J4G.2 PRELIMINARY EVALUATION OF VEGETATION CHANGE

ON A LARGE PRESCRIBED BURN IN ALASKA

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1. INTRODUCTION

The boreal forest of interior Alaska is primarily open, slow-growing spruce (*Picea* spp.) interspersed with occasional dense, well-developed stands and treeless bogs (Viereck 1973). Wildland fire is the major disturbance that influences vegetative succession, forest composition, and ecological processes on boreal upland sites (Foote 1983, Viereck 1983). Fire can remove the forest canopy and the organic duff layer of the forest floor. With increased sunlight and decreased duff insulation, the soil typically warms (thawing on permafrost sites), which accelerates nutrient cycling after a burn (Viereck 1973).

Although Native peoples historically used fire to maintain openings in the forest for hunting and other purposes across northern Canada (Lewis and Ferguson 1988) and Alaska (Roessler 1997), concerns over human- and lightning-caused fires increased with the start of the gold rush and influx of European inhabitants to Alaska starting in the 1890s (Jewkes 1999, p. 7). Fire suppression began near settlements and spread further into wildlands in the 1950s with technological improvements in detection and delivery of resources (Jewkes: 1999, 49-52). However, increasing costs of suppression and recognition of ecological values from fires led to fire management plans in the 1970s and 80s that assigned suppression options based on resources at risk (AIWFMP 1998).

In the mosaic of stand types and stand ages in boreal forest, conifer food webs are often characterized by invertebrates and their avian predators, whereas young deciduous or broadleaf forest is more generally the forage base for mammalian food webs (Pastor et al. 1996). Wildlife managers in boreal forest recognize that species diversity, and the abundance and productivity of wildlife, are often positively correlated to recent disturbance that creates early-successional habitats (Haggstrom and Kelleyhouse 1996). Maintaining or improving opportunities for hunting and wildlife viewing in interior Alaska requires active habitat management, particularly near populated, road-accessible areas (Haggstrom and Kelleyhouse 1996). Habitat enhancement must be effective, affordable, and acceptable to optimize use of limited financial resources and to address often conflicting public concerns over wildlife and associated land management practices. Conducting prescribed burns puts an onus on managers to objectively evaluate whether results of the treatment met the stated goals, thus justifying the expense and risk of the treatment.

The Alaska Department of Fish and Game (ADF&G), Division of Wildlife Conservation (DWC) has encouraged landowners and managers to allow wildland fires for habitat enhancement wherever possible. Since the mid-1990s, DWC has also received dedicated funds from the Alaska Legislature for enhancement and restoration of wildlife habitat by means of prescribed fire and

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mechanical treatments. Whereas stand-scale burns (≤12 ha) have been relatively expensive because of firefighter labor and other fixed costs ($790/ha), three landscape-scale burns of 2700-18,500 ha conducted by aerial ignition from helicopters in 1998 and 1999 were relatively inexpensive ($0.85/ha).

2. EAST FORK PRESCRIBED BURN

The primary goal of the East Fork burn in eastern interior Alaska was to produce combination of severe and moderate burn intensities to restore age diversity among vegetative types that would benefit wildlife species needing early to mid-successional habitat. A secondary goal was to reduce the continuity of crown fuels, thus reduce the risk of unmanageable, expensive, and potentially dangerous wildland fires that would threaten resources on adjacent lands.

A maximum allowable perimeter (MAP) of 158,000 ha defined the area within which prescribed fires could spread without need for suppression action. Four areas of 34,290 ha combined were delineated for prescription and operations planning within the MAP. The objectives of the burn (Kraemer and Haggstrom 1998, 4-5) were to "(1) treat 50-70% of each unit under weather and fuel moisture conditions where duff removal will range from moderate to maximum; (2) kill ≥50% of the black spruce occurring in the final burned area with a burn of varying intensities where duff removal is close to mineral soil to allow shrub understory component to proliferate by seeding; and (3) kill ≥50% of the above ground stems of black spruce, aspen, poplar and willow occurring in the final burn with less fire intensity to promote root or basal sprouting." The plan allowed burning between 1 June and 30 September (Kraemer and Haggstrom 1998).

