PREDICTING DOMINANT SPECIES ON GRASSLANDS AT THE NATIONAL BISON RANGE, MOIESE, MONTANA

by

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ABSTRACT

Under ecologically sustainable conditions, a landscape should retain representative climax vegetation. Thus, a method to predict the climax species component of a functioning vegetation community is an important tool for restoration projects. Based on descriptions of the Palouse Prairie grassland the National Bison Range managers selected bluebunch wheatgrass, Idaho fescue, and rough fescue as target species for management and restoration objectives. An indicator called Relative Effective Annual Precipitation (REAP) was created by Montana Natural Conservation Service (NRCS) to express the amount of water available to the plants, at a specific location, taking into account precipitation, slope and aspect, and soil properties. Using Geographic Information System (GIS) and REAP as the predictor variable, a map to predict the occurrence of species within grassland communities was developed to guide restoration and management efforts on the USFWS National Bison Range. REAP values were calculated for sample sites from three earlier rangeland assessments and related to actual field measures of the target species. Classes of REAP intervals were defined to bracket the range in value for each species. Classes were also created for target groups (bluebunch and fescue) sorted by genus. REAP values for sites dominated by bluebunch wheatgrass were significantly different from values for sites dominated by Idaho fescue and rough fescue ($P < 0.0001$). However, there were no statistical differences between REAP values for Idaho fescue and rough fescue (P=0.989).The mean probability of the REAP model to accurately predict the occurrence individual target species was 0.55 and for the target group was 0.64. NBR and should be dominated by grasses, but there were patches of conifer forest. The values of REAP related to the forest patches were compared against REAP values for grassland areas to learn if the model could differentiate between the two major cover classes. The REAP values for the forest patches were higher than values predicted for grasslands (P=0.0026). So, prediction of areas dominated by grasslands was different from forest sites. However, the discrimination between Idaho and rough fescue was not successful.

INTRODUCTION

The National Bison Range (NBR) lies in the Flathead Valley of western Montana, and its grassland vegetation communities are reported to resemble the Palouse Prairie (Mitchell 1958), where the expected climax vegetation should be co-associations of Idaho fescue (*Festuca idahoensis* [Elmer]) and bluebunch wheatgrass (*Pseudoroegneria spicata* [(Pursh) A.Love]). Within this vegetation association rough fescue (*Festuca campestris* [Torr.]) is reported to occur on deeper and more fertile soils (Daubenmire 1940, Young 1943, Humphrey 1945).

The actual policy of the US Fish and Wildlife Service states that management and restoration efforts on the national wildlife refuges should address preservation or recovery of pristine vegetation, as well as the wildlife species that the refuge was created to protect (Schell 2012). Therefore, protection or recovery of pristine native vegetation communities has become a management goal for conservation efforts on many federal units. For example, the NBR managers are putting a tremendous effort into development of a comprehensive conservation plan that includes protection of the pristine Palouse Prairie vegetation component. Within this plan they have identified bluebunch wheatgrass, Idaho fescue, and rough fescue as the target grassland species for conservation efforts. However, to accomplish this broader goal they needed to know landscape locations within the refuge where these target species were likely to dominate.

Geographic Information Systems (GIS) have been used to develop models that predict where certain species may occur using geographical data as predictor variables. However, all three species (bluebunch wheatgrass, Idaho fescue, rough fescue) are adapted to the NBR environment; all three can occur at any site within the refuge. Therefore, this study details much more than identification of suitable habitats; it is designed to predict where each target species dominates within grasslands at a refuge rather than plot scale.

Common suitability parameters included in GIS based models are climate and environmental components such as temperature, precipitation, landform, elevation, slope, aspect, and soil characteristics (van de Rijt 1996, Jensen et al 2001, Franklin 2002, Store and Jokimaki 2003). The Relative Effective Annual Precipitation (REAP) was developed by the Montana Natural Resources Conservation Service (NRCS) and published in 2008; it is an effort to organize such variables into a raster format that can be used with GIS tools. This indicator has great potential to predict species occurrence because it takes into account several species occurrence drivers like aspect, slope, and soil characteristics. Factors which ultimately reflect the relationship between water, soil and plant (Graetz et al. 1988, Pellant et al. 2005). However, there is no indication that REAP has been used as a species dominance predictor.

