Land Use – MTRI Documenting Land Use and Land Cover Conditions Synthesis Report

Colin Brooks, Rick Powell, Laura Bourgeau-Chavez, and Dr. Robert Shuchman
Michigan Tech Research Institute (MTRI)

Project Introduction

Transportation projects require detailed environmental information to support the Environmental Impact Statement process, both before and during the NEPA process. Critical geospatial data are needed to make NEPA-related determinations such as Categorical Exclusions, Findings of No Significant Impact, and the need to complete an EIS for factors that must be addressed. Current methods widely used for these determinations rely on methods that are frequently time-consuming, or use pre-existing information that may not be appropriate in accuracy, scale, or timeliness. The NEPA process has the potential for greater time efficiency if geospatial tools can help meet these data needs, including timely and accurate land use and land cover, habitat fragmentation patterns in corridors, hydrologic flow analyses, locations of potential wetlands mitigation sites, identifying habitat for threatened and endangered species, likely and known archaeological sites, the status of hazardous waste sites, and traffic noise modeling. This report focuses on streamlining the process for making up-to-date, accurate land cover data available to transportation agencies.

In this Synthesis Report, we review the current practices used to document existing and projected land use and land cover conditions. We then compare new and innovative approaches to using commercial remote sensing and geospatial information (CRS&SI) to meet these needs, including identifying environmental factors that need to be addressed and mitigated in the decision-making process.

For new and innovative approaches, we draw strongly from the recently completed phases of the Transportation Applications of Restricted Use Technology (TARUT) Study led by the Michigan Tech Research Institute (MTRI), as well as the experience of the National Consortium on Remote Sensing in Transportation – Environmental Assessment (NCSRST-E), led by the Mississippi State part of our team). We also refer to other recent relevant team land cover projects, such as agricultural land cover mapping for the Michigan office of the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service and mapping wetlands with advanced Synthetic Aperture Radar (SAR) data.

The need for up-to-date and accurate data in order to effectively evaluate the environmental impacts of transportation projects is clear. By applying CRS&SI data and tools, there is great potential to contribute towards streamlining the EIS process, as reviewed in this report.

Traditional Approaches

Land Use and Land Cover Mapping

Land use and land cover data can be derived from a number of sources such as regional comprehensive plans, remote-sensing derived land cover maps, and field-based surveys. However, these data sources may be less than optimal due to issues of accuracy, scale, and temporal resolution.

Land-use data found in comprehensive or master plans may be based on statistical information from sources such as the U.S. Natural Resources Conservation Service (NRCS) Natural Resources Inventory (NRI). Statistical sampling used to develop the NRI data is appropriate for estimating land cover/use over large regions such as entire states, but is less accurate over small areas such as transportation corridors.

Maps derived from moderate resolution remote sensing systems such as Landsat are well suited to determine general thematic land cover classes such as Forest and Grasslands. However, generalized classes are of little utility to the assessment of land uses such as High-Density Residential or Industrial. This lack of suitability can be a source of uncertainty in environmental inventories and assessments.

Another challenge using land cover/use data is that the most widely available products may be outdated and not reflect changes to the landscape due to urbanization and farmland conversion. In a recent Michigan Department of Transportation study it was determined that environmental assessment projects relied upon land cover and land use data that ranged from 5 to 25 years old (Michigan 2001 IFMAP land cover and MIRS 1978 respectively).

The production of up-to-date and accurate land cover/use maps is expensive and time consuming. Traditional methods of developing land use maps from aerial photographs rely on time consuming manual methods which require skilled interpreters and an expert workflow process to manually delineate features from aerial photographs.

Traditional methods of semi-automated image classification, introduced largely in the 1980s, rely on spectral signatures to extract features from multi-spectral remote sensing images. These methods, such as supervised and unsupervised classification algorithms, focus only on the spectral characteristics of a single pixel and neglect the spatial context of the surrounding pixels which may compromise the accuracy of results. These methods are well suited to moderate resolution remote sensing imagery such as data from the Landsat (30m) or SPOT (10m) systems for identifying broad land cover classes. High-resolution remote sensing imagery such as IKONOS (4m) and QuickBird (2.4m) produces a data set that is comparable to aerial photographs and is capable of capturing more detailed land use classes. However the greater radiometric resolution of data from these systems is computationally intensive to process with traditional classification algorithms.

