Long-term Trends in Wooded Draw Vegetation in the North Dakota Badlands

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Abstract - Wooded draws comprise about 1% of the landscape in the Northern Great Plains but provide various mammalian and avian species, including some listed as species of conservation priority, with food, cover, and protection. However, understanding the status of wooded draw health is lacking. Therefore, our objectives were to identify if wooded draws were regenerating by assessing long-term trends of sampled wooded draws while using predictive equations to assign the seral stage of each sampled wooded draw as an indicator of wooded draw health in North Dakota, USA. We found decreasing numbers of Green Ash (*Fraxinus pennslyvanica*) and American Elm (*Ulmus americana*) stems temporally while percent cover of *Prunus* spp. and *Symphoricarpos* spp. increased temporally. However, we found a general trend for percent shrubby cover to decrease within our microplots. Using predictive equations, we classified 61% of wooded draws as late seral stage, 7% as late intermediate, 8% as early intermediate, and 24% as early successional by their last year of data collection. Our results indicate most wooded draws in North Dakota are aging and not regenerating. Given the importance of this rare cover type, management strategies aimed at regenerating wooded draws are discussed.

Introduction

Wooded draws only comprise about 1% of the entire landscape in the Northern Great Plains but serve an important role in providing wildlife habitat for numerous species (Bjugstad and Girard 1984, Rumble and Gobeille 2001). They provide wildlife species with food, cover, and protection, particularly during winter months (Bjugstad and Sorg 1985, Hodorff et al. 1988, Severson and Boldt 1978). Based on a United States Forest Service (USFS) songbird monitoring program report, over 84 percent of the land birds found on the Little Missouri National Grasslands (LMNG) are dependent at some level upon woodland habitat types (Hutto 1995). Consequently, wooded draws are used by several avian species including Wilson's Warblers (*Wilsonia pusilla* Wilson), Eastern Kingbirds (*Tyrannus tyrannus* Linnaeus), and Orchard Orioles (*Icterus spurius* Linnaeus; Rumble and Gobeille 1998). Various small mammal species, such as Meadow Voles (*Microtus pennsylvanicus* Ord), Pocket Gophers (*Geomys bursarius* Shaw), White-footed Mice (*Peromyscus leucopus*, Rafinesque), and Deer Mice (*P. maniculatus* Wagner) also are commonly found in wooded draws. Species such as Golden Eagles (*Aquila chrysaetos* Linnaeus), Red-headed Woodpeckers (*Melanerpes erthrocephalus* Linnaeus), Merriam's Shrews (*Sorex merriami* Meriam), and Long-eared Bats (*Plecotus auritus* Linnaeus) are included on North Dakota's list of "species of conservation priority" and depend upon wooded draws (Dyke et al. 2015). Therefore, understanding various aspects of wooded draws, such as current health status and age, is important because losing this habitat type on the landscape could negatively impact wildlife biodiversity.

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Given the importance of wooded draws on the landscape, the USFS in collaboration with North Dakota Game and Fish (NDGF) have monitored up to 138 research macroplots on the LMNG for the past 30 years collecting data, such as basal area of various tree species, the number of seedlings and saplings found in each macroplot, and percent coverage of several understory shrub species. Recently, however, there has been concern by NDGF biologists regarding the consistency in which data from these research macroplots has been collected and how that might affect the ability to detect changes in wooded draw health over time. Therefore, our objectives were to evaluate this dataset and identify if wooded draws were regenerating by assessing the long-term trends of sampled wooded draws and to use the equations presented by Uresk et al. (2015) to assign the seral stage of each wooded draw as an indicator of wooded draw health.

