Ecological Land Classification and Mapping of the Wrangell-St. Elias National Park and Preserve

By Torre Jorgenson, Ken Stumpf, Joanna Roth, Trish Miller, Eric Pullman, Tim Cater, Michael Duffy, Wendy Davis, Matt Macander, and Jess Grunblatt

Introduction

Ecosystems of the Wrangell-St. Elias National Park and Preserve (WRST) are highly diverse owing to extremely variable geologic terrain and to the large climate gradient that ranges from the wet Gulf of Alaska coast to the cold and dry continental climate of Interior Alaska. At 13.2 million acres, it is the largest park in the NPS system. Its national and global significance was recognized by its designation as a national park and preserve under the Alaska National Lands Conservation Act in 1980 and as a "World Heritage" site by the United Nations in 1979 that includes the Canadian Kluane National Park.

Ecological field surveys and landcover mapping are essential for evaluating land resources and developing management strategies that are appropriate to the varying conditions of the landscape. Land classification and mapping can be used to efficiently allocate inventory and monitoring efforts, to partition ecological information for analysis of ecological relationships, to develop predictive ecological models, and to improve techniques for assessing and mitigating impacts. To satisfy this wide range of needs, we used an integrated approach of inventorying and classifying ecological characteristics from the "bottom up" and used satellite image processing and environmental modeling to map landcover from the "top down." This integrated effort also required a team with diverse skills—ABR, Inc. conducted the intensive field inventory, ecological analysis and classification work, Geographic Resource Solutions (GRS) performed aerial surveys and satellite image processing, and NPS provided logistical support, data management, and product review.

The structure and function of natural ecosystems are regulated largely along gradients of energy, moisture, nutrients, which disturbance. These gradients are affected by climate, physiography, geomorphology, soils, hydrology, vegetation, and fauna, which are referred to as ecological components or 'state factors' (*Bailey 1996*). An ecological land classification also involves organizing ecological components in a hierarchy of spatial and temporal scales, where local-scale features (e.g., vegetation) are nested in regional-scale components (e.g., climate and physiography).

Methods

We used a multi-step process to sample and assess the variability in vegetation and other ecological characteristics in order to implement the ecological land classification segment of the overall mapping effort (*Jorgenson et al. 2008*). These included: (1) an integrated ecological land survey to characterize vegetation, soils, and other ecological characteristics; (2) classification of plant communities (floristic associations), soils, and local-scale ecosystems (termed "ecotypes") that integrate co-varying ecological

Photograph courtesy of T. Jorgenson

Photograph courtesy of T. Jorgenson

Figure 1. Field surveys were done in teams of two with a botanist and a soil scientist to document geomorphology, hydrology, soil stratigraphy, site chemistry, and vegetation structure and composition. Each plot required about an hour to complete.

properties; and (3) analysis of relationships among ecological components. Relationships among ecological components then were used in map development by incorporating a simplified integrated-terrain-unit approach based on climate zone, physiography, surface form, and vegetation. These are features which can be readily mapped or modeled. Physiographic units were derived from the existing landscape-level ecological maps (subsections) for WRST (*Swanson and Anderson 2001*) and are closely related to geology and geomorphology (*Winkler 2000*). Surface forms (primarily slope-related features) were derived from a digital elevation model (DEM). Vegetation classes were obtained from the landcover types developed by the spectral classification performed by GRS. This integrated-terrain-unit (ITU) approach, along with the landscape relationships developed from the analysis of the field survey information, allowed us to develop a set of map classes from remote sensing that better differentiated ecosystems and their floristic and pedologic characteristics.

We conducted ecological field surveys in WRST during 2004-2006 using a gradient-directed sampling scheme across climatic, geologic, and topographic gradients to sample the range of ecological conditions and to provide the spatially-related data needed to interpret ecosystem development. Intensive sampling was done along transects located in climatic subzones and major physiographic units, including coastal, glacial, riverine, lacustrine, lowland, upland, subalpine and alpine areas. Data were collected at 569 plots along 77 transects. Along each transect, four to 14 plots were sampled, each in a distinct vegetation type or spectral signature identifiable on aerial photographs. At each plot (~33 ft/10 m radius), descriptions or measurements were made of GPS location, geology, surface form (micro- and macrotopography), hydrology, soil stratigraphy, and vegetation cover (*Figures 1-3*).

