Appendix F. Methods for Analyzing Ecosystem Services and Benefits and Costs of Mitigation Activities

The assessment results will be important to a broad range of users to help quantify potential effects and effectiveness of mitigation strategies (land-use and land-cover change, land-management activities), ancillary effects on ecosystem services, and associated economic and social costs for carbon sequestration and reduction of greenhouse-gas emissions. This appendix includes additional material on quantifying ecosystem services and estimating the present value of the benefits of those services and costs of a management activity.

F.1. Ecosystem Services

Quantifying and projecting changes in carbon stocks and greenhouse-gas (GHG) emissions resulting from climate change, management actions, and mitigation strategies will be based on the spreadsheet and the General Ensemble Modeling System (GEMS) approaches described in section 3.3.4 and appendix D of this report. Many of these primary assessment data products also can be categorized as ecosystem services, including carbon stocks in soils and vegetation, carbon sequestration, methane and nitrous-oxide emissions, net ecosystem production (NEP), timber production, grain production, and soil erosion. These ecosystem service estimates can be produced for each ecoregion reporting unit because they will be based on the primary assessment data products.

For other services not produced within the GEMS biogeochemical models or spreadsheets, the assessment will use an integrated ecosystem modeling approach (Starfield and Chapin, 1996) to quantify the ancillary effects of management activities and mitigation strategies on important ecosystem services. This approach builds on the state-transition model concept by linking conceptual, statistical, and mechanistic models in a spatially explicit framework. The modeling and data components contained within the framework of the integrated ecosystem services model use "forcasting scenarios of land cover change" (FORE–SCE) outputs as the initial basis for the spatial distribution of land use and land cover (LULC) in a given landscape. Biophysical production functions are constructed from known relations between the LULC class ecosystem attributes and the relevant ecosystem services (Nelson and others, 2008, 2009). For wildlife habitat, habitat-suitability index methods will be used wherein the composition and structure at the site and landscape scales control the amount and quality of suitable habitat for a given species or guild (Wakely and Roberts, 1996; Villard and others, 1998; Tirpak and others, 2009). Because forest-stand composition and structure is correlated with habitat suitability, growth and yield models such as the Forest Vegetation Simulator (FVS) (Crookston and Dixon 2005, Chivoiu and others, 2006) and the Forest Landscape Disturbance and Succession Model (LANDIS–II) model (He and others, 2005) are two that will be used. Site-occupancy modeling (MacKenzie and others, 2006) accounts for variation in detection probability and produces robust estimates of the proportion of area occupied (PAO) for specific species. For a service like waterfowl habitat, values can be computed as a function of the energy values of different crops (mapped according to U.S. Department of Agriculture's (USDA) National Agricultural Statistical Service (NASS) program) and vegetation types and converted into duck energy days (DEDs, the amount of energy required by one mallard-size duck for one day) (Kross and others, 2006).

Other services, such as sediment and nutrient retention, require data on relevant driver-stressor relations, which can be derived from current research, primary scientific literature, and expert workshops. The widely used Soil and Water Assessment Tool (SWAT) can be used to estimate the land-phase processes (for example, surface runoff, soil erosion, nonpoint-source nutrient loss, groundwater recharge, and base flow) and water-phase processes (for example, water routing, sediment transport, and nutrient transport and its fate in the aquatic systems). GEMS will link with SWAT to assess the climate-change effects on water availability, and sediment and nutrient transport over landscape.

A distributed geospatial-model-sharing platform will be used to model ecosystem services and provide decision support (fig. F1). This platform is necessary to facilitate sharing and integrating geospatial disciplinary models. A platform based on Java Platform Enterprise Edition (J2EE) and open-source geospatial libraries (Feng and others, 2009) is in development. Shared models on the platform can be accessible to applications through the Internet using the Open Geospatial Consortium (OGC) Web Processing Service (WPS) standard (fig. F2). A pilot platform, EcoServ, was developed in the Prairie Pothole Region (PPR) to simulate diverse ecosystem services simultaneously at the landscape scale.

Given the need to have regionally specific information and the limited understanding of the complex relations among ecosystem processes, management actions, climate change, and ecosystem services, this part of the assessment will be limited to case studies within selected ecoregional assessment units where data and models have been developed and can be readily incorporated into the assessment framework. Likely areas include the Mississippi Alluvial Valley, Prairie Pothole Region, southern Florida, and the Chesapeake Bay Basin.