The 1998 East Fork burn was the first landscape-scale prescribed burn in Alaska to our knowledge. Our evaluation goal was to conduct a vegetative change detection to determine how much area burned within the fire perimeter and how vegetation types were changed. We chose to compare use of an existing media within our equipment capabilities (aerial photography) to use of high-resolution satellite imagery for cost-benefit evaluation and a multi-view approach that would enhance data collection and vegetative inference (Lillesand and Kiefers 1994, p. 36).

Our objectives were to obtain aerial photography and satellite imagery of the burn study area; make a GIS base map for the study area; classify vegetation types with a verified error rate; determine vegetation type change by comparing pre-burn aerial photography to post-burn photography and imagery; determine influence of elevation, slope, and aspect on vegetation type change; and discern ability to distinguish among deciduous shrub types in early post-burn succession by use of remote sensing. This preliminary report describes the early stages of defining the burned area and producing the initial vegetative classification.

3. STUDY AREA

The prescribed burn was conducted in the Fortymile River drainage of eastern interior Alaska about 75 km northeast of Tok and 40 km west of the Yukon border (63° 43' N, 141° 52' W). The area is uninhabited public land, and developed access is minimal. The MAP was centered on part of a ridge system oriented roughly northeast from the confluence of the East Fork and the Dennison Fork rivers. Terrain varies from the rivers confluence at 615 m through rolling hills and steep ravines to rock peaks at 1410 m.

Vegetation in the burn area was typical of Alaskan boreal forest and varied with elevation, aspect, and drainage (Viereck et al. 1992). Expanses of black spruce (*Picea mariana*) with tamarack *(Larix laricina*) and paper birch (*Betula papyrifera*) dominated cooler, wetter sites, whereas white spruce (*Picea glauca*), quaking aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*) occupied warmer or drier sites. Substantial areas were black spruce-needleleaf woodland with 10-25% canopy cover (Viereck et al. 1992, 20-21). Mosaics of shrub and herbaceous communities occurred among forested areas. Tree line occurred at about 1400 m with alder (*Alnus crispa*), bog birch (*B. glandulosa*), dwarf birch (*B. nana*), and willow (*Salix* spp.) typical in the transition zone from forest to alpine tundra. We have not yet sampled tree age to establish burn history on the site.

The prescription for the burn (Kraemer and Haggstrom 1998) was prepared using the Canadian Forest Fire Danger Rating System and the 1993 Canadian Fire Behavior Prediction System as tools to track forest fuel moistures, predict spread rates, and estimate burn intensities (Taylor et al. 1993). The prescription was intended to allow ignition under a wide range of mid-summer burning conditions while avoiding the extremes: conditions so marginal that only a light surface burn is obtained and conditions so flammable that a very severe burn is obtained over most of the area.

After no precipitation the previous 8 days, ignition occurred within prescription parameters on 21 July 1998 (observations: relative humidity 33%, wind 18 km/hr, Duff Moisture Code 49.5, Drought Code 246; calculations: Initial Spread Index 9.7, Buildup Index 67.3, Fire Weather Index 25.2). A helicopter was used to distribute plastic spheres containing potassium permanganate that was activated by injection of ethylene glycol to produce a delayed exothermic reaction.

Most of burning occurred within a few hours of ignition, and 14.7 mm of precipitation fell the next day. A strong convection column created by the firing carried smoke to an estimated 8000-12,000 m altitude and helped hold the fire inside the intended burn area by creating surface winds toward the column base. Our initial impression was a favorable result of unburned areas interspersed among burned areas of varying severity with the vast majority of the 18,540 ha final perimeter achieved on 21 July. An aerial observer on 5 August noted numerous points of smoke on the perimeter and within the interior, with fire visible only on the northwest corner (R. Kraemer 1998, Alaska Division of Forestry [DOF] files). Planning and implementation costs for the fire specialists, excluding wildlife staff time for planning, was $1.10/ha for this burn.