Results and Discussion

For ecological classification, individual ecological components (e.g., geomorphic unit, Alaska Vegetation Classification) were classified using standard classification schemes for Alaska, but modified when necessary to differentiate unique characteristics in the study area. We identified 67 plant associations through multivariate classification techniques (*Figure 4*). Soils described at 423 plots were classified into 53 soil types (subgroup level), of which 15 were rare occurrences and not used in the analysis of soil-vegetation relationships. We used the hierarchical relationships among ecological components to develop 68 ecotypes that best partition the variation in ecological characteristics across the entire range of aquatic and terrestrial environments. Thirty-nine ecotypes were described from the boreal climatic zone, 23 from the maritime zone, and an additional six water and snow/ice classes. The most prevalent ecotypes included: Snow and Glacier (42.6%), Boreal Alpine Barrens (21.4% of area), Boreal Subalpine Willow and Birch Scrub (7.1%), Boreal Alpine Sedge-Dwarf Willow Meadow (4.1%), Boreal Alpine Dryas Dwarf Scrub (4.0%), Boreal Glaciated Barrens (3.7%), Boreal Upland White Spruce Forest (2.9%), Boreal Subalpine Spruce Woodland (2.8%), Maritime Glaciated Barrens (2.8%), and Boreal Lowland White Spruce Forest (2.6%).

Soil landscape classes, were developed by cross-tabulating soils with the ecotypes assigned for each plot. The cross-tabulation revealed that two to five closely related soil types usually were associated with two to three ecotypes. These groupings were used to identify 21 terrestrial and five water and glacier landscapes, which provide a set of 26 classes with broad application for resource management.

Multiple environmental site factors contributed to the distribution of ecotypes and their associated plant species, resulting in large differences among ecotypes. Mean surface organic-horizon thickness (an indicator of land surface age), anaerobic soil conditions, and distur-


Photograph courtesy of T. Jorgenson

Figure 2. Visual estimates of percent cover were made of all vascular plant species and the dominant nonvascular plants.


Photograph courtesy of T. Jorgenson

Figure 3. Soil profiles were described at each plot. Relationships among soil, vegetation, and other landscape components were used to develop rules to model the landcover map into a soils landscapes map.

Photographs courtesy of T. Jorgenson

Figure 4. Views of some of the wide range of ecosystem types in WRST. Photos left to right, in rows top to bottom: Boreal Alpine Dryas Dwarf Shrub, Boreal Glaciated Barrens, Boreal Subalpine Forb Meadow, Boreal Upland Aspen Forest, Boreal Lowland Black Spruce Bog, Boreal Riverine Dryas Dwarf Shrub and Barrens, Boreal Lacustrine Pondlilly, Maritime Upland Sitka Spruce Forest, and Maritime Coastal Angelica Meadow.

bance, ranged from 0 inches (0 cm) in alpine, coastal and riverine barrens to 5 feet (150 cm) in boreal lowland sedge-shrub fens and boreal lacustrine sedge meadows (*Figure 5*). Mean depth to rock, an indicator of surficial deposit depth and drainage, ranged from 0 inches (0 cm) in alpine barrens to >6.5 feet (>200 cm) in numerous ecotypes that occurred on thick, eolian surficial deposits. Permafrost presence varied in the boreal zone. Areas where permafrost was at >5 ft (>1.5 m) depth or was absent, included upland, subalpine, younger riverine, and lacustrine fens. In other lacustrine, lowland and alpine areas, permafrost was usually present at 1.6-3.3 ft (50-100 cm) depth, with a minimum depth of 6 in (15 cm). Permafrost was absent in the maritime zone, except for high elevation mountainous areas and areas underlain by glacial ice. Mean water depth (negative when below ground) for terrestrial ecotypes ranged from >-6.5 ft (>-200 cm) in Boreal Upland Sagebrush Meadow to 4 in (10 cm) in Maritime Coastal Sedge Meadow. Mean pH, which affects nutrient availability, ranged from 3.4 in Maritime Upland Tall Alder Shrub to 8.3 in Maritime Coastal Barrens. Mean electrical conductivity (EC), important for osmotic regulation in plants, ranged from 30 µS/cm in Alpine Lake to 37,500 µS/cm in Nearshore Water in aquatic ecosystems, and from 33 µS/cm in Maritime Alpine Barrens to 613 µS/cm in Maritime Coastal Sedge Meadow in terrestrial ecosystems.