The goal of this study was to use literature, historical records and archived assessments to define the location and dominance of bluebunch wheatgrass, Idaho fescue, and rough fescue within the NBR grasslands. Accomplishing this goal would create an important reference for management decisions and restoration projects on the refuge.

Specific objectives of this study were: 1) to determine if sufficient information existed to describe the historical climax community on the NBR and if bluebunch wheatgrass, Idaho fescue, and rough fescue dominated within these communities; 2) to develop a target species map for the refuge and then; 3) assess the REAP indicator as a method for delineating grassland communities where these Palouse prairie species would dominate.

LITERATURE REVIEW

Habitat Description for Target Species

Individual communities exist because of unique biological, climatic, and abiotic interactions at that point on the landscape. In temperate grasslands, the vegetation community and species dominance change in response to the amount and timing of precipitation, temperature, and soil characteristics (Epstein et al. 1997, Sikkink et al. 2007). At the National Bison Range (NBR) the most significant environmental variables affecting plant communities are spring precipitation, frequency of rock, and percentage of organic carbon in the soil (Sikkink et al. 2007).

Bluebunch Wheatgrass

Bluebunch wheatgrass, a key species in the Palouse Prairie system, is a native, cool season perennial. This species usually occurs at elevations between 900 and 2,300 m on gentle or even very steep slopes. It is found most often on south-facing slopes (Miller et al. 1980, Mueggler and Stewart 1980).

Bluebunch wheatgrass usually occurs on loamy soils with few rock fragments, and slightly acidic pH (Platou et al. 1986) and soil depth varies from 0.25 to 0.89 m (Heady 1950, Mueggler and Stewart 1980). While found on soils representative of mesic and frigid temperature regime, bluebunch wheatgrass prefers the cryic regime (Platou et al. 1986).

Bluebunch wheatgrass tolerates a wide range of precipitation, occurring on aridic, xeric, ustic, and udic soils. It can be considered a moderately arid type of species because most of the occurrences (60%) are on aridic (Platou et al. 1986). This species has a broad precipitation tolerance, but most frequently occurs within 360 to 560 mm precipitation zone (Miller et al. 1980, Mueggler and Stewart 1980).

Idaho Fescue

Idaho fescue is a native, perennial, cool-season bunchgrass that is widely distributed in western North America from British Columbia to northern New Mexico. Within the Palouse Prairie, it occurs at elevations between 900 to 2,300 m. It can be found on steep slopes but more commonly occurs on slopes less than 30%. While this species can occur on any exposure, it will dominate on north-facing exposures (Miller et al. 1980, Mueggler and Stewart 1980, Goodwin 1993).

Idaho fescue usually is found on well drained, moderately deep, loamy soils; the soil depth can vary from 0.41 to 0.90 m. Generally this species occupies soils in the neutral to slightly acid range, and may be indicative of a large amount of surface organic matter (Mueggler and Stewart 1980, Platou et al. 1986, Goodwin 1993). Like bluebunch wheatgrass, Idaho fescue often occupies soils with high percentage of rock fragments. Platou et al. (1986) reported the occurrence of this species on soils with greater than 15% of rock fragments.

Concerning effective moisture, Idaho fescue prefers wetter soils than bluebunch wheatgrass and most often occurs on xeric or ustic soils. The range of precipitation varies from 230 and 860 mm (Daubenmire 1942, Mueggler and Stewart 1980, Platou et al. 1986, Goodwin 1993).

Idaho fescue is an indicator of cryic soils, but it also occurs on warmer soils representative the frigid regime (Platou et al. 1986).

Rough Fescue

Rough fescue is a cool-season perennial bunchgrass, growing in erect, tufted bunches, with stalks 0.3 to 1.2 m, high basal leaves usually 0.10 to 0.30 m long, and individual bunches 0.30 to 0.35 m in diameter (Hodgkinson and Young 1973, Jourdonnais 1985). It occurs widely in Canada from British Columbia to Newfoundland; in the United States from eastern Washington and eastern Oregon to North Dakota; and also in Michigan, Wyoming, Montana, and Colorado (Cosby 1965, Hodgkinson and Young 1973).

