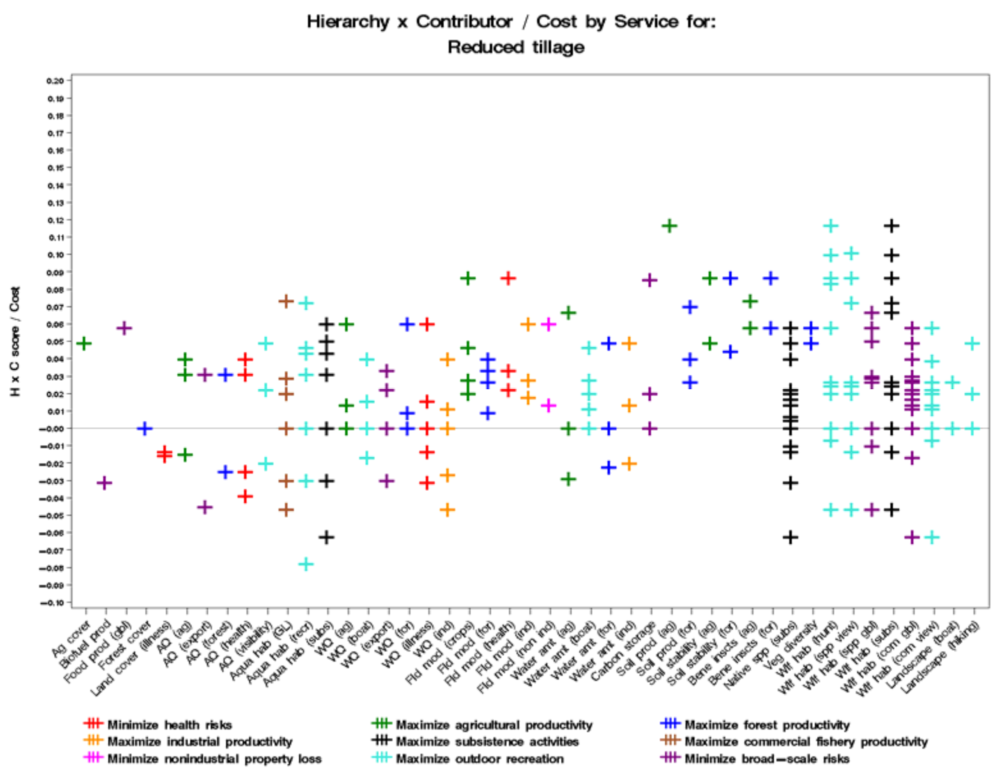

Figure D.6.2. Reduced tillage.

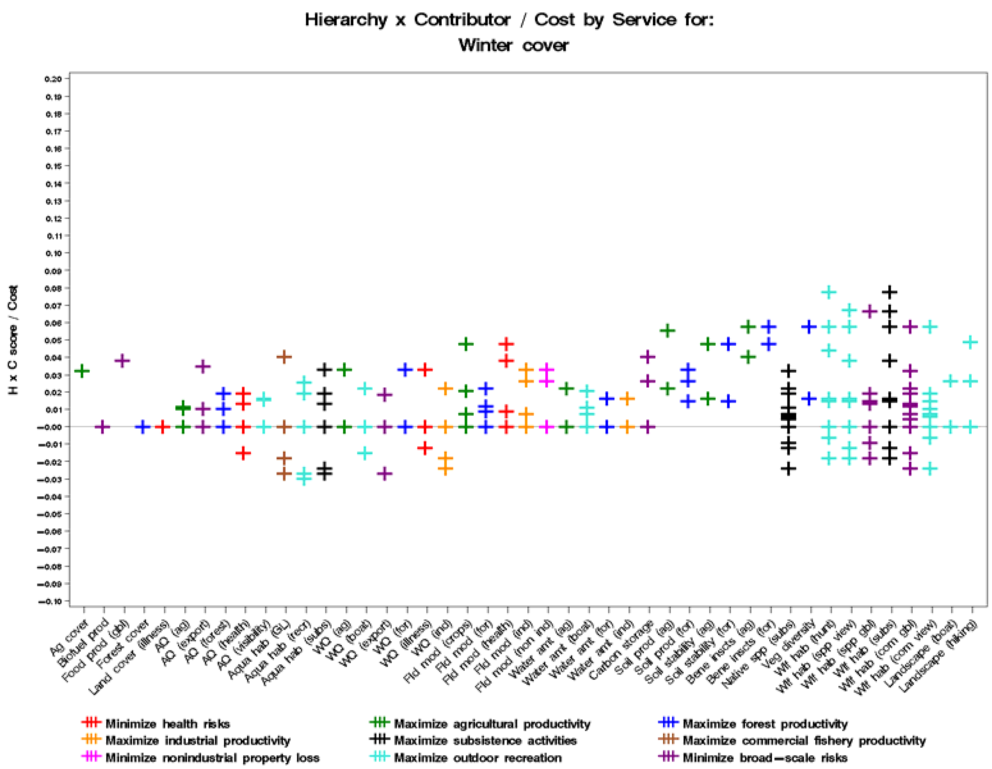

Figure D.6.3. Winter cover.

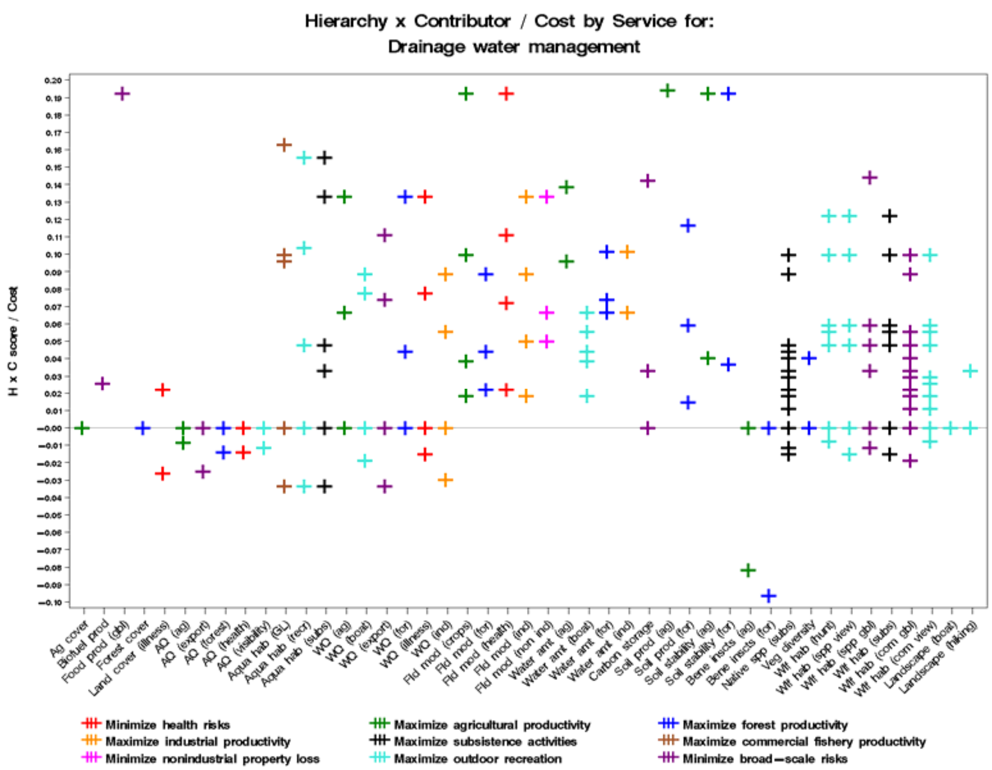

Figure D.6.4. Drainage water management.

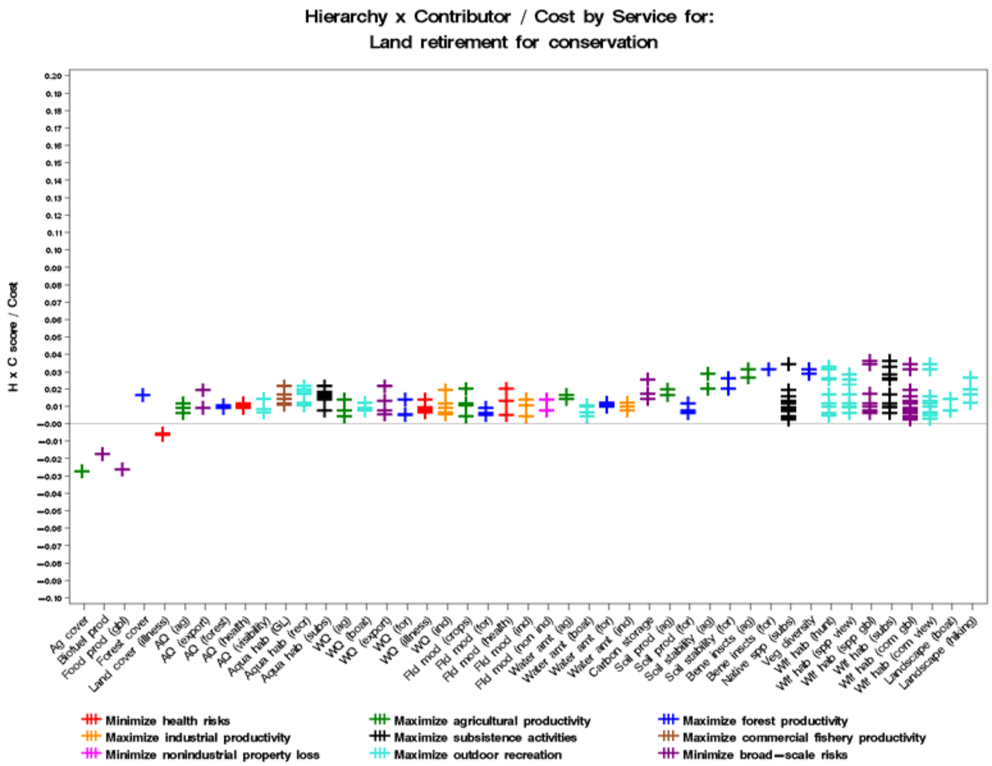

Figure D.6.5. Land retirement for conservation.

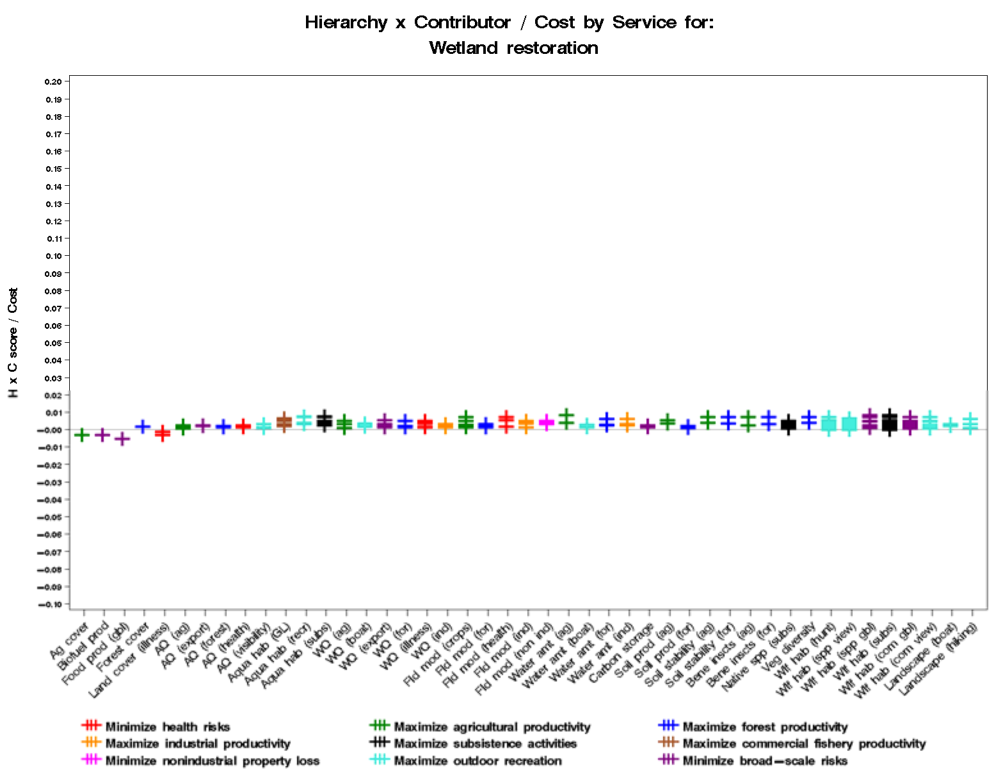

Figure D.6.6. Wetland restoration.

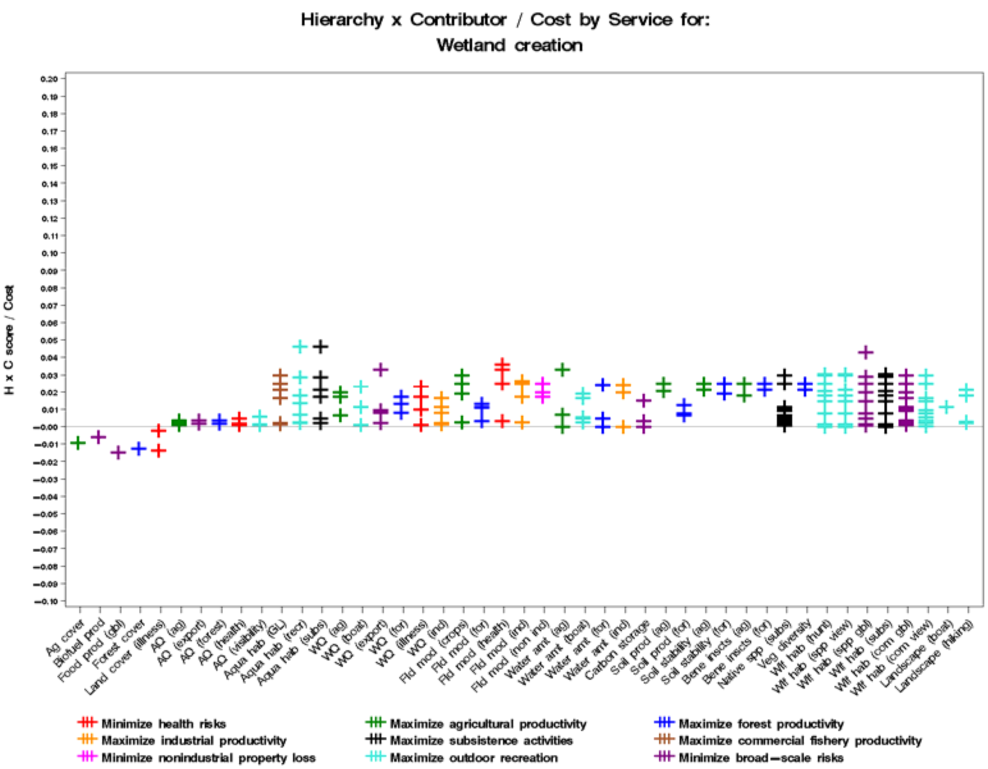

Figure D.6.7. Wetland creation.

