MARYLAND COASTAL BAYS PROGRAM

Maryland Coastal Bays
Terrestrial Monitoring Plan
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5.0. REFERENCES
1.0. CHAPTER 1: INTRODUCTION TO THE TERRESTRIAL MONITORING PLAN (TMP)

1.1. Background
This Terrestrial Monitoring Plan (TMP) is designed to assess the effectiveness of management actions and to recommend monitoring changes within the Maryland Coastal Bays watershed, with particular emphasis on terrestrial habitats and living resources. This Plan is a companion to the Eutrophication Monitoring Plan, which was approved in 1999 and is being used to assess the effectiveness of management actions focused on aquatic ecosystems; such as impacts to general water quality, aquatic habitats, and aquatic-based living resources. These monitoring plans are part of the Maryland Coastal Bays Comprehensive Monitoring Strategy and are designed to assess actions identified in the Maryland Coastal Bays Comprehensive Conservation Management Plan (CCMP). Actions in the CCMP address five priority problems: degraded water quality, loss of habitats, changes in living resources, unsustainable growth and development, and poorly planned recreational use of the bays.

1.1.1 History
The US Environmental Protection Agency’s (EPA) National Estuary Program was established by Congress in 1987 to improve the quality of estuaries of national importance. The Clean Water Act Section 320 directs the EPA to develop plans for attaining or maintaining water quality in an estuary. Estuaries within the program are required to develop a Comprehensive Conservation and Management Plan (CCMP) to meet the goals of Section 320.

The Comprehensive Monitoring Strategy was contained in the CCMP and described the Eutrophication Monitoring Plan, which articulated a three tiered strategy to address issues associated with land use and land cover changes within the coastal bays. Landscape monitoring comprised Tier 1, stressor monitoring was Tier 2, and response monitoring was Tier 3. For example, tracking nutrient and sediment inputs and exports was considered to be Level 1. Nutrient and sediment loading was considered Level 2. Level 3 consisted of the effects of nutrient and sediment loading on chlorophyll, water column nutrient concentrations, water clarity and impacts to aquatic living resources, including submerged aquatic vegetation (SAV), macroalgae, phytoplankton, benthos/shellfish, and finfish.

Environmental indicators were sought that would efficiently provide insight and information on how effective management actions were in achieving the overall goals of the CCMP. These environmental indicators facilitated assessments of the status and trends in the environmental condition in the Maryland Coastal Bays related to specific actions and programs. In 2002, the Science and Technical Advisory Committee (STAC) had proposed a set of environmental indicators in three major categories:

- Water Quality - includes dissolved oxygen content, chlorophyll, algae, and stream base-flow nitrate concentration.
• Aquatic Habitat - includes SAV acreage and distribution, forage fish index, and percent indigenous species.
• Terrestrial/Landscape - includes forested watershed area (acres and percent), percent interior forest, wetland acres, stream miles with buffers, and interior/edge ratio.

Water Quality and Aquatic Habitat assessment protocols were implemented, but the monitoring program for the Terrestrial/Landscape category lacked execution. This Terrestrial Monitoring Plan is designed to fulfill and expand the terrestrial category.

1.1.2. Purpose
In general, ecological or ecologically-relevant indicators are monitored to assess conditions and trends on the terrestrial landscape. These indicators are more difficult to categorize than those for aquatic ecosystems. Public attention has historically been focused on the estuarine system and pollutant/contaminant transport into the receiving system. However, what happens in the aquatic ecosystems is determined in large part by what happens in the watershed it drains. Habitat loss and degradation are among the major stressors to aquatic ecosystems in the Mid-Atlantic Region (EPA 2002).

The purpose of an upland watershed Terrestrial Monitoring Plan is to provide watershed municipal governments, citizens, and businesses with a document that elucidates watershed conditions and watershed terrestrial monitoring planning tools. It will also provide a menu of implementation techniques that can help stakeholders design strategies and implement solutions that protect, preserve, and restore the terrestrial habitat resources. Municipal governments, citizens, and businesses are all affected by problems, such as habitat loss, polluted and reduced water supplies, that can be directly related to land uses that damage or strain local water resources.

1.1.3. Justification
Section 302 (b)(6) of the Water Quality Act of 1987 specifies that the National Estuary Programs shall “monitor the effectiveness of actions taken in pursuit of the plan,” referring to implementation of the challenges that comprise their CCMP. This responsibility has two major components: (a) monitor and document progress in implementing each action plan, and (b) monitor and document the results of implementation (effectiveness) for each plan. To accomplish this, a set of environmental indicators needs to be established.

In applying a comprehensive monitoring strategy to the coastal bays, an understanding of land use and land cover is important. Quite simply, land use is how the land is utilized and typically connotes an economic use, such as residential, commercial, or agricultural. Land cover is how the land is covered, such as forest, wetlands, row crops, and/or water.

Changes in land use and land cover impact both environmental quality and economic quality. Changes in habitat, water and air quality, and the quality of life are some of the environmental, social, and economic concerns associated with land use and land cover changes. Areas affected by changes in land use and land cover include:
• Habitat: Land use by humans leads to changes in land cover that can affect biodiversity. Conversion of forest and meadows to more developed uses decreases the amount of habitat available. Human land use also tends to result in a patchy landscape that fragments habitats. Some species of plants and animals do better in patchy, fragmented environments, while others need large, uninterrupted areas.

• Water Quality: Changes in land use can affect the volume, timing, and quality of runoff water. More developed land uses have higher proportions of impervious surfaces. As the amount of impervious surface increases, stormwater runoff increases in volume, increasing the risk of flooding and the amount of pollutants carried into ditches, creeks and bays. Human use of land also disturbs natural land cover, increasing the potential for soil erosion into streams and lakes.

• Quality of Life (aesthetics, recreation, congestion): Land-use and land-cover changes can affect quality of life when those changes impact landscapes that have aesthetic value (scenic views), or when the quality and quantity of the landscapes are reduced in areas that are attractive for recreational activities. Also, changes in land use and land cover can affect traffic patterns that can have positive or negative effects on congestion.

• Air Quality: The pattern of land use in a region can affect its air quality. If residential areas are located far from shopping and work centers, automobile use and emissions will be higher. If forests or other natural areas that purify air are developed, local air quality can worsen. Changes in vegetative cover can also lead to local changes in climate.

• Global Carbon Cycles: More-natural landscapes can capture and store carbon in the soil, decreasing the amount of carbon dioxide in the atmosphere. If vegetation is cut (or burned), and/or the soil is disturbed, stored soil carbon can be released back into the atmosphere.

1.1.4. Comprehensive Conservation and Management Plan (CCMP)
The Maryland Coastal Bays Estuary Program was initiated in 1996 and its CCMP was developed over a three-year period, from 1996 to 1999. The CCMP was approved in 1999 and contains approximately 500 actions. The CCMP includes a Comprehensive Monitoring Strategy that presents broad monitoring goals:

• To measure the effectiveness of implementing the management actions identified in the CCMP and subsequent goals,
• To provide information that can be used to direct and focus the CCMP over time, and,
• To provide information that will assist in predicting future trends related to implementation of management actions.

The CCMP establishes priorities for activities, research, and funding for the estuary. It also serves as a blueprint to guide future decisions and actions, addressing a wide range of environmental protection issues including water quality, habitat, fish and wildlife, pathogens, land use, and introduced species. The CCMP is based on a scientific characterization of the estuary and is developed and approved by a broad-based coalition of stakeholders.
1.1.5. Maryland Coastal Bays Program Scientific and Technical Advisory Committee (STAC)
The Maryland Coastal Bays Program Scientific and Technical Committee (STAC) initiated the idea of developing a Terrestrial Monitoring Plan to pair with its Eutrophication Plan. Technical specialists (scientists, community and environmental planners, watershed stakeholders, analysts, technology experts), many of whom are members of STAC, participated in a Terrestrial Monitoring Plan development meeting on September 18, 2007 at the Horn Point Laboratory in Cambridge, MD.

The group was tasked with identifying ecological indicators to be monitored, existing monitoring data sets, monitoring data gaps, and other concerns related to terrestrial monitoring; such as collection protocols, data analysis, data availability, funding, and applications. The meeting was set up as a series of workgroups focused on each of three monitoring tiers as discussed in three work groups (red, green, and blue).

1.2. Conceptual Framework
The Terrestrial Monitoring Plan contains a conceptual framework that addresses three monitoring tiers of spatial and temporal scale (See Appendix 4.1.) as applied to six major terrestrial ecosystems. Each ecosystem could be monitored at all three temporal/spatial scale groupings. The temporal/spatial scale grouping would dictate the types of ecological indicators that can be monitored, the monitoring technologies and protocols that may be used, the types of actions that may be implemented as a result of data analysis, and the connections between all three groupings.