Wetlands Assessment

The process of detecting and identifying jurisdictional wetlands is traditionally laborious and expensive. Wetlands must be identified, categorized, and accurately mapped by trained professionals in the field using guidelines established by the U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (USFWS), and other Federal agencies.

Consequently, there can be great economic and environmental benefits if the distribution of wetlands is known during the early stages of the project while alternate routes are under consideration. Though remote sensing technology is not usually applicable to delineating jurisdictional wetlands, it is a useful tool for surveying potential wetlands during the early planning stages of a project.

Existing wetland habitats within a project study area are often summarized using USFWS National Wetland Inventory (NWI) maps. These maps show the location, size and type of wetland habitats within defined geographical areas. NWI maps attempt to describe both jurisdictional wetlands and special aquatic habitats; however, these maps are limited by the scale, quality, and temporal resolution of the aerial photographs from which they are derived. NWI maps typically lack field verification and tend to omit forested wetlands and wetlands less than 3 acres in size. Forested wetlands have been a particular problem for accurate mapping with NWI data, with one recent estimate indicating that 30% to 85% of wetlands may be missed by NWI maps (Pantaleoni 2007).

Streamlining Approaches

Land Use and Land Cover Mapping

To evaluate the Affected Environment and Environmental Consequences of proposed routes an object-based image analysis technique using multiple sources of data integrated within a knowledge-based classification system is recommended to produce up-to-date, accurate land cover/use maps.

Object-based image processing is a relatively new image processing technique which uses the characteristics of single pixels as well as those of surrounding pixels to create image objects for classification. Unlike single pixels, image objects capture important semantic and contextual information that can be used for accurate feature extraction using classification algorithms (nearest-neighbor, maximum likelihood), knowledge-based approaches, fuzzy classification, and a combination of methods. In addition, image objects may be derived from any spatially distributed variable. Data such as orthophotographs, bare earth terrain models, and digital surface models can be used to create image objects and develop classification models to extract features such as building footprints and impervious surfaces.

The multi-source, object-based approach to land cover mapping has been successfully employed for Michigan Department of Transportation projects. The projects integrated multi-source, multi-temporal data with object based image analysis techniques to classify both upland and lowland land cover classes into detailed classes (Figure 1). The approach used multiple dates of Landsat multispectral data, elevation models, and USDA soil data. Multiple dates of imagery allowed the variation of land cover types across the season to be captured while the use of soil and elevation data allowed lowland classes to be accurately mapped.