Materials and Methods

Study Area

We collected data at 138 unique macroplots in Billings, Golden Valley, McKenzie, and Slope counties, in southwestern North Dakota, USA. Badlands terrain encompasses 6,200 km^2 and is restricted to the drainage system of the Little Missouri River (Fig. 1). Elevation ranged from a low of 615 m above mean sea level in the Little Missouri River bottoms to a high of 913 m at plateau tops. This region is characterized by abrupt changes in substrate, slope, and soils. Badlands are a type of dry terrain where clay-rich soils and softer sedimentary rocks have been widely eroded by wind and water that result in steep slopes, minimal vegetation, and high drainage density. Native prairie is generally the main habitat on shallow slopes. Rocky Mountain Juniper (*Juniperus scopulorum* Sargent) dominates much of the remainder of the badlands, with stand densities increasing on a south to north gradient. Important tree species include Green Ash (*Fraxinus pennsylvanica* Marshall) and American Elm (*Ulmus americana* Linnaeus), with Ash-hardwood stands found on about 2% of the study area and generally occuring on gradual slopes with a northeastern orientation (Jensen 1988). Important shrub species include Wild Plum (*Prunus americana* Marshall), Pin Cherry (*P. pensylvanica* Linnaeus), Chokecherry (*P. virginiana* Linnaeus), Snowberry (*Symphoricarpos* spp.), Wood's Rose (*Rosa woodsii* Lindley), Serviceberry (*Amelanchier alnifolia* Nuttal), Poison Ivy (*Toxicodendron rydbergii* Greene), Wild Black Currant (*Ribes americanum* Miller), Missouri Gooseberry (*Ribes missouriense* Nuttal), and Golden Currant (*Ribes odoratum* Wendland).

North Dakota's climate is continental and characterized by large variance in temperature, both on a seasonal and daily basis. Mean annual temperature is 4^o C, ranging from a mean of -6^o C in January to 31^o C in July (Ciuti et al. 2015, Seabloom 2020). Average yearly precipitation is about 43 cm. Snow cover typically occurs between November and April. Snow cover is variable and often sparse, with cover maintained throughout the winter only in shaded areas. Large herbivores found on the LMNG include Domestic Cattle (*Bos taurus*; Linnaeus, 1758), Domestic Horse (*Equus caballus* Linnaeus), Mule Deer (*Odocoileus hemionus* Rafinesque), White-tailed Deer (*Odocoileus virginianus* Zimmermann), Pronghorn (*Antilocapra americana* Ord), several small herds of Bighorn Sheep (*Ovis canadensis* Shaw), and Elk (*Cervus elaphus* Linnaeus; Jensen 1988, Seabloom 2020).

Data Collection

All sample macroplots were located on USFS, National Park Service, or North Dakota State School public-owned lands within the jurisdictional boundaries of the LMNG. Macroplots were generally limited to one per township, and we randomly selected sections for sampling. We then positioned macroplots based on slope that were large enough to encompass a 9.1 m by 22.9 m macroplot. A large "tag" tree served as one corner of the macroplot with metal stakes marking the other three corners. We recorded aspect, percent slope, and elevation of the macroplot. Soil-types, occurrence of erosion, and general condition of the wooded draw was noted, and photo points were established. We recorded the GPS location of the tag tree and corner stakes in 2001.

Initially, vegetation sampling of the canopy species involved each tree within the macroplot being classified by diameter at breast height (DBH, 137 cm above ground). We categorized trees as sapling (<2.5 cm), young (≤10.2 cm), or pole (>10.2 cm) and recorded if the tree was living, decadent, or dead. We determined basal area and species composition for all live trees in each macroplot. In 1993, we only measured tree DBH to the nearest 2.5 cm but did not place them into a category. We established five microplots, each 45.7 cm by 1.8 m, along the width of the macroplot by the tag tree. Shrubs were classified as either <45.7 cm or >45.7 cm tall. Broadleaf trees <45.7 cm tall were classified as seedlings, trees >45.7 cm, but <1.8 m tall were classified as