4. METHODS

Pre-burn vegetation was characterized from commercially available 1:63,360-scale color-infrared (CIR) aerial photos taken on August 1981 and July 1983. Post-fire succession was inferred from satellite imagery and CIR photos obtained in 2002. We obtained a 272 km^2 Quickbird image (2.6 m multispectral, 0.6 m panchromatic; DigitalGlobe™, Longmont, Colorado) of the study area on 15 September. We subsequently purchased a 25 km^2 Quickbird image archived from 14 July for more direct phenological comparison to photos on a subset of the larger image. We took photos at 1:12,570 scale on 30 July with a Zeiss RMK-A mapping camera (153 mm focal length) using Kodak Aerochrome III CIR film 1443©. All photos were scanned at 14 microns to produce pixels of 0.33 m that subsequently can be re-sampled to a lower resolution.

In October 2002 we used a helicopter to obtain global position system (GPS) fixes for ground control points (GCPs). We ortho-rectified the satellite image for a base map using Geomatica Orthoengine (PCI Geomatics, Richmond Hill, Ontario). Subsequent field visits by helicopter to begin verifying reflectance signatures of vegetation, burned ground, and exposed soil occurred on 27 June and 28 July 2003. Standing fire-killed trees and uneven terrain afforded few landing spots, which hindered ground access. On the first visit we hovered over several pre-selected sites of interest across the entire scene to obtain GPS fixes, and on the second visit we walked a circuit around a landing spot in the July imagery subset to obtain precise fixes.

We are developing a vegetative classification with eCognition Vers. 3.0 (Definiens Imaging, Munich), a PC-based software that performs object-oriented analysis on image files up to 2GB. Objects were derived by segmenting fused and multispectral Quickbird imagery (bands 1- 4) based on spectral homogeneity and shape. The resulting objects were then classified on the resulting layer values (i.e., mean band 1) for the object. A normalized difference vegetative index (NDVI) is commonly used to define vegetative response after fire disturbance in boreal forest (Kasischke and French 1995). We added an NDVI layer (4-3)/(4+3) to aid the segmentation process and create objects that corresponded more closely with the shape of the vegetated areas. To date our preliminary classification work has focused on trials with segmentation parameters to examine tradeoffs between processing time and polygon resolution.

5. RESULTS

The burn perimeter derived from the image (Fig. 1) was verified using the 2002 photos, and we are currently developing the classification to define unburned inclusions for estimating the proportion of area within the perimeter that actually burned. Our initial classification of the July 2002 scene attempted to distinguish robust growth of herbaceous and deciduous woody vegetation following the burn from conifers and bare soil (Fig. 2). This initial product will help us focus locations for field work on mapping community types and distinguishing among deciduous woody species.

6. DISCUSSION

The lag of four growing seasons between the burn date and remote sensing acquisition hindered detection of recently-burned ground but allowed sufficient regeneration of shrubs and trees to influence spectral signatures. The Quickbird resolution permits classification of habitats with small-scale heterogeneity and objects on the scale of individual trees or shrubs. The image discerned 3-4 m diameter patches of grass and herbaceous species such as fireweed (*Epilobium angustifolium*), which provide abundant post-fire forage for rodents that are the base of avian and mammalian food webs in boreal forest (Paragi et al. 1996). However, one tradeoff of higher resolution imagery is that the off-nadir angle of acquisition detects subtle shadows (particularly on taller objects) that complicate segmentation choices for constructing polygons.

Satellite imagery and aerial photography each have practical advantages and constraints. Imagery provides seamless digital coverage of large areas in four color bands that can be geo-rectified with a few GCPs. We had desired acquisition of the imagery during 15 July to 15 August to correspond to pre-burn CIR photos for change detection during similar phenology. However, tolerances for cloud cover ($\leq$20%) and competing orders delayed successful Quickbird acquisition until mid-September, after vegetative senescence and substantial leaf fall.