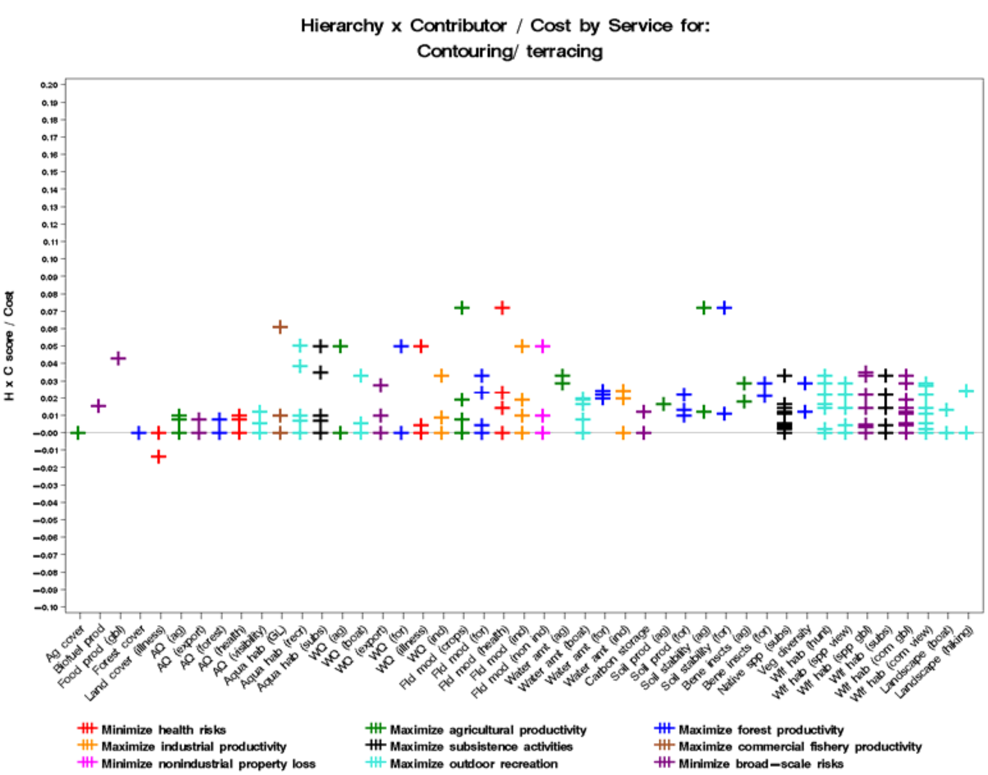

Figure D.6.8. Contouring/ terracing.

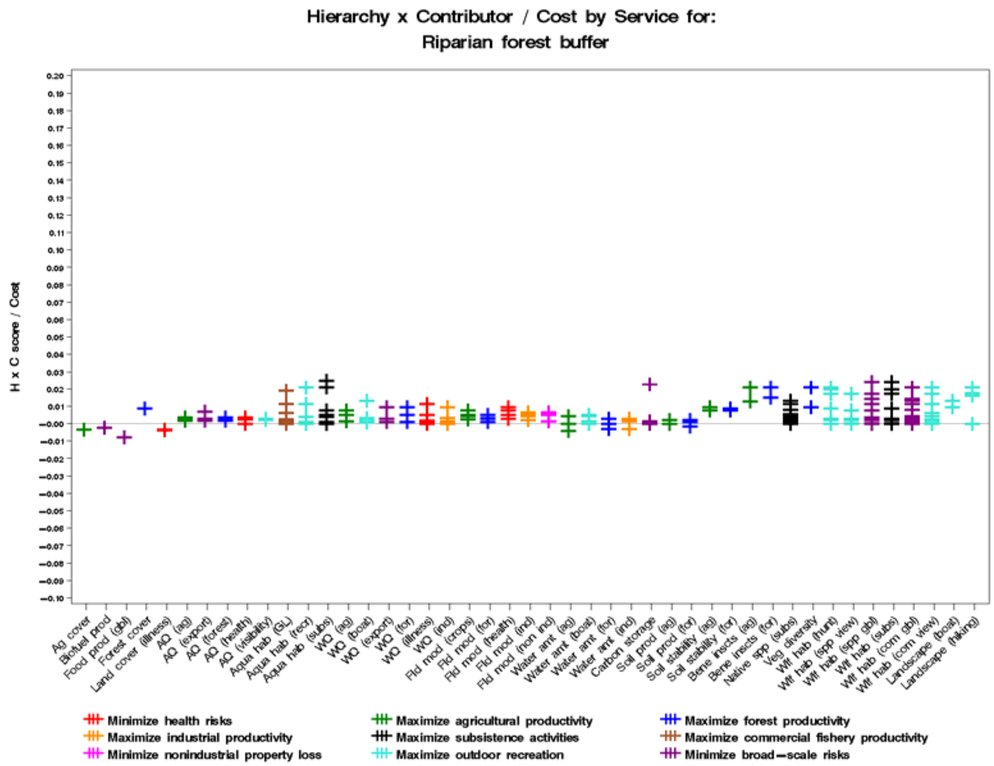

Figure D.6.9. Riparian forest buffer.

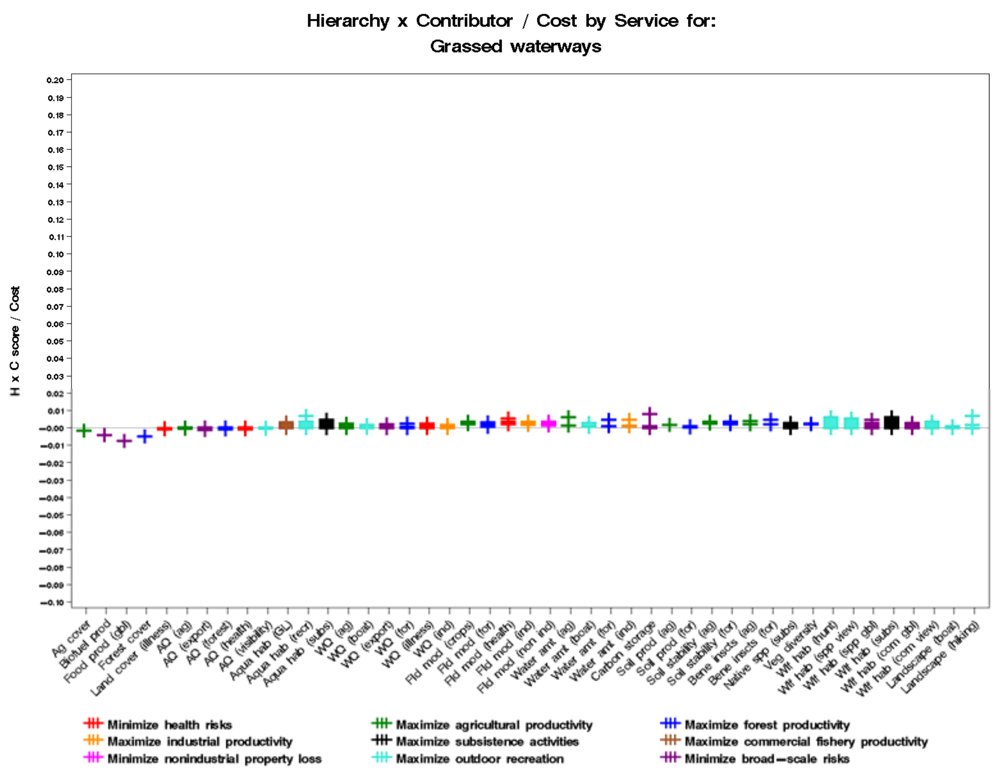

Figure D.6.10. Grassed waterways.

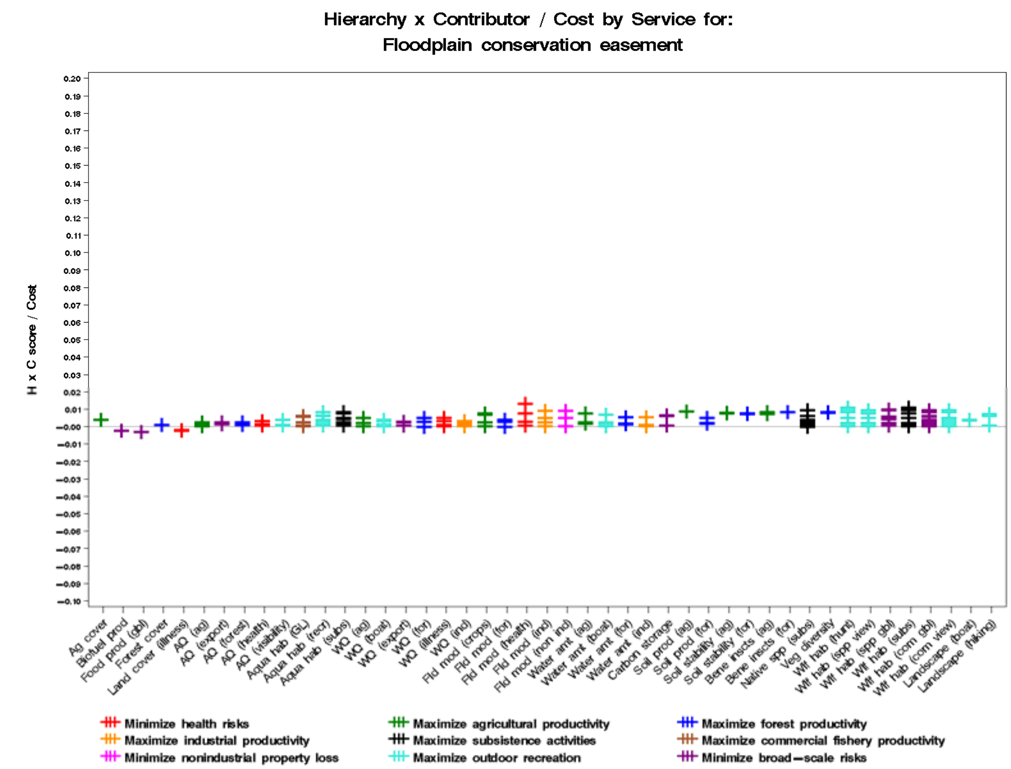

Figure D.6.11. Floodplain conservation easement.

Appendix D.7. Sum of Cost-weighted HxC Values by Service for the MS Scenario.

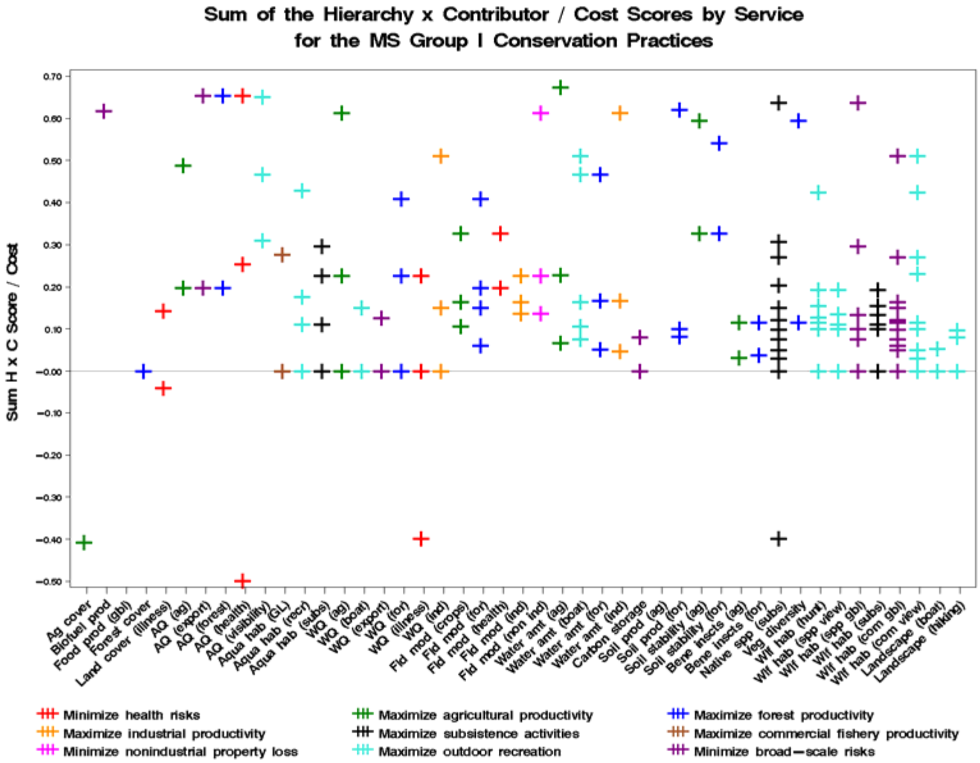

Figure D.7.1. MS Group I conservation practices.

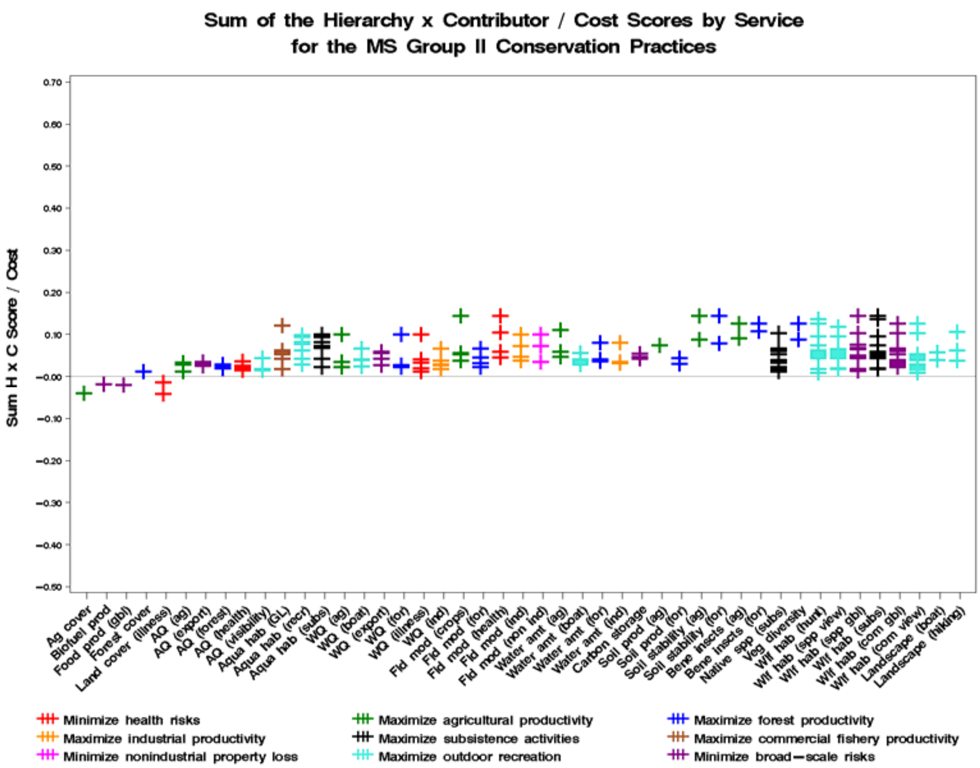

Figure D.7.2. MS Group II conservation practices.

