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Examination of Fire-Related Succession Within the Dry Mixed-Grass Subregion of Alberta With the Use of MODIS and Landsat

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Abstract

Fire is an important disturbance process historically present across the northern Great Plains. Previous research from northern dry mixed-grass prairie suggests that C4 (warm season) grasses replace C3 (cool season) climax species with increasing fire, particularly in the spring. This hypothesis was tested at a landscape scale at Canadian Forces Base Suffield Alberta, by exploring the relationship between ecosystem states (C3 dominant, C3/C4 codominant, C4 dominant) inferred from a MODIS multitemporal plant functional type classification (pseudo R^2: 0.598, overall accuracy: 0.74) and interyear fire history digitized from the Landsat archive (1972–2007). Probit regression showed that succession processes were different between range sites, where C4-dominant pixels were positively related to fire ($P < 0.001$, pseudo $R^2 = 1$) and completely replaced C3-dominant pixels on loamy range sites after 14 fires in 36 yr. In contrast, C3- and C3/C4-codominant pixels were related with fire on Blowouts range sites ($P < 0.001$, pseudo $R^2 = 1$), where C3/C4-codominant pixels replaced C3-dominant pixels with increasing fire. Finally, there were no statistically significant relationships between ecosystem states and fire for Sands range sites. Analysis of recovery showed that after loamy pixels experienced three to six fires in 18 yr followed by 18 yr of rest, C3-dominant pixels were reduced by over 30% compared to unburned pixels. Finally, intrayear fire timing (2001–2009) was explored with the use of Wilcoxon signed-rank tests between the spatial extent of spring and summer fires, with the use of MODIS burned-area data. Results indicate that fires are not limited to the spring season ($P < 0.05$), but occur across the entire growing season. Although fire timing does not appear to play a role in driving succession, this ecosystem is generally sensitive to repeated fire, with recovery of C3 climax species taking decades.

Key Words: dry mixed grass, fire ecology, plant functional type, rangeland, succession

INTRODUCTION

Fire is a landscape-level disturbance historically present across the Great Plains, serving an important role in nutrient cycling, modifying vegetative structure, and plant succession (Daubenmire 1968; Wells 1970; Wright and Bailey 1982; Bragg 1995; Anderson 2006). However, human activities have altered fire regimes in the Great Plains (Hart and Hart 1997) such that the extent, frequency, and timing of fires are departed from their historical norms (Leach and Givnish 1996; Umbanhowar 1996). Because of a lack of historical information, experimental research is important in guiding the management of fire in rangelands (Scheintaub et al. 2009).

The effects of fire are different among rangeland ecosystems in North America. In tall-grass prairie (dominated by warm-season grasses with the use of the C4 photosynthetic pathway), fire has been shown to increase productivity (Wright and Bailey 1982; Briggs and Knapp 1995) and alter species composition (Abrams and Hulbert 1987; Stueter 1987; Collins and Gibson 1990). However, in northern mixed-grass prairie (dominated by cool-season grasses using the C3 photosynthetic pathway), fire can reduce productivity (Clarke et al. 1943; Redmann 1978), modify the ratio between C3 and C4 species (Steuter 1987), and the recovery of water-conserving litter can take many years (Dix 1960).

In northern mixed-grass prairie, regressive changes in species composition (retrogression; Glenn-Lewin and van der Maarel 1992) have been observed as a result of fire. In northern mesic mixed-grass prairie, fire reduced the cover of C3 climax species, including fescue (*Festuca hallii* [Vasey] Piper; Gerling et al. 1995), and wheatgrass (*Agropyron* [Hook.] Scribn.; Coupland 1973). Furthermore, spring fires have been shown to stimulate the production of western wheatgrass (*Pascopyrum smithii* [Rybd.] A. Love) and the warm-season grass blue grama (*Bouteloua gracilis* [Willd. Ex Kunth] Lag. Ex Griffiths; White and Currie 1983), particularly as a result of repeated fire (Shay et al. 2001). Within northern dry mixed-grass prairie, Vermeire et al. (2011) showed that western wheatgrass replaced needle and thread (*Hesperostipa comata* [Trin. & Rupr.] Barkworth) as the dominant species, following a single fire. In contrast, Erichsen-Arychuk et al. (2002) found that a single summer fire and drought did not affect the cover of needle and thread, but did differentially affect the cover of wheatgrass; wheatgrass cover was higher in burned than unburned treatments on upland sites, but the reverse was found on lowland sites.

Fire-related retrogression in northern mixed-grass prairie may be directly related to the selective suppression of a species or functional group (e.g., C3 species) based on fire timing, particularly spring fires (Anderson et al. 1970; White and Currie 1983; Schacht and Stubbendieck 1985; Redmann et al. 1993; Shay et al. 2001), or indirectly through the modification of structure (litter) important for conserving scarce moisture (Dix 1960; Redmann 1978; Willms et al. 1986; Dormaar and

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