Aerial photography should have a reduced effect from atmospheric contamination by natural and anthropogenic sources because of a shorter path from sensor to target than satellite imaging. Also, local flight crews can readily assemble in response to good conditions at specific locations. Disadvantages to high-resolution photography include only three color bands and a smaller image footprint that requires several photos to assemble a mosaic. Base maps are commonly absent in remote regions of Alaska, so each photo requires GCPs. Producing a mosaic from flightlines overlapping in opposite directions can be challenging because of solar angle and shadows.

The digitized CIR photos cost \$3.25/km^2 without overlap or \$21/km^2 with 60% endlap and 30% sidelap for stereoscopic viewing, whereas the Quickbird imagery was \$30/km^2, including the ephemeris data needed for image processing. The smaller Quickbird scene from July 2002 was \$24/km^2 because it was a public archive. Our use of existing equipment (camera and aircraft) to produce film negatives that were digitally scanned likely compromised resolution compared to contracting for digital photography; however, the latter would be a substantially greater expense (estimated at \$120/km^2 for 4 m multispectral / 0.6 m pan with GCPs).

Data storage and software capabilities to handle large files are important considerations as imagery resolution increases. We chose a photography scale of roughly 1:12,000 because it provides high resolution, but it results in large file size (900 MB per frame). The file size of the full Quickbird scene fused with pan was 7.0 GB at 16 bit or 3.5 MB at 8 bit. To improve processing time, we divided the full scene into nine parts for analysis. Definiens Imaging is presently working with DigitalGlobe to upgrade eCognition for accommodating larger files and processing more polygons in a classification (currently limited to 2 million polygons in Version 3.0 of eCognition).

As part of evaluating conversion of conifer-dominated stands to early-seral broadleaf forest for habitat enhancement and fuels management, we hope to learn how terrain features (slope, aspect, elevation) influenced vegetation response under the fire weather conditions of this burn. We intend to analyze the imagery with a 30 m digital elevation model to produce predictive models from terrain features. We also seek to find the extent to which we can discern among deciduous woody genera (*Alnus, Betula, Populus, Salix*) for quantifying browse distribution.

Because enhancement of wildlife habitat was the primary intent of this burn, we intend to monitor response of selected wildlife where remote sensing is feasible and the scale of inference is appropriate. We have already noted the diggings of yellow-cheeked voles that are a preferred prey of martens (*Martes americana*) in burns (Paragi et al. 1996). Use of aircraft to conduct track counts of forest carnivores such as lynx (*Lynx canadensis*) may also be feasible for comparing habitat selection between the burn and adjacent forest of different age and species composition (Paragi et al. 1997). We also intend to monitor changes in moose (*Alces alces*) distribution caused by the burn through surveys from fixed-wing aircraft in early winter to quantify age and sex composition of the herd.

7. ACKNOWLEDGMENTS

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Future progress reports on this project will posted on the DWC website (http://www.state.ak.us/adfg/wildlife/wildmain.htm) under Wildlife Management.

8. LITERATURE CITED

AIWFMP. 1998. Alaska interagency wildland fire management plan. 61 p. (unpublished document; contact author for copy.)

Foote, M.J. 1983. Classification, description, and dynamics of plant communities after fire in the taiga of interior Alaska. Res. Pap. PNW-307, U.S.D.A. Forest Service, Portland, OR, 108 pp.

Haggstrom, D.A., and D.G. Kelleyhouse. 1996. Silviculture and wildlife relationships in the boreal forest of interior Alaska. For. Chron., 72:59-62.

Jewkes, H.A. 1999. History of fire control in Alaska. M.S. Thesis, Univ. Alaska, Fairbanks, 153 p.

Kasischke, E.S., and N.H.F. French. 1995. Locating and estimating areal extent of wildfires in Alaskan boreal forests using multiple-season AVHRR NDVI composite data. Remote Sens. Environ., 51:263-275.