Appendix E. Plots by Scenario-related Change for each First Level Hierarchy Value

Appendix E.1. Unweighted HxC Values by Scenario-related Change.

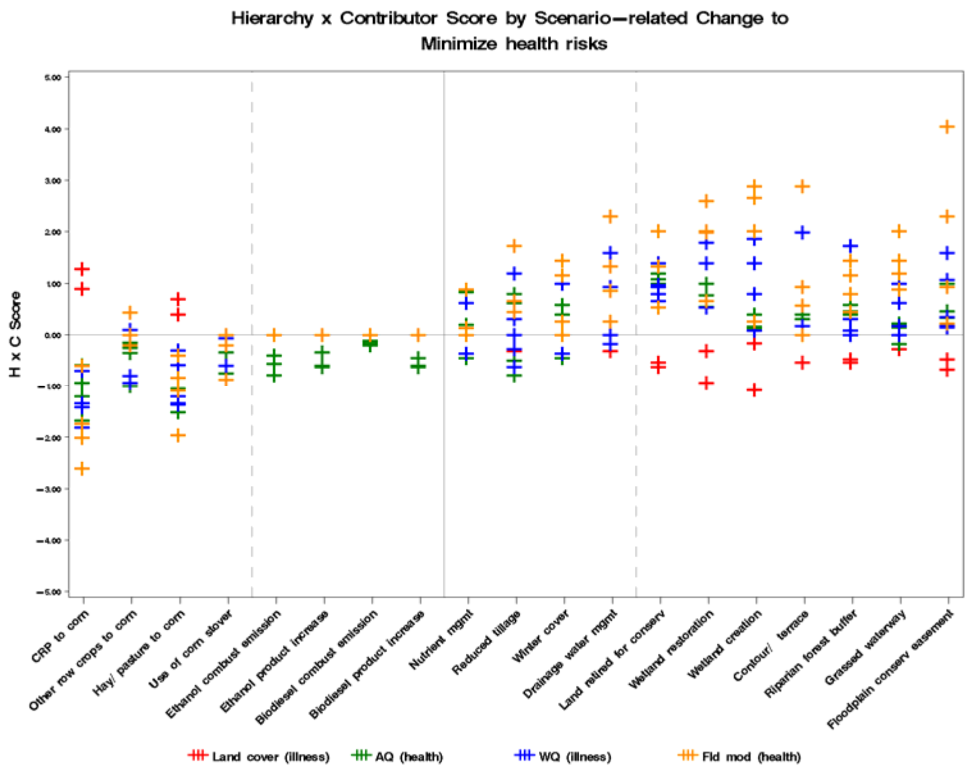

Figure E.1.1. Minimize health risks.

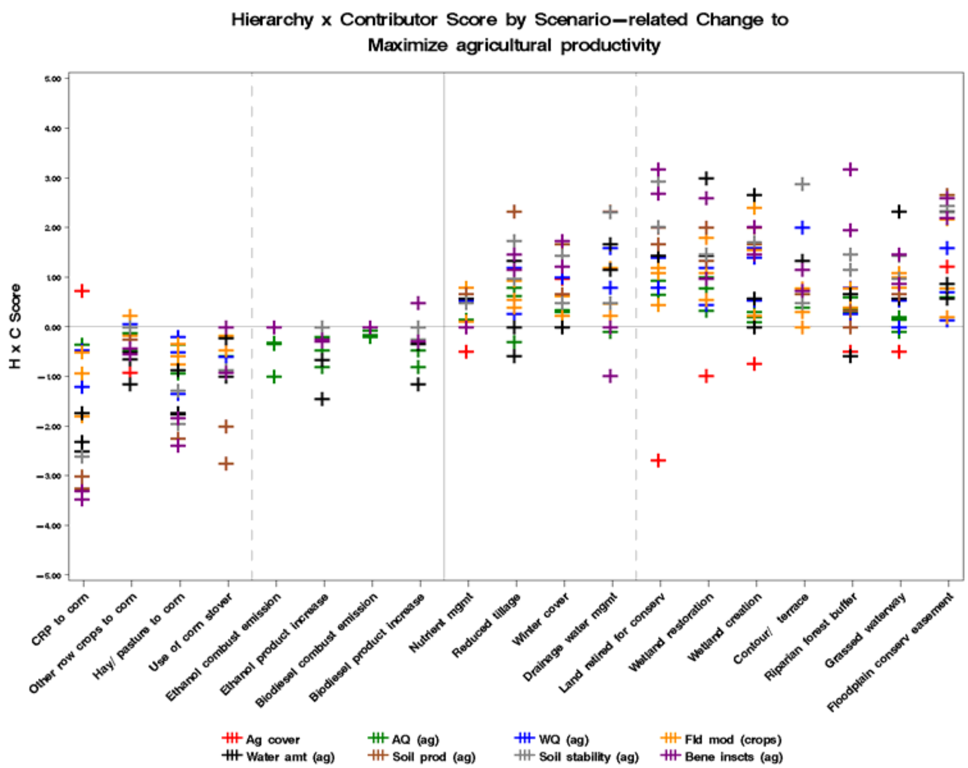

Figure E.1.2. Maximize agricultural productivity.

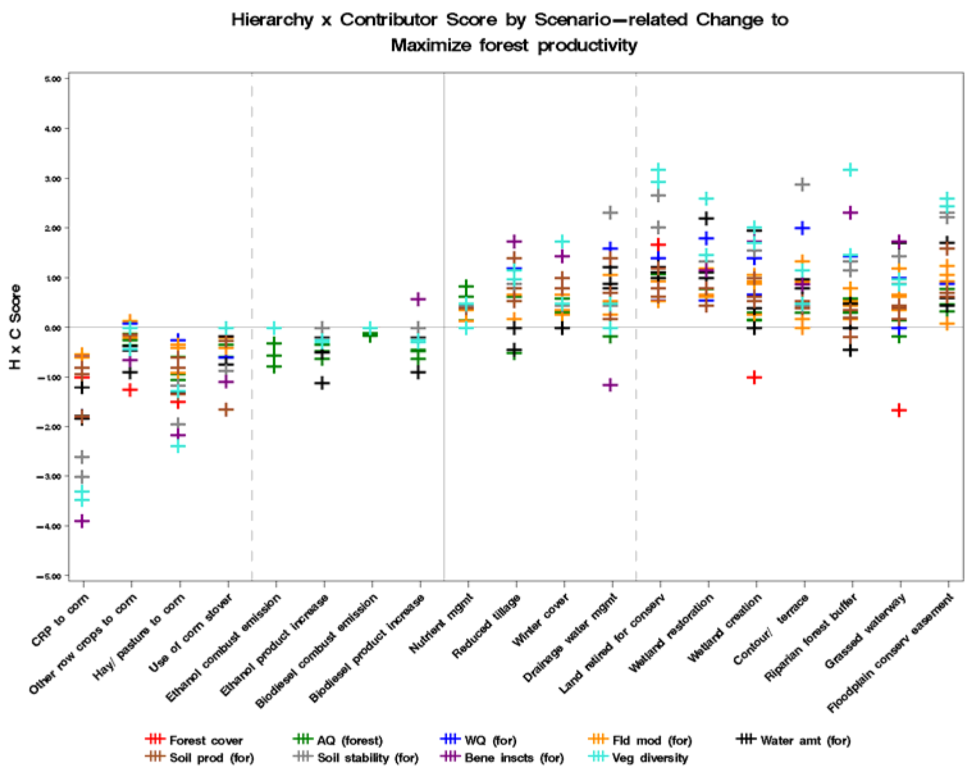

Figure E.1.3. Maximize forest productivity.

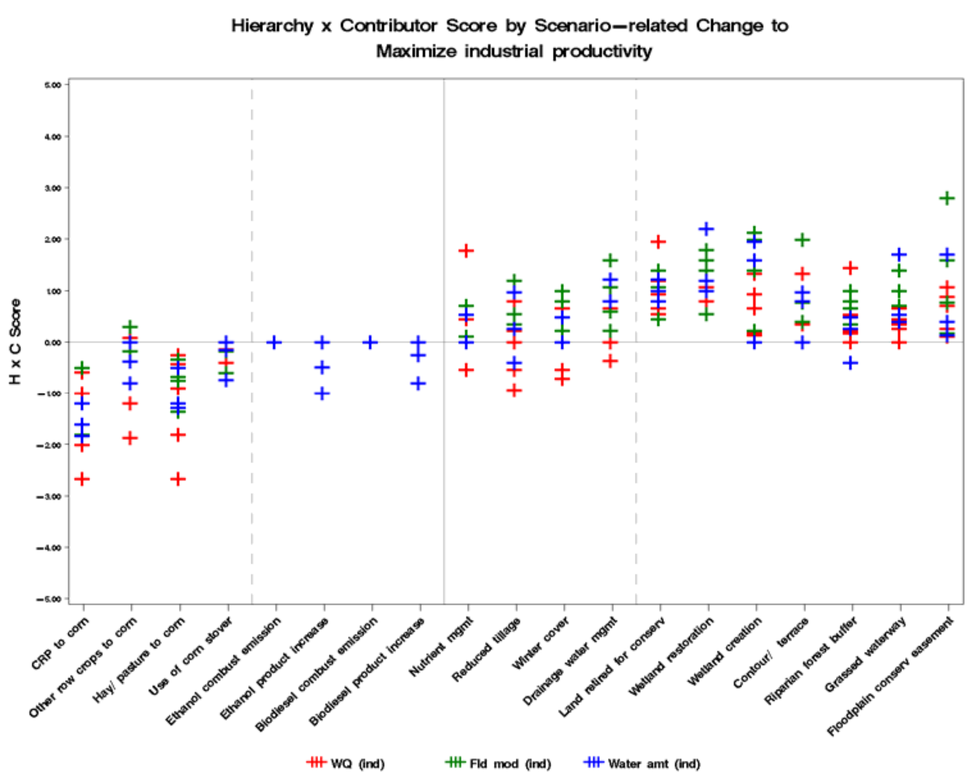

Figure E.1.4. Maximize industrial productivity.

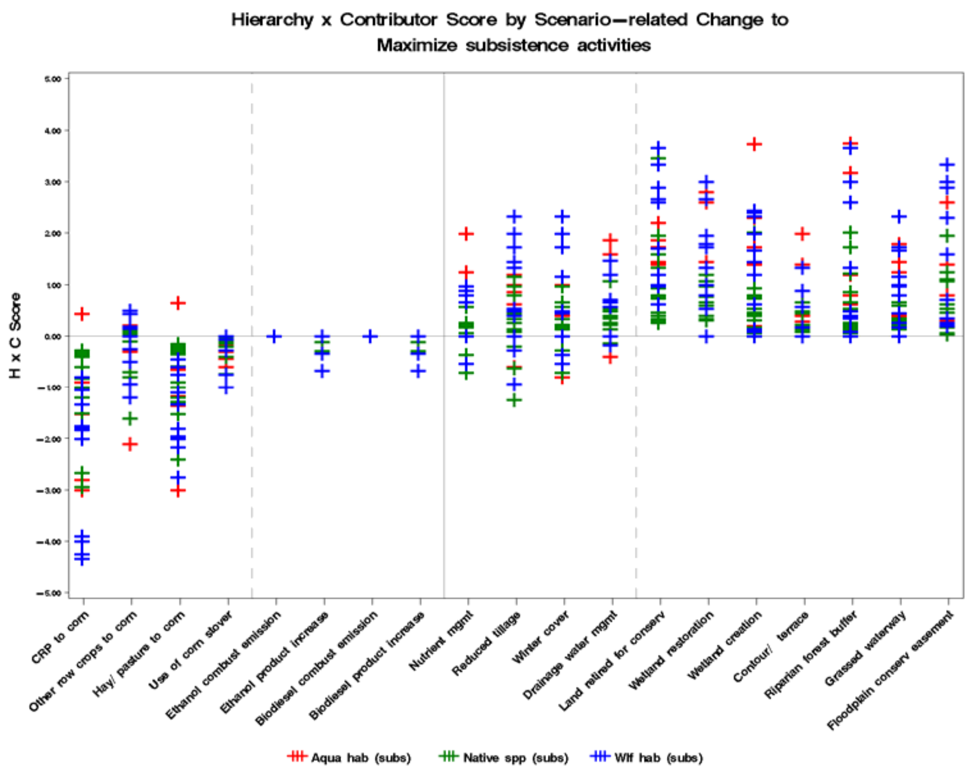

Figure E.1.5. Maximize subsistence activities.

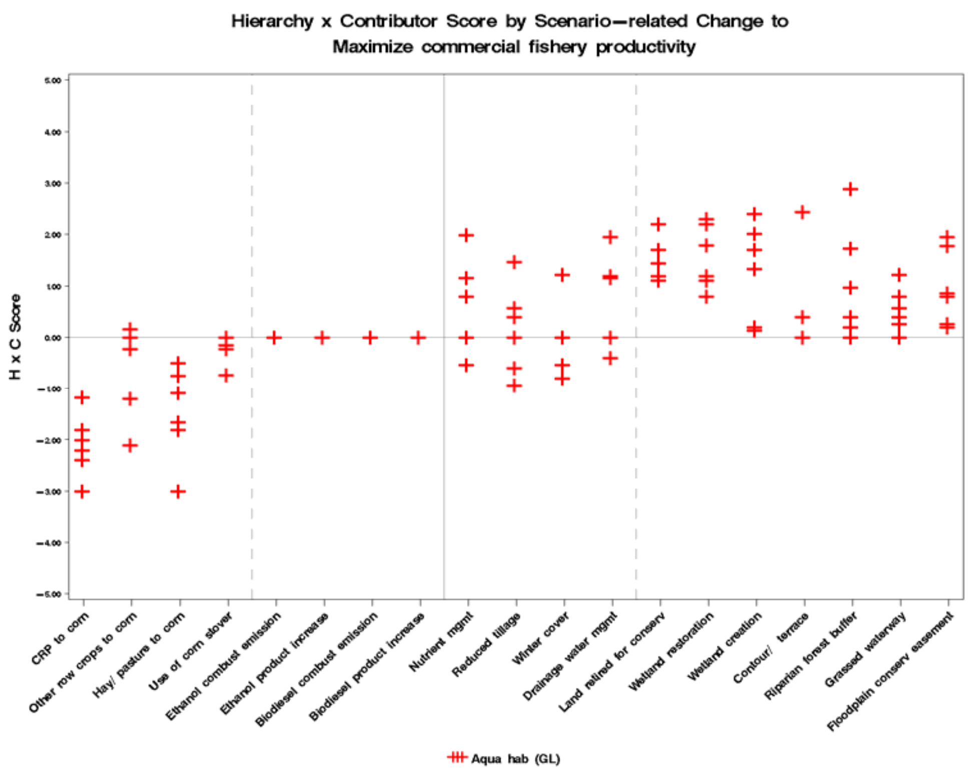

Figure E.1.6. Maximize commercial fishery productivity.