Rough fescue occurs at elevations between 900 m and 1,800 m on all exposures, especially on cool moist exposures (Hodgkinson and Young 1973). Unlike the previous species this grass grows on level or gently rolling topography (Aiken and Darsbyshire 1990).

Rough fescue grows on a number of soil types including loam and silty loam; however, it prefers fine loamy range sites (Mueggler and Stewart 1980). On the other hand, Mitchell (1958) found rough fescue in clay soil indicating a preference for conditions that retain more moisture. This grass occurs on ustic or aridic soils, but is most common in mesic enviroments (Aiken and Darsbyshire 1990).

Soil depth can vary from 0.25 to 0.9 m, and the amount of surface rocks averages about 5% (Mueggler and Stewart 1980). Thus, nearly rock free soils with a high level of organic carbon are preferred by rough fescue (Van Ryswyk et al. 1965, Mitchell 1958).

Table 1 summarizes the environmental preferences for each of the dominant species that will be the focus of this study.

Table 1. Environment occurrence by species.

environmental variables	bluebunch wheatgrass	Idaho fescue	rough fescue
elevation	900-2,300 m	900 - 2,300 m	900 - 1,800m
slope	gentle or steep	< 30%	Level or gently rolling
aspect	mainly south-facing	north-facing	n/a
soil texture	loamy	Loamy	loam, silty loam, clay
soil depth	0.25-0.89 m	0.41-90 m	0.25-0.90 m
rock fragment	few	High	few
soil pH	slightly acid	neutral, slightly acid	n/a
temperature	mesic, frigid, cryic	cryic, frigid	frigid
moisture	most aridic	xeric or ustic	mesic
precipitation	360 - 560 mm	230 - 860 mm	>35 mm
organic matter	n/a	surface o.g.	high

Models to Predict Plant Distribution

The need to combine vegetation types with related spatial information to create occurrence maps has been recognized by natural resource managers as a conceptual basis for the description of resource potentials (Mueggler and Stewart 1980, Clark et al. 2001, Jensen et al. 2001). Historically, land management agencies use three different ecological land classification schemes: habitat type, range site, and community type to describe reoccurring vegetation associations. Habitat type represents all the land that supports or has supported the same specific climax vegetation (Hironaka 1986). It does not matter what the successional stage is (Mueggler and Stewart 1980). Range site is a second classification approach that also relies on climax vegetation but is based on site productivity and species composition rather than position on the landscape. This classification has evolved into the current concept of "ecological site" which now takes into account successional status. Community type is based on current vegetation and is not specific in regards to successional stage; consequently, it works best with disturbed vegetation communities. None is better than the other. Each classification scheme has a purpose; each provides different information about the vegetation communities (Hironaka 1986).

Vegetation classification and mapping can be very expensive if conventional methods, such as aerial photograph interpretation and ground survey, are used (Clark et al. 2001). Remote sensing techniques have been successfully used to identify the plant community under different ecological classification schemes such as habitat type and community type. Clark et al. (2001) working on a 23,400 ha study area, developed a community type classification for Intermountain Rangelands using Landsat TM and SPOT HRV data. Using Landsat TM imagery, Jensen et al. (2001) developed a potential vegetation map of habitat type for the Little Missouri National Grasslands, an area of 809,380 ha. Gessner et al. (2013) used a multi-resolution approach to develop a land cover classification on the African savannah. Their results pointed errors between 4.4% and 9.9% when compared to field surveys, indicating that their maps matched with soil surveys. All these studies were developed at the level of vegetation classes a much coarser detail than needed by NBR managers.

Because plants exhibit emissivity signatures related to species and chemical variations that are remotely discernible, remote sensing-based studies have attempted to map at the species level. Successful plant species identification is related to:1) spectrum shape; 2) morphology of leaves; 3) disposition of leaves; canopy closure; 5) size of the canopy but, advances in atmospheric compensation and spectral analysis methods are still necessary to improve the discrimination capability (Da Luz and Crowley 2010). For example, a study conducted at the State Arboretum of Virginia using high spatial and spectral resolution thermal infrared imagery identified only half of the fifty tree species on the grounds (Da Luz and Crowley 2010). Cho and others (2012) were able to discriminate tree species on the African savanna using hyperspectral data with accuracy between 65% to 77%. Thus, the accuracy of remotely acquired forest species identification is still limited.