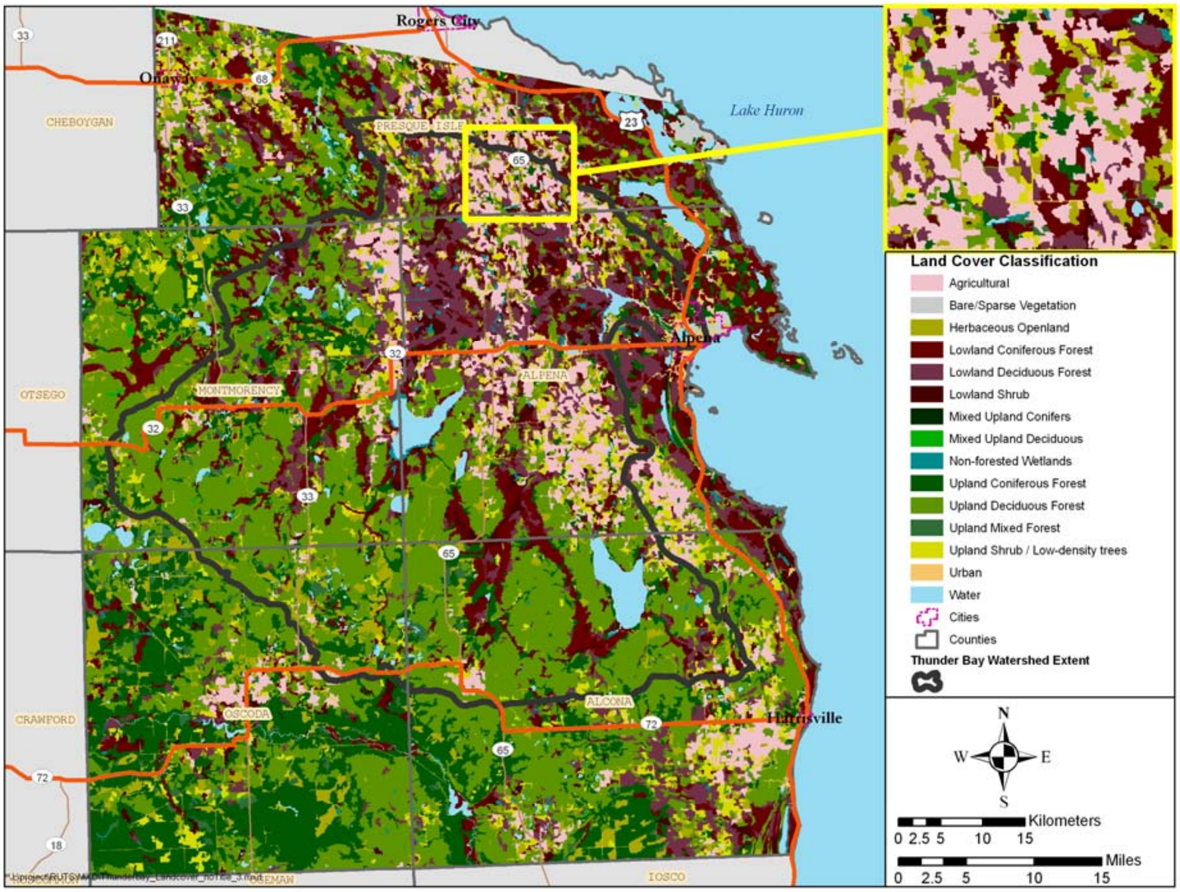

Figure 1. Detailed land cover classes derived from multi-source, multi-temporal data using object-based image classification methods for part of northern central Michigan. *The Michigan DOT was interested in mapping lowland forest to accurately map wetlands usually underrepresented in traditional land cover maps, and in mapping updated agricultural areas as areas for possible wetlands mitigation sites.*

Multi-temporal, multi-resolution object-based methods have also proven useful in MTRI projects for the accurate mapping of agricultural areas. This can be important to transportation agencies because agricultural areas are typically where new mitigation sites are constructed, in part because of land available and the status of much agricultural land as former wetlands. Using methods first described by Brooks et al. in 2006, MTRI researchers were able to map agricultural land with 80-90% accuracy (see (http://www.definiens.com/binary_secure/164_asprs2006_0021.pdf?binary_id=164&log_id=15188&session_id=d023255dd296d170ce9141231b256870 for 2005 methods; 2006 methods improved on these). Potentially most critically was how land cover could be generated within the same year as the imagery was collected, meaning that agencies could have access to maps that were not years out-of-date, as is the case of most state and national land cover maps. Figure 2 shows an example of agricultural land cover for 14,000-ha watershed study area (called the Upper Tiffin River) in southeastern Michigan, near the Ohio border, mapped using MTRI's object-based methods.