1.2.1. Six Major Terrestrial Ecosystems
Specific to the Terrestrial Monitoring Plan, six main ecosystem types were identified in a MCBP Science and Technical Advisory Committee (STAC) supported workshop to be inclusive of important habitats within the coastal bays watersheds. These important habitats would reflect ecological conditions within the watersheds and would benefit from management actions expected to improve conditions. The six ecosystems are:

1. Upland Forests - include wooded acreages, tree farms, and orchards
2. Wetlands - include tidal and nontidal wetlands, and surface waters
3. Herbaceous/shrub - includes abandoned fields, perennial crops (e.g. hay), golf courses, and fields with regularly mowed grass, such as playing fields
4. Cultivated - includes seasonal crops
5. Developed lands - include residential, industrial, and commercial land uses
6. Beaches and dunes

1.2.2. Three Monitoring Tiers
Each ecosystem requires indicator data to be collected and analyzed at three different spatial and temporal scales. The spatial scales range from landscape-wide distribution and connection, to drainage catchments physical processes, to species success at specific monitoring sites. The temporal scales range from multiple decades, to years, to seasons. The spatial and temporal scales consist of the following three levels:
**Tier I** - A landscape assessment based on remote sensing techniques to evaluate the general condition of the landscape (i.e., wetland, forest, herbaceous/shrub, etc.). Indicators that can be gathered with remote sensing imagery including areal extent and change over time will be used.  
*Spatial Scale*: bay watershed, high order stream drainage area  
*Temporal Scale*: decades  
*Content Areas*:  
- land use (what is the land used for?)  
- land management (how is that use managed?)  
- land cover (how does use and management impact land cover?)  
*Study Methods*: remote sensing (GIS, LIDAR, etc.), long term, periodic change detection

**Tier II** - Rapid assessment to determine the condition of major stressor processes in the sub-watershed. Systems will be assessed qualitatively using specialized rapid assessment tools.  
*Spatial Scale*: subwatershed/catchment, low order stream drainage area  
*Temporal Scale*: years  
*Content Areas*:  
- topography (slope, relief)  
- geomorphology (landscape process), (erosion, deposition, etc.)  
- hydrology: surface runoff rate (peak flows, etc.), groundwater recharge rate (wells, baseflow), stream flow rate (channel forming flow recurrence interval, flushing flows, etc.), water quality and quantity, drainage density (perennial, ephemeral, ditches, etc.)  
- landscape mosaics/dynamics (eg. fragmentation, geometry, etc.)  
*Study Methods*: rapid site assessment, short term gross change alert

**Tier III** - Fixed monitoring stations that assess site scale changes associated with major stressors and shifts in appropriate, base forcing functions within the watershed. These stations will be sampled with intensive measurements to assess appropriate functions and conditions.  
*Spatial Scale*: stream reach, wetland, forest, any patch  
*Temporal Scale*: annual, seasonal  
*Content Areas*:  
- abiotic ecology (local transport, storage, and inputs)  
- biotic ecology (species, populations, communities)  
*Study Methods*: detailed field survey; long term, frequent, in-depth change investigation

Each monitoring tier can inform and be informed by the other two tiers, consequently supporting a comprehensive monitoring and assessment program (EPA 2001). Tier I is a landscape analysis, which relies on mapping data and aerial imagery. This Tier characterizes land uses and identifies wetland distribution and abundance in a watershed. Tier II is a rapid assessment that involves both office and field assessments. During the field assessment, Tier I data are verified and field observations are collected to identify stressors (James 2007). Tier III assessments are intensive field surveys that collect more detailed physical, chemical, and biological data. Data collected in the Tier III assessment can be used to inform restoration and management practices. The Tier III validates the
Tier II indicators of condition, and the Tier II helps to refine the Tier I landscape analysis. From this relationship, it is clear that rapid assessments are central to a monitoring and assessment program.

1.3. Monitoring

1.3.1. Technology
New and emerging technologies are expanding the resolution, accuracy, and repeatability of ecosystem monitoring at all spatial and temporal scales. Technological advances in remote imaging at all scales and real-time data streaming are exponentially increasing the amount of raw data available. Data analysis, reporting, and application are lagging. However, new and more flexible modeling techniques are also being developed that can use large data sets and permit variable scenarios.

Modern science has developed various landscape science approaches to environmental assessment. These approaches include both landscape characterization (land cover/land use mapping) and ecological (landscape indicator) techniques. These new developments have been made possible through the use of remotely sensed data from aerial photography and satellite images coupled with sophisticated computer applications. Landscape approaches require a multi-disciplinary perspective and reflect a convergence of geography, ecology, remote sensing and other sciences.

Landscape metrics or indicators are calculated by combining various scientific databases using technologies from geographic information sciences. They embrace all of the ecological resources in a given spatial area; such as lakes, streams, farmland, wetlands, forests, urban and suburban areas, etc. The condition of each of these resources might influence other resources. For example, the condition of agroecosystems has a direct effect on the condition of adjacent or associated ecosystems, even if these systems are very distant. Additionally, the shape, size, and condition of natural resources have a direct bearing on the health and function of their plant and animal communities.

Landscape science has progressed to a stage where these approaches can be used to conduct ecological monitoring and assessments on areas of different sizes (O’Neill et al. 1997). Examples of the application of this approach are contained in two landscape atlases focused on the mid-Atlantic area of the United States (Riitters et al. 1996 and Jones et al. 1997). (Kutz et al., Appendix 4.4.)

A considerable amount of data is needed to monitor the condition of each ecosystem and its influence on adjacent or associated ecosystems in the watersheds. Both on-the-ground information as well as remotely sensed (aerial photography and satellite) images are required. Additionally, experience in geographic information sciences is required to interpret the information into scientific and policy-relevant conclusions.

With the advent of GIS, build-out scenario modeling is an increasingly important and effective land-use planning tool in developing a comprehensive plan. Build-out scenarios can be used to illustrate and analyze probable future development intensities and patterns.
on a landscape. A build-out analysis produces maps that show development patterns reflecting different assumptions (e.g., different zoning scenarios); and tables indicating the number of new units, residents, and acreage consumed under each scenario. Build-out maps help citizens and officials to visualize likely future development patterns for their community. The information can be used to evaluate existing and proposed planning policies and growth trends, and adjust policies and programs to meet desired ecological goals.

1.3.2 Data Management
Regardless of the variety and volume of terrestrial indicator data collected, the Maryland Coastal Bays Science and Technical Advisory Committee (STAC) will have to ensure that it is accessible for ongoing synthesis and analysis. The particular scientists, institutions, and organizations involved, along with the nature of the data itself, will all influence the manner in which the data is stored and the degree to which it is freely distributed. Some data may actually be delivered to the Coastal Bays STAC, while in other cases only metadata will be provided due to policy or practical considerations. In any case, the Coastal Bays STAC will want to commit resources for a mechanism and one or more individuals to guarantee proper stewardship of terrestrial monitoring data that is developed for the region over time.

The Maryland Coastal Bays Program STAC Stewardship of terrestrial monitoring data will make use of advancing methods and technologies as they emerge over time. A minimal approach may consist of a spreadsheet of data references which is kept up to date by a designated data manager who will enter references to datasets as presented to him via STAC derived protocols. This spreadsheet may be made available to analysts as needed via published bulletin board, web page, or other mechanisms to distribute references to data among the science community. A more robust system may collect actual data to a database server that can be accessed for direct download via internet services. Such an arrangement would place the burden directly on STAC to provide increasing disk storage capacities, data quality assurance or disclaimers, and to handle other issues associated with data distribution. Currently, new technologies permit users to visualize various related data that may reside online in disparate locations and formats by using a combination of data server and display software such as ERDAS Titan in conjunction with Google Earth, Earth Explorer and others. The main underlying requirement for the science community will be to have access to information regarding technical details of the data, and where and what protocol must be followed to visualize and ultimately obtain the data for further work.
2.0. CHAPTER II. TERRESTRIAL MONITORING TIERED APPROACH

2.1 State of Bays
Maryland’s coastal bays, a complex estuarine system, provide habitat for a wide range of aquatic life. The bays’ water quality shows many warning signs of ecosystem change, even though some areas still have good water quality. Like many coastal systems, the bays are threatened by development, nutrients, sediments, and other anthropogenic stresses that may begin in the upland watersheds. Human population in these watersheds is expected to continue to grow and to further stress this fragile system.

Figure 1. Land use in Maryland Coastal Bays watersheds, 1994 data from Maryland Department of Planning (then Office of Planning). (MD DNR Forest Service, 2002)
The Maryland Coastal Bays watersheds are located in the Lower Coastal Plain physiographic region on Maryland’s Eastern Shore. This region is characterized by predominantly flat terrain that supports the establishment of extensive nontidal wetlands, including broad interfluvial wetlands between coastal plain streams (Tiner and Burke 1995). Interfluvial wetlands are characterized by poor drainage, often surrounded by upland, and dominated by forested flats. Surface water runoff and ground water discharge are the hydrologic forces that regulate water levels and soil saturation in nontidal wetlands of the region. Reaching their highest level at or near the surface in winter to mid-spring, water tables usually begin to drop in May and reach their lowest levels from late August through October. Many of the nontidal wetlands, such as the forested flats, are seasonally saturated and never experience inundation (Tiner and Burke 1995). Drainage ditching and channelization, as well as habitat fragmentation, have greatly altered the hydrology of the region’s wetlands (Tiner et al. 2000).