Kraemer, R., and D.A. Haggstrom. 1998. Prescribed burn plan for the East Fork of the Dennison Fork of the Fortymile River. Alaska Dept. Fish and Game/Alaska Dept. Natural Resources, Fairbanks, 29 pp. (unpublished document; contact author for copy.)

Lewis, H.T. and T.A. Ferguson. 1988. Yards, corridors, and mosaics: How to burn a boreal forest. Human Ecol., 16:57-77.

Lilliesand, T.M. and R.W. Kiefer. 1994. Remote sensing and image interpretation. 3rd ed. John Wiley and Sons, 750 pp.

Paragi, T.F., W.N. Johnson, D.D. Katnik, and A.J. Magoun 1996. Marten selection of postfire seres in the Alaskan taiga. Can. J. Zool., 74:2226-2237.

Paragi, T.F., W.N. Johnson, D.D. Katnik, and A.J. Magoun 1997. Selection of postfire seres by lynx and snowshoe hares in the Alaskan taiga. Northwest. Nat., 78:77-86.

Pastor, J., D.J. Mladenoff, Y. Haila, J. Bryant, and S. Payette. 1996. Biodiversity and ecosystem processes in boreal forest. Pages 33-69 in H.A. Mooney, J.H. Cushman, E. Medina, O. Sala, and E-D. Schulze, editors. Functional roles of biodiversity: a global perspective. SCOPE 55 (International Council of Scientific Unions and United Nations Environmental Program). John Wiley and Sons, 493 pp.

Roessler, J.S. 1997. Disturbance history in the Tanana River basin of Alaska: Management implications. M.S. Thesis, Univ. Alaska, Fairbanks, 220 p.

Taylor, S.W., R.G. Pike, and M.E. Alexander. 1996. Field guide to the Canadian forest fire behavior (FBP) system. FRDA Handbook. B.C. Ministry of Forests and Northern Forestry Centre, Victoria. 60 pp. + preface.

Viereck, L.A. 1973. Wildfire in the taiga of Alaska. Quat. Res., 3:465-495.

Viereck, L.A. 1983. The effects of fire in black spruce ecosystems of Alaska and northern Canada. Pages 201-220 in R.W. Wein and D.A. Maclean, ed. The role of fire in northern circumpolar ecosystems. John Wiley and Sons, 322 pp.

Viereck, L.A., C.T. Dyrness, A.R. Batten and K.J. Wenzlick. 1992. The Alaska Vegetation Classification. Gen. Tech. Rep. PNW-GTR-286, U.S.D.A. Forest Service, 278 pp.