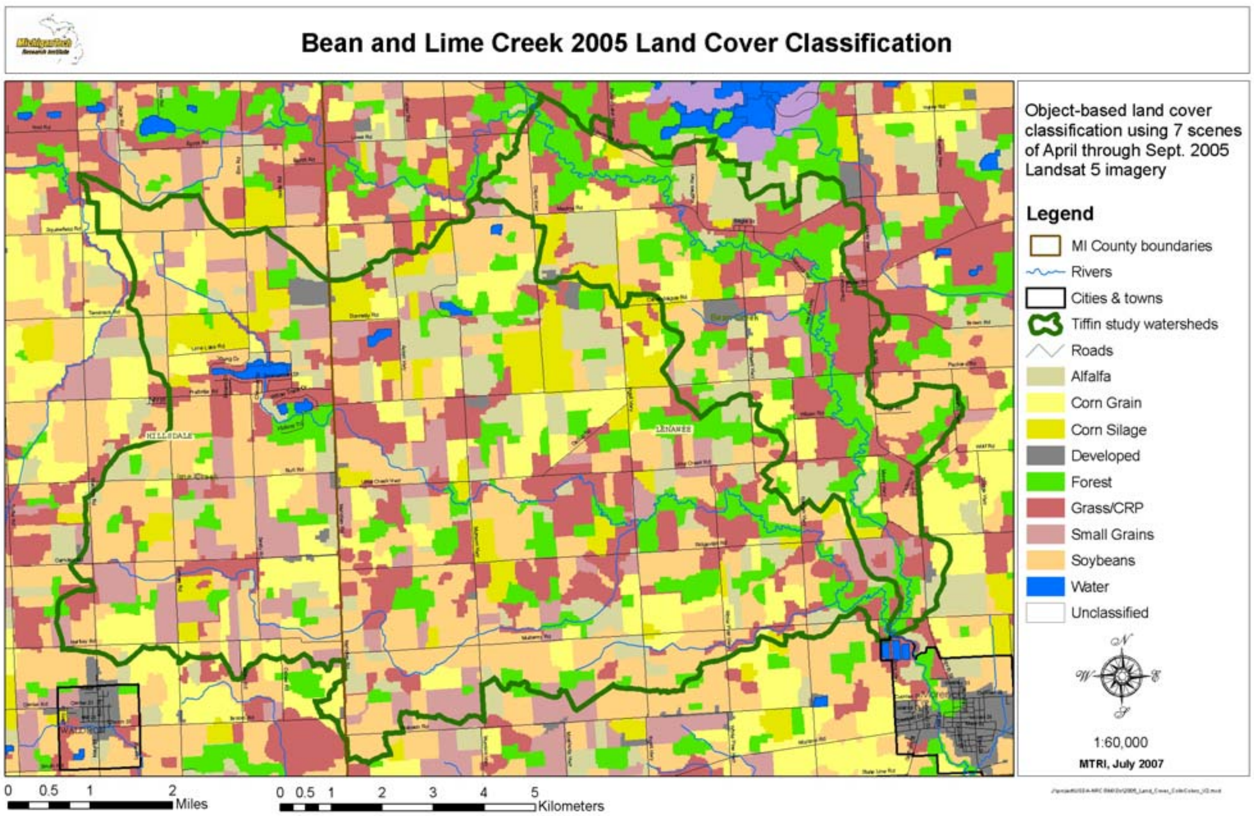

Figure 2: An example of multiple agricultural land cover types mapped with over 80% accuracy using multiple dates of Landsat imagery. *Having accurate maps of the extent of agricultural land can be critical to transportation agencies when selection potential wetlands mitigation sites*.

Object-based methods have also shown promise for mapping land cover types at higher-resolutions, potentially even for species-level mapping. During the TARUT Study, MTRI demonstrated that it was possible to map some wetlands type at the species level using one meter resolution imagery that included 14 spectral bands (visible and near-infrared) plus daytime and nighttime thermal data. Also included in the analysis was the profiling of spectral reflectance of land cover types (such as emergent wetlands) using a hand-held ASD Fieldspec 3 Spectroradiometer, as a method of identifying potentially unique classes of wetlands. While the final maps needs formal accuracy evaluation, this innovative approach to combining high-resolution multispectral remote sensing with field spectral measurements is an approach that transportation agencies may wish to consider for some mapping needs. These higher- resolution methods are most appropriate for project-specific tasks where field work is incomplete, impractical, or not available on a timely basis. Figure 3 shows an example of Argon ST multispectral imagery with 1.0-m resolution, and the resulting species-specific land cover map created with object-based image processing methods.