Nitrogen inputs to the bays are dominated by nonpoint sources (99%); while 30% come from atmospheric deposition, with probable sources outside of the watershed (Wazniak et al. in press). The remaining sources of nutrients are land-based. These nutrients make their way to the bays via either surface runoff, groundwater.

Nearly three quarters of the coastal bays’ historic forest and wetland habitats—areas vital to many plant and animal species—have been lost since colonial times. Upland activities that cause habitat loss include development, loss and fragmentation of forests, and stream bank and shoreline hardening. To protect and preserve remaining habitats and to restore lost or damaged habitats, the impacts of human land use on land cover must be identified and managed. Land use and land cover management should take place through comprehensive planning based on ecological science informed by adequate data at several spatial and temporal scales.

2.2.1 State of Monitoring
Many ecological indicators have been monitored in the coastal bays' terrestrial ecosystems and at various temporal and spatial scales. Specific ecological goals, as presented in the CCMP, have also been developed for the coastal bays' watersheds. However, the links between monitoring indicators and meeting goals have not been made in a way that either consistently directs monitoring efforts or refines ecological goals. The conceptual framework outlined in this plan links monitoring goals to monitoring direction by considering a range of temporal and spatial scale parameters. The selection of ecosystems, ecological indicators, monitoring protocols, and collection and analysis technologies are more likely to be focused to specific monitoring goals when all three monitoring tiers are considered.

2.2 Six Major Ecosystems
The following sections provide introductions to the six major ecosystems that comprise the Maryland Coastal Bays' watershed. They conflate land cover with land use under a variety of land management approaches.
2.2.1 Ecosystem type: Forests

The Maryland Coastal Bays' watersheds spread over more than 117,000 acres, 35% of which are forested. It accounts for approximately 39% of Worcester County's land base, largely in the eastern portion of the county (Hairston-Strang et al. 2002). Most of today's forests are mixed with agricultural and urban land uses. As forests are fragmented, their habitat and ecosystem values diminish. Losses of riparian forests are of particular concern because of the unique habitat and water quality benefits they provide.

Forests provide habitat for many wildlife species and supply critical elements for aquatic habitat in streams. Forests have one of the lowest nutrient export rates of any major land cover. Forest canopies and soils filter most rainfall, promote infiltration, and sustain the base flows in streams essential for aquatic life (Hairston-Strang et al. 2002). Forests as riparian buffers reduce water temperature and provide the coarse organic particulate matter that provides food to aquatic animal species. In addition, forests stabilize stream banks and prevent erosion.
Figure 2. Map of forest type in Maryland Coastal Bays watersheds, 1998 vegetation from Mid-Atlantic GAP. (MD DNR Forest Service, 2002)

The following is a partial list of forestry assistance programs, assistance type, and some sponsoring organizations. These programs may provide forest monitoring data or a framework within which monitoring data might be collected.

- Forest Legacy - Assists with: conservation easements. USDA Forest Service
- Forest Stewardship Program (FSP) - Assists with: forest management, technical assistance. State forester
- Forestry Incentive Program (FIP) - Assists with: tree planting or timber stand improvement.
- TAXMOD Income Tax Incentives (State) - Assists with: tree planting, timber stand improvement.
- Conservation Resource Enhancement Program (CREP) - Assists with: riparian forest planting.

### 2.2.2 Ecosystem Type: Scrub/Open Space/Successional Habitat

This ecosystem exists as a result of human or natural disturbance and is usually an intermediate successional stage. Land cover may include grasses; brush areas that do not currently produce timber or other wood products; and abandoned agriculture fields. These areas are often considered to be marginal land, not suitable for agricultural uses due to poor soil, drainage limitations or steep slopes.

This ecosystem also includes urban open space, such as lawns, golf courses, parks, recreation areas, cemeteries, and undeveloped land within urban areas. These last areas are limited in Worcester County, yet this type of land may provide key habitat and connections between habitat fragments.

To enhance the habitat function on marginal lands, programs have been put into place that either maintain the land cover (warm and cool weather grasses), encourage the progression of successional stage (forest planting), or remove and control exotic and/or invasive species. In addition, the habitat function of urban open spaces is improving through best management techniques, such as environmentally appropriate golf course design and management, backyard wildlife landscaping, and limiting mowing in parks.

The following is a partial list of marginal lands assistance programs, assistance types, and some sponsoring organizations. These programs may provide monitoring data or create a framework within which monitoring data might be collected.

- Conservation Reserve Program (CRP) - Assists with: tree planting on agricultural land. USDA
- Conservation Reserve Enhancement Program (CREP) - Assists with: planting trees or appropriate grasses on agricultural land. USDA

### 2.2.3 Ecosystem Type: Wetlands
Natural shoreline habitat loss is prevalent in the Maryland Coastal Bays. Wetlands have decreased substantially, especially in the northern coastal bays. Since settlement, the coastal bays' watershed has lost over 250,000 acres of wetlands, including salt marsh and forested wetlands, due to draining, construction of canals and bulkheads, and conversion to agriculture and development. Existing wetlands are increasingly fragmented by human intrusions.

There are two main categories of wetlands in the Maryland Coastal Bays' watershed: tidal and non-tidal. Most of the coastal wetlands have formed as marshes along the region’s tidal rivers and estuarine bays. The low marsh is generally flooded daily, whereas the high marsh typically only floods during high spring or storm tides. Vegetation growing in the marshes is strongly influenced by salinity. Increased sediment inputs may change marsh hydrology and increased runoff may change marsh salinity.

The Maryland Coastal Bays' watershed includes 31% of the land occupied by wetlands, covering 36,435 acres. Wetlands associated with estuaries (tidal fresh, brackish, and salt) account for greater than 50% of the wetland acreage. Terrene wetlands, those surrounded by upland, tend to be much smaller in size than estuarine wetlands and comprise 36% of the acreage. Lotic wetlands associated with flowing streams and rivers constitute 10% of the wetland acreage, and island wetlands account for about 4% (Tiner et al. 2000).

Coastal Bays' wetlands are essential to watershed biodiversity and include rare wetland types, such as interdunal wetlands, tidal freshwater wetlands adjacent to salt marshes, and two types of emergent wetlands. However, the cumulative natural habitat integrity index for the wetlands indicates high levels of human disturbance. Approximately 40% of the wetlands have been converted to other land uses and 50% of the wetland and water body buffers are now developed. Although 60% of pre-settlement wetlands still exist, 70% have been altered by ditching, impounding, or other influences (Tiner et al., 2000).
The following is a partial list of wetlands assistance programs, assistance types, and some sponsoring organizations. These programs may provide wetlands monitoring data or a framework within which monitoring data might be collected.

- Ducks Unlimited Stewardship Assistance (DU) - Assists with: creating wetlands, including forested. Non-profit organization
- Partners for Wildlife (PFW) - Assists with: tree planting on hydric soils, degraded wetlands. US Fish and Wildlife Service
- Wetlands Reserve Program (WRP) - Assists with: planting trees on hydric soils or degraded wetlands, conservation easements. USDA

2.2.4. Ecosystem Type: Agriculture
An agroecosystem is defined as 'semi-domesticated ecosystems that fall on a gradient between ecosystems that have experienced minimal human impact, and those under maximum human control, like cities.' Thus agroecosystems are generally defined as novel ecosystems that produce food and fiber via farming under human guidance (Hecht
1995). While farming methods vary, traditional manipulated agroecosystems generally differ from natural ecosystems in six ways: maintenance at an early successional state, monoculture, crops generally planted in rows, simplification of biodiversity, intensive tillage (which exposes soil to erosion), and use of genetically modified organisms and artificially selected crops (Botkin and Keller 2005).” (Kutz et al. Appendix 4.4.)

According to the 2002 Census of Agriculture, 43%, or 131,249 acres, of Worcester County is in farms. Much of this is in seasonal agriculture use. Agricultural land use/land cover trends are of interest for several reasons. Employment of Best Management Practices (BMPs) will reduce nutrient input to the bays by ensuring that no excess fertilizer is applied, soil erosion is minimized, livestock is removed from waterways, and barnyard and feedlot runoff is captured and treated. Loss of agricultural lands is generally caused by increased development, which has often greater negative impact on bay quality and continued fragmentation of agricultural lands may contribute to erosion of economic viability of farming, thus putting more land at risk for development. Finally, seasonal agriculture, when properly managed, provides habitat for certain native species.

The following is a partial list of agricultural assistance programs. These programs may provide agricultural monitoring data or create a framework within which monitoring data might be collected.

- Environmental Quality Incentives Program (EQIP) - Assists with: tree planting on agricultural land. NRCS.
- Wildlife Habitat Incentive Program (WHIP) - Assists with: wildlife habitat creation.
- Pheasants Forever - Assists with: planting grasses and grains that are harvested after juveniles have fledged.

2.2.5. Ecosystem Type: Impervious Surface/ Urban Uses
Imperviousness represents the imprint of land development on the landscape. The Critical Area Program’s definition of impervious surface is: “an area covered with solid material or that is compacted to the point where water cannot infiltrate underlying soils (e.g. parking lots, roads, houses, patios, swimming pools, tennis courts, etc.).” Stormwater runoff velocity and volume can increase in areas covered by impervious surfaces. New impervious surfaces change natural drainage patterns and impact the environment by affecting the way that stormwater and, in some cases, tidal water moves over the landscape and through the soil. New impervious surfaces can affect the quantity, velocity, and quality of stormwater, resulting in impacts to nearby lands, groundwater recharge areas, and water bodies.