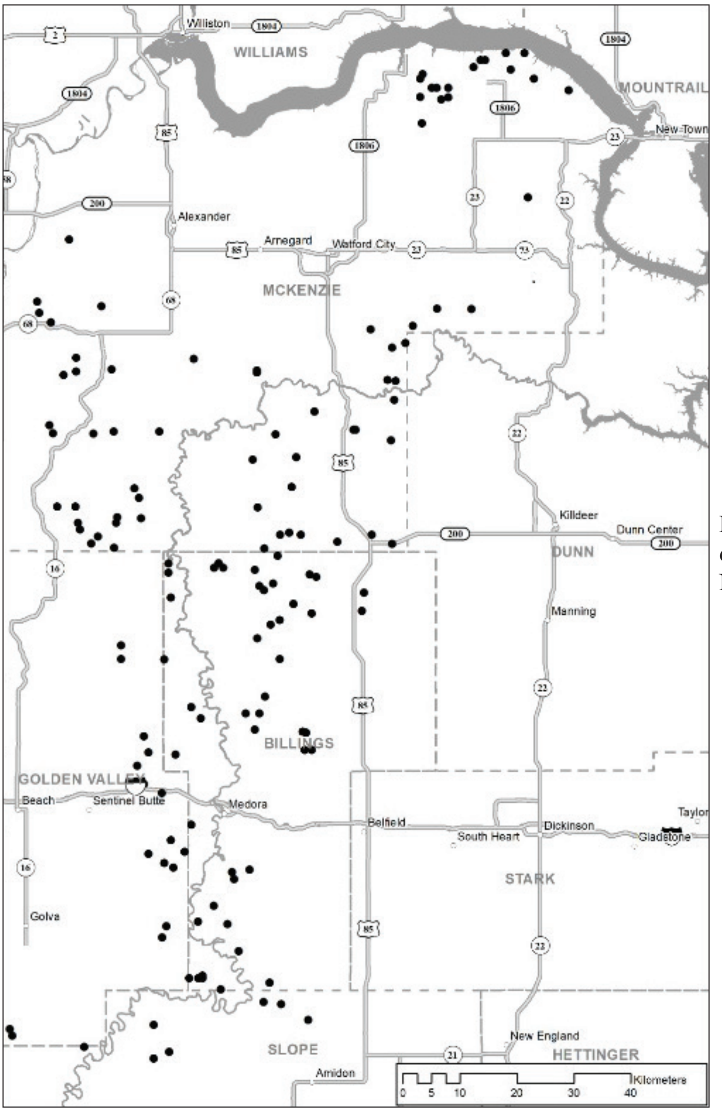

Figure 1. Distribution of woody draw macroplots in western North Dakota (n = 138).

saplings. We classified taller trees as either pole (height > 1.5 m and <10.2 cm DBH) or mature (>10.2 DBH). In 1993, we added two belt transects, 46 cm by 22.9 m, about 4.5 m apart running the length of the macroplot. We counted all tree seedlings (<46 cm tall) and saplings (46 cm to 183 cm tall) and identified them to species. Twenty-five Daubenmire plots (26 cm by 52 cm) were evenly spaced about 1m apart down each belt transect and were scored for shrub canopy cover of *Prunus* spp. and *Symphoricarpos* spp. (Daubenmire 1959). Score cards consisted of six potential cover classes (i.e., 0–5%, 5–25%, 25–50%, 50–75%, 75–95%, and 95–100% shrub canopy cover). We then calculated the mean percent cover for each belt transect and classified shrub canopy as either closed (>75%), moderately open (50 to 74%), or open (<50%) based upon the Daubenmire (1959) score card for 50 microplots. Resampling of each macroplot was scheduled for five-year intervals because of logistical constraints.

Statistical Analysis

Given the potential variation in data collection methods across time and the lack of an initial designation of seral stage and stand age, we analyzed data in several ways to identify if similar trends amongst analyses existed. We assumed wooded draws followed the traditional Clementsian pattern of succession (Clements 1916). Therefore, we attempted to detect changes across time by using a mixed linear model framework in Program R (R Core Team 2017 version 3.3.1; Bates et al. 2015). Our response variables included number of Green Ash and American Elm stems, seedlings, and saplings, as well as other understory vegetation, including *Prunus* spp., *Amelanchier* spp., Snowberry, and Wood's Rose (Table 1). We included year as our dependent variable and individual macroplot ID as a random effect to account for repeated measurements of the same macroplot across years. We then used the r.squaredGLMM function in the MuMIn package (Barton 2017, Nakagawa et al. 2017) to establish the marginal (fixed effects only) and conditional (fixed and random effects) R^2 values.

Using this same model structure, we attempted to account for additional variation by grouping the data five ways. First, we restricted our database to study macroplots for which we had data recorded for each year. We then combined data by the tree canopy closure category assigned in the first year of data collection. This allowed for three additional groupings of the data: open, moderate, and closed canopy. Lastly, we used this mixed model structure to assess variation across time for our microplot data.

Table 1. Description of variables used in mixed linear models to describe age/seral stage and health status of wooded draws in North Dakota, USA.