F.2. Costs and Benefits

The present value of the benefits (PVB) of a management activity are entered into the formula for calculating the present value of benefits in equation F1. Carbon sequestration is assumed to start accruing in the 10^{th} year of the activity. All

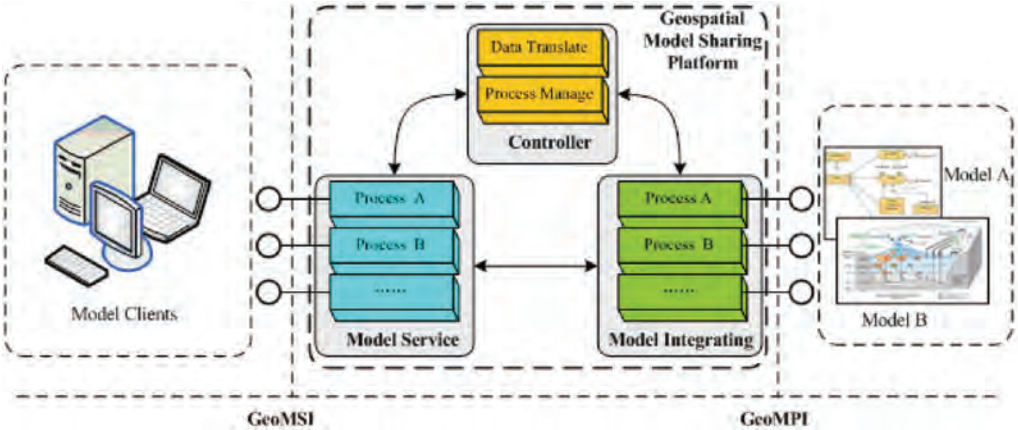

Figure F1. Diagram showing the system structure of the geospatial-model-sharing platform. GeoMSI, geospatial model service interface; GeoMPI, geospatial model processing interface.

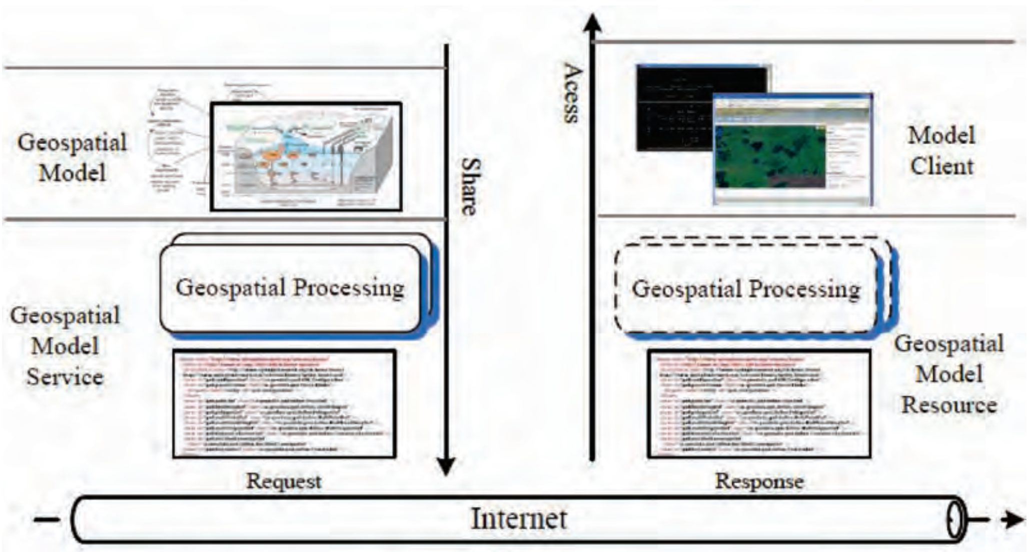

Figure F2. Conceptual flow diagram of accessing shared geospatial model.

other benefits begin in year 1 of the activity or 1 year after the initial investment in establishing the activity.

$$PVB = \sum_{t=1}^{T} \frac{B_t}{(1+r)^t}, \qquad \text{(F1)}$$

where t is time,
T is the terminal year for the mitigation activity,
r is a discount rate, and
B is the gross ecosystem service benefits associated with a management activity.