The following is a partial list of urban assistance programs. These programs may provide urban monitoring data or create a framework within which monitoring data might be collected.

- Urban and Community Forestry (UCF) - Assists with: tree planting and maintenance in communities. MD of Natural Resources Forest Service
2.2.6. **Ecosystem Type: Beaches and Dunes**

A definition of beaches from the Maryland Department of Planning is “extensive shoreline areas of sand and gravel accumulation, with no vegetative cover or other land use.” Beaches provide a crucial habitat for marine life and coastal species. Moreover, beaches often adjoin wetland ecosystems, recognized for their ecological value.

Dunes are high relief landscape features made from drifting sands. They may be vegetated or non-vegetated and usually lie between beaches and inland areas, particularly wetlands. They may provide significant flood protection to inland areas, but are extremely fragile and mobile. Dunes may also provide significant nesting sites for birds. Human activities cause levels of structural and vegetative disturbance that can result in the complete destruction of dunes.

The following is a partial list of beach and dune assistance programs, assistance types, and sponsoring organizations. These programs may provide beach and dune monitoring data or a framework within which monitoring data might be collected.

- **Shore Erosion Control (SEC)** - Assists with: shoreline stabilization.
  - MD Department of Natural Resources
CHAPTER III. CONCLUSIONS AND RECOMMENDATIONS

As a result of the effort to develop this initial Terrestrial Monitoring Plan, the conclusion reached is that, while many scientists, governmental agencies, non-profit organizations, and watershed groups have monitored or are monitoring many aspects of the Maryland Coastal Bays’ watershed, efforts have not been coordinated. As a result, monitoring goals are not integrated, data sets are widely dispersed, metadata documentation is not easily available, monitoring protocols are not standardized, data analyses are not widely disseminated, and appropriate planning and management actions are not taken. This Terrestrial Monitoring Plan provides the Conceptual Framework needed to build an effective and ongoing terrestrial monitoring program that coordinates monitoring by spatial and temporal scales and ecosystems. Within this framework, monitoring goals can be delineated and addressed, data sets can be inventoried, metadata developed and checked, monitoring protocols described and refined, data analyses widely distributed and peer-reviewed, and useful actions taken with measurable results.

3.1. Future Monitoring
During a workshop in September 2007, scientists, municipal planners, and agency staff identified numerous areas of concern about terrestrial habitat resources. The participants tried to identify the appropriate ecological indicators for each of the six ecosystems at each monitoring tier. In addition, they attempted to identify data sets and data gaps. The three work groups generated lengthy lists (See Appendix 4.3.) of indicators, sets, and gaps, but it became apparent that intensive research needed to be done to refine all of the lists. The research steps were generally broken into the following steps:

- Intensively survey all potential data collection sources of raw data for data sets
- Review all metadata documentation for each data set
- Assign each data set to the appropriate ecosystem(s) and monitoring tier(s)
- Identify data gaps for each ecosystem within each monitoring tier
- Assess and refine monitoring protocols
- Assess the use of existing and emerging monitoring technologies for meeting monitoring goals
- Review data analysis methods and reports
- Create an on-line data storage and data analysis library
- Address proprietary and sensitivity issues for data and data analysis accessibility

3.2. Data Collection and Management
Once data, datasets, protocols, metadata, data analyses, and location are determined, the information must be generally available to scientists, policy and decision makers, students, and citizen stakeholders. A centralized database, the CCMP Terrestrial Monitoring Database, accessible to all users, except where access control is necessary to protect copyright or specific sensitive species location information, is recommended. A data base structure would need to be developed. Data update frequency/processing/scale/resolution requirements and specifications would need to be addressed. The exact mechanisms for how monitoring data are endorsed and entered into
the CCMP Terrestrial Monitoring Database will evolve over time with changing technology and prevailing customs.

3.3 Meeting CCMP Goals
While the health and function of the Maryland Coastal Bays may not be of obvious concern to upland watershed municipal governments and citizens because it is geographically removed and comprises very different ecosystems, the function and health of the bays' ecosystem is a direct reflection of the health and function of each of its upland watersheds. As long as the bay's ecosystem remains damaged, each upland watershed must be examined for its contribution to this damage. While eliminating stressors is important to the ecology of the bays, the removal of upland stressors also improves the ecology in which the citizens of the upland watershed live. For example, increased stormwater runoff may transport damaging sediment and associated toxins to the bays, while in the upland watershed, the same runoff is depriving local wells of water, destroying local fisheries, dirtying municipal water supplies and clogging municipal water intakes, scouring local bridge abutments, removing valuable topsoil, and eroding property along streams.

The CCMP has been reviewed in light of the conceptual framework of this TMP so that CCMP Action Plan Categories and Goals are matched to monitoring tiers with examples of ecological indicator categories that may be monitored. (See Appendix 4.2.) Once a particular CCMP goals or set of goals is selected, the temporal and spatial scales of the goals may be determined. This determination will direct the monitoring plan to the appropriate monitoring scales. Some ecological indicators may be monitored at several tiers. In many cases, analysis of data monitored within a particular tier will indicate that the same indicator or related indicators should be monitored at other tiers.

3.3. Land Planning Applications
The 2006 Worcester County Comprehensive Plan calls for development of conservation subdivision regulations to ensure protection of the most ecologically sensitive elements on a site and to minimize habitat/forest fragmentation in the identified “growth areas”. Residential and commercial development threatens to, and often does, alter and destroy natural resources. Land planning programs, processes, and regulations can serve to minimize impacts and conserve natural resources.

Two types of planning occur at the local level: site level and comprehensive planning. The site review process is triggered when individual developments are proposed. During site review, factors such as compliance with zoning, adequate water supply and sewage disposal, compatibility with soils, adequate road access, as well as impacts on terrestrial and aquatic resources (notably Atlantic Coastal Bays Critical Area Program or the Forest Conservation Program, as well as state and federal wetlands regulations) are addressed. Also in the category of site level planning, are local park and other facilities planning and agricultural and conservation easement purchase.

Comprehensive planning guides site level planning. It provides a "vision" and establishes the long-term goals and policies for land use decisions. Comprehensive plans
are advisory, not regulatory; the political will of the local, elected officials and the support of citizens will determine implementation.

Tier I terrestrial monitoring data is essential to land planning decision-making that effectively incorporates conservation goals by quantifying habitat loss or gain, and ecological degradation/fragmentation or restoration (Theobold and Hobbs, 2002). Land protection planning (identifying the areas most important to preserve with easement or fee simple purchase) is an element of comprehensive planning. Tier I terrestrial monitoring data is also important for establishing land protection goals and priorities. The state developed a Maryland Green Infrastructure Assessment map in 2002 that used GIS data to identify and prioritize the most ecologically important lands remaining in the state. Land identified as “green infrastructure” was characterized as either “hubs” or “corridors.” The assessment then analyzed each hub using 27 ecological parameters and 11 development risk parameters to establish an overall ecological value and development risk rank. This comprehensive analysis could be augmented by terrestrial monitoring data at a scale finer than the state-wide project, allowing for more refined analysis and identification of key areas to protect with local, state, and federal funding.

Build-out (maximum developed land use under existing zoning regulations) statistics alone, such as acreage consumed, population growth, and units built, provide a limited view of the impact on natural systems. Build-out analyses can be enriched by incorporating terrestrial monitoring data. Habitat fragmentation, loss of biodiversity hotspots, impervious surface coverage area and associated stormwater runoff rates, and other measures of ecological impacts can be incorporated into a build-out scenario to enhance local decision-making. Monitoring Tiers II and III permit planners to determine the ecological effectiveness of their planning decisions and implementation. Since terrestrial systems are dynamic, ideally this analysis should be revisited on a regular basis.

Evaluation of land use planning policies is important to demonstrate and ensure the most effective and efficient programs and regulations. Improved information about impervious surface cover percent change over time, locations of urban BMPs, development density, riparian forest cover and gaps, and upland forest cover fragmentation, among others, can facilitate analysis of the impact programs and regulations are having on the health of the terrestrial ecosystem.

3.5. Future of the TMP
The TMP is only useful if it is not relegated to a bookshelf and actively used. Three types of actions can make this happen: officially adopting the TMP and its concepts, allowing the TMP to evolve as state of the art evolves, and using the TMP to inspire new monitoring-based research and to leverage funding for that research.

3.5.1. MCBP STAC Adoption
The Maryland Coastal Bays Program Scientific and Technical Advisory Committee (STAC) will review the Terrestrial Monitoring Plan. After any changes are completed, STAC will vote to adopt the plan. Adoption will permit the MCBP, STAC, and its individual members to use the TMP for guidance in developing future research goal development and monitoring efforts.
3.5.2. Living Document Updates
The Terrestrial Monitoring Plan is intended to be a "living document" that can be updated and redistributed with new information as it is developed. MCBP STAC will take responsibility for maintaining the plan as a living document. The MCBP STAC will keep pace with protocol and resources to ensure that monitoring results are readily available to scientists and decision makers over time, as natural and anthropogenic pressures continue to bear upon this intricate ecosystem.