Remote sensing also has been used to identify invasive plant occurrence. Although leafy spurge (*Euphorbia esula* [L.]) discrimination was possible at as little as 10% cover in a one 3.5 m pixel imagery, further investigation indicated that for consistency purposes and minimization of errors, the discrimination threshold would be about 40% (Glenn et al. 2005).

Adjorloo et al. (2012) analyzed remote sensing techniques, especially hyperspectral imagery, to assess the potential discrimination between C_3 and C_4 grass species; they concluded that these techniques have the potential to discriminate between these growth forms of grasses. However, challenges still remain to link physical observations made in specific wavebands to ecosystem functional processes. They also indicated that:

- “differences in the structural composition between C_3 and C_4 grasses affect the amount and shape of radiation reflected, absorbed, and/or transmitted in the wavelength spectrum.
- leaf/canopy structural and biochemical properties relate differently to and affect different aspects of the electromagnetic spectrum.
- Leaf and canopy radioactive transfer modeling approaches can effectively measure species or communities of C_3 and C_4 grass reflectance characteristics
- C_3 and C_4 grass canopies can be discriminated by using reflectance and absorption features and a combination of temporal tractor vegetation indices
- the interpretation of remote sensing techniques, solar radiation patterns, wetness gradients, and topographic elements such as slope orientation and altitudinal gradients, could improve the detection and mapping of C_3 and C_4 grass canopies in tropical montane grasslands landscapes.”

Dale et al. (2011) studied single species of grass in a laboratory and they were able to discriminate individual species, with 96% accuracy. They concluded that hyperspectral imagery has potential to recognize species in the field; however, prior to this, a database containing information of each species spectral signal must be developed.

Vegetation classification using remote sensing imagery achieves higher accuracy on forest environments, then shrublands, and the least on grasslands (Dibenedetto 1999, Jensen et al. 2001). If remote sensing techniques cannot discriminate between C_3 and C_4 grasses with a reasonable accuracy (Adjorloo et al. 2012), it is reasonable to assume that it would be more difficult to segregate bunchgrass species like bluebunch wheatgrass, Idaho fescue and rough fescue because they are phenotypically similar.

Due to the failure of remote sensing-based methods to discriminate plant species, a great number of researchers have turned to existing field inventories to predictively map species distribution (Franklyn 2002). Predictive vegetation mapping means defining the geographic distribution of the vegetation composition across a region from mapped environmental (topographic and climatic) variables (Franklin 1995). Another option to map grass species is to use Geographical Information Systems (GIS) combined with topographic and climatic data as explanatory variables to predict the species occurrence. However, the final accuracy is dependent on how fine the scale is and the spatial resolution of the variables (Franklin 2002). Importantly, in GIS approaches the final accuracy is totally dependent on the accuracy of the input variables (Longley et al. 2011).

Franklin (1995) summarized the environmental variables used on several predictive plant distribution studies (Table 2). This information highlights the importance of slope, elevation, and aspect in predictive mapping.

Other important explanatory variables to plant dynamics include soil moisture, soil properties, runoff patterns, and regions of water accumulation (Lauenroth et al. 1993, Moharana and Kar 2002). However, several authors agree that precipitation is the most important driver of plant composition on semi-arid or arid environments (Pechanec et al. 1937, Noy-Meir 1973, Passey et al. 1982, Graetz et al. 1988, Foin and Platenkamp 1989, Jensen et al. 2001, Bates et al. 2006, Petersen and Stringham 2008). Thus, precipitation, temperature and the hydrological characteristics of soil interact to determine plant available water (Graetz et al. 1988).

Table 2. A list of environmental variables that were used as predictors in vegetation distribution modeling efforts[1,2].