Variable	Description
Mean Percent Snowberry	Percent Snowberry recorded from Daubenmire plot measurements
Mean *Prunus* spp.	Percent *Prunus* spp. recorded from Daubenmire plot measurements
Basal Area	Basal Area
Total Number of Saplings	Total number of saplings regardless of tree species
Total Number of Seedlings	Total number of seedlings regardless of tree species
Total Number of FRAPEN Saplings	Total number of Green Ash saplings
Total Number of ULMAME Saplings	Total number of American Elm saplings
Total Number of FRAPEN Seedlings	Total number of Green Ash seedlings
Total Number of ULMAME Seedlings	Total number of American Elm seedlings
Total Number of FRAPEN Stems	Total number of Green Ash stems
Total Number of ULMAME Stems	Total number of American Elm stems

We also combined data based on the canopy closure category assigned during the last year of data collection. This allowed us to determine what percentage of macroplots could be classified as immature or mature. We then ran an Analysis of Variance (ANOVA) in Program R to assess if the same variables we used in our linear mixed models varied by tree canopy closure. If significant, we ran a Tukey's post hoc test to assess which canopy closures differed. This analysis would allow us to assess whether wooded draws in North Dakota were potentially regenerating by establishing whether saplings and seedlings were more prevalent in open or closed canopied macroplots. If macroplots were regenerating, we would expect an increased number of tree stems in open canopied macroplots.

Finally, we adapted the equations presented by Uresk et al. (2015) to estimate seral stage (Late, Late Intermediate, Early Intermediate, Early) in the most recent year of data collection for 138 wooded draw macroplots. Uresk et al. (2015) calculated Fisher's coeffecients to use with basal area of Green Ash and canopy cover of American Plum and Chokecherry along with a constant to estimate seral stages of wooded draws in South Dakota, USA. The equation that produced the largest value was the seral stage that is designated (Uresk et al. 2015; Table 2). Although we had most data for this analysis, specific *Prunus* spp. (e.g., *Prunus viginiana* and *P. americana*) Daubenmire plot (Daubenmire 1952) data were not available. Therefore, we used all available *Prunus* spp. data and not the combination of *P. virginiana* and *P. americana*. We also did not have tree-specific DBH for *F. pennsylvanica*, so we calculated basal area using the average of the group within which each stem was placed. For example, if two stems were recorded in the 13 to 15 cm category, we used an average DBH of 14 cm to calculate basal area.

Results

Assessing Long-term Trends

Between 1986 and 2014, we sampled 138 macroplots a total of 828 times. We established long-term trends of wooded draws by assessing how vegetative characteristics varied across time within our macroplots. We found that the number of stems of tree species generally decreased throughout time while percent shrubby cover increased. For example, the total number of Green Ash stems and American Elm stems decreased across time. Conversely, percent *Prunus* spp. and percent Snowberry (Table 3) increased across time. We further assessed how vegetative characteristics varied across time for macroplots where data were collected each year (Supplemental Table 1; for all Supplemental Tables, see Supplemental File 1, available online at https://eaglehill.us/prnaonline/suppl-files/prna-005-michel-s1.pdf) and after grouping by canopy closure (closed canopy, Supplemental Table 2; moderate canopy, Supplemental

Table 2. Example of variables used in the equations proposed by Uresk et al. (2015) to assign seral stage of wooded draws in South Dakota, USA as either Late, Late Intermediate, Early Intermediate, and Early. Table adapted from Uresk et al. (2015).

	Green Ash		*Prunus* spp.				
Seral Stage	(Coeff[1]*Var[2])	+	(Coeff*Var)	+	Constant	=	Score
Late	(0.497*44	+	0.071*26)	-	23.415	=	0.299
Late Intermediate	(0.099*44	+	0.350*26)	-	11.632	=	1.824
Early Intermediate	(0.260*44	-	0.033*26	-	6.607	=	**3.975**[3]
Early	(0.072*44	+	0.022*26)	-	1.905	=	1.835

[1]Coeff = Fisher's coefficients used for classification.
[2]Var = variable, basal area (ft^2/a) and canopy cover (%).
[3]Assigned seral stage.

Table 3; open canopy, Supplemental Table 4) and found similar relationships as we did when analyzing all data combined; Green Ash and American Elm generally decreased across time while Snowberry and *Prunus* spp. generally increased.

Results from our microplot data differed from our previous results. Although our microplot data showed the amount of *Symphoricarpos* spp. increased temporally, which was consistent with our other linear models, other shrub species decreased temporally (Table 4). For example, *Amelanchier* spp. significantly declined temporally.