3.5.3 Future Research and Funding
The TMP may be used to leverage funding for future monitoring research. Funding agencies and organizations are more apt to support work that is laid on a firm foundation. This plan demonstrates that overarching planning has taken place and that a conceptual framework has been created for designing and implementing future monitoring efforts. This should make it possible to fund the detailed research needed to locate and assess existing data, metadata, protocols, and analyses; to identify data gaps; and to develop future monitoring research goals and implementation projects.
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Maryland Coastal Bays Program. Are Nutrients Harming the Bays? Fact Sheet. No Date.

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Maryland Department of Natural Resources. 2002. Maps: Land Use Land Cover; Forest Cover Types Based on GAP DATA; and SSURGO Hydric Soils. Annapolis, MD.


### 6.0. APPENDICES

#### 4.1. Three Monitoring Tiers of Spatial and Temporal Scale

<table>
<thead>
<tr>
<th>Tier</th>
<th>Spatial Scale</th>
<th>Temporal Scale</th>
<th>Subject Areas</th>
<th>Examples</th>
<th>Study Methods</th>
</tr>
</thead>
</table>
| I    | Bay Watershed: High Order Stream Drainage Area | Decades | Land Use | • Agricultural  
• Urban  
• Open Space | remote sensing (GIS, LIDAR) |
|      |               |                |               | • Engineered/Designed Landscapes  
• Smart Growth  
• Cultural Resources  
• Conservation/Preservation  
• Agricultural BMPs  
• Transportation Corridors | |
| II   | Subwatershed/Catchment: Low Order Stream Drainage Area | Years | Topography | • Slope  
• Relief | Rapid Site Assessment |
|      |               |                |               | • Erosion  
• Deposition | |
<table>
<thead>
<tr>
<th>Hydrology</th>
<th>Landscape Mosaics</th>
<th>Abiotic Ecology</th>
<th>Biotic Ecology</th>
</tr>
</thead>
</table>
| • Surface Runoff Rate  
• Groundwater Recharge Rate  
• Stream Flow Rate  
• Water Quality  
• Water Quantity  
• Drainage Density | • Patch Dynamics  
• Patch Size  
• Patch Health | • Energy Transport  
• Energy Storage Capacity  
• Energy Flow Continuity | • Species Density  
• Population Distribution  
• Community Structure  
• Trophic Complexity  
• Invasives  
• Threatened or Endangered Species/Habitats |

III long term, frequent, in-depth change investigation  
Site Stream Reach Forest Wetland Any Patch  
Annual/ Seasonal  

26
4.2. Comprehensive Conservation and Management Plan (CCMP) Goals to be Addressed by Terrestrial Monitoring Plan (TMP)

<table>
<thead>
<tr>
<th>CCMP ACTION PLAN CATEGORIES</th>
<th>CCMP GOALS</th>
<th>PROPOSED CCMP GOAL SOLUTIONS</th>
<th>TMP SPATIAL/TEMPORAL SCALE TIERS</th>
<th>ECOLOGICAL INDICATOR CATEGORIES (examples; more to be added)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Quality</td>
<td>GOAL 1</td>
<td>Decreased nutrient inputs to groundwater from residential and commercial land uses.</td>
<td>WQ 1.3 Perform studies to determine the types, sources, spatial extent, and degree of groundwater contaminants…</td>
<td>T1: Landscape</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wellhead Protection Zones</td>
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<td>High Risk Geology</td>
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<td></td>
<td></td>
<td></td>
<td>Land Use</td>
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<td></td>
<td></td>
<td>Land Management</td>
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<td></td>
<td>Land Cover</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Recharge Areas</td>
</tr>
<tr>
<td></td>
<td>GOAL 2</td>
<td>WQ 2.1 Ensure that (1) new</td>
<td>T3: Monitoring Site</td>
<td>Well Testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Irrigation Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>groundwater quality</td>
</tr>
<tr>
<td>GOAL 3</td>
<td>Decrease nutrient inputs from the atmosphere.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WQ 3.1</td>
<td>Perform study to identify sources (local and non-local) of atmospheric deposition of nutrients to the coastal bays and identify actions to decrease these inputs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1: Landscape</td>
<td>T3: Monitoring Site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• atmospheric tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• soil tests</td>
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</tr>
<tr>
<td>• point source monitoring</td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GOAL 4</th>
<th>Decrease nutrient inputs from agricultural sources.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WQ 4.2</td>
<td>Take greater advantage of recent technological advances, such as Precision Farming Techniques</td>
</tr>
<tr>
<td>T1: Landscape</td>
<td>T2: Rapid Assessments/Drainage Catchment T3: Monitoring Site</td>
</tr>
<tr>
<td>• area analysis</td>
<td></td>
</tr>
<tr>
<td>• riparian buffers</td>
<td></td>
</tr>
<tr>
<td>• non-point source runoff monitoring</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GOAL 5</th>
<th>Reduce nutrient</th>
</tr>
</thead>
<tbody>
<tr>
<td>WQ 5.1</td>
<td>Encourage wastewater reuse and sludge</td>
</tr>
<tr>
<td>T2: Rapid Assessments/Drainage</td>
<td>T3: Monitoring Site</td>
</tr>
<tr>
<td>• water quality testing</td>
<td></td>
</tr>
<tr>
<td>• BMP utilization</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decrease nutrient inputs from stormwater runoff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>stormwater management devices are designed to address water quality as well as flood control needs, (2) impacts to on-site waste water treatment systems on adjacent properties are considered, and (3) the cumulative impact of runoff from many small properties is treated</td>
</tr>
<tr>
<td>Assessments/Drainage Catchment T3: Monitoring Site</td>
</tr>
<tr>
<td>• stormwater runoff rates</td>
</tr>
<tr>
<td>• BMP retention &amp; treatment drainage area</td>
</tr>
<tr>
<td>inputs from point sources.</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>WQ 5.2 Determine adequacy of existing systems and implement corrective actions as necessary</td>
</tr>
<tr>
<td>GOAL 6 Improve water clarity by reducing sediment inputs.</td>
</tr>
<tr>
<td>GOAL 7 Decrease inputs of chemical contaminants.</td>
</tr>
<tr>
<td>Fish and Wildlife</td>
</tr>
<tr>
<td>Goal 2 Enhance</td>
</tr>
<tr>
<td>Goal 1: Enhance forest habitats to protect songbirds, other wildlife populations and aquatic resources.</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Goal 2: Protect existing and new wetlands to benefit water quality, aquatic resources, waterfowl and other wildlife.</td>
</tr>
<tr>
<td>Goal 3: Protect and enhance wetlands to benefit water quality, aquatic resources, waterfowl and other wildlife.</td>
</tr>
</tbody>
</table>
| Go...
<table>
<thead>
<tr>
<th>Goal</th>
<th>Description</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Metrics</th>
</tr>
</thead>
</table>
| 3.3  | Protect existing wetlands; where impacts cannot be avoided or minimized, encourage effective private wetland mitigation | T1: Landscape | T2: Rapid Assessments/Drainage Catchment | T3: Monitoring Site | • ecological impact assessment  
• species inventories  
• community complexity |
| 3.5  | Synthesize and evaluate information on the impacts of mosquito ditching and existing ditches on tidal wetlands | T2: Rapid Assessments/Drainage Catchment | T3: Monitoring Site | • water quality  
• water table lowering  
• sediment loads  
• breeding site testing |
| 4.2  | Identify threatened populations in order to retain, restore, and create habitats needed to preserve and enhance populations | T1: Landscape | T2: Rapid Assessments/Drainage Catchment | T3: Monitoring Site | • species inventories  
• habitat inventories  
• extent of mitigation  
• territory adequacy |
| 4.3  | In order to reduce decline of select populations, reintroduce select threatened & endangered species as feasible | T1: Landscape | T2: Rapid Assessments/Drainage Catchment | T3: Monitoring Site | • habitat adequacy  
• patch connectivity & dynamics  
• predator/prey/competitor studies |
| 5.1  | Reduce and control invasive/exotic species (such as phragmites, mute swans, etc.) | T1: Landscape | T2: Rapid Assessments/Drainage | T3: Monitoring Site | • areal extent  
• habitat disturbance  
• community complexity |

FW 5.1: Reduce and control invasive/exotic species (such as phragmites, mute swans, etc.)

FW 3.3: Protect existing wetlands; where impacts cannot be avoided or minimized, encourage effective private wetland mitigation.

FW 3.5: Synthesize and evaluate information on the impacts of mosquito ditching and existing ditches on tidal wetlands.

Goal 4: Protect threatened and endangered species.