Study [1]	Environmental variables
Franklin et al., 1986	*elevation, aspect*
Cibula and Nyquist, 1987	*elevation, aspect*
Walker et al., 1992	*elevation*, topographic moisture
Martinez-Taberner et al., 1992	water chemistry(to predict aquatic macrophytes)
Miller, 1986	*elevation, slope, aspect* diversity
Ostendorf, 1993	runoff(from terrain-based hydrological model)
Fels, 1994	*elevation, slope, aspect*, slope curvature
Frank, 1988	*elevation, aspect*, relief, slope-aspect index, satellite spectral data
Burke et al, 1989	*elevation, slope, aspect*, fetch
Franklin and Wilson, 1991	*elevation, slope, aspect*, satellite spectral data
Palmer and van Staden, 1992	*elevation*, annual rainfall
Lowell, 1991	original vegetation type, soil, fire history, distance to forest
Fischer, 1990	*elevation, slope*, radiation, geology, soil type, snow cover, land use
Brzeziecki et al., 1993	temperature, precipitation, *slope, aspect*, soil properties
David and Goetz, 1990	*elevation, slope, aspect*, radiation, upslope catchment area, geology
Noest, 1994	groundwater height, dune age, duration of inundation, antecedent climate,
Nicholls, 1989	temperature, precipitation, *elevation*, lithology, topography, *exposure*
Austin et al., 1994	temperature, precipitation
Brown, 1994	*elevation*, radiation, topographic moisture, snow accumulation
Mackey and Sims, 1993	average daily temperature of the warmest quarter
Mackey, 1994	temperature, precipitation, radiation, nutrient index based on parental material
Mackey et al., in press	soil texture, *slope*, topographic moisture
Twery et al., 1991	*slope* position
D.M. Moore et al. 1991	*slope, aspect*, geology, hillslope position, upslope catchment area
Lees and Ritman, 1991	*slope, aspect*, geology, hillslope position, upslope catchment area, satellite spectral data
Fitzgerald and Lees, 1992	*elevation, slope, aspect*, geology, upslope catchment area, satellite spectral data
Payne et al., 1994	*slope, aspect*, geology, flow length, flow accumulation, satellite spectral data

[1] For more details about the papers cited refer to Franklin 1995. [2]Table adapted from Franklin 1995.

Plant available water is the amount of water that can be used by growing vegetation; it is the amount of liquid water that reaches the soil minus the water amount that leaves the soil. When an amount of snow falls it will contribute to available soil water only when it melts; timing is the key to differentiate precipitation from the amount of liquid water that reaches the soil. Couple with the timing of snow melts, evaporation further impact the water balance. Therefore, to calculate accurately the available water, the water-holding capacity of the soil must be known (Stephenson 1990). For example organic matter and soil texture are important drivers of water-holding capacity (Platou et al. 1986). This concept is tremendously important because it differentiates precipitation from water availability, which more appropriately represents the balance of soil water. The water balance will vary through the landscape in accordance with landform and soil properties (Stephenson 1990).

Relative Effective Annual Precipitation

The concept of water balance explained by Stephenson (1990) is encompassed by the Relative Effective Annual Precipitation (REAP), an indicator of the amount of moisture available at a specific location, taking into account precipitation, slope and aspect, and soil properties. Two sites that receive the same amount of precipitation may display different values of REAP because soil and landform factors differ between two sites. This indicator was created by the Montana branch of Natural Resources Conservation Service (NRCS). It was developed in a raster format so it could be used with GIS packages (NRCS 2012).

The process to develop the REAP indicator started with a model that generates daily surface precipitation, humidity, temperature and radiation, the Daily Surface Weather and Climatological Summaries (DAYMET). This information is adjusted to a 30 year frame using the county database and then re-sampling to 10m Digital Elevation Model (DEM). The output accuracy is strengthened through use of GIS software to adjust the precipitation values accordingly to aspect and slope. The last step is the input of soil properties by the specialists from NRCS to create a raster, with cell size of 10x10 m, where the final output represents centimeters of water available to the plant community or crop (NRCS 2012). The REAP indicator raster is available to the public at the Montana Natural Heritage Program website (NRIS 2013).

The set of variables affecting dominance in plant communities is much more complex than the REAP model can address, but there is a strong evidence that treating soil moisture as the principal environmental variable can overcome some of these limitation (Foin and Platenkamp 1989). It will be necessary to apply the REAP indicator to a vegetation predictive effort to learn if the inherent limitations are too great to achieve a reasonable accuracy.