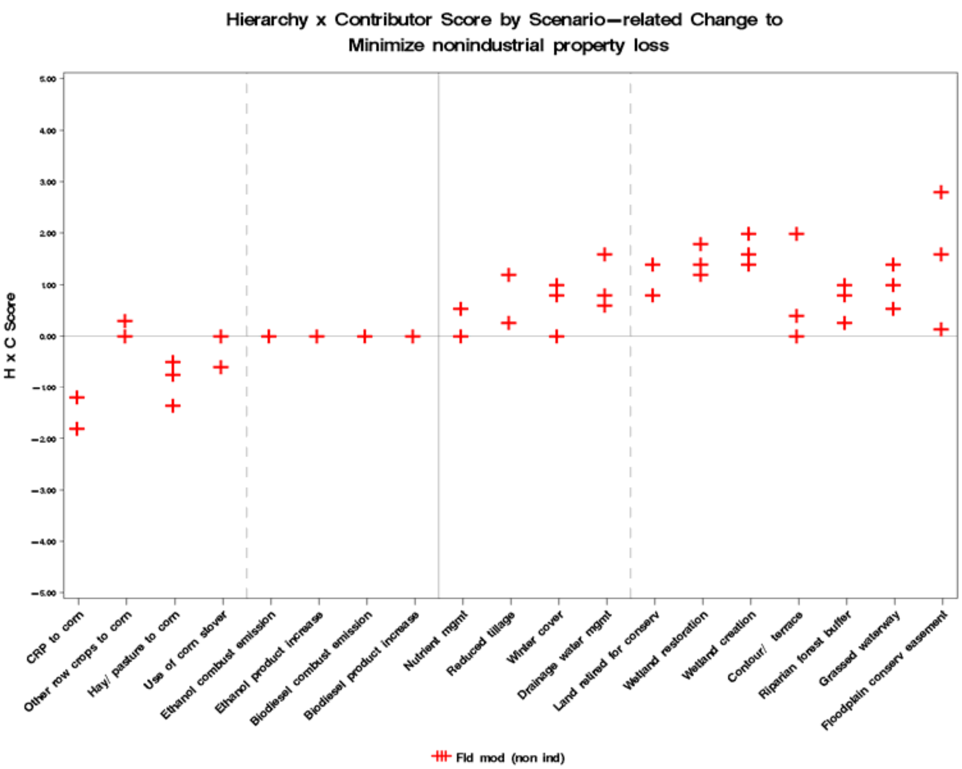

Figure E.1.7. Minimize nonindustrial property loss.

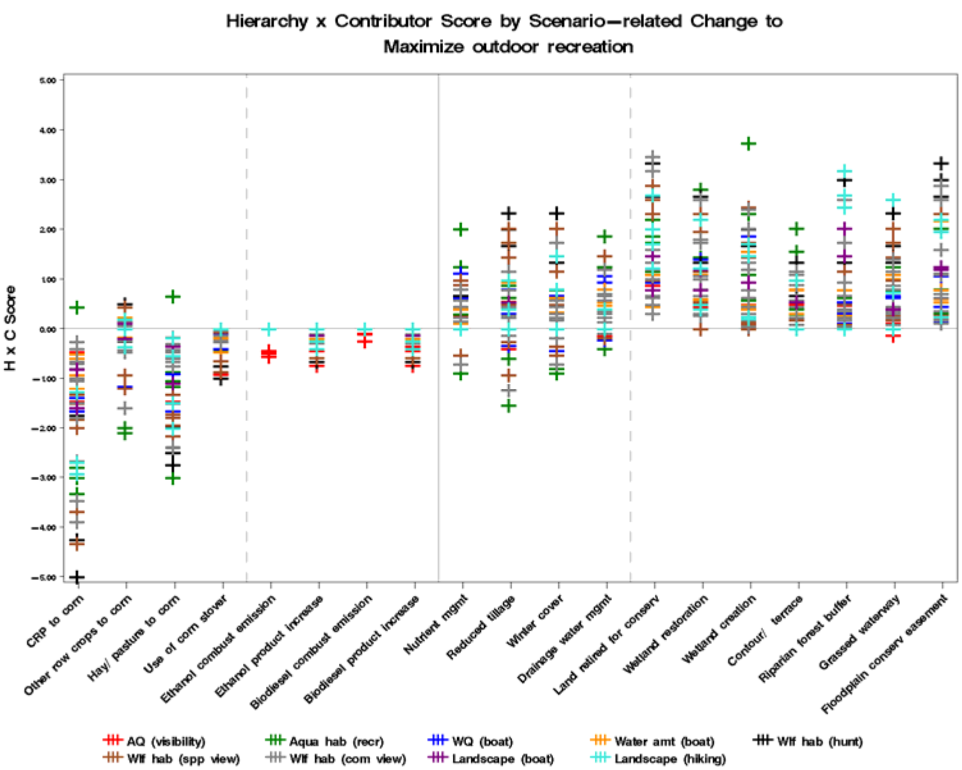

Figure E.1.8. Maximize outdoor recreation.

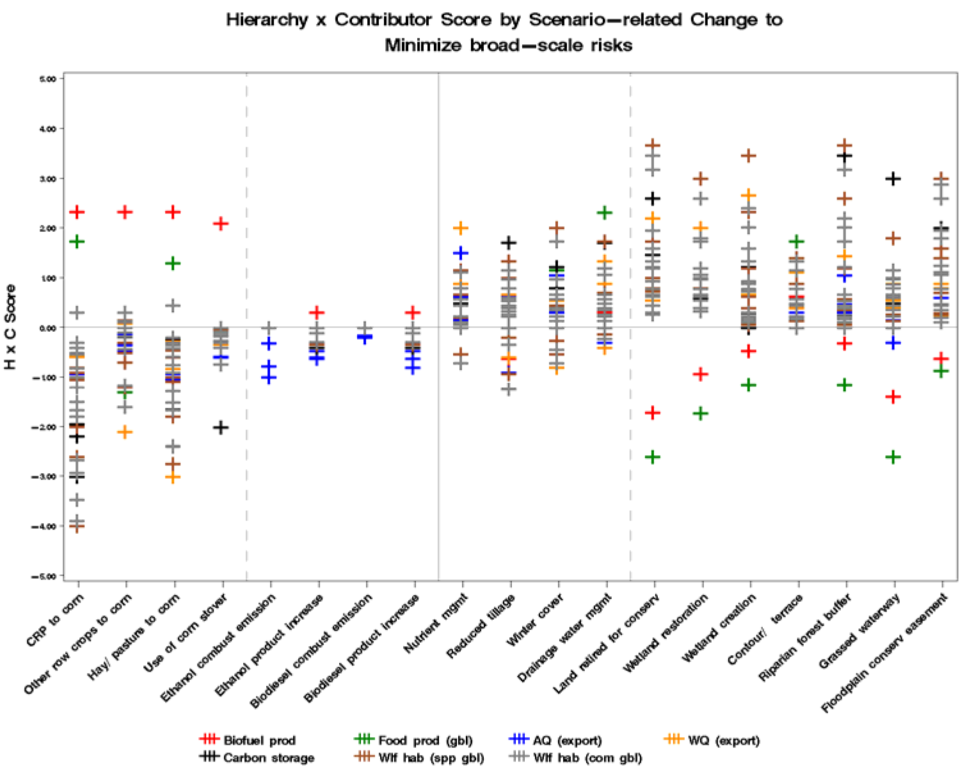

Figure E.1.9. Minimize broad-scale risks.

Appendix E.2. Area-weighted HxC Values by Scenario-related Change.

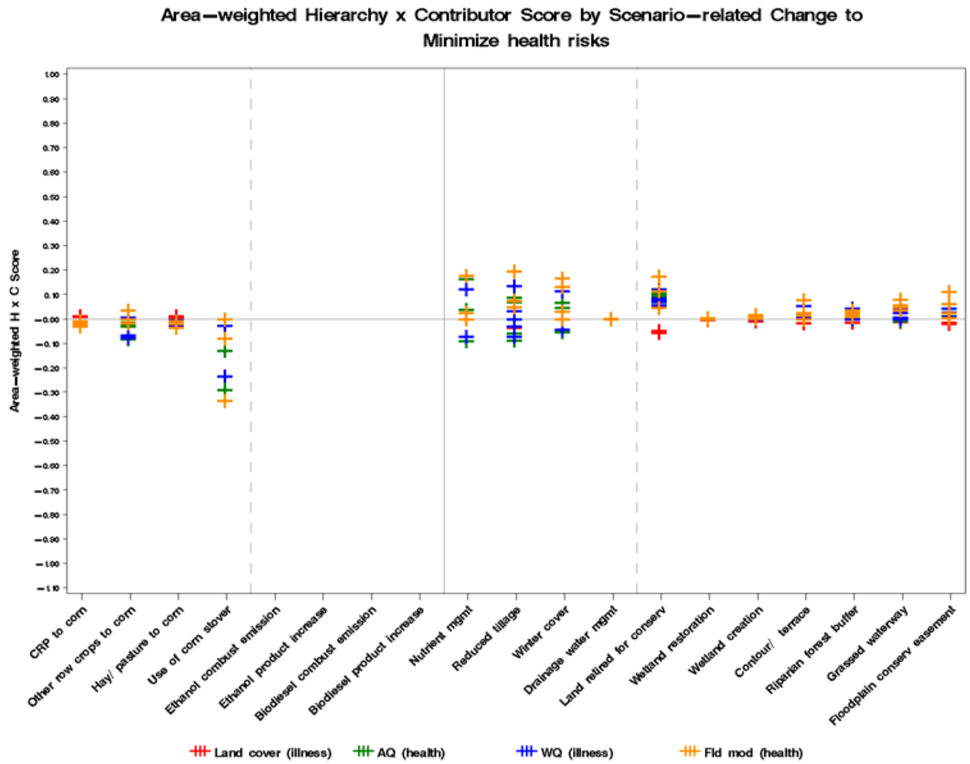

Figure E.2.1. Minimize health risks.

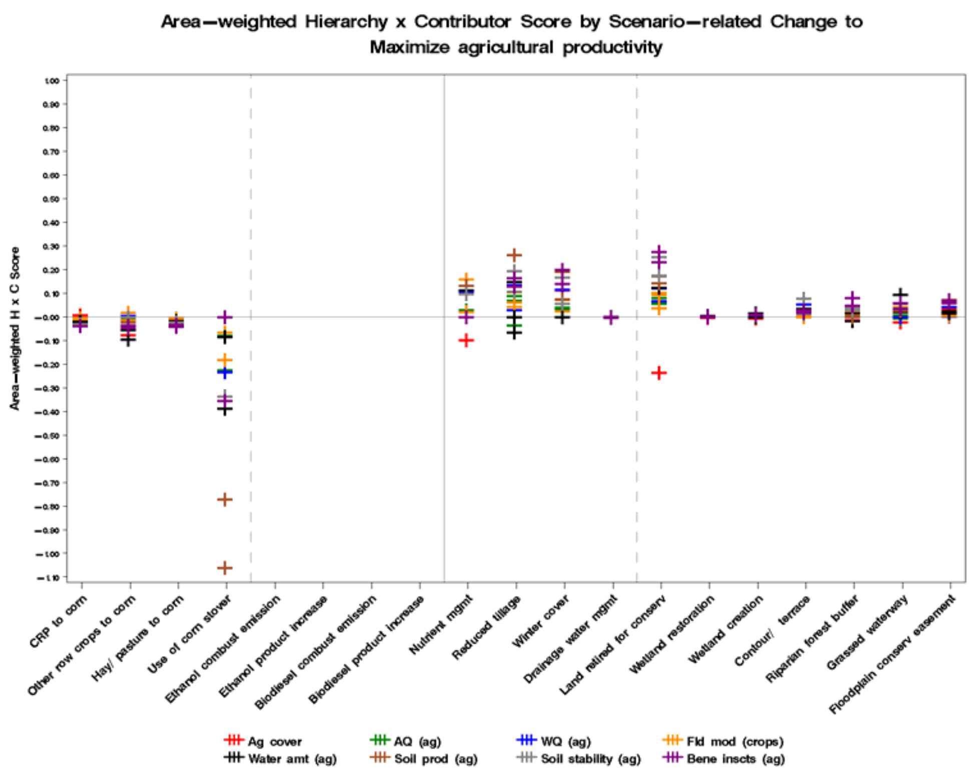

Figure E.2.2. Maximize agricultural productivity.

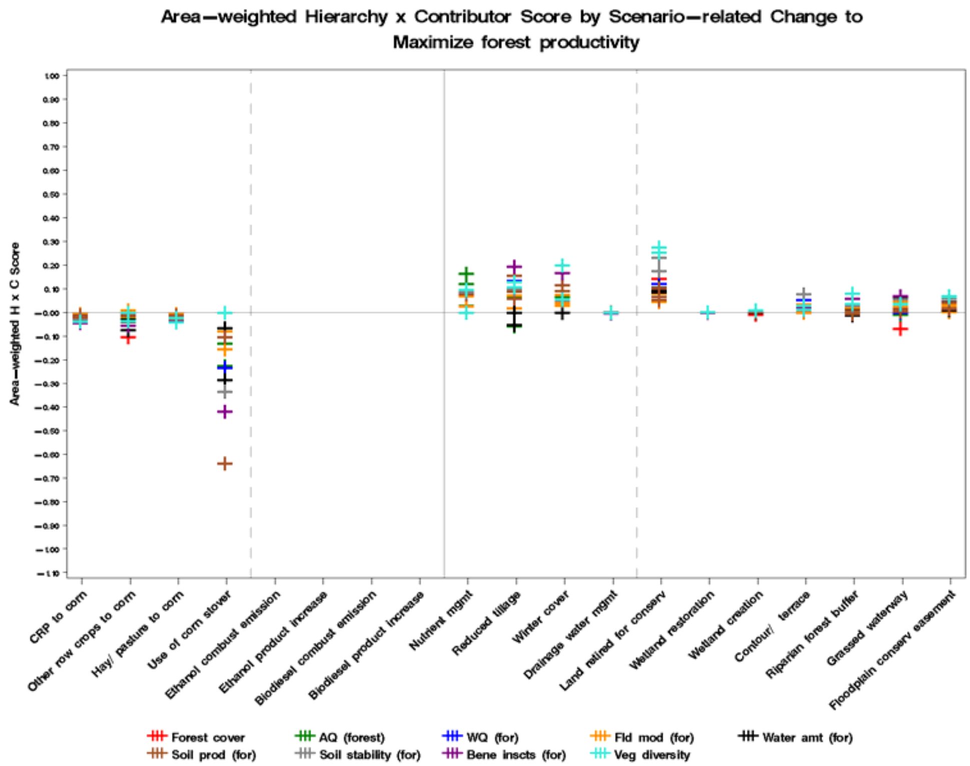

Figure E.2.3. Maximize forest productivity.