Goal 5: Limit impacts to native plants.
| and animals from non-native and nuisance species. | nutria, …[multiflora rose, Japanese knotweed] and reduce further introductions to protect native species habitat | Catchment T3: Monitoring Site | • level of control practices |
| | FW 5.2 Reduce impacts to native plants and animal habitats from “nuisance” species like macroalgae, resident Canada Geese and the over abundance of snow geese | T2: Rapid Assessments/Drainage Catchment T3: Monitoring Site | • habitat destruction  
• patch connectivity & dynamics  
• water quality  
• land management practices  
• species inventories |
# Appendix 4.3. STAC Workshop Notes

## Ecosystems

<table>
<thead>
<tr>
<th>Tier</th>
<th>What are the ecological indicators for each ecosystem at each spatial scale?</th>
<th>What are the ecological indicators for each ecosystem at each spatial scale?</th>
<th>What are the ecological indicators for each ecosystem at each spatial scale?</th>
<th>What are the ecological indicators for each ecosystem at each spatial scale?</th>
<th>What monitoring data gaps exist?</th>
<th>Where are the raw data sets and metadata?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Tier I</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What monitoring data gaps exist?</td>
<td>Where are the raw data sets and metadata?</td>
</tr>
<tr>
<td>Reef Tier I</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What monitoring data gaps exist?</td>
<td>Where are the raw data sets and metadata?</td>
</tr>
<tr>
<td>Red Tier I</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What monitoring data gaps exist?</td>
<td>Where are the raw data sets and metadata?</td>
</tr>
</tbody>
</table>

### forest
- **Goals** - protected water quality
- **Indicators**
  - forest condition
  - % of wetland
  - forest type
  - forest health (gypsy moth)
  - connectivity
  - age
  - % of forest land
  - % of protected land

### wetlands
- **Indicators**
  - wetland type/class
  - % of buffer
  - land base in buffer
  - % of protected land
  - extent

### Ecosystems Summary
- **Indicators**
  - forest condition
  - % of wetland
  - forest type
  - forest health (gypsy moth)
  - connectivity
  - % of forest land
  - % of protected land
  - % of buffer

### wetlands
- **Indicators**
  - wetland type/class
  - % of buffer
  - land base in buffer
  - % of protected land
  - extent

### Heعصاечeen Shrub/Pasture
- **Indicators**
  - % of land cover
  - % of land cover
  - % of land cover
  - % of land cover
  - % of land cover
  - % of land cover

### seasonal row crop ag
- **Indicators**
  - % of buffer
  - % of buffer
  - % of buffer
  - % of buffer
  - % of buffer
  - % of buffer

### Developed Land
- **Indicators**
  - % of urban open land
  - % of urban open land
  - % of urban open land
  - % of urban open land
  - % of urban open land
  - % of urban open land

### beach/dunes
- **Indicators**
  - % of buffer
  - % of buffer
  - % of buffer
  - % of buffer
  - % of buffer
  - % of buffer

### Data sets
- **Datasets**
  - DNR records
  - Flood safety data
  - Level 1 (VIMS, Spring '08)
<table>
<thead>
<tr>
<th>Ecosystems</th>
<th>forest</th>
<th>wetlands</th>
<th>seasonal row crop ag</th>
<th>Developed Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
<td></td>
</tr>
<tr>
<td><strong>Composite</strong></td>
<td><strong>Forest</strong></td>
<td><strong>Wetlands</strong></td>
<td><strong>Seasonal Row Crop Ag</strong></td>
<td><strong>Developed Land</strong></td>
</tr>
<tr>
<td>Density</td>
<td><strong>Species richness</strong></td>
<td><strong>Vegetation type</strong></td>
<td><strong>Crop type</strong></td>
<td><strong>Soil texture</strong></td>
</tr>
<tr>
<td><strong>Species richness</strong></td>
<td><strong>Vegetation type</strong></td>
<td><strong>Crop type</strong></td>
<td><strong>Soil texture</strong></td>
<td><strong>Soil texture</strong></td>
</tr>
<tr>
<td><strong>Vegetation type</strong></td>
<td><strong>Crop type</strong></td>
<td><strong>Soil texture</strong></td>
<td><strong>Soil texture</strong></td>
<td><strong>Soil texture</strong></td>
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<tr>
<td><strong>Crop type</strong></td>
<td><strong>Soil texture</strong></td>
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<td><strong>Soil texture</strong></td>
<td><strong>Soil texture</strong></td>
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</tbody>
</table>

**NOTES:** These plans would be implemented through the following: 
- Groundwater flow (some from permits) 
- **Invasive species:** (some of the examples are): 
  - **Soil texture:** 
  - **Soil texture:** 
  - **Soil texture:** 

**How are monitoring data collected?**
<table>
<thead>
<tr>
<th>Ecosystems</th>
<th>Blue Tier III</th>
<th>Red Tier III</th>
<th>Green Tier III</th>
<th>Composite</th>
<th>What indicators are useful?</th>
</tr>
</thead>
<tbody>
<tr>
<td>forest</td>
<td>Upland Forest – Need to define assessment area</td>
<td>FORESTES – Lake Wetlands</td>
<td>Upland Forest – Need to define assessment area, Like</td>
<td>Upland Forest – Forest Wetlands</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
</tr>
<tr>
<td>wetlands</td>
<td>Delaware method (like forests) + birds</td>
<td>Delaware method (like forests) + birds</td>
<td>Delaware method (like forests) + birds</td>
<td>Delaware method (like forests) + birds</td>
<td>What indicators are useful?</td>
</tr>
<tr>
<td>Hebesaceous Shrub/Pasture Land</td>
<td>same as forest (trees)</td>
<td>same as forest (trees)</td>
<td>same as forest (trees)</td>
<td>same as forest (trees)</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
</tr>
<tr>
<td>seasonal row crop</td>
<td>Plant management (MDA) plan information, BMP's</td>
<td>Plant management (MDA) plan information, BMP's</td>
<td>Plant management (MDA) plan information, BMP's</td>
<td>Plant management (MDA) plan information, BMP's</td>
<td>What indicators are useful?</td>
</tr>
<tr>
<td>Developed Land</td>
<td>same right of year – e.g. Plant rotation time</td>
<td>same right of year – e.g. Plant rotation time</td>
<td>same right of year – e.g. Plant rotation time</td>
<td>same right of year – e.g. Plant rotation time</td>
<td>What are the ecological indicators for each ecosystem at each spatial scale?</td>
</tr>
<tr>
<td>beach/dunes</td>
<td>Species Comp/ Veg &amp; Density</td>
<td>Species Comp/ Veg &amp; Density</td>
<td>Species Comp/ Veg &amp; Density</td>
<td>Species Comp/ Veg &amp; Density</td>
<td>What indicators are useful?</td>
</tr>
<tr>
<td>Monitoring well, watershed or stream</td>
<td>Water Quality</td>
<td>Water Quality</td>
<td>Water Quality</td>
<td>Water Quality</td>
<td>What indicators are useful?</td>
</tr>
<tr>
<td></td>
<td>Direct Measure of Nutrients, Salinity, Turbidity</td>
<td>Direct Measure of Nutrients, Salinity, Turbidity</td>
<td>Direct Measure of Nutrients, Salinity, Turbidity</td>
<td>Direct Measure of Nutrients, Salinity, Turbidity</td>
<td>What indicators are useful?</td>
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<tr>
<td></td>
<td>Chemical constituents</td>
<td>Chemical constituents</td>
<td>Chemical constituents</td>
<td>Chemical constituents</td>
<td>What indicators are useful?</td>
</tr>
</tbody>
</table>
MONITORING DELMARVA AGROECOSYSTEMS AT LANDSCAPE LEVELS

Frederick W. Kutz; John M. Morgan, III; Jeremy Monn; and Chad P. Petrey

Geospatial Research and Education Laboratory
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An agroecosystem is defined as "semi-domesticated ecosystems that fall on a gradient between ecosystems that have experienced minimal human impact, and those under maximum human control, like cities." Thus agroecosystems are generally defined as novel ecosystems that produce food and fiber via farming under human guidance (Hecht 1995). While farming methods vary, traditional manipulated agroecosystems generally differ from natural ecosystems in six ways: maintenance at an early successional state, monoculture, crops generally planted in rows, simplification of biodiversity, intensive tillage, which exposes soil to erosion, use of genetically modified organisms and artificially selected crops (Botkin and Keller 2005).

The objective of this report is to outline a strategy to monitor and assess agroecosystems in the Delmarva Peninsula using principles of landscape science. Modern science has developed various landscape science approaches to environmental assessment. These approaches include both landscape characterization (land cover/land use mapping) and ecological (landscape indicator) techniques. These new developments have been made possible through the use of remotely sensed data from aerial photography and satellite images coupled with sophisticated computer applications. Landscape approaches require a multi-disciplinary perspective and reflect a convergence of geography, ecology, remote sensing and other sciences.

Landscape metrics or indicators are calculated by combining various scientific databases using technologies from geographic information sciences. They embrace all of the ecological resources in a given spatial area, such as lakes, streams, farmland, wetlands, forests, urban and suburban areas, etc. The condition of each of these resources might influence other resources. For example, the condition of agroecosystems has a direct effect on the condition of adjacent or associated ecosystems, even if these systems are so distance removed. Additionally, the shape, size and condition of natural resources have a direct bearing on their intrinsic plant and animal

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2 Center for Geographic Information Sciences, Towson University

3 Formerly graduate student in environmental science, Towson University
communities that they support and adjacent communities that might be dependent upon them for some part of their development or succession.