Two types of map products were developed: landcover maps produced by GRS (*Stumpf 2007*) that use vegetation classes similar to the AVC classification, and ecosystem maps derived from landcover maps through rule-based modeling with ancillary maps. A landcover map was developed through classification of spectral characteristics of 11 Landsat scenes that covered the area. The process involved: (1) compiling and preprocessing 11 Landsat ETM scenes; (2) developing an unsupervised classification of the scenes to guide field surveys; (3) developing spectral training areas by sampling spectrally homogenous patches by helicopter; (4) developing a spectral database that included both spectral and vegetation characteristics; (5) evaluating similarities and differences among spectral signatures; (6) classifying the vegetation type of each spectral signature using cut-point rules from the AVC and the quantitative vegetation data; (7) performing a supervised classification of all the scenes using the classified signatures; and (8) reducing errors in the resulting scenes through rule-based modeling with ancillary data. These data included a DEM, winter Landsat scenes, and an ecosection map to help with regional differences. The resulting landcover map has four levels of aggregation from 123 calculated vegetation types to 11 major physiognomic classes.

We developed a set of three ecosystem maps from

Figure 5. Mean thickness (± SD) of surface organic layer, depth to rock (>15% coarse fragments) and depth of thaw for boreal ecotypes in Wrangell-St. Elias National Park and Preserve, 2004-2006. Sample sizes are in parentheses.

the GRS landcover maps, based on rule-based modeling. First, a map of integrated terrain units (ITUs) for WRST was developed by overlaying and combining the detailed 123 classes from the GRS landcover map and four terrain layers: climatic subregions (7 classes), physiography (floodplains, glaciers, coastal, and other), elevation (<800m, 800–1000 m, and >1000 m), and slope (< 7° and ≥7°). This initial set of 6,465 combinations, or ITUs, was aggregated into a reduced set of 66 ecotype map classes (two ground classes could not be mapped) based in large part on terrain relationships developed from analysis of field data (*Figure 6*). Third, we developed a soil-landscapes map with 25 classes derived from aggregating similar ecotypes with similar soils (*Figure 7*).

Ecotype distribution was affected by numerous landscape-level factors. Tectonics and regional mountain building have created barriers to atmospheric movement and topographic climate gradients, resulting in strong differences between boreal and maritime ecotypes. Oceanographic conditions have lead to salt-affected ecotypes along the coast and the prevalence of lowland ecotypes on the coastal plain. Soil pH and nutrient status are strongly affected by underlying bedrock types and geomorphology. Geomorphic environments associated with active sediment erosion and deposition create a wide range of soil conditions and disturbance regimes (*Figure 8*). Areas underlain by permafrost have impeded subsurface drainage, and the varying volumes of ground ice affect the magnitude of permafrost degradation. Fires are a strong modifier of ecosystem dynamics, particularly in interior areas vegetated by black spruce. Finally, recent spruce beetle infestations have severely damaged large areas of spruce forest.