Because there has been limited use of the REAP as a predictor of species dominance, the several hypotheses were formulated: 1) The REAP values for the sites related to each of the three target species (bluebunch wheatgrass, Idaho fescue, and rough fescue) are not different; 2) the probability of the REAP indicator to correctly determine the dominant species on landforms within the NBR area is not greater than 0.33 (casual probability) and 3) REAP values for forested areas on the refuge are not different from REAP values for associated grasslands.

METHODOLOGY

Study Site and Wildlife

The National Bison Range (NBR) was established in 1909 to restore and conserve the American buffalo (*Bison bison*). It lies in the Flathead Valley about 45 km north of Missoula, MT; at 47° 19' N 114° 13" W (Figure 1) with landforms ranging in elevation from approximately 763 m to 1490 m. According to the refuge weather station records the annual precipitation is 315 mm with average high and low temperatures of 21.6°C and -5.5°C, respectively. The NBR holds several ungulate species that can cause grazing disturbance such as bison (*Bison bison* [Linnaeus, 1758]), elk (*Cervus elaphus* [Linnaeus, 1758]), bighorn sheep (*Ovis Canadensis* [Shaw, 1804]), mule deer (*Odocoileus hemionus* [Rafinesque, 1817]), white-tailed deer (*Odocoileus virginianus* [Zimmermann, 1780]), and pronghorn (*Antilocapra americana* [Ord, 1815]). As part of the National Wildlife Refuge System, the NBR is also tasked with the maintenance and recovery of pristine vegetation on the refuge.

General Approach

Development of a predictive map of areas within the NBR where bluebunch wheatgrass, Idaho fescue and rough fescue dominated the plant communities was used to test the three hypotheses. The amount of plant available water (centimeters) predicted by the REAP indicator was compared to measures of species frequency obtained from three separate vegetation assessments.

Figure 1. Location of the National Bison Range, Moiese, MT.

<u>Sample Site Sources</u>

Selection of vegetation data for comparison to the REAP output was based on two criteria: 1) previously sampled sites that had geographic references; and 2) detailed survey data from which the species abundance could be computed. Following these criteria, three vegetation community assessments were identified: “1970”, “2010” and “2011”. The “1970” data was drawn from the NBR archives. The “2010” and “2011” assessments were conducted during the course of this study.

This study was focused on identification of areas where each of the target grass species would dominate the survey community. Therefore, surveyed sites where none of the target species occurred were omitted. Additionally, there were sites where none of the target species were dominant, but they were present at lower levels. In these cases, the target species that scored the most hits on the respective transect was considered dominant. Consequently, for the purpose of this study dominance was defined as the most abundant between bluebunch wheatgrass, Idaho fescue, and rough fescue.

“1970” Assessment

The “1970” assessment was done by Fish and Wildlife Service (FWS) personnel between 1967 and 1971. Data from the four years was combined into the same assessment (“1970”) because all transects were not read each year. This assessment followed the Parker 3 Step method (BLM 1992, Ruyle and Dyess 2010) where the sample sites are in clusters of two or three transects of 100 feet each. To fully utilize GIS processes, geographic coordinates are essential, so only transects that been ground-marked were used. For the purpose of this study the initial ground-mark of each transect was considered the sample site. The species frequency was recorded and summarized to identify the dominant species for each transect (Table A1 on Appendix A). The summarization identified, 36 sample sites out of 49 that were used in this study; 19 were dominated by bluebunch wheatgrass; 11 by Idaho fescue; and 6 by rough fescue.

“2010” Assessment

The “2010” assessment was conducted by a crew from the Animal and Range Sciences Department, Montana State University (MSU) in July and August 2010. Their efforts were to re-visit sample sites with descriptive rather than geo-referenced locations from a previous assessment done by NRCS in 1990. These locations represented vegetation communities not included in the 1967-1971 Parker 3 Step assessments. The

"2010" survey added geographic coordinates to the vegetation assessment. This survey included "point data" using the "Line Intercept Method" (Canfield 1941) to generate frequency data similar to the Parker 3 Step Method. Two lines were laid out with a common starting point; one oriented to the North and the second to the east. Each line was 50 m long and a "point" was recorded at one meter intervals producing 100 hits per sample site. The number of hits for each species, bare ground and litter were tallied and divided by 100 to arrive at the frequency measure. From this assessment, 32 data sets out of 34 were used for this study; 12 were dominated by bluebunch wheatgrass; 18 by Idaho fescue; and 2 by rough fescue (Table A2 on Appendix A).