We further investigated whether wooded draws were regenerating by calculating the percent of macroplots that were classified as either closed, moderate, or open canopies in their last year of data collection. Most macroplots were categorized as either open (48%) or moderate (40%), while only 12% of macroplots were categorized as closed. These results alone indicate that wooded draws may be regenerating. However, after comparing vegeta-

Table 3. Results from linear mixed models assessing how variables varied temporally for 566 data points collected from 138 wooded draw plots located in western North Dakota, USA. Plot ID was used as a random effect to account for repeated measurements. Model structure was: response variable~year+(1|plot.id).

Response Variable	*Beta*	STD Error	*P-Value*	Marginal R^2	Conditional R^2
Mean Percent Snowberry	0.241	0.099	0.015	0.004	0.683
Mean *Prunus* spp.	0.684	0.094	<0.001	0.024	0.790
Basal Area	-0.208	0.190	0.273	0.000	0.851
Total Number of Saplings	-0.199	0.048	<0.001	0.024	0.176
Total Number of Seedlings	-1.939	0.622	0.002	0.013	0.056
Total Number of FRAPEN Saplings	-0.019	0.053	0.724	0.000	0.204
Total Number of ULMAME Saplings	-0.078	0.042	0.063	0.060	0.051
Total Number of FRAPEN Seedlings	-0.201	0.577	0.728	0.000	0.013
Total Number of ULMAME Seedlings	-1.420	0.716	0.048	0.070	0.025
Total Number of ULMAME Stems	-0.232	0.025	<0.001	0.640	0.067
Total Number of FRAPEN Stems	-0.714	0.064	<0.001	0.083	0.069

Table 4. Results from linear mixed models assessing how variables varied temporally for 703 data points collected from 145 wooded draw microplots located in western North Dakota, USA. Plot ID was used as a random effect to account for repeated measurements. Model structure was: response variable~year+(1|plot.id). Only microplot data were used in these analyses.

Response Variable	*Beta*	STD Error	*P-Value*	Marginal R^2	Conditional R^2
FRAPEN	0.019	0.085	0.821	0.00	0.145
ULMAME	-0.105	0.096	0.274	0.002	0.020
PRUNUS	0.107	0.102	0.298	0.001	0.606
AMEALN[a]	-0.111	0.023	<0.001	0.006	0.833
SYMPHO[a]	1.489	0.253	<0.001	0.023	0.554
ROSWOO[a]	-0.558	0.052	<0.001	0.104	0.396
RIBES[a]	-0.071	0.026	0.006	0.006	0.489
TOXRYD	-0.034	0.039	0.391	0.001	0.380

[a]Shrubby species.

tive characteristics among the three canopy closure categories, we found the number of Green Ash stems ($F_{2,78}$ = 6.05, p = 0.004), number of American Elm stems ($F_{2,78}$ = 9.72, p < 0.001), and percent Snowberry ($F_{2,78}$ = 5.51, p = 0.006) varied among the three canopy closure categories, while the number of Green Ash seedlings approached significance ($F_{2,78}$ = 2.57, p = 0.083; Table 5). Tukey's post hoc test results indicated that there were more Green Ash and American Elm stems in closed canopy macroplots compared to open canopy macroplots ($p \leq 0.004$; Table 6). If stands were regenerating, we would expect there to be more stems, seedlings, and saplings in open and moderate canopies; however, our results show the opposite indicating that stands are likely old and not regenerating.

Table 5. Analysis of Variance results comparing vegetative characteristics among wooded draw plots described as open, moderate, or closed canopied in their last year of data collection in western North Dakota, USA.

Variable	Num DF	Den DF	*F-Value*	*P-Value*
FRAPEN Stems	2	78	6.05	0.004
ULMAME Stems	2	78	9.72	<0.001
FRAPEN Saplings	2	78	1.84	0.166
ULMAME Saplings	2	78	0.80	0.454
FRAPEN Seedlings	2	78	2.57	0.083
ULMAME Seedlings	2	78	0.39	0.680
Total Saplings	2	78	1.10	0.338
Total Seedlings	2	78	2.05	0.135
Mean Percent Snowberry	2	78	5.51	0.006
Mean *Prunus* spp.	2	78	1.19	0.310

Table 6. Results of Tukey's post hoc test comparing vegetative characteristics among wooded draw plots categorized as open, moderate, or closed canopied in their last year of data collection in western North Dakota, USA. Different letters indicate significance at $p \leq 0.05$.