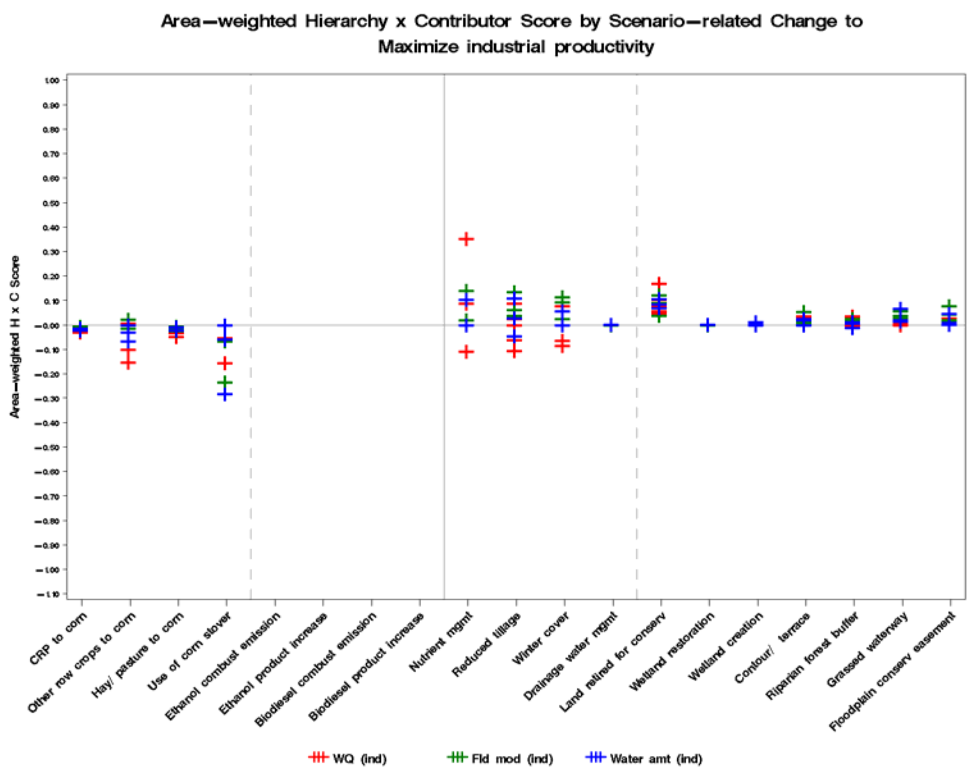

Figure E.2.4. Maximize industrial productivity.

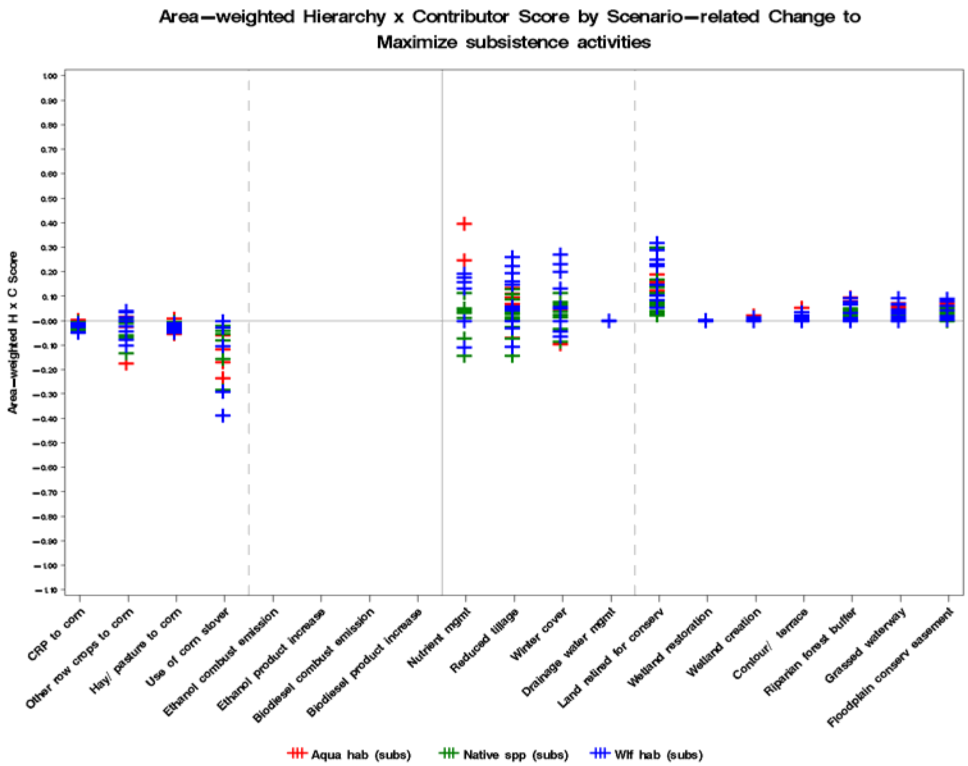

Figure E.2.5. Maximize subsistence activities.

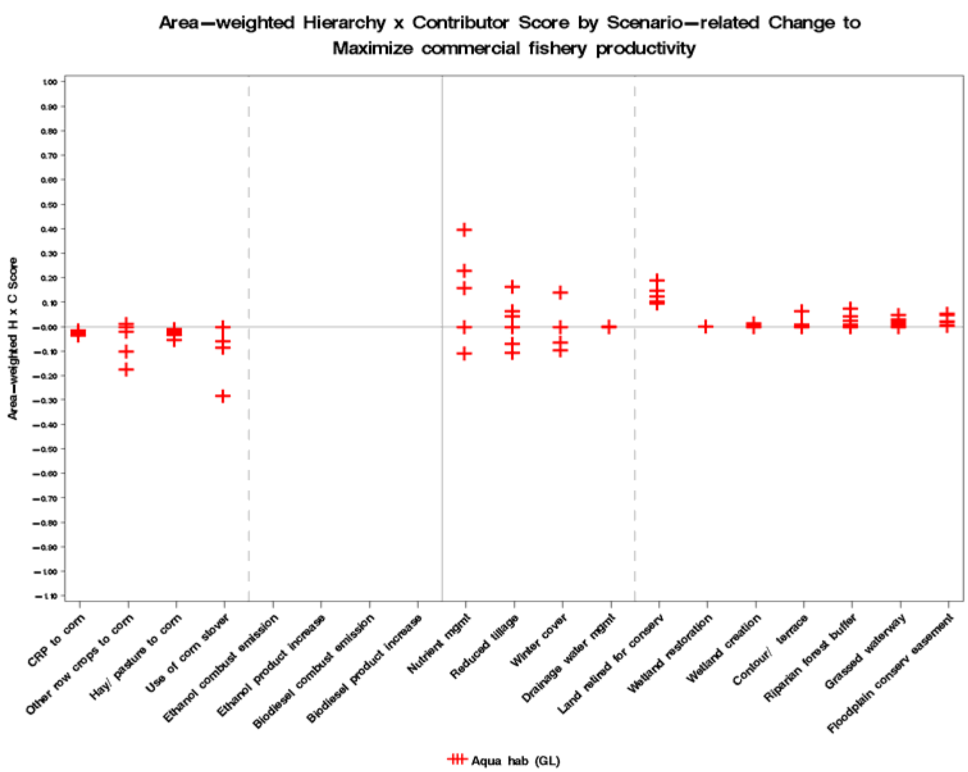

Figure E.2.6. Maximize commercial fishery productivity.

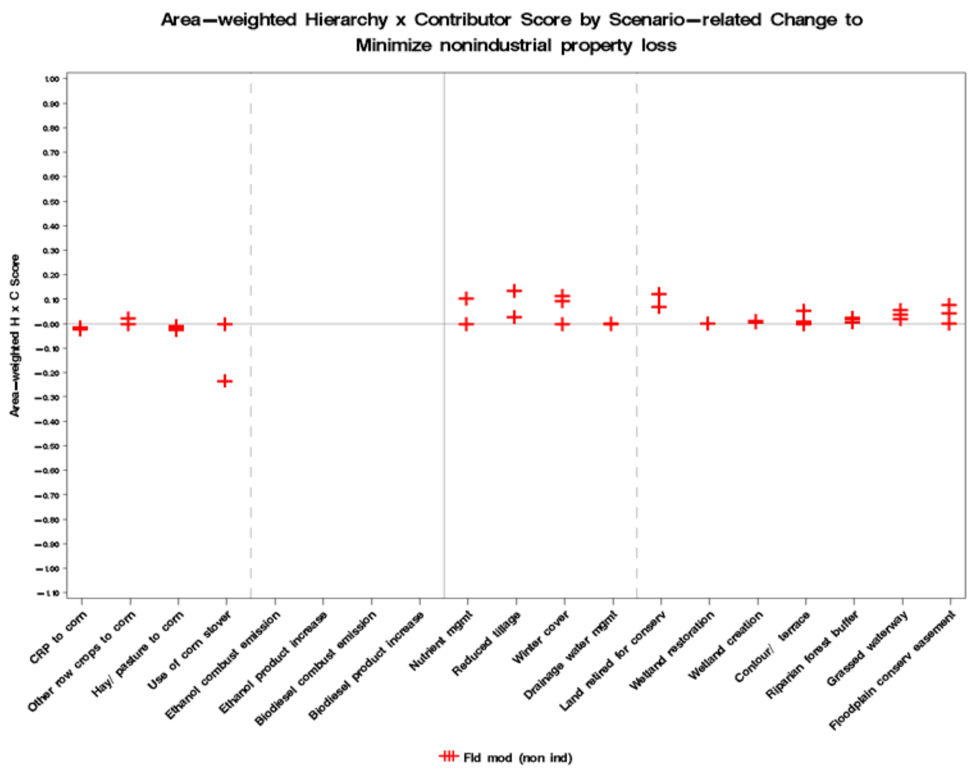

Figure E.2.7. Minimize nonindustrial property loss.

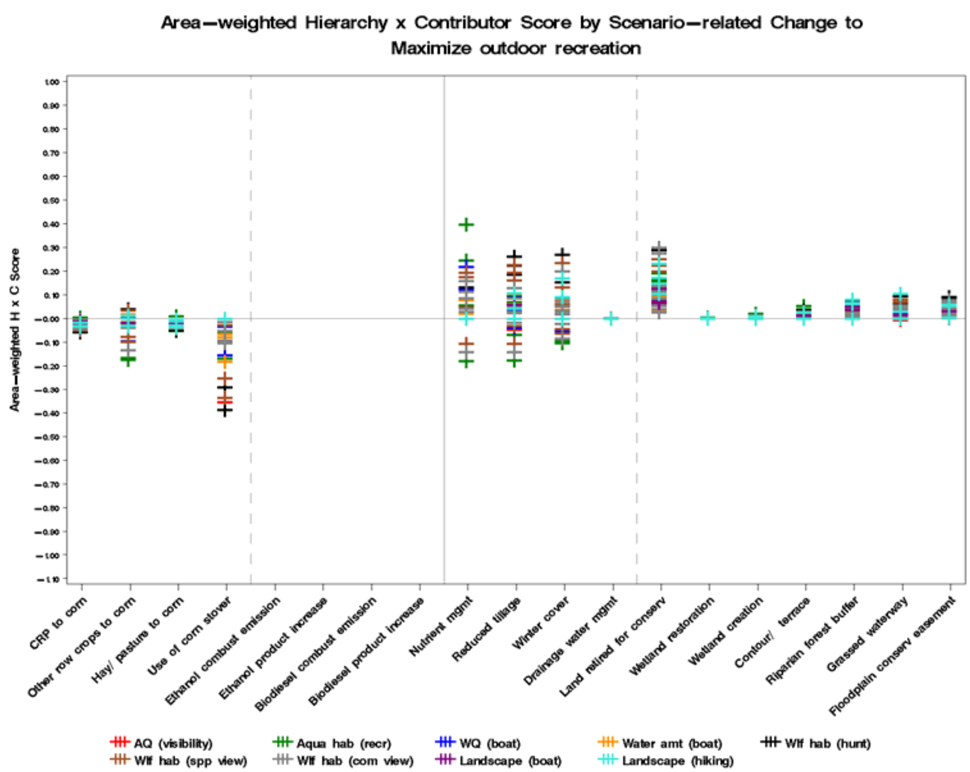

Figure E.2.8. Maximize outdoor recreation.

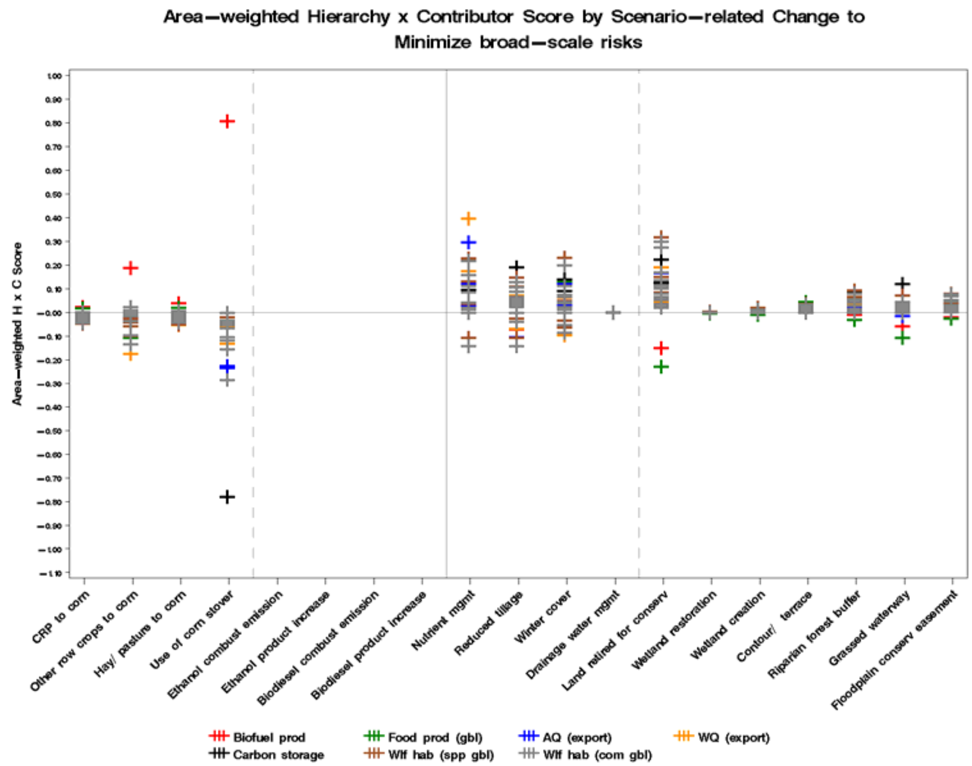

Figure E.2.9. Minimize broad-scale risks.