Conclusions

This integrated ecological land survey approach has

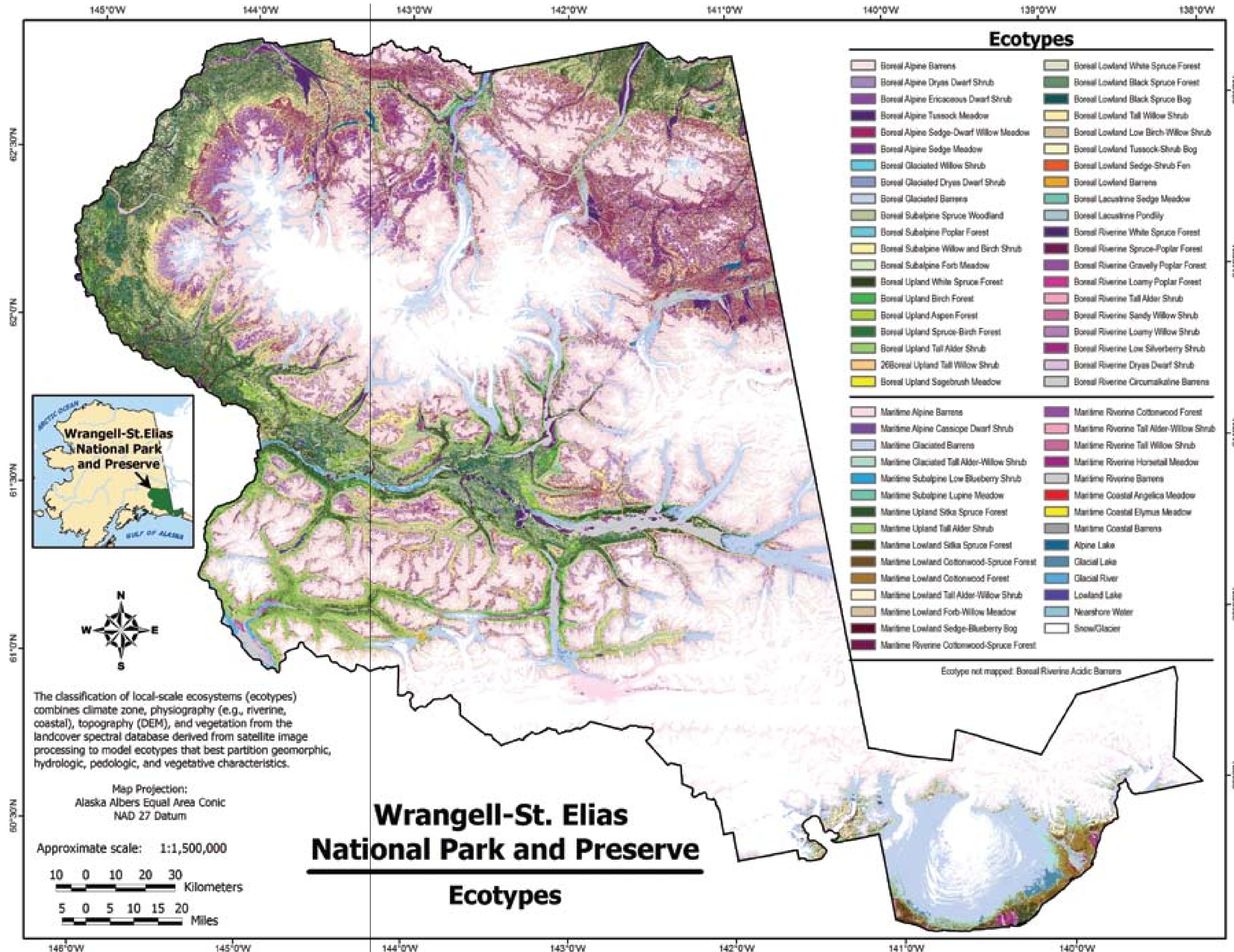

Figure 6. Map of ecotypes of the Wrangell-St. Elias National Park and Preserve.