	ANOVA Comparisons		
	Canopy Cover at Last Data Collection Period		
Variable	Open	Moderate	Closed
Mean FRAPEN Stems	4.51a	8.81ab	14.00b
Mean ULMAME Stems	0.10a	0.16ab	2.20c
Mean FRAPEN Saplings	1.31a	3.75a	2.10a
Mean ULMAME Saplings	1.23a	0.56a	0.90a
Mean Total Saplings	2.74a	4.81a	3.00a
Mean FRAPEN Seedlings	7.36a	24.09b*	12.50ab
Mean ULMAME Seedlings	2.26a	1.66a	3.40a
Mean Total Seedlings	9.67a	25.78a	16.10a
Mean SYMPHO Average	28.56a	17.58b	11.85b
Mena PRUNO Average	19.96a	18.39a	10.16a

*p = 0.068

Assigning Seral Stage

We assigned seral stage by adapting equations presented by Uresk et al. (2015). We classified 61% of wooded draws as late seral stage in their last year of data collection. Only 7% and 8% were classified as late intermediate and early intermediate, respectively, while 24% were classified as early successional.

Discussion

Results from our linear mixed models and ANOVAs support the classifications we obtained through the Uresk et al. (2015) equations but should be interpreted with caution given the changes we made with our available data (e.g., using all available *Prunus* spp. data instead of combining *P. virginiana* and *P. americana*). Ground truthing these macroplots is therefore necessary to accurately and confidently identify seral stage and stand age. Nevertheless, total number of Green Ash stems and American Elm stems decreased across time indicating that total number of important tree species are declining in wooded draws in North Dakota. Conversely, percent *Prunus* spp. and percent Snowberry increased across time. Regardless of whether we restricted analyses to macroplots where data were collected in each year or we grouped data by canopy closure, we found similar results as when we analyzed all available data. Therefore, our data indicate that understory vegetation increased temporally while the number of tree stems decreased. Although this trend appears to indicate that these macroplots are early successional, the decrease in tree stems across time indicates these stands are aging and not regenerating trees into the overstory canopy.

Although we documented temporal changes in vegetation, there is much variation associated with each macroplot. The marginal R^2 (fixed effects only) for significant variables using all data ranged from 0.004 to 0.083 whereas the conditional R^2 (fixed and random effect) for important variables ranged from 0.025 to 0.790, which suggests there is much variation attributed to individual macroplots. As such, creating criteria to categorize each macroplot into a seral stage and health status would likely be more appropriate and would allow for easier data manipulation, potentially allowing for better use. Given we used all data in our analyses and we did not have specific criteria to establish current age/seral stage for each macroplot, we could not determine what percentage of wooded draws are currently in a healthy state in North Dakota. Rather, we were only able to assess what the long-term trends were for these macroplots.

Collecting additional data may help improve our ability to monitor wooded draws in North Dakota, USA. For example, future data may include not only the diameter at breast height (DBH; ≥2.5 cm) and height of living trees but also the height of all living shrubs (Rumble and Gobeille 1998; Uresk et al. 2009). All dead trees (snags) along transects also should be recorded (Rumble and Gobeille 1998). In addition to overstory canopy cover, canopy cover and foliage height density of important grass, forb, and shrub species should be measured (Rumble and Gobeille 1998), which will help assess whether the macroplot is regenerating, though, this needs to be ground truthed. To establish seral stage and increase accuracy of the Uresk et al. (2015) equations we used, the percent canopy cover of *P. virginiana* and *P. americana* should be collected as well as tree-specific DBH (Uresk et al. 2015). Measurements could then be averaged by site for analyses (Uresk et al. 2009). Efforts must also be made to locate stakes at each transect, make them visible, and record their GPS coordinates so they can be maintained for future data collection.

Additionally, obtaining more accurate information on the distance from a wooded draw to a water structure may help assessments of wooded draw health. Although we could measure the distance from the center of each wooded draw to the nearest water structure, results from that information would also need to be interpreted with caution as distances would need to be ground truthed for the presence of obstructions. For example, a water structure may be in close proximity of a wooded draw, but that distance may not be related to any impact that cattle may have on the health of wooded draws if a fence or steep terrain is present and if cattle use of the wooded draw is restricted. Presence of structures like fences may or may not be detected from aerial photos. Therefore, identifying if cattle can access water structures or if there are any potential features that might limit their access is needed before we can accurately assess the influence of the distance from wooded draws to water structures on wooded draw health. Information gained from these types of analyses would help direct future management efforts.