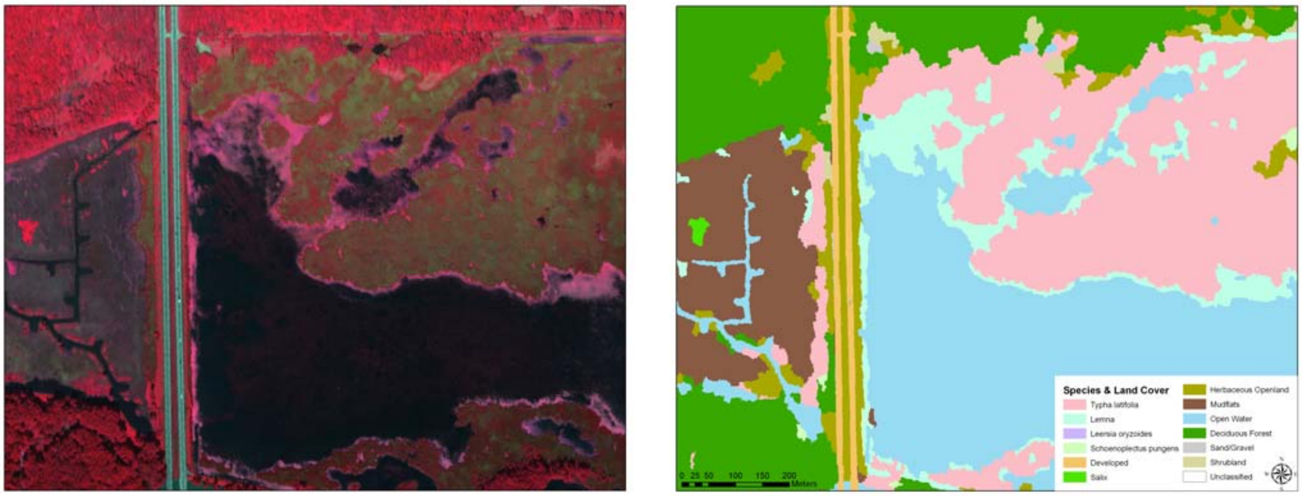

Figure 3: An example of multi-spectral one-meter resolution imagery (left) that was classified into species-specific land cover for a wetland area in central Michigan, using object-based image processing methods. *Individual species were mapped because the Michigan DOT was interested in knowing the extent of possible rare species habitat near a road corridor that is planned for widening.*

Wetlands Assessment

For wetlands assessment, recent studies using a combination of data, such as multispectral imagery, Synthetic Aperture Radar (SAR) data, and topographic information have shown success in detecting wetlands. Multispectral information can discriminate major groups of vegetation and can detect standing water in open canopies. SAR can detect areas of inundation underneath dense vegetation canopies. Topographic information can be used to identify areas with shallow slopes, characteristics of all wetlands.

Studies in Michigan have demonstrated how a combination of SAR, multispectral, and other GIS data sources have been used to detect forested wetlands in Northern Lower Michigan near Interstate 75 and the Mackinac Bridge (which links Michigan's upper and lower peninsulas). The project leveraged the ability of SAR sensors to penetrate the vegetation canopy and can detect standing water.

In this study, MTRI researchers and collaborators used Landsat multispectral data to classify upland and water classes. Multiple dates of JERS SAR data were used to identify inundation areas under the vegetation canopy. GIS techniques were used to buffer water features and classify slope from a Digital Elevation Model. A decision tree classifier was used with the land cover classes, SAR data analysis, and GIS data sources to identify potential wetlands. Results from this approach are comparable to information from the National Wetlands Inventory that is more than 25 years old (for the study area) and provides an important source of updated wetlands data for environmental assessment.

Because wetlands share some characteristics with upland ecosystems, it can be challenging to distinguish these areas with multispectral remote sensing data using traditional semi-automated image classification techniques.

SAR represents one of the most promising sensor types for improving wetland mapping capability. While multispectral data measure spectral reflectance and emittance characteristics of various cover types and wetness in open canopied ecosystems, SAR is sensitive to variations in biomass, structure and soil moisture and flood condition of landscapes including forests and other closed canopy ecosystems. Forested wetlands are the most difficult to identify remotely because of the inability of traditional multispectral sensors to 'see' beneath the canopy. Radar systems are capable of penetrating a closed canopy to detect flooding, and also, since radars are active systems, data are acquired independent of solar illumination and cloud cover. Thus data can be collected during specific conditions relevant to finding seasonally flooded wetlands. Further, SAR data can be used not only to detect and define wetlands but also to monitor extent of inundation and in some cases level of inundation (Bourgeau-Chavez et al. 2005).