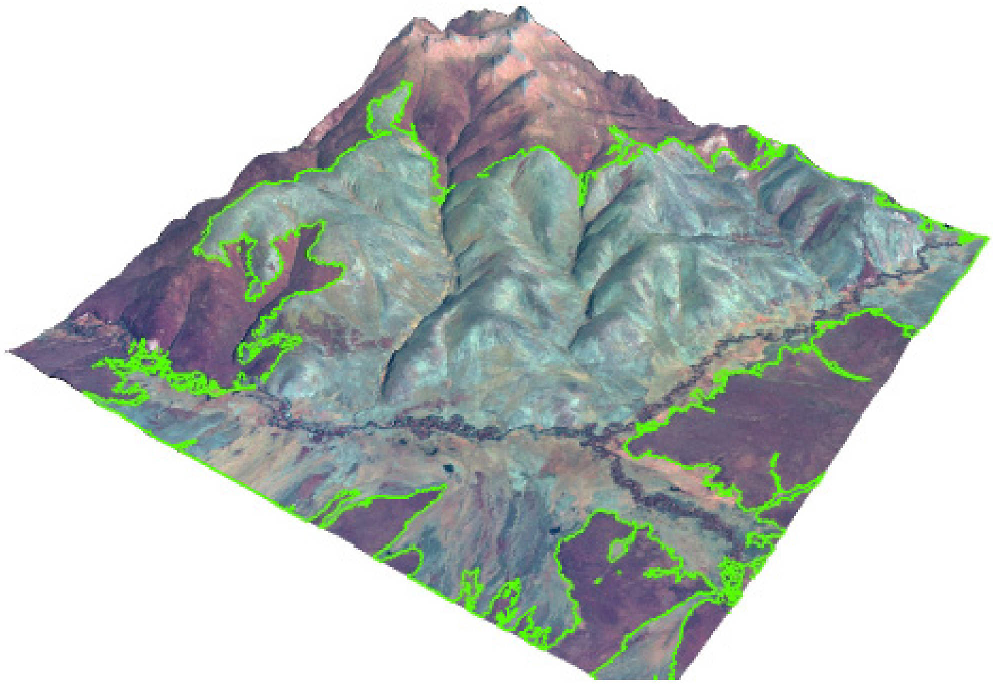

Fig. 1. A 272 km^2 Quickbird scene from 15 September 2002 showing the perimeter of the 18,540 ha East Fork prescribed burn conducted 21 July 1998 in eastern interior Alaska. The image was draped over a 60 m digital elevation model; the top of the image is northeast.

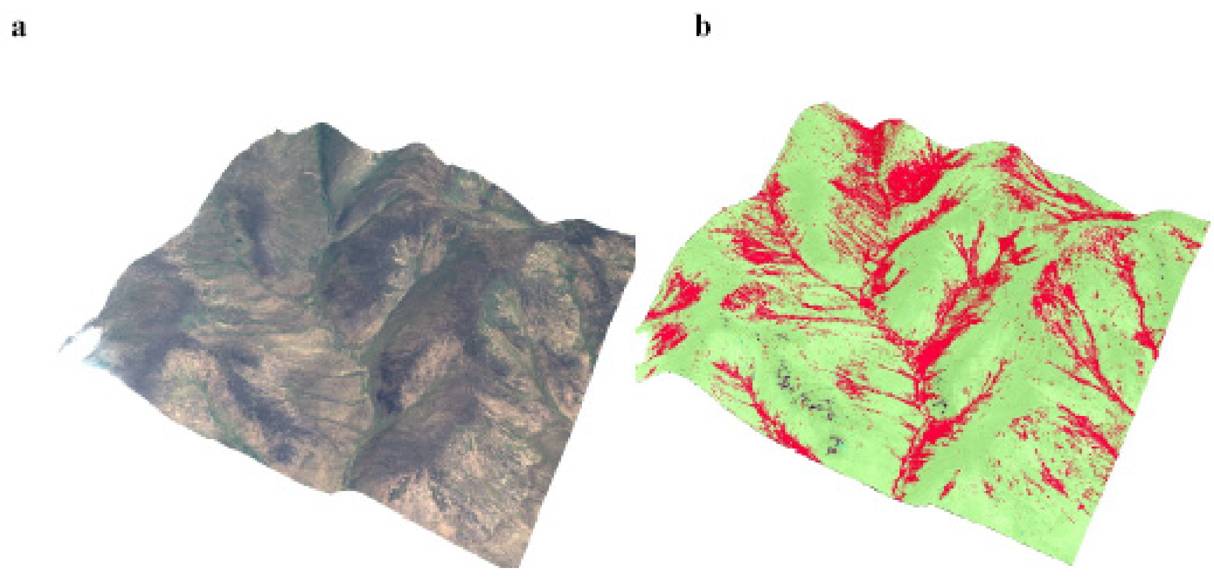

Fig. 2. Raw imagery (a) and a preliminary classification (b) of a 25 km^2 Quickbird scene on 14 July 2002 from within the 1998 East Fork prescribed burn in eastern interior Alaska. The images were fused with 0.6 m panchromatic, and a NDVI was applied to highlight (red) the post-fire response by herbaceous and deciduous woody species in Figure 2b. The image was draped over a 60 m digital elevation model; the top of the image is northeast.