Conclusions

Although our results should be interpreted with caution, wooded draws in North Dakota seem to be aging and potentially not regenerating, though, more specific data and analyses are needed to verify regeneration status. Collaboration among agencies would facilitate obtaining needed information. For example, cooperating with USFS requires that it provide data relating to grazing systems and GIS layers in a timely manner. Even more importantly, the USFS must maintain consistent data collection methodology, so long-term datasets can be analyzed. Concomitantly, if management goals include regenerating wooded draws, then strategies such as excluding livestock and removing decadent overstory trees should be implemented (Uresk et al. 2009). These strategies can be implemented on local scales to assess efficacy before implementing management at broad scales.

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Literature Cited

Barton, K. 2017. MuMIn: Multi-Model Inference. R package version 1.40.0. Available online at https://cran.r-project.org/package=MuMIn. Accessed 15 February 2019.

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67:1–48.

Bjugstad, A.J., and D.F. Sorg. 1985. The value of wooded draws on the northern high plains for hunting, furs, and woodcutting. Pp. 5–9, *In* D. Noble and R. Winokur (Eds.). Wooded draws: characteristics and values for the northern Great Plains. South Dakota School of Mines and Technology, Rapid City, SD, USA.

Bjugstad, A.J., and M. Girard. 1984. Wooded draws in rangelands of the northern Great Plains. Guidelines for increasing wildlife on farms and ranches. Great Plains Agriculture Council and Kansas State University, Manhattan: 27B–36B.

Ciuti, S., W.F. Jensen, S.E. Nielsen, and M.S. Boyce. 2015. Predicting Mule Deer Recruitment from Climate Oscillations for Harvest Management on the Northern Great Plains. Journal of Wildlife Management 79:1226–1238.

Clements, F. E. 1916. Plant succession: An analysis of the development of vegetation. Carnegie Institution of Washington, Washington, DC. 512 pp.

Daubenmire, R. 1952. A canopy-coverage method of vegetational analysis. Northwest Science 33:43–64.

Dyke, S.R., S.K. Johnson, and P.T. Isakson. 2015. North Dakota State Wildlife Action Plan. North Dakota Game and Fish Department, Bismarck, ND, USA. 458 pp.

Hodorff, R.A., C.H. Sieg, and R.L. Linder. 1988. Wildlife responses to stand structure of deciduous woodlands. Journal of Wildlife Management 52:667–673.

Hutto, R. L. 1995. Northern Regional Landbird Monitoring Program: Distribution and Habitat Relationships. USFS Region 1. 120 pp.

Jensen, W. F. 1988. Summer and fall ecology of mule deer in the North Dakota badlands. Ph.D. Dissertation, University of North Dakota, Grand Forks, ND, USA. 220 pp.

Nakagawa, S., P.C. Johnson, and H. Schielzeth. 2017. The coefficient of determination and intra-class correlation coefficient from generalized linear mixed-effects models revisited and expanded. Journal of the Royal Society Interface 14:20170213.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rumble, M.A., and J.E. Gobeille. 1998. Bird community relationships to succession in green ash (*Fraxinus pennsylvanica*) woodlands. American Midland Naturalist 140:372–381.

Rumble, M.A., and J.E. Gobeille. 2001. Small mammals in successional prairie woodlands of the Northern Great Plains. Rocky Mountain Research Station, Fort Collins, CO, USA. 9 pp.

Seabloom, R.W. 2020. The Mammals of North Dakota (2nd Edition). North Dakota State University Press, Fargo, ND, USA. 470 pp.

Severson, K.E., and C.E. Boldt. 1978. Cattle, wildlife, and riparian habitats in western Dakota. Pp. 90–103, *In* J. Shaver (Ed.). Management and Use of Northern Plains Rangeland. North Dakota State University, Fargo, ND, USA.

Uresk, D.W., J. Javersak, and D.E. Mergen. 2009. Tree sapling and shrub heights after 25 years of livestock grazing in green ash draws in western North Dakota. 2009. Proceedings of the South Dakota Academy of Science 88:99–108.

Uresk, D.W., K.E. Severson, and J. Javersak. 2015. Model for classification and monitoring green ash—Ecological type in the Northern Great Plains. Proceedings of the South Dakota Academy of Science 95:213–226.