Present value cost (PVC, equation F2) of management activities is the discounted sum of land value, variable costs of production (McKenney and others, 2004), and the equivalent annual cost (EAC, equation F3) values for the time horizon of the analysis (Stavins and Richards, 2005). Estimation of the PVC and EAC use the following equations. PVC in equation F2 represents the formulation of the present value of the economic costs of a sequestration mitigation activity:

$$PVC = \sum_{t=0}^{T} \frac{PC_t}{(1+r)^t}, \qquad \text{(F2)}$$

where PC is $C_{Est} + C_{O\&M} + C_{MGMT}$,
t is time,
T is the terminal year for the mitigation activity,
r is a discount rate,
C_{Est} are periodically recurring capital costs, including annual land rental payments and other initial investment costs required in establishing the management activity,
$C_{O\&M}$ are annual operating and maintenance costs of the activity with time, and
C_{MGMT} are annual and periodic management costs including administration, insurance, and other transaction costs.

Possible local combinations of soil quality and other land characteristics (nutrients, moisture, composition), access from roads, slope, aspect, water availability (precipitation, irrigation), plants (type, density, composition) can affect the costs of specific management activities. The data used in estimating the present value of costs are listed in table F1. These establishment and continuing costs occur at different times during the lifetime of a management activity.

The EAC in equation F3 is a conversion of the PVC into an annual value (Stavins and Richards, 2005):

$$EAC = PVC \times \left[\frac{r}{1-(1+r)^{-T}} \right], \qquad \text{(F3)}$$

The stumpage value is estimated as follows:

$$W_{Mg(timber)/ha} = W_{C/ha} \times 2, \qquad \text{(F4)}$$

$$W^{Change}_{Mg(timber)/ha} = W^{ENH}_{Mg(timber)/ha} - W^{REF}_{Mg(timber)/ha}, \qquad \text{(F5)}$$

$$W^{Change}_{Mg(timber)} = W^{Change}_{Mg(timber)/ha} \times hectares, \qquad \text{(F6)}$$

$$W^{Change}_{Tons(timber)} = W^{Change}_{Mg(timber)} \times 0.907, \qquad \text{(F7)}$$

$$V_{timber} = W^{Change}_{Tons(timber)} \times \$/_{ton}, \text{ and} \qquad \text{(F8)}$$

$$PVB = \sum_{t=1}^{T} \frac{V_{timber(t)}}{(1+r)^t}, \qquad \text{(F9)}$$

where $W_{C/ha}$ is the weight of carbon in megagrams per hectare,
$W_{Mg(timber)/ha}$ is the weight of timber in megagrams per hectare,
$W^{REF}_{Mg(timber)/ha}$ is the weight of timber in megagrams per hectare for the reference case,
$W^{ENH}_{Mg(timber)/ha}$ is the weight of timber in megagrams per hectare for the enhanced case,
$W^{Change}_{Mg(timber)/ha}$ is the change in weight of timber in megagrams per hectare from the reference case to the enhanced case,
$W^{Change}_{Mg(timber)}$ is the total weight change for the areal unit,
$W^{Change}_{Tons(timber)}$ is the total tons of the change for the areal unit,
$\$/ton$ is the price of the timber commodity, and
V_{timber} is the economic value of the timber.

Table F1. Establishment and other capital and operating costs for management activities in U.S. Environmental Protection Agency Level III ecoregions 73 (Mississippi Alluvial Plain) and 74 (Mississippi Valley Loess Plains) (modified from Omernik, 1987; Omernik, 2004).

[Source: Huang and others, 2004; Brown and others, 2005; U.S. Department of Agriculture, 2010. ha, hectares; ha/yr, hectares per year]

Mitigation activity	Establishment (one-time costs)	Periodic	Annual
Afforestation, hardwood	Land[a] (fee simple if purchased) Saplings and planting = $209/ha Site preparation = $145/ha Supervision = $109/ha	Herbicide application one time per year for 5 years = $72/ha Management update every 10 years = $38/ha Boundary maintenance every 10 years = $8/ha	Land rental price = $77per ha/yr Measuring, monitoring and administration (for example, insurance) = $4 per ha/yr.
Afforestation, evergreen	Seedlings and planting = $281/ha Site preparation = $412/ha Herbicide site preparation = $731/ha Management (initial) = $18/ha	Management update every 10 years = $38/ha Boundary maintenance every 10 years = $8/ha Burning every 10 years = $150/ha	Land rental price = $77per ha/yr Measuring and monitoring administration (for example, insurance).
Grazing			Land rental price (or mortgage payments) = $77 per ha/yr. Management and administration = $37 per ha/yr.
Reforestation		Thinning every 15 years; fertilization every 15 years; and herbicide application 5th and 15th years = $912/ha	Management and administration.
No-till agriculture			Annuity payment = $22 per ha/yr–$48 per ha/yr.

[a]Land could be purchased through annual mortgage payments.

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[Reports that are only available online may require a subscription for access.]

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