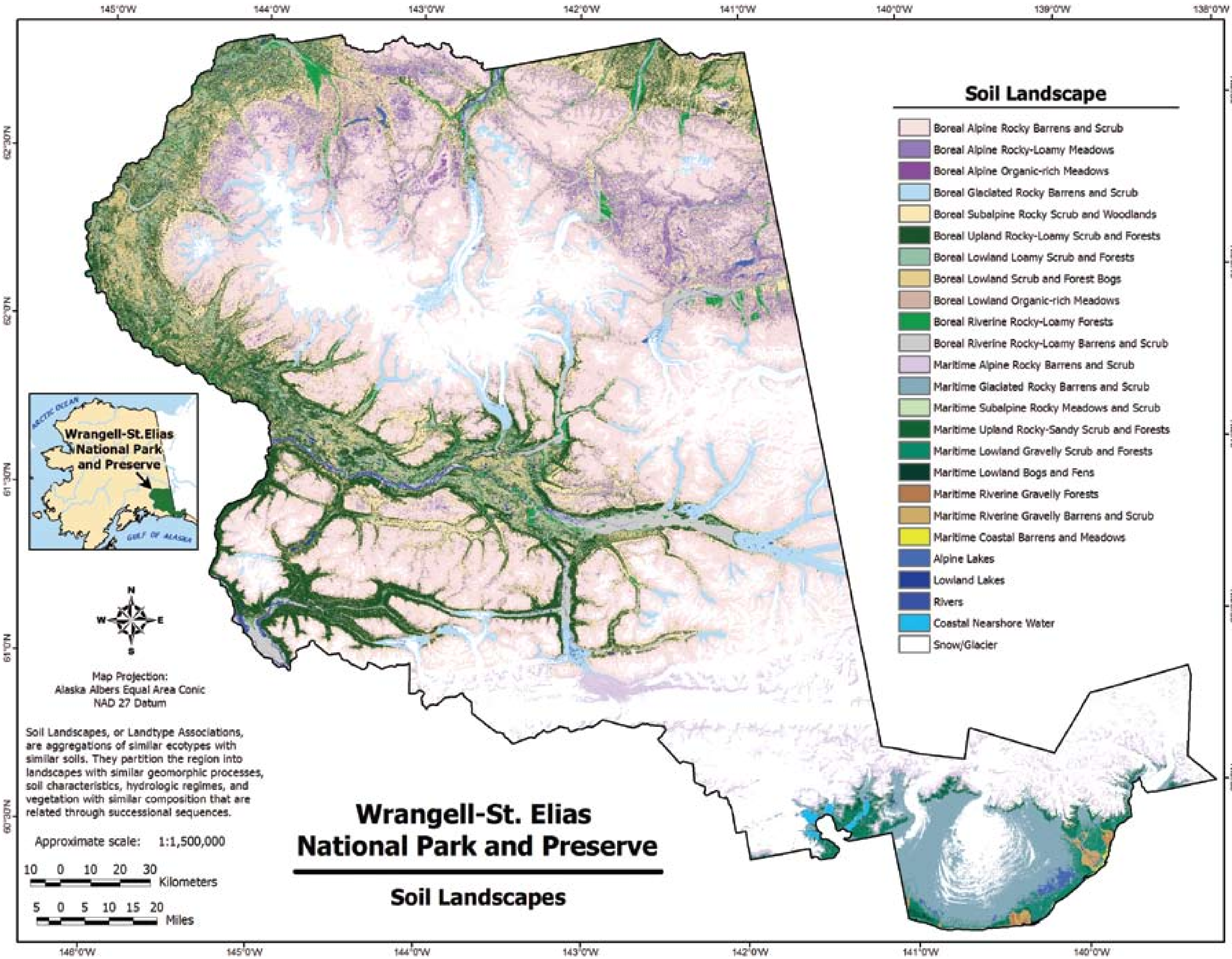

Figure 7. Map of soil landscapes of the Wrangell-St. Elias National Park and Preserve.

several benefits for understanding landscape processes and their influence on ecosystem functions. First, it analyzes landscapes as ecological systems with functionally related parts. This hierarchical approach, which incorporates numerous ecological components into ecotypes with co-varying properties, allows users to partition the variability of a wide range of ecological characteristics. Second, it recognizes the importance that geomorphic and hydrologic processes have on disturbance regimes, the flow of energy and material, and ecosystem development. Third, development of a spectral database for landcover mapping, which integrates spectral and field vegetation information for use in satellite image processing, facilitates the analysis of vegetation distribution across the landscape. Finally, the linkage of landcover maps to climatic, physiographic, and topographic variables in the development of ecosystem maps serves as a spatial database with differing ecological components. Construction of a map as a spatial database can help resource managers evaluate ecological impacts and develop land management strategies appropriate for a diversity of landscape conditions.