Landscape science has progressed to a stage where these approaches can be used to conduct ecological monitoring and assessments on areas of different sizes (O’Neill et al. 1997). Examples of the application of this approach are contained in two landscape atlases focused on the mid-Atlantic area of the United States (Riitters et al. 1996 and Jones et al. 1997).

**Landscape Approach to Agroecosystems on a Watershed Basis**

For the purposes of this report, the coastal bays watershed is comprised of six subwatersheds: Dirickson-Little Bay, Assawoman Bay, Isle of Wight Bay, Newport Bay, Sinepuxent Bay and Chincoteague Bay. The watersheds used in this report were the third-order watersheds as delineated by the MD Department of Natural Resources (MD DNR 2006). These watersheds are denoted as MD-8 watersheds and extend into both Delaware and Virginia. The largest of these watersheds in land features is Chincoteague Bay followed by the Isle of Wight Bay. A newer watershed delineation is under development by NRCS (2008).

**Characterizing Agriculture in the Coastal Bays Watersheds**

The following characterization of the coastal bays agroecosystems is taken from selected elements of the 2002 Ag Cropland Data Layer (CDL) produced by a joint venture of Towson University and the National Agricultural Statistics Service (NASS) of the U.S. Department of Agriculture (USDA). The CDL covered ten States of the Mid-Atlantic region and the full extent of the Chesapeake Bay and Delmarva Coastal Bays Watersheds for crop year 2002. The CDL permitted detailed analysis of many agricultural and environmental parameters. Besides defining the crops grown in a specific area, the CDL can be combined with other information to estimate cropping practices, and pesticide and nutrient usage for the area. Methodology used to produce the CDL is described by NASS (2005). An image of the CDL for the MD coastal bays watershed is shown in Figure 1.
Approximately 25 percent of the dry land area in the coastal bays watershed is devoted to cropland. In 2002, corn (field and sweet corn) was the most prominent crop exceeding cropland in soybeans and winter wheat followed by soybeans by only a few hundred acres. Soybeans either singly or double-cropped with winter wheat were the second most predominant crop grown in the watershed. Although the coastal bays watershed is relatively small, cropping practices in the northern part were different from those in the southern portion. Other crops, such as fresh vegetables and vegetables grown for processing, were less than 10 percent of the total cropland in the watershed. A conservative estimate of the total pesticide loading in the watershed in 2002 was over 95,000 pounds of active ingredients. Herbicides represented the most frequently used pesticide in the watershed, both in number (17) and in total active ingredients (over 90,000 lbs). Ten insecticides were used in the watershed, while only small quantities of three fungicides were used. Although the heaviest pesticide usage (in lbs. a.i.) was in the Chincoteague Bay watershed, the highest intensity of pesticide applications (in lbs. a.i./A) was in the Isle of Wight Bay watershed (Kutz et al. 2007). Over 6,300 tons of nitrogen and over 1,500 tons of phosphorus are applied on croplands in the coastal bays watershed through the use of animal wastes and chemical fertilizers as well as atmospheric deposition.

Data Needs for Monitoring Agriculture at a Landscape Level

A considerable amount of data is needed to monitor the condition of agroecosystems and their influence on adjacent or associated ecosystems in the watersheds. Both on-the-ground information as well as remotely sensed (aerial photography and satellite) images are required. Additionally, experience in geographic information sciences is needed to interpret the information into scientific and policy-relevant conclusions.

Some of the databases needed to achieve landscape level monitoring of agroecosystems are listed in the following table (Table 1):

<table>
<thead>
<tr>
<th>Database</th>
<th>Description</th>
<th>Possible Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite Images</td>
<td>Satellite images with multiple sensors useful in land use/land cover classification</td>
<td>NASA, MD agencies</td>
</tr>
<tr>
<td>LiDAR Images</td>
<td>LiDAR database with bare earth and first returns</td>
<td>DNR or other state agencies</td>
</tr>
<tr>
<td>Agricultural Cropland Data</td>
<td>Georeferenced agricultural information</td>
<td>NASS/USDA, MDA</td>
</tr>
<tr>
<td>Aerial Photography</td>
<td>Georeferences aerial images sufficient to identify agricultural entities</td>
<td>NAPA, State agencies</td>
</tr>
<tr>
<td>Watershed Delineations (and other natural resource identifications)</td>
<td>Watershed delineations should be consistent with management orientation</td>
<td>USGS, NRCS/USDA, MDE and DNR</td>
</tr>
<tr>
<td>Nutrients and Pesticides Data</td>
<td>Pesticide and nutrient use recommendations</td>
<td>DE, MD and VA agricultural agents and experts</td>
</tr>
</tbody>
</table>
Because of its economic and strategic importance, a significant amount of confidentiality surrounds agricultural data. Arrangements will have to be made to maintain this confidentiality with appropriate corporate and government authorities.

**Potential Landscape Metrics for Agroecosystems**

Several of the environmental landscape indicators used in this study were slight modifications of those presented by Jones et al. (1997). Landscape-level indicators that might be considered for use in monitoring agroecosystems include, but are not limited to the following:

- Agricultural land-to-water ratio
- Areal extent of land features, and of land and water features
- Areal extent of agricultural cropland
- Areal extent of major crops grown in watershed
- Pesticide loading
- Nutrient Input
- Extent of riparian buffers in agricultural areas
- Delineation of tax ditches
Agricultural Land-to-water Ratio. This indicator estimates the amount of land per unit area of water in a watershed. In most interpretations, the larger the amount of agricultural land to unit water, the higher the potential might be for the land-based pollution to contribute to the aquatic resources in a watershed. The calculation of general land-to-water ratios by watershed also might be considered. In the DE inland coastal bays watershed, some ratios as high as 50:1 have been observed (Price, 2004). Critical interpretations of these indicators require additional knowledge of the land use/land cover and other features of the watershed. For example, a heavily forested watershed might be considered beneficial, as forests provide a variety of advantageous ecological services in pollution reduction. In certain cases, this indicator may be scale and land cover dependent.

Percent Cropland. This flexible indicator may be calculated in several forms. The first form is calculated by dividing the acreage of a crop by the total acreage of the watershed, thus providing a percent cropland measurement that includes both land and water features. Another form is calculated by dividing the acreage of a crop by only the land acreage of the watershed.

Table 2. Selected characteristics of subwatersheds in the MD coastal bays, 2002

<table>
<thead>
<tr>
<th>Subwatershed</th>
<th>Area of Entire Subwatershed (Acres)</th>
<th>Area of Land Features of Subwatershed (Acres)</th>
<th>Percent Cropland of Entire Subwatershed</th>
<th>Percent Cropland of Land Features of Subwatershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assawoman Bay</td>
<td>17,518</td>
<td>11,132</td>
<td>17</td>
<td>26</td>
</tr>
<tr>
<td>Chincoteague Bay</td>
<td>164,755</td>
<td>79,245</td>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td>Dirickson-Little Bay</td>
<td>21,612</td>
<td>19,102</td>
<td>27</td>
<td>30</td>
</tr>
<tr>
<td>Isle of Wight Bay</td>
<td>46,020</td>
<td>38,701</td>
<td>26</td>
<td>31</td>
</tr>
<tr>
<td>Newport Bay</td>
<td>32,491</td>
<td>27,893</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>Sinepuxent Bay</td>
<td>13,710</td>
<td>7,538</td>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>

thus providing a percent cropland measurement that does not include water features. As crops are not grown in the aquatic portion of a watershed, the second, land feature only form probably imparts more significant information as to the potential contribution of croplands to environmental quality. In 2002, these metrics were measured as presented in Table 2.

Specific Cropland Acreage. The cropland acreages may be calculated using GIS software. Cropland acreages can be calculated on a watershed basis by using two datasets: the subwatershed vector dataset obtained from the Maryland Department of Natural Resources (MD DNR 2006) and the agricultural cropland data layer (a raster dataset) (NASS 2005). The major cropland in 2002 consisted of approximately 46,479 acres and the specific cropland estimates are presented in Table 3.

