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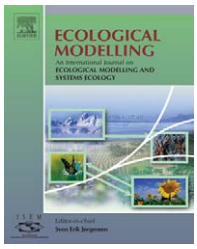

Habitone analysis of quaking aspen in the Utah Book Cliffs: Effects of site water demand and conifer cover

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ABSTRACT

Quaking aspen (*Populus tremuloides* Michx.) is the most widely distributed tree species in North America, but its presence is declining across much of the Western United States. Aspen decline is complex, but results largely from two factors widely divergent in temporal scale: (1) Holocene climatic drying of the region has led to water limitation of aspen seedling recruitment, and (2) anthropogenic fire suppression during the 20th century has allowed shading of aspen clones by fire-intolerant conifers. These processes interact variously and often diffusely, but traditional, binary habitat mapping approaches can only resolve their net effect after complete loss of aspen patches. To provide information for preemptive land management in the Book Cliffs – a biogeographic link between the Utah and Colorado Rocky Mountains and a location experiencing aspen decline typical of the region – we developed a regression-based generalization of niche/habitat analyses that is usable in GIS, is capable of detecting anomalies in cover before complete patch conversion, and can be incorporated smoothly into the decision-making process. We estimated the realized Hutchinsonian niche of quaking aspen to potential evapotranspiration (PET) by nonparametric, likelihood-based regression techniques, projected (continuous) values of aspen's niche expectation and uncertainty geographically, and correlated differences between observed and expected aspen cover to remotely sensed conifer cover. Results confirm the strong constraint of site water demand on aspen cover and suggest that conifer cover decreases aspen cover beneath its expectation given the PET environment. Compared to sites without quaking aspen, our aspen sites have lower PET in every month of the growing season, but the difference increases over the growing season as drought effects become more extreme. Superimposed on this broader environmental constraint, conifer cover displaces aspen cover and shows a positive correlation with model deviance ($r = 0.344$). Ultimately, the thematic information conserved by our approach allowed us to resolve detailed rasters of management potential and map a modest potential increase of aspen cover – 14.63 ha (0.14%) of the study area, or +2.46% of current aspen cover – within one management cycle.

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1. Introduction

With a range extending from the Arctic Circle to the tropics, quaking aspen (*Populus tremuloides* Michx.) is the most widely distributed native tree species in North America (Little, 1971). However, aspen coverage in the Intermountain region of the Western United States is in apparent decline (Table 1) due to factors acting at disparate spatial and temporal scales. Aspen decline is most often attributed to Holocene climate change (Baker, 1925; Cottam, 1954; Maini, 1968) and succession to conifers following 20th century fire suppression (Baker, 1925, 1949; Meineke, 1929; Jones, 1967; Loope, 1971; Schier, 1975; Mueggler, 1976; Jones and DeByle, 1985), but also to overgrazing by wild and domestic ungulates (Gruell, 1970; Krebill, 1972; DeByle, 1985; Kay, 1993, 1997, 2001a, 2001b, 2001c, 2001d; Hart and Hart, 2001a, 2001b; Rolf, 2001a, 2001b) and disease (Gruell, 1970; Krebill, 1972; Hart and Hart, 2001a, 2001b). Of special interest to local human populations, substantial hydrological (Gifford et al., 1984), aesthetic and recreational (Johnson et al., 1985), and biodiversity (Kay, 1997) amenities will likely be forfeited with further losses of the region's aspen cover.

Quaking aspen's climatic environment appears to be the broadest constraint on its geographic distribution. Its seeds are short-lived, and its seedlings have a narrow tolerance with respect to temperature and moisture (Maini, 1968). In the Intermountain West, soil moisture conditions favoring germination and recruitment occur extremely rarely, and so disturbance-triggered asexual reproduction, or "suckering," is credited with maintaining extant quaking aspen coverage (Baker, 1966). In many locations, chronic disturbances such as fire, wind-throw, disease, and insect outbreak result in the persistence of large, spatially discrete aspen patches. These patches are composed of one or more clones, each ranging from a few square meters to nearly 200 ha (Baker, 1976).

Quaking aspen is shade-intolerant (Baker, 1949), and adult stem mortality has been attributed to shading by conifers (Loope, 1971; Schier, 1975). In the absence of canopy disturbance sufficient to remove competitors and trigger suckering, sites require from 70 to 200 years (Baker, 1925; Meineke, 1929; Jones, 1967) to convert from aspen- to conifer-dominated communities (Mueggler, 1976). Thus, by removing wildfire's constraint on coniferous tree establishment and its triggering effect on aspen's asexual reproduction, 20th century fire suppression programs appear to have exacerbated aspen decadence and type-conversion (Jones and DeByle, 1985).

Realizing the importance of aspen decline to hydrologic, biological, aesthetic, and other land values, land managers seek means of assessing and rehabilitating aspen over large areas in the Intermountain West. These goals require flexible, informative means of assessing aspen's cover and potential over large areas, while retaining as much information as possible on aspen cover at individual sites. To this end, we report an analysis of quaking aspen's relationship to site water demand and conifer encroachment in the Book Cliffs of Utah (Fig. 1), an area that is both biogeographically important to aspen's range and ideally suited for studying the relationship between climatic and successional constraints. These constraints operate at vastly different spatial and temporal scales, and their interaction should be most apparent on the receding edges of aspen's biogeographic range (Brown, 1995).

We studied the effects of these constraints on aspen in the Book Cliffs hierarchically, in a regression-based habitat framework, which we refer to as habitone analysis. Although we were at first reluctant to beleaguer ecologists with yet another term, we found the term "habitone" an intuitive contraction between "habitat" and "ecotone" and expedient in comparison to repeated explanation of its divergence from binary, classification-based habitat analyses. Habitone analysis draws from conventional niche/habitat ordination and classification techniques, but is regression-based and supports ecological interpretation of model validation, and so is therefore a novel enhancement to be distinguished from these approaches.

2. Methods

2.1. Study area

The 10,450-ha study area is located in the Book Cliffs near the Utah-Colorado (U.S.A.) border (Fig. 1), on the steeply dissected, north-facing slope of the southern crest of the Tavaputs Plateau. In the Ecoregion framework (Bailey, 1998; McNab and Avers, 1994), the 2000- to 3000-m-elevation Tavaputs Plateau is an approximately 230-km latitudinal band that descends gently into the semiarid Uinta Basin to the north and drops abruptly into the arid Northern Canyonlands of the Colorado Plateau to the south. Bounded longitudinally by these comparatively arid regions, the Tavaputs Plateau forms the most

Table 1 – Current and historical (i.e., prior to European settlement) aspen cover in the Interior West (from Bartos and Campbell, 1998a)

State	Current aspen (ha)	Historical aspen (ha)	Decline (ha)	Decline (%)
Colorado	444306	875201	430896	49
Utah	571189	1172274	601084	51
New Mexico	56091	456671	400580	88
Wyoming	81586	174584	92998	53
Arizona	11604	288352	276748	96
Idaho	248608	643819	395175	61
Montana	84418	236270	151851	64
Nevada	47507	No data	–	–
Total	1545309	3847170	2349332	60