Appendix E.3. Cost-weighted HxC Values by Scenario-related Change, MS only.

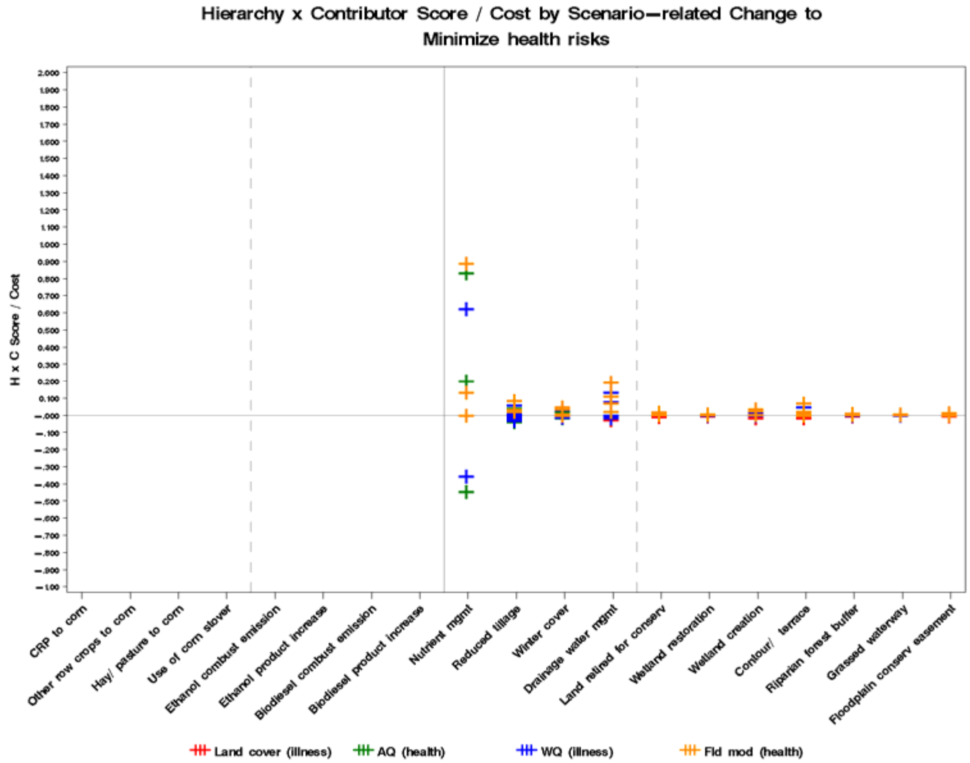

Figure E.3.1. Minimize health risks.

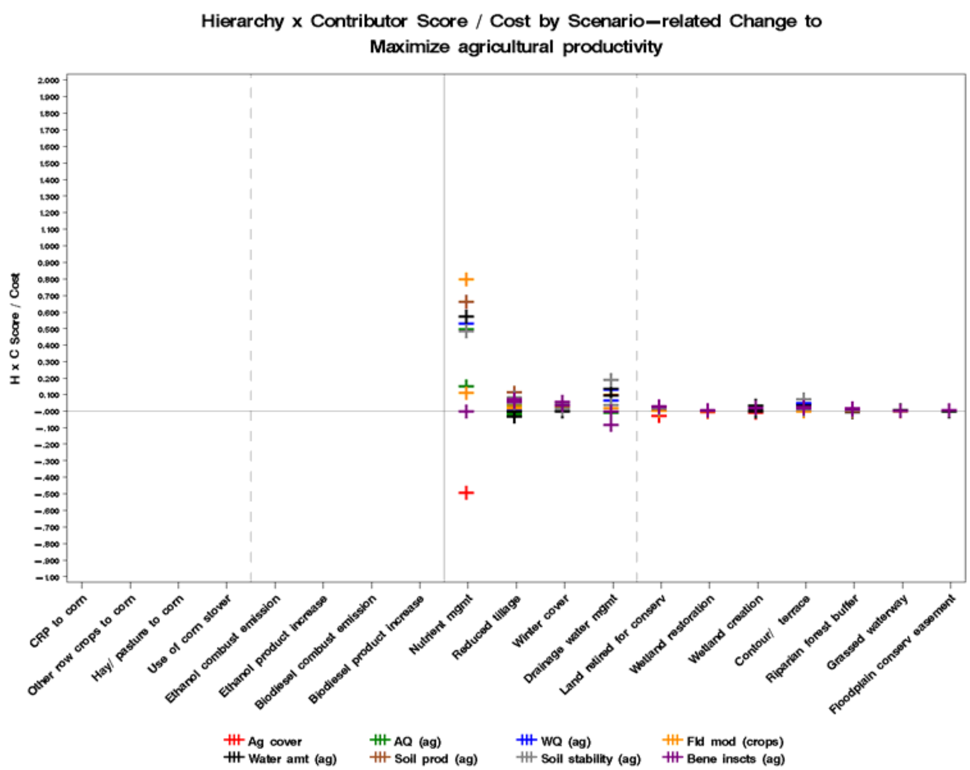

Figure E.3.2. Maximize agricultural productivity.

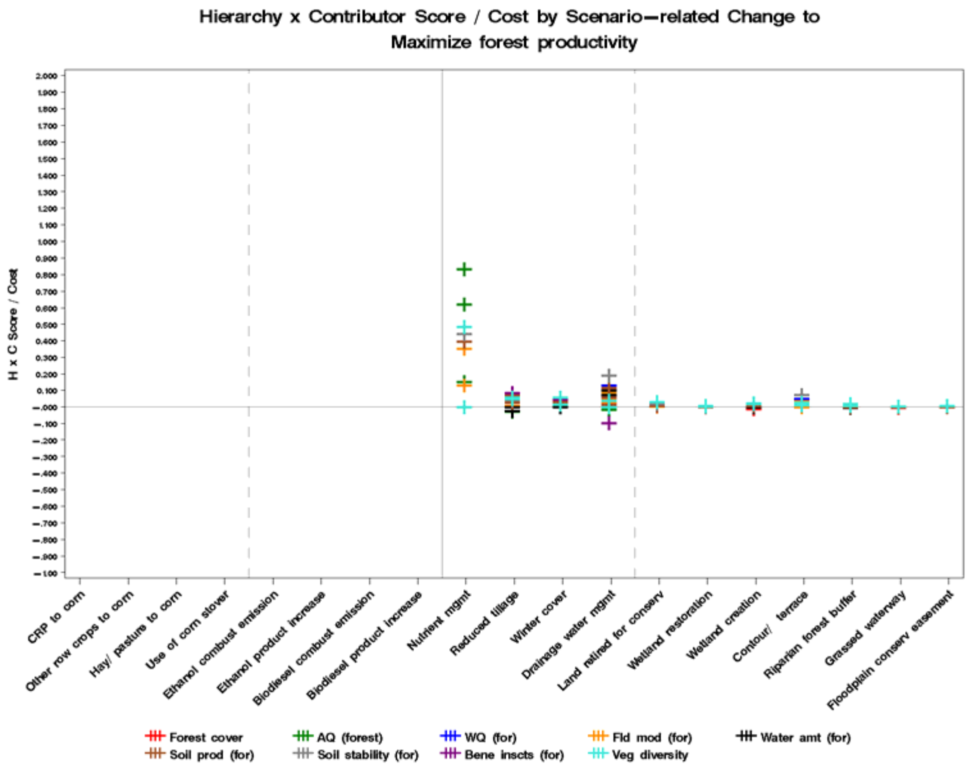

Figure E.3.3. Maximize forest productivity.

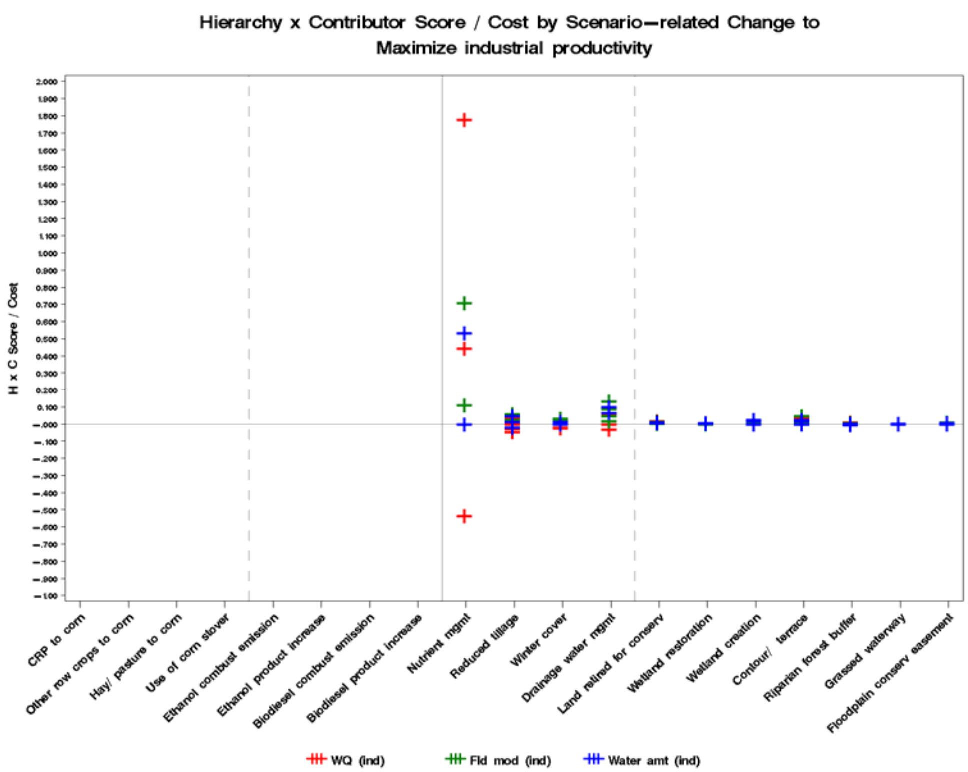

Figure E.3.4. Maximize industrial productivity.

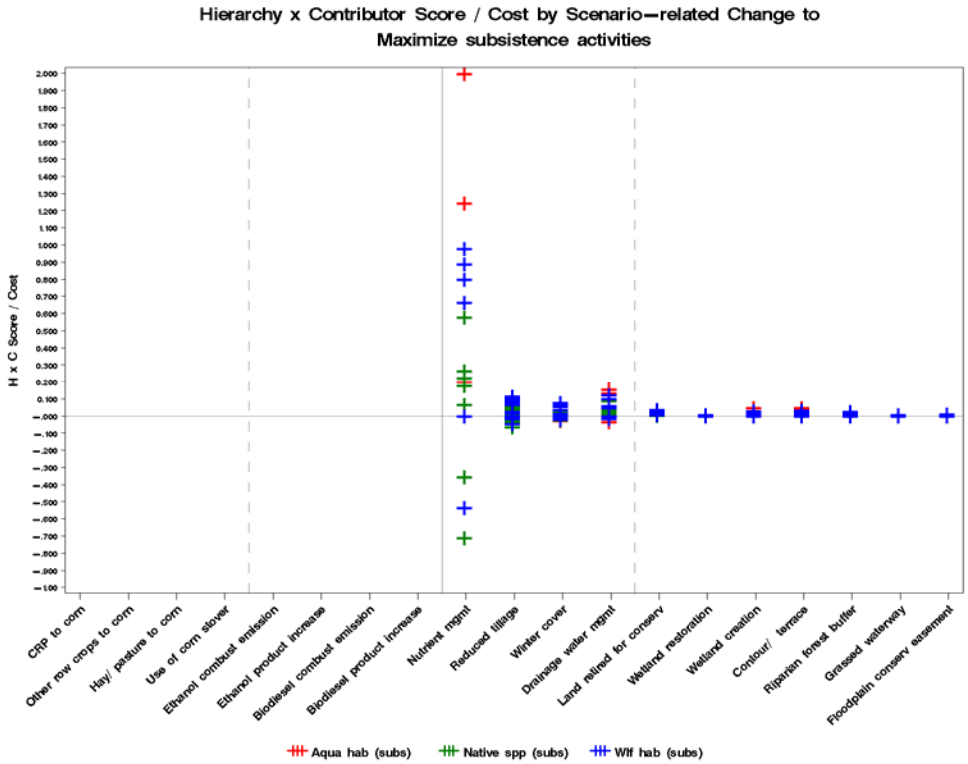

Figure E.3.5. Maximize subsistence activities.

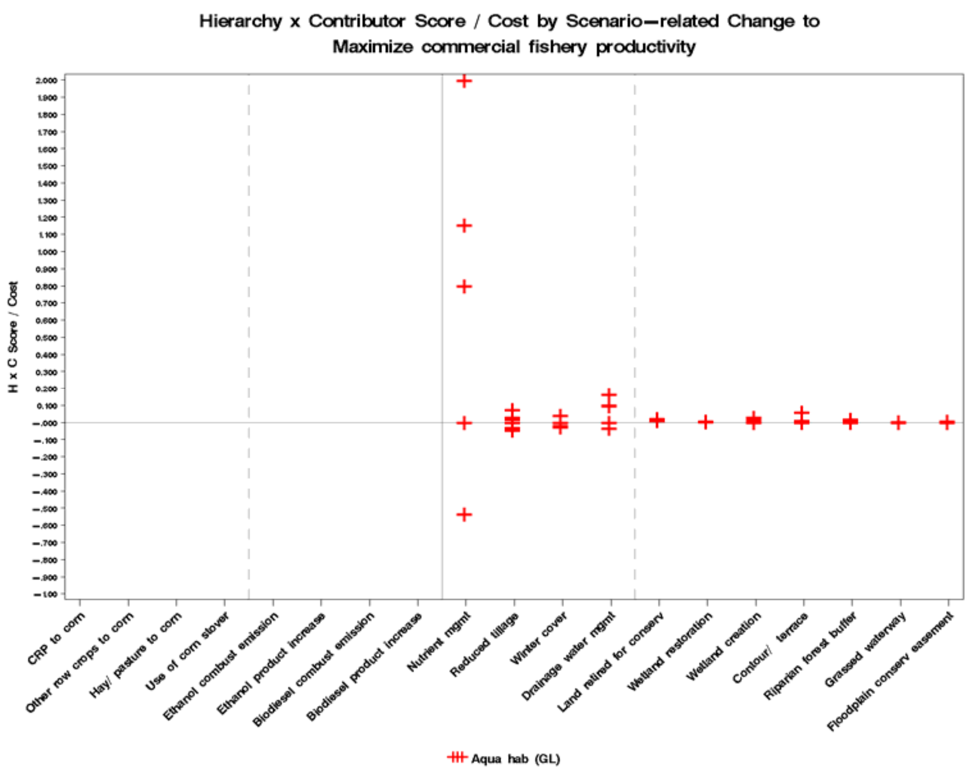

Figure E.3.6. Maximize commercial fishery productivity.