Table 3. Major cropland in MD coastal bays
<table>
<thead>
<tr>
<th>Major Cropland</th>
<th>Extent in Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>20,462</td>
</tr>
<tr>
<td>Double cropping of winter wheat followed by soybeans</td>
<td>11,013</td>
</tr>
<tr>
<td>Soybeans</td>
<td>9,246</td>
</tr>
<tr>
<td>Vegetables (fresh &amp; processed)</td>
<td>3,305</td>
</tr>
<tr>
<td>Other grains and hay</td>
<td>1,234</td>
</tr>
<tr>
<td>Potatoes</td>
<td>591</td>
</tr>
<tr>
<td>Other crops</td>
<td>404</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>123</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>62</td>
</tr>
<tr>
<td>Barley</td>
<td>19</td>
</tr>
<tr>
<td>Berries</td>
<td>16</td>
</tr>
<tr>
<td>Peanuts</td>
<td>4</td>
</tr>
</tbody>
</table>

**Pesticide Loading.** Pesticide loadings may be calculated by using information from the agricultural extension agents and experts. Pesticides are applied on a crop specific basis, so that cropping practices are critical for these calculations. Estimating pesticide usage is a complex endeavor. The agribusiness community considers numerous parameters in determining whether to apply pesticides and exactly what pesticides to use. These factors included economic considerations, existing inventories, individual farmer preferences, possible future regulatory actions, etc., to name a few. One major factor is the use of integrated pest management (IPM). IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment (U.S. EPA 2005). Another agricultural practice that has a significant impact on pesticide usage is conservation farming. In conservation farming, the soil is left undisturbed from harvest to planting. Planting is accomplished using specialized equipment. In a properly designed conservation system, pest (weeds, disease, and insect) control is accomplished primarily with the following cultural practices: rotation, sanitation, and competition. Judicious use of herbicides usually is involved to provide the crop with a competitive advantage over the weeds. Although no-till farming generally employs more pesticides than traditional methods, it has been shown to lower the net export rate of "greenhouse gases" that have been implicated in global warming (Elstein 2004). Knowledge of the pesticides applied to an area not only provides information as to the basis of what might be found within and outside of watershed areas, but also can guide pesticide monitoring programs. For example, a recent USGS survey of ground water (Denver and Ator 2006) indicated that exposure indicators (parent compounds or degradation products) for 17 pesticides were detectable following the analytical protocol; however, over 30 pesticides were used on major cropland in the area. Table 4 shows the top 10 pesticides applied in the MD coastal bays watershed in 2002 (Kutz et al. 2007).
Table 4. Ten Most Commonly Used Pesticides on Cropland in the MD Coastal Bay Watershed, 2002

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Class of Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyphosate</td>
<td>Herbicide</td>
</tr>
<tr>
<td>Atrazine</td>
<td>Herbicide</td>
</tr>
<tr>
<td>s-Metolachlor</td>
<td>Herbicide</td>
</tr>
<tr>
<td>Paraquat</td>
<td>Herbicide</td>
</tr>
<tr>
<td>Acetochlor</td>
<td>Herbicide</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>Herbicide</td>
</tr>
<tr>
<td>2,4-D</td>
<td>Herbicide</td>
</tr>
<tr>
<td>Terbufos</td>
<td>Herbicide</td>
</tr>
<tr>
<td>Mancozeb</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Metribuzin</td>
<td>Herbicide</td>
</tr>
</tbody>
</table>

**Nutrient Loading.** Nutrients are another significant environmental issue that is difficult to quantify accurately. Nutrients may be added to agroecosystems in three main ways: animal manure, chemical fertilizer and atmospheric deposition. Major nutrients of concern are nitrogen and phosphorous. Most nutrient models recognize that fertilizer of some form is applied based on cropping practice. Using a landscape approach, nutrient loadings may be calculated based on groups of crops in a known geospatial area. Atmospheric deposition also can be estimated by the proximity of pollution sources, i.e. power generation plants, airsheds, etc. Table 5 presents estimates of nutrient loadings to the MD coastal bays watershed, as calculated using the Chesapeake Bay Program model (Sweeney 2008). Based on this model, 12,710,627 pounds of nitrogen and 3,056,047 pounds of phosphorus were applied to or deposited on the MD coastal bays watershed in 2002. Sources at the Maryland Department of Agriculture believe that the estimates for chemical fertilizer loadings may be inaccurate by as much as 50 percent (MDA 2008).
Table 5. Nutrient Inputs to agricultural croplands of the MD coastal bays watershed
(All units are lbs.)

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Tilled Crops</th>
<th>No-Till Crops</th>
<th>Hay</th>
<th>Pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen from manure</td>
<td>1,580,636</td>
<td>2,930,410</td>
<td>118,889</td>
<td>3,976,873</td>
</tr>
<tr>
<td>Nitrogen from fertilizer</td>
<td>1,092,170</td>
<td>2,201,153</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nitrogen from atmospheric deposition</td>
<td>159,753</td>
<td>298,351</td>
<td>10,329</td>
<td>341,060</td>
</tr>
<tr>
<td><strong>Total Nitrogen</strong></td>
<td><strong>2,832,560</strong></td>
<td><strong>5,429,915</strong></td>
<td><strong>129,219</strong></td>
<td><strong>4,318,933</strong></td>
</tr>
<tr>
<td>Phosphorous from manure</td>
<td>475,816</td>
<td>890,487</td>
<td>50,562</td>
<td>1,328,587</td>
</tr>
<tr>
<td>Phosphorous from fertilizer</td>
<td>106,525</td>
<td>200,906</td>
<td>3,163</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Phosphorous</strong></td>
<td><strong>582,341</strong></td>
<td><strong>1,091,394</strong></td>
<td><strong>53,725</strong></td>
<td><strong>1,328,587</strong></td>
</tr>
</tbody>
</table>

**Riparian Buffers in Agricultural Lands.** Riparian buffers are areas along streams, rivers, marshes, or shorelines that form the transition between land and water environments. Riparian buffers are usually composed of forested areas but can also be made up of grass, low-level brush, or small trees. Forests are the most effective type of riparian buffer available. Riparian forest buffers improve water quality while providing habitat for wildlife and fish. Riparian buffers are key to controlling non-point source pollution. They help maintain the integrity of stream channels and shorelines; reduce the impact of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals; and supply food, cover, and thermal protection to fish and other wildlife. The type, size, width, and effectiveness of riparian buffers vary greatly. In order to assess the quality of riparian buffers in the Maryland Coastal Bays watershed, this metric integrates satellite images with LiDAR (Light Detection and Ranging) impressions from aircraft sensors. LiDAR provides information from laser beams that indicates the height and slope of buffers. Therefore, it was possible to detect the location of buffers as well as the dimensional characteristics that influence their effectiveness. For example, the most effective buffer—a riparian forest buffer—would be detected as a tall structure, whereas less effective buffers such as grass or low-level brushes would be detected as a much lower object. Although riparian buffers are critical in providing ecological services in many land cover classes, they are particularly important in agricultural situations where they come into direct contact with pesticides and nutrient as these chemicals are found in runoff. The condition of riparian buffers in five of the six subwatersheds of the coastal bays is illustrated in Table 6. It would be possible and appropriate to determine the condition of riparian buffers in agricultural croplands. This approach to characterizing riparian buffers easily could form the basis of a targeting strategy for identifying where ecological restoration is needed.
Table 6. Forested Proportion of selected MD coastal bays watersheds

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Percentage of 100-Foot Buffer That is Forested</th>
<th>Percentage of 1,000-Foot Buffer That is Forested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assawoman Bay</td>
<td>5.97</td>
<td>16.41</td>
</tr>
<tr>
<td>Chincoteague Bay</td>
<td>14.65</td>
<td>22.04</td>
</tr>
<tr>
<td>Isle of Wight Bay</td>
<td>21.84</td>
<td>27.58</td>
</tr>
<tr>
<td>Newport Bay</td>
<td>19.63</td>
<td>30.26</td>
</tr>
<tr>
<td>Sinepuxent Bay</td>
<td>10.23</td>
<td>18.83</td>
</tr>
</tbody>
</table>

**Tax Ditches.** Drainage ditches or tax ditches are commonplace in the MD coastal bays watershed. The tax ditch pattern in a portion of the Isle of Wight subwatershed is shown in Figure 2. These ditches assist in drainage from cropland, forests, roadways, commercial areas and home sites, conveying storm water runoff and ground water. Assessments are imposed upon the owners of these drainage ditches. The assessments are for ditch maintenance and are referred to as taxing of the beneficiaries, hence the term tax ditches. These ditch systems were originally designed for agricultural drainage, they are now supporting storm and ground water drainage from urban town centers, state highways and county roads, and new commercial and residential development. Tax ditches are important in nutrient and sediment export; and thus, knowing the location and extent of them, and changes to them play an important role in...
effective ecological monitoring, assessment and restoration.

Other Landscape Opportunities for Agroecosystems

Several investigators have used agricultural cropland data to study various aspects of agriculture. Bekkedal (2006) used the cropland data as an input for a public health pesticide hazard analysis. Seelig et al. (2002) studied the potential of nitrogen contamination of groundwater using cropland information. Agricultural spatial data can be utilized to develop a GIS-based groundwater model for wellhead protection areas (Radhakrishnan and Sengupta 2002). More detailed agricultural vegetation land cover data provide a part of the process in habitat threat analysis (Hagen 2005). Heinsch et al. (2005) used the cropland data as a component in regional scale models of agricultural net primary productivity. Both Lant (2005) and Sengupta (2000) used these data to develop a decision support model to study agricultural and land use policies. Shultz et al. (2007) used information on croplands to develop a regression model to detect suspect ratios of productivity-based tax assessment values to actual sale values for agricultural properties. Linz et al. (2004) used the agricultural land information to aid in quantifying blackbird habitat in an investigation of a dual-purpose wildlife management strategy. Scheffran et al. (2007) used cropland data to create a land use map for the purposes of developing a model that explores the spatial and economic impacts that the introduction of bioenergy crops would have on agriculture.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of the Maryland Coastal Bay Program for providing partial funding to characterize agriculture in the coastal bays watersheds. Additionally, we wish to thank the Eastern Shore Regional GIS Cooperative at Salisbury University for providing information about riparian buffer zones and tax ditches.

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