NORTH AMERICAN LAND COVER SUMMIT: SUMMARY

K. Bruce Jones

U.S. Geological Survey
Reston, Virginia USA

INTRODUCTION

The North American Land Cover Summit brought together scientists and practitioners who develop land cover products at national, continental, and global scales. It provided a forum for end-users of land cover data on applications and issues and offered an opportunity for scientists from Mexico, Canada, and the United States to initiate discussions on development of a North American Land Cover Change program.

A number of crucial applications and issues related to the generation and use of land cover data were discussed during the three-day conference. Details of these applications, issues, and opportunities are addressed in the 16 papers and four breakout group summaries included in this special issue. The following summary is intended to condense and categorize the applications of land cover described in those papers and breakout sessions and to identify broad issues that need to be resolved in order for land cover data to be more effectively generated and used by scientists, decision makers, and stakeholders.

MULTI-SCALE LAND COVER PRODUCTS AND CHANGE DETECTION

A number of papers dealt with the development of land cover products and databases at broad spatial scales, including efforts across Canada (Wulder *et al*.), the U.S. (Homer *et al*), Mexico (Jiménez), Europe (Kleeschulte and Büttner), Australia (Barson), and the entire globe (Latham). Many of these programs have nested land cover classifications, but each of the programs use different approaches which makes cross-country and cross-continental comparisons difficult. Latham presented a nested classification approach that would facilitate comparisons among different regions of the world.

Monitoring land cover change is a primary objective of several of the programs discussed in this special issue. Wall-to-wall land cover change products have been developed for the lower 48-United States, large parts of Europe, and Mexico. For example, two-date land cover products from Landsat Thematic Mapper (TM) data have been generated for the U.S. (at 30-meters) and for Europe (at 100 and 250 meters) for the early 1990s and the early 2000s. Land cover change products have been developed for both of these geographies between these periods of time. Australia also has used Landsat TM data as the foundation for its change program as well (Barson), and similar to the FAO program, uses a nested sampling design to evaluate status and change at multiple scales. The FAO uses coarser-scale spatial data from the Advanced Very High Resolution Radiometer (AVHRR, 1-km), Spot 4 (1-km), and the Medium Resolution Imaging Spectrometer (MERIS, 300 m) to generate global land cover, and Landsat and other finer spatial resolution imagery to generate more detailed land cover on sub-continental scales.

Some of these broad geographic programs have developed sets of derivative products. For example, the National Land Cover Database (NLCD) includes databases on impervious surfaces and canopy density (Homer *et al*). Additionally, some of these programs are working with in-situ monitoring programs to develop spatially explicit estimates of certain types of land use. Latifovic and Pouliot used a combination of remote sensing imagery and agricultural census data to develop a spatial database of crop type. Similarly, the U.S. Department of Agriculture's National Agricultural Statistical Service has developed a cropland data layer by using the NLCD and survey-based, agricultural statistics (http://www.nass.usda.gov/research/Cropland/ SARS1a.htm).

Some variation exists in the way these programs have been designed and implemented. In Australia, land cover databases are generated through the States and Territories. The U.S. implements its NLCD program through a consortium of ten Federal agencies. Similarly, land cover mapping of forested areas in Canada is accomplished through collaboration among Federal agencies. The European Corine land cover database involves close coordination with a number of European Union member countries. Finally, Mexico land cover databases are generated through partnerships with universities and Federal and State agencies. Common to the success of all of these programs has been development of strong partnerships - partnerships that are essential in securing the resources to acquire and process imagery and to provide land cover products. Strong partnerships also have been critical in ensuring that the land cover products meet the needs of a wide range of potential users, including those in the science community, governments, conservation organizations, communities, private companies, and citizens

APPLICATIONS

Australia's land cover change program is used to track changes in carbon stocks, and fluxes and flows across landscapes. The EEA's Corine Land Cover program provides important information on habitat and watershed modeling and across large areas of Europe. The NLCD program provides data that are crucial to habitat modeling, wildfire modeling and restoration, watershed modeling, and natural hazard risk analysis. Mexico's land cover products help protect the country's exceptionally rich biological diversity, and Canada's land cover programs help protect and restore its important forested landscapes. FAO's land cover program helps evaluate status and changes in food security, and provides for early warning and climate change analysis, disaster preparation and response, and analysis of populations and areas at risk. It also uses a set of indicators and models derived from land cover and other biophysical data to conduct these analyses.

Several papers in this volume discussed the use of land cover data in environmental monitoring, assessment, and management applications. Although many authors felt that land cover played a critical role in these applications, they also concluded that land cover by itself was insufficient to address some of the specific environmental issues of concern.

Land cover is an important element of ecosystem and landscape characterization programs. Sayre *et al*. described how land cover can be used in combination with other biophysical data to map ecosystems across entire continents. Spatially extensive and consistently mapped ecosystem maps are important in establishing priorities for ecosystem conservation and protection. Wickham and Norton

(1994) developed a landscape composition and pattern classification (Landscape Pattern Types or LPTs) using land cover data and this approach has been used in several national-scale environmental assessments in the U.S., including the State of the Nation's Ecosystems report (Heinz Center 2002).