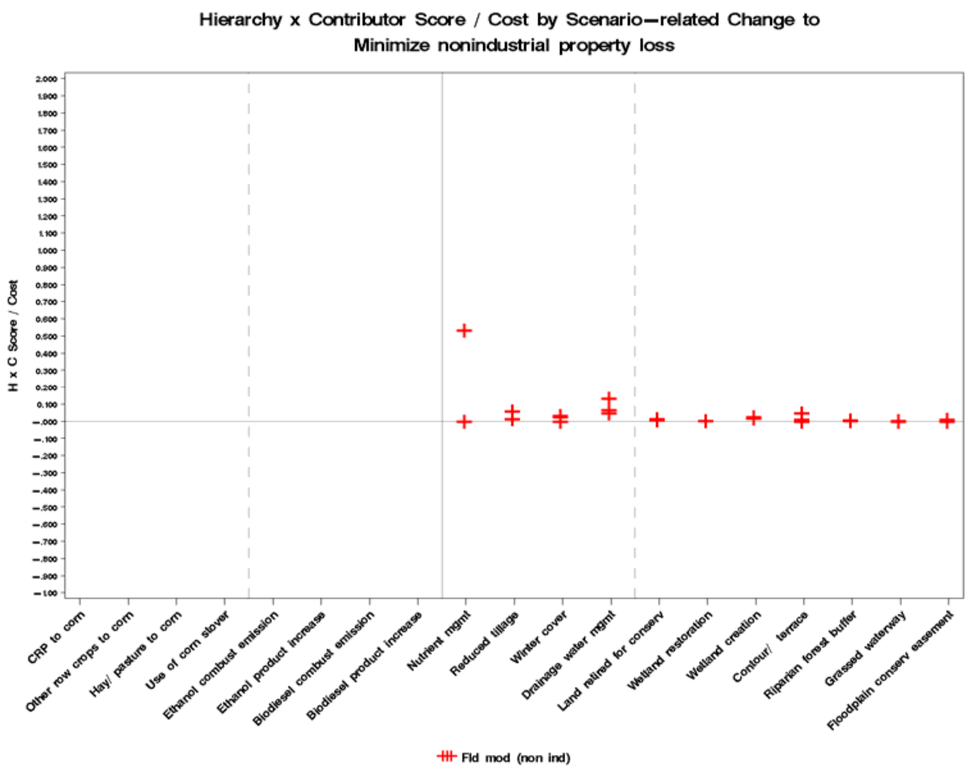

Figure E.3.7. Minimize nonindustrial property loss.

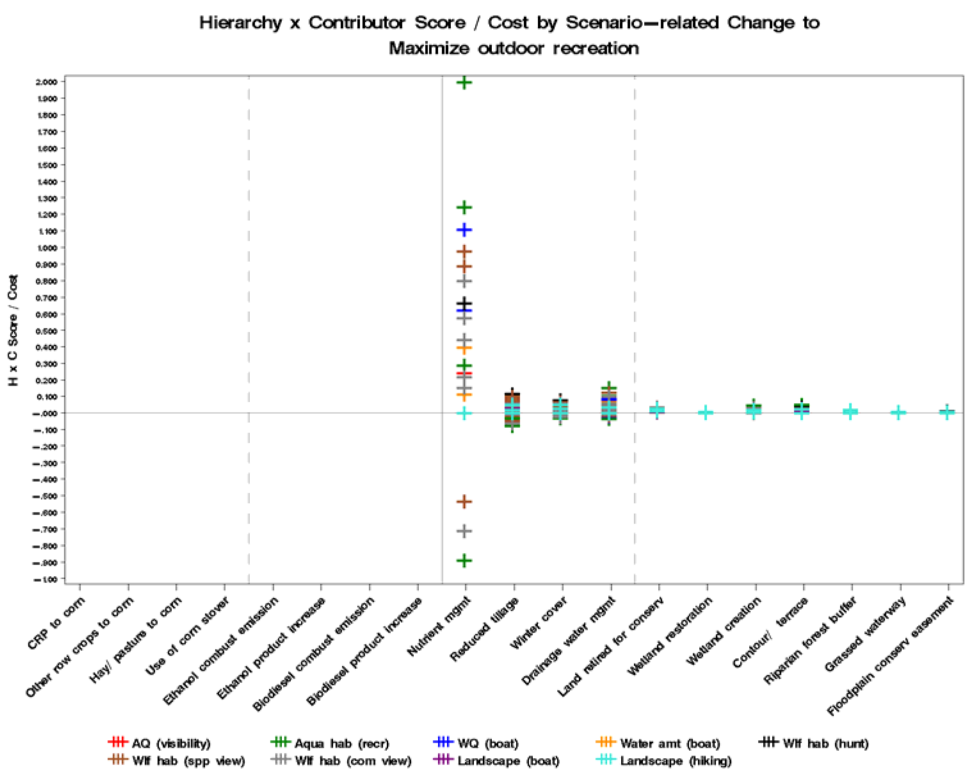

Figure E.3.8. Maximize outdoor recreation.

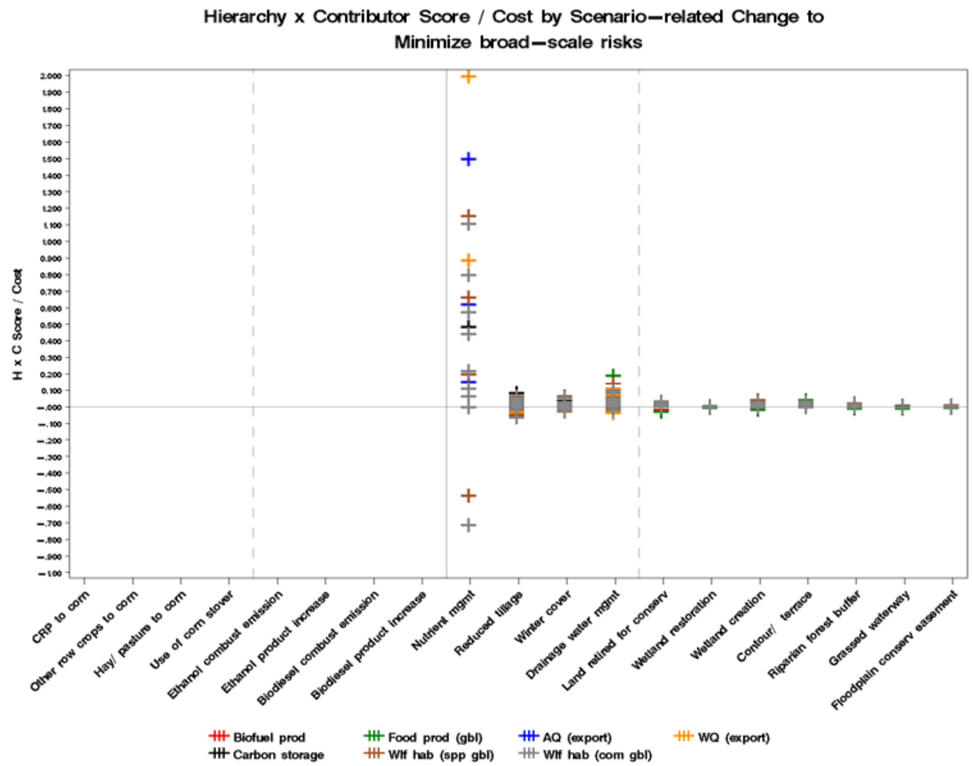

Figure E.3.9. Minimize broad-scale risks.

Appendix E.4. Cost-weighted HxC Values by Scenario-related Change, Omitting Nutrient Management.

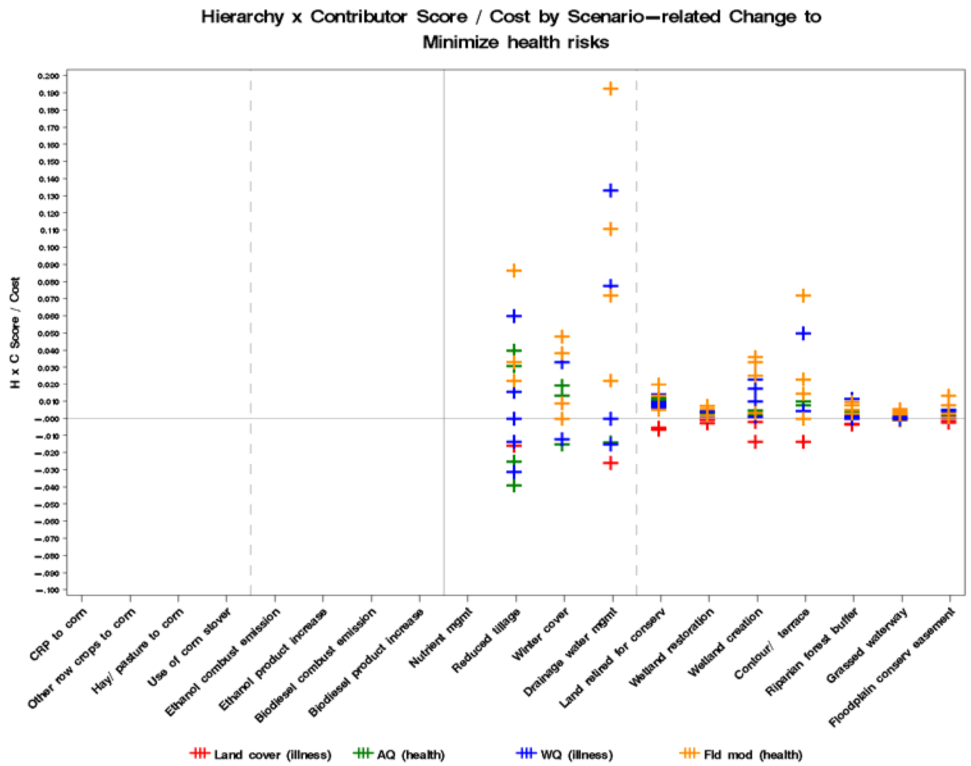

Figure E.4.1. Minimize health risks.

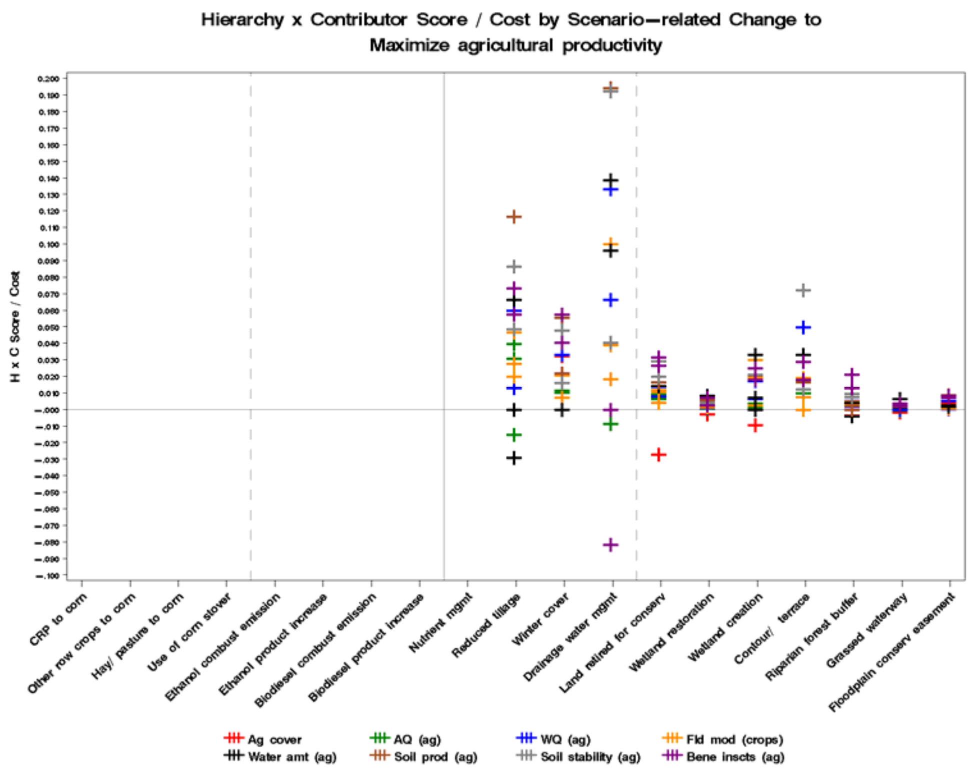

Figure E.4.2. Maximize agricultural productivity.

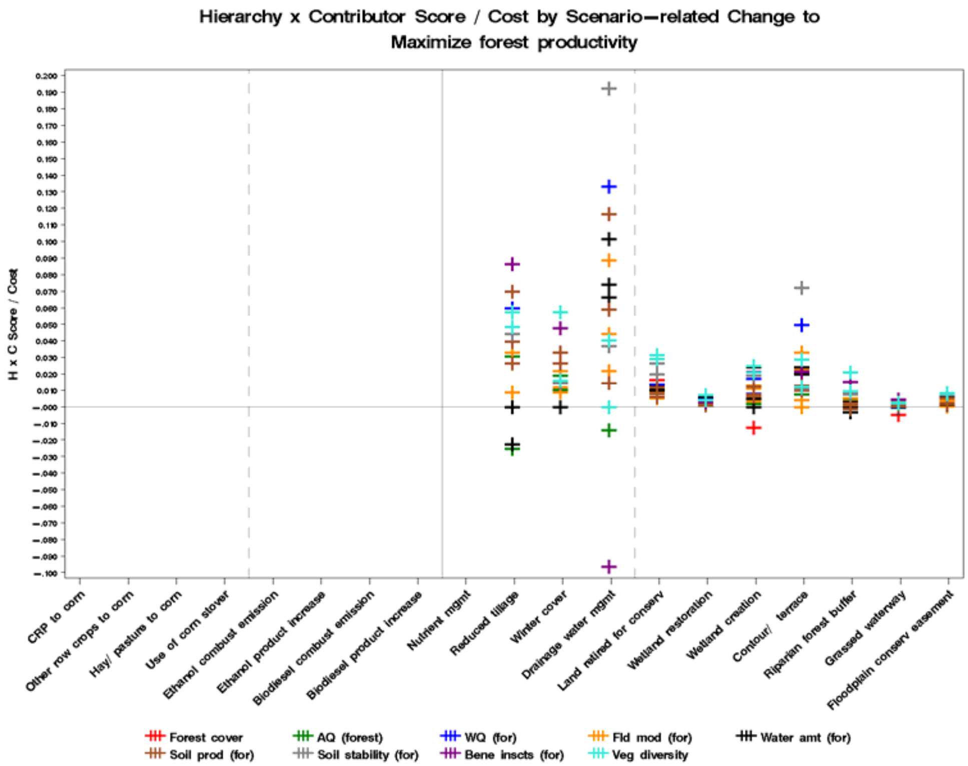

Figure E.4.3. Maximize forest productivity.