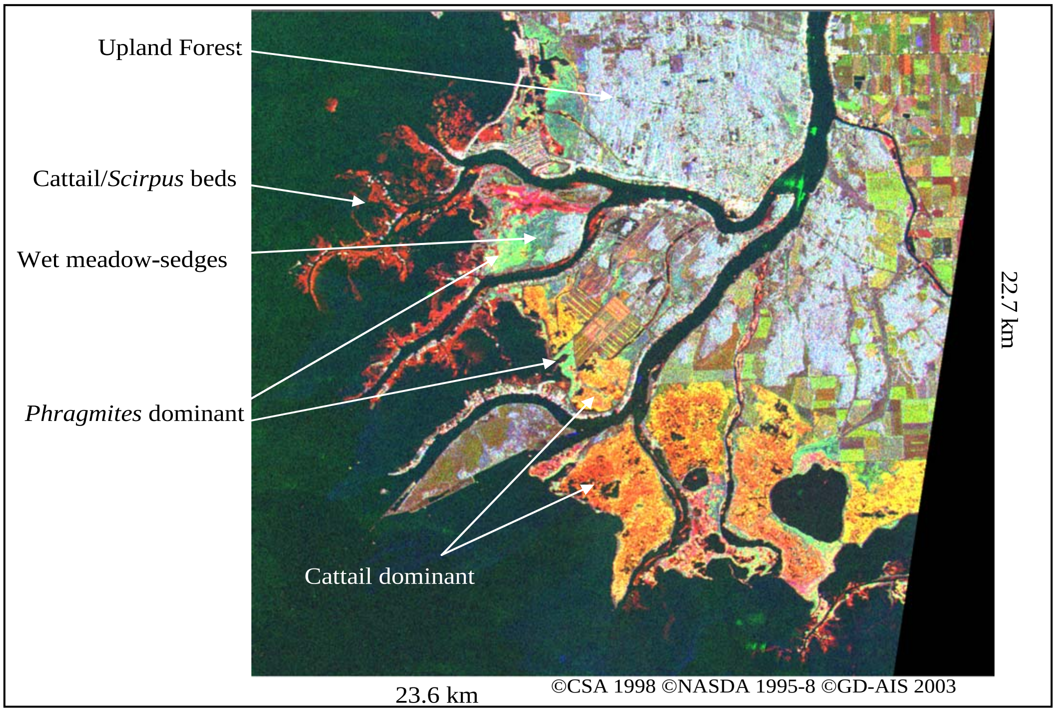

Figure 4. Three date false color composite of Radarsat 3 Oct 98 (red), JERS 10 Aug 98 (green), and JERS 28 Mar 95 (blue) illustrating fine-resolution mapping of wetland plant cover in Lake St. Clair, Michigan.

Wetlands have historically been one of the most difficult ecosystems to classify using remotely sensed data, partially due to the high variability in wetland morphology. Hybrid Synthetic Aperture Radar (SAR) and multi-spectral imaging methods have been developed and demonstrated to monitor Great Lakes' coastal and inland ecosystems and surrounding land uses.

The 1995-1998 SAR imagery displayed in Figure 4 as a multi-sensor false color composite was used in combination with multi-spectral Landsat data to create a wetland map with 94% accuracy when compared to the National Wetlands Inventory of 1978. The two-sensor (Radarsat and JERS) SAR data allowed for a greater discrimination of wetland types (e.g. cattail, Phragmites, wet meadow) than Landsat alone.

Recommendations for Research Opportunities

Multi-resolution, multi-temporal object-based land cover classification holds promise as a new and innovative method of meeting the land use / land cover mapping needs of state transportation needs. We recommend that the Streamlining Environmental and Planning Processes (SEPP) project pursue this as one of it research demonstrations for documenting and project land use / land cover conditions. In addition to mapping all major land cover types across study areas of interest, such as the I-269 Bypass, we recommend that the mapping of individual land cover types that are traditionally poorly mapped, such as forested wetlands, also be pursued as a priority research opportunity. In particular, integrating advanced Synthetic Aperture Radar data has the potential to improve the accuracy of mapping challenging wetlands classes that are not always accurately captured with the National Wetlands Inventory and other traditional methods and data sources. Using resulting maps to identify agricultural areas that may be good locations for wetlands mitigation sites, along with mapping potential rare species habitat, is another possible research opportunity, depending on transportation agency priorities.

By having access to accurate, up-to-date land cover that meets the specific needs of transportation agencies, there is the potential for significant time and cost savings over traditional methods of land use / land cover mapping. Uses of updated, object-based land cover could include assessing wetlands impacts of corridor alignments, locating potential rare species habitat, mapping locations of farm fields where wetlands mitigation sites could be created, and capturing the current extent of residential and commercial development. When integrated with spatial growth models, land cover data generated for this project could also be used to calculate the likely future state of the landscape for study areas. The project's research team will move forward with these ideas, as directed by feedback from the SEPP Advisory Group.