Availability of digital land cover data at regional to continental scales has led to development of a number of spatial or landscape metrics, indicators, and models. Riitters and Reams described how the NLCD was used to assess forest fragmentation across the U.S. at different spatial scales. The wall-to-wall nature of the NLCD makes it possible to apply a "sliding window" approach to assess forest fragmentation at a range of scales. This approach has been used to assess fragmentation in Europe (applied to the Corine land cover data), as well as to assess global forest fragmentation using 1-km AVHRR land cover data (Riitters *et al*. 2000). Jones provided a summary of the different types of land cover-based indicators and their applications. Although some of these indicators are based entirely on land cover composition and pattern, many are based on the spatial intersection of land cover with other biophysical data. For example, land cover is intersected with digital data on slopes to provide an indicator of potential soil and nutrient loss. Land cover is intersected with stream network data to evaluate riparian habitat conditions. Intersection of land cover data with other biophysical data, such as soil texture (derived from soil databases), slopes, precipitation, often form the basis for spatial explicit landscape models. Land cover change is also being used to track carbon stocks and flows across landscapes in Australia (Barson).

Wiens *et al.* emphasized the importance of land cover in conservation planning. Land cover data are critical in assessing environmental conditions both inside and outside of conservation areas, but especially in putting individual conservation areas into a regional landscape context. Connectivity and conditions of landscapes adjacent to and outside of conservation areas will be important factors in determining the long-term viability of habitats and populations in the face of global climate change. Wiens *et al.* also emphasized the importance of monitoring land cover and land use change.

Land cover-based metrics have been used extensively in environmental vulnerability assessments. White *et al.* used land cover to generated metrics of ecosystem condition, environmental stressors (anthropogenic influences), and rarity (land cover and diversity). Indices of each of these three categories were combined into a spatially explicit measure of vulnerability. The U.S. Environmental Protection Agency's Regional Vulnerability Assessment Program (ReVA) uses a set of land cover and landscape-based metrics to evaluate environmental vulnerability at multiple scales across broad regions (Bradley and Smith 2004). Wood (this volume) used the NLCD to map the vulnerability of coastal communities to tsunami waves. Additionally, land cover change information can be used to help forecast future landscape change and to assess potential environmental consequences and outcomes (Wickham *et al.* 2002, Claggett *et al.* 2004).

Land cover data play important roles in environmental decision support tools and web-based systems. The Automated Geospatial Watershed Assessment tool uses land cover and other biophysical data to model important hydrologic changes associated with different alternative future landscape scenarios (Kepner). As such, it provides decision makers with a power tool to develop environmental management strategies. Shi *et al*. described a web-based decision support system that uses land cover in several of its applications, including modeling tools and on-line data searches and inquires by watershed. This web-based system is used by a wide range of stakeholders, including communities, counties, state and federal agencies, universities, NGOs, and citizens. Watermolen emphasized the importance of land cover and spatial decision support tools for natural resource agencies, but raised a number of issues that prevent decision makers from using these data and tools in an effective manner. These and other issues are summarized in the following section.

ISSUES, NEEDS, OPPORTUNITIES

Certain issues, needs, and opportunities that were raised during the Summit are reflected in the papers found to this volume.

(1) *Standards and Data Policies*. With perhaps the exception of Europe, the lack of classification and data policy standards has reduced our ability to map land cover across country boundaries at moderate spatial resolution (e.g., 30 m). Lack of standardized classifications also precludes cross-country land cover change analyses and environmental assessments, especially those

that utilize indicators generated in part from land cover data. Moreover, the lack of consistent national policies on land cover data access and distribution prevents the acquisition of satellite and other imagery needed to develop cross-country land cover maps. One solution is to develop a nested classification framework similar to that proposed by Latham (this volume). Additionally, the USGS Earth Resources Observation and Science (EROS) Center is in the process of making the entire Landsat archive (Landsat 1 -7) available via its website for free.

(2) Continuity of Landsat and other Moderate Resolution Data. Land cover change detection and change analysis of indicators generated from land cover data require acquisition of data that are similar in spatial resolution and spectral properties from one period to the next. Landsat sensors have been the primary source of data for land cover change analysis, but there is concern that both Landsat 5 and 7 may fail before Landsat 8 is launched (projected for October 2011). Additionally, problems with Landsat 7 have lead organizations to use other moderate resolution imagery, including but not limited to the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), the Advanced Wide-field Sensor (AWiFS), the China-Brazil Earth Resources Satellite (CBERS), and SPOT. Although land cover data can be produced from these and other sensors, cost and limitations in historical spatial and temporal coverage make land cover change and trend analysis problematic.

(3) Methods to Assess the Accuracy of Land Cover Change Estimates. Most of the published literature on accuracy assessment methodologies have focused on individual land cover maps (see for example Stehman *et al.* 2003). However, land cover change detection introduces additional complexity into accuracy assessments and requires development of new methodologies.