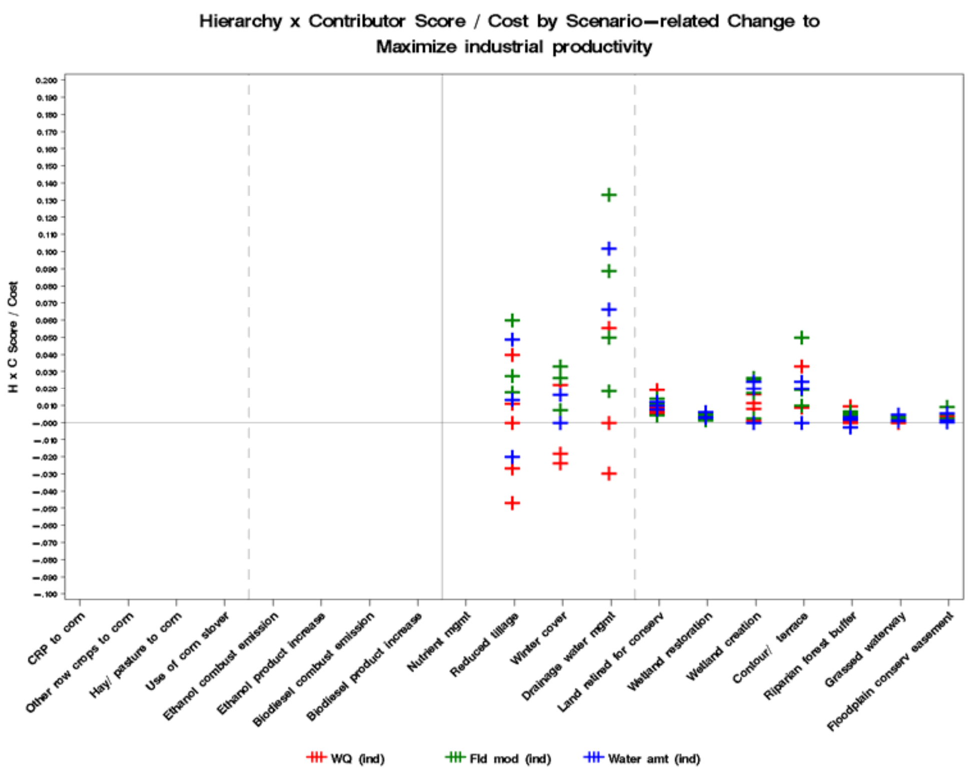

Figure E.4.4. Maximize industrial productivity.

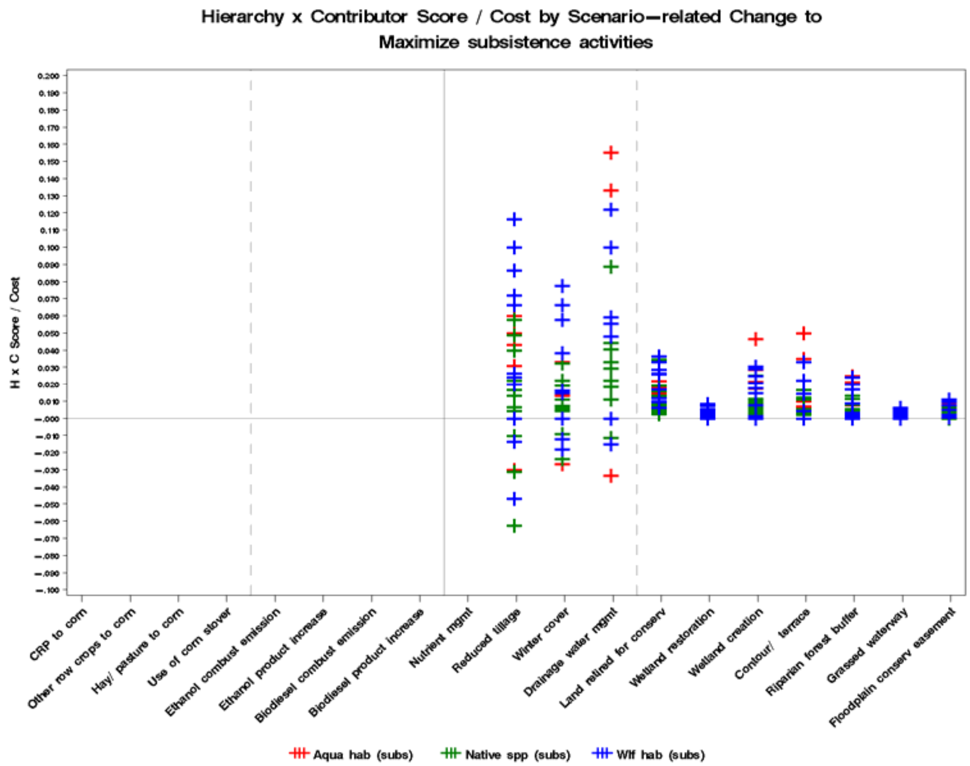

Figure E.4.5. Maximize subsistence activities.

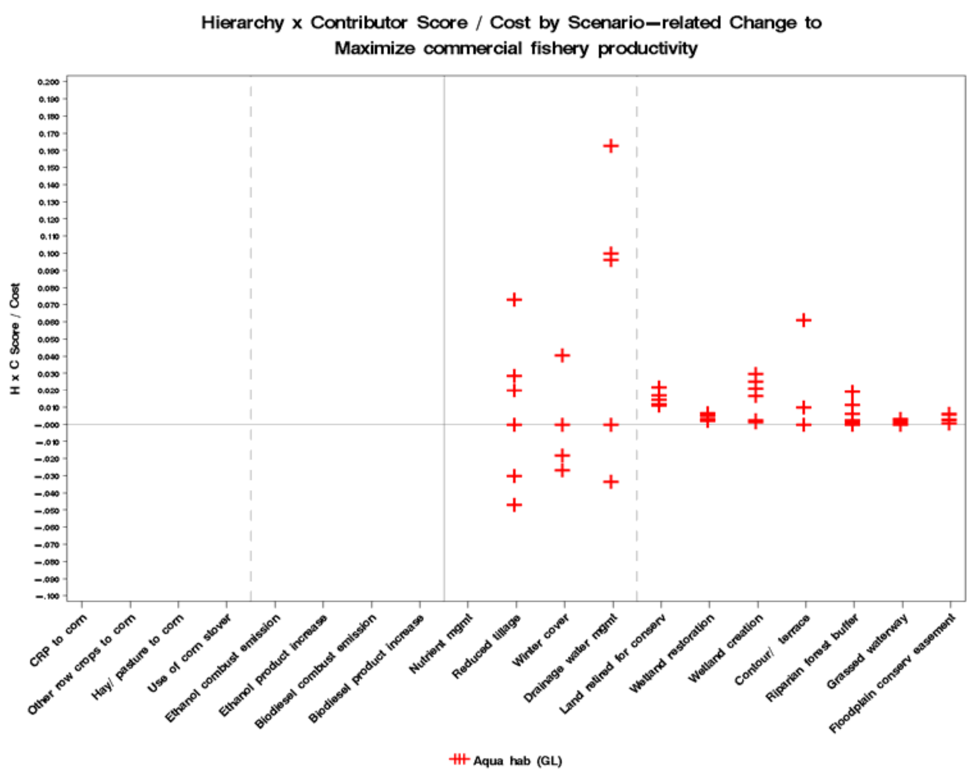

Figure E.4.6. Maximize commercial fishery productivity.

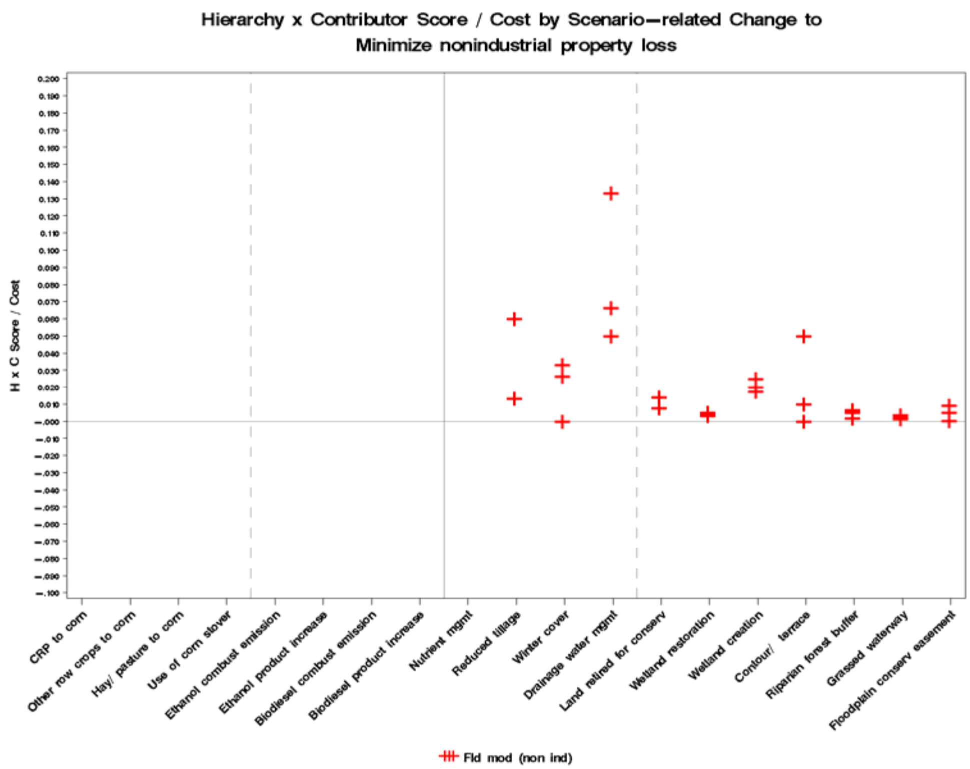

Figure E.4.7. Minimize nonindustrial property loss.

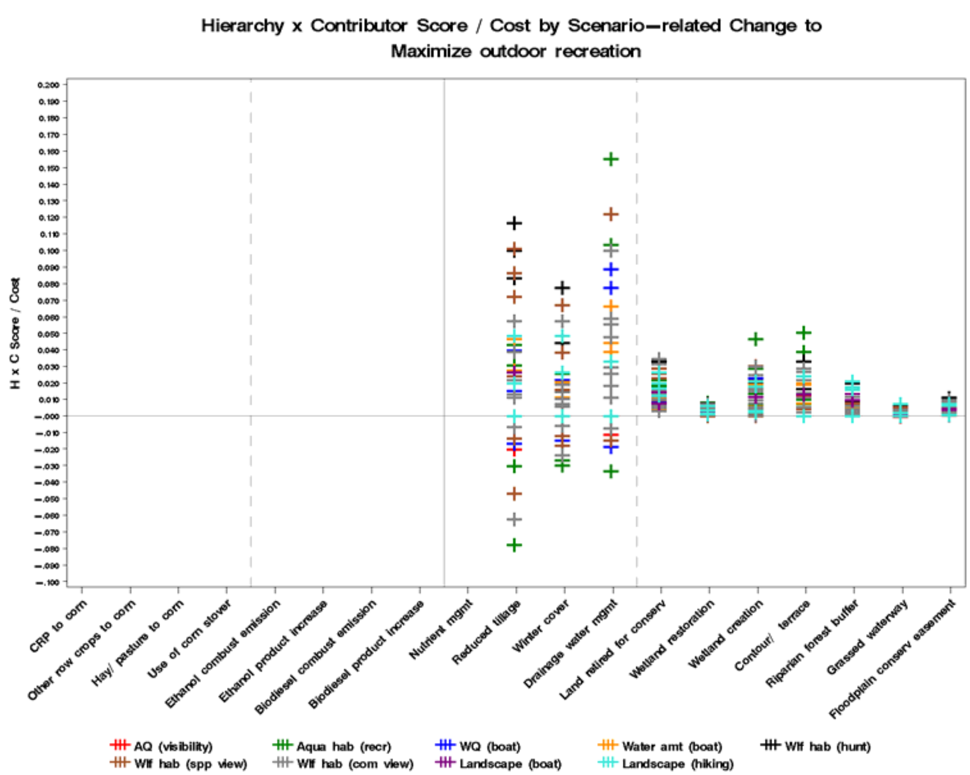

Figure E.4.8. Maximize outdoor recreation.

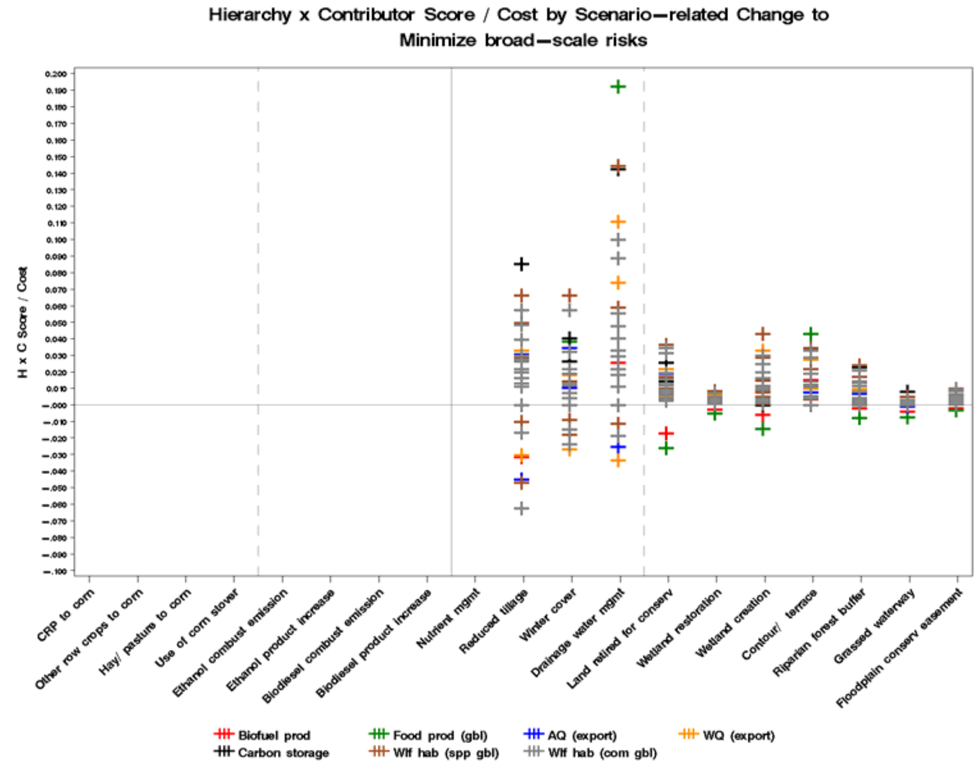

Figure E.4.9. Minimize broad-scale risks.

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