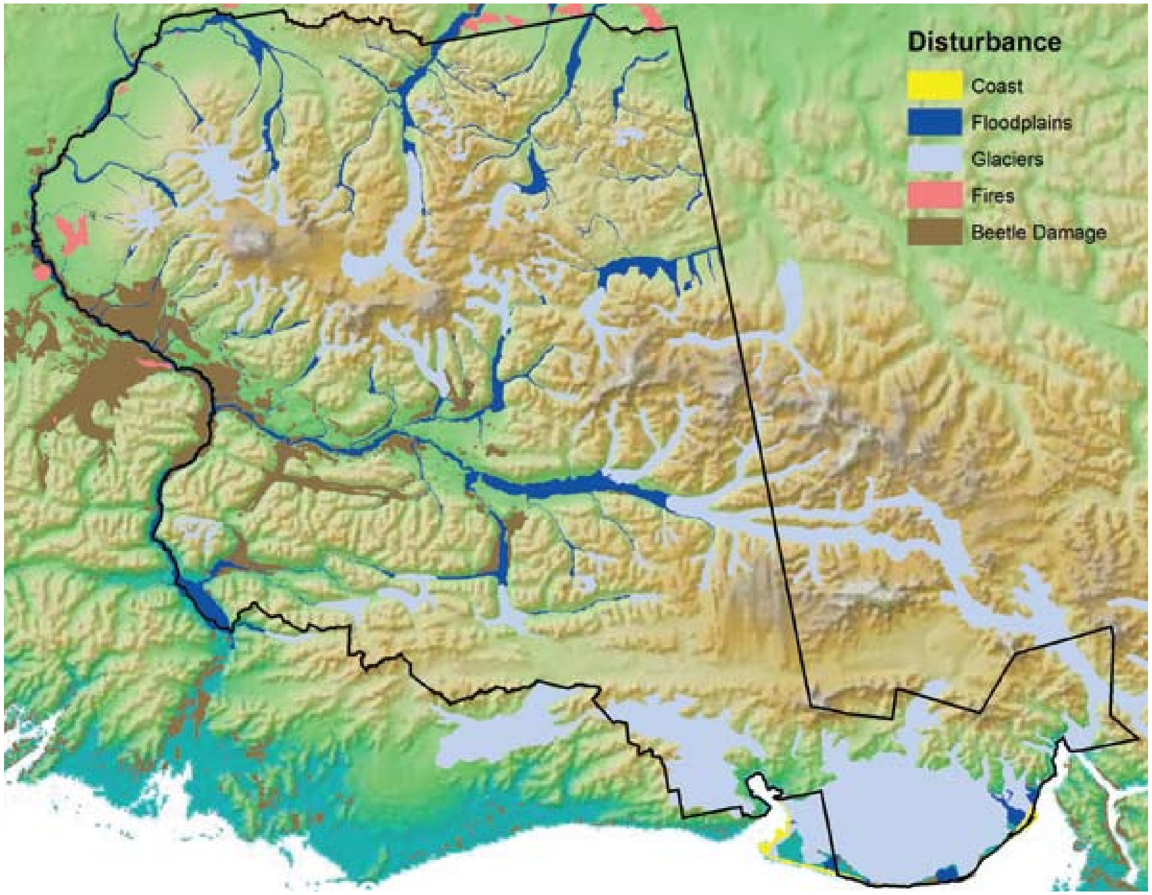

Figure 8. Distribution of large-scale disturbances associated with geomorphic processes, fires, and insects.

REFERENCES

Bailey, R.G. 1996.
Ecosystem Geography. Springer-Verlag. New York.

Jorgenson, M.T., J. Roth, T. Miller, E. Pullman, T. Cater, M. Duffy, W. Davis, M. Macander, and J. Grunblatt. 2008.
Ecological Land Classification and Mapping of the Wrangells-St. Elias National Park and Preserve. Natural Resource Technical Report, NPS/WRST/NRTR-2008/094. National Park Service. Anchorage, AK.

Stumpf, K. 2007.
Wrangell-St. Elias National Park and Preserve Landcover Mapping Project. Natural Resource Technical Report, NPS/WRST/NRTR-2008/095. National Park Service. Fort Collins, CO.

Swanson, D.K., and B. Anderson. 2001.
Mapping and delineation photographs: Ecological units of Wrangell-St. Elias National Park and Preserve, Alaska. Alaska Region Inventory and Monitoring Program, National Park Service. Anchorage, AK.

Winkler, G.R. 2000.
A Geologic Guide to the Wrangell-Saint Elias National Park and Preserve, Alaska. U.S. Geological Survey, Professional Paper 1616. Washington, DC.