(4) Derivative Data Important to Environmental Studies. Several participants at the Land Cover Summit emphasized the need to develop digital databases that are derivatives of land cover data, but especially land use. Additionally, derivative products, such as canopy height and structure provide a third dimension of land cover and vegetation important in a wide range of models, including watershed and hydrologic models, carbon storage and balance models, and habitat models. These derivative data offer great potential to improve environmental decision

making. The most significant advances in mapping these types of derivative data have been achieved by linking land cover programs with in-situ and census-based monitoring programs. Examples include crop-type (Latifovic and Pouliot) and vegetation height (Zhu *et al.* 2006). Another approach is to implement a nested, multi-tiered monitoring design similar to that being used in the United Kingdom (Haines-Young *et al.* 2006). Finer-scale landscape features are derived through random samples involving higher resolution imagery and/or in-situ field sampling.

(5) Downscale Land Cover Data. Many of the decisions affecting land cover and land use changes occur at the local and community scales. Watermolen concluded that existing land cover data, such as that provided from the NLCD, were marginally useful for environmental planning at local and community scales. He indicated that there was a need for finer-scale land cover data (spatial resolution and number of land cover classes) to increase the use of land cover data in local-scale planning. Spatial data exist for many places at relatively fine spatial scales (one to a few meters), but the cost of their acquisition and labelling (into land cover, vegetation, or land use types) limits creation of detailed land cover maps. However, increased access to inexpensive land cover labelling tools (http://edcintl.cr.usgs.gov/rlcm/index/php) and high resolution data may increase the generation and use of detailed land cover at local and community scales.

(6) Time to Delivery of Land Cover Data. Many participants raised the issue that it takes too long for land cover data to be produced and made available. For example, some NLCD data were 5 or more years old before they were made available. Similar problems exist for the Corine program. Improvements in image processing and reduced costs of image acquisition may decrease the time between data collection and delivery of land cover products, but national-scale land cover programs will continue to be challenged with this issue. One solution is for regional organizations to update (refresh) land cover databases using newer imagery as it becomes available. Each regional organization would be responsible for updating land cover within their region.

(7) *Validate Land Cover-Based Indicators*. Land cover-based metrics and indicators offer great potential to assess status and trends in environmental conditions at multiple scales based on land cover databases. They also hold great promise to assist in formulating alternatives to restore and maintain environmental quality. However, quantitative linkages between landscape metrics and indicators and ecological and hydrological processes are mostly lacking. Studies are needed to establish quantitative associations.

(8) *Identify and Preserve At-Risk Archives of Spatial and Land Cover Data.* Historical data are critical in establishing baseline conditions and trends in key environmental attributes and indicators. They also are critical in conducting retrospective studies or "back-casts" to develop predictive models of potential future changes. Therefore, there is a need to identify and protect spatial data archives, especially those that are a risk of being lost due to poor maintenance and/or the age of the materials.

(9) *Increase Involvement of Stakeholders in Development of Land Cover Data and Decision Support Tools.* Over the last 15 years, local communities and organizations have gained consider interest and capability in analyzing spatial data and applying the results to community and environmental planning. However, as pointed out Watermolen, dialogue between local communities, state agencies, and large land cover programs such as NLCD, have been limited. Partnerships involving stakeholders and agencies at multiple scales (Shi *et al.*) are one way to improve stakeholder input into the development and improvement of land cover programs.

(10) *Cost-Benefit Accounting for Land Cover.* Free, Internet-based access to land cover data has lead to an explosion in the use of land cover data for a variety of purposes. Despite great increase in use and demand, we lack an accounting of cost-benefit of comprehensive land cover products. Kleeschulte and Büttner reported that users of the Corine land cover database generated about 20 times more revenue than the cost of developing the database. Similar cost-benefit accounting systems need to be developed for other land cover programs in order to maintain their support.

CONCLUSION

The North American Land Cover Summit brought together a unique combination of scientists, practitioners, and stake holders who work at scales ranging from communities to the entire globe. The papers included in this volume identify a number of important uses of land cover data. They also identify limitations and needs related to the generation, distribution, and use of land cover data.

Developing and maintaining comprehensive land cover programs presents significant challenges that include acquiring imagery that is of sufficient spatial and temporal resolution to be relevant to a wide range of clients. At the same time, the producers of land cover data have resource constraints that limit the spatial scale and temporal frequency of the land cover data that can be delivered to the public. Maintaining a productive balance between relevancy to stake holders and resource constraints is the daily hard work of land cover programs. Despite limited resources, the demand and use of land cover data are increasing exponentially.

Finally, a substantive result of the Summit was the exchange of ideas and development of collaborative projects among participants. One specific outcome has been a shared project between Mexico, Canada, and the U.S. to monitor landscape change across North America. The hope is to develop similar collaborative projects through initiatives such as the Global Earth Observation System of Systems (GEOSS 2005).

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