"2011" Assessment

The "2011" sample sites are from a co-related bison grazing behavior study conducted by Guffey et al. (2011). The data from this assessment was collected in 2010 and 2011 following the same method as the "2010" assessment (Table A3 on Appendix A). From this assessment, 81 out of 96 vegetation data sets were used for this study; 24 were dominated by bluebunch wheatgrass; 42 by Idaho fescue; and 15 by rough fescue.

REAP Values for Grassland Communities

The GIS software, ArcMap 10, from the Environmental Systems Research Institute (ESRI 2011), was used for all the GIS processes. A shapefile containing National Wildlife Refuges was downloaded from the USFWS website (2012). The shapefile was further clipped defining the NBR boundaries as the study area. The REAP raster for the NBR was then downloaded from the NRCS (2012) website and labelled as NBR_REAP.

Next the geographic coordinates for the three assessments were input to ArcMap and overlaid on the NBR_ REAP. Using the tool “extract” the REAP value for each sample site was built into a table for statistical comparison (Table A4 on Appendix A).

To fully test the indicator output, 30% of the sample sites were reserved for output validation. Segregation of the vegetation into developer and validation sets was done randomly for each assessment.

The ‘REAP model’ developed in this study resulted from a simple interval classification of the NBR_REAP. This process was done using the tool ‘reclassify’ from ArcMap package.

REAP Values for Target Species

The ‘reclassify’ tool required the definition of the NBR_REAP value intervals that would predict the dominance of each target species. The outcome was a raster with 3 values only, where each value was associated with one target species.

A routine was implemented to determine which REAP intervals most correctly predicted the dominance of each target species from a range of 861 possible intervals. This routine was applied to the developer set of sample sites and the resulting outcome was labeled as REAP_Model_S.

To assess the accuracy of the REAP_model_S model, the validation set of sample sites were overlaid on the REAP_Model_S and the raster value for each of these sites was extracted and used to create a new table for the validation set.

REAP Values for Target Groups

Based on preliminary analysis REAP could not differentiate between the fescues, so the decision was made to test by groups. For this analysis two groups were defined: the bluebunch group and the fescue group. The bluebunch group is composed by only bluebunch wheatgrass. On the other hand, the fescue group is represented by the rough fescue and Idaho fescue because both species belong to the same genus and they require very similar environmental characteristics. The next step was to recalculate the REAP value for each group and identify the REAP value or values that best differentiates the two groups. A routine, similar to that for the first run was implemented to determine the interval that maximized the correct prediction for the target groups. The intervals of REAP values in each group were used to reclassify the REAP raster. The outcome was a raster (REAP_Model_G) with two values only, where each value was associated to one target group.

REAP Values for Forest Area

The NBR contains several patches of coniferous forest; therefore, the dominant grass species predictions should not apply to these. However, to make sure this expectation was valid we chose to develop a REAP interval for conifer dominated communities. To define the conifer forest suitable area, the ‘component table’ available at Soil Survey Geographic (SSURGO) Database (Soil Survey Staff 2012) was used to create two layers. One layer represented areas that were classified as “fair” or “good” for forest and the second layer represented areas that were classified as “very poor” for grass. The new class, “Conifer Habitat” resulted from the intersection of these two layers.

Statistical Analyses

All the statistical analyses were done using the “R 2.15.2” statistical package (R Core Team 2012).

REAP Values for Grassland Communities

Because REAP value distribution across all the sample sites was not normally distributed (Figure 2) the Kruskal-Wallis test was used to determine if the REAP values, obtained for each target species or target group were different from each other.

A second test, Wilcoxon Rank Sum was performed to determine the possibility of statistical differences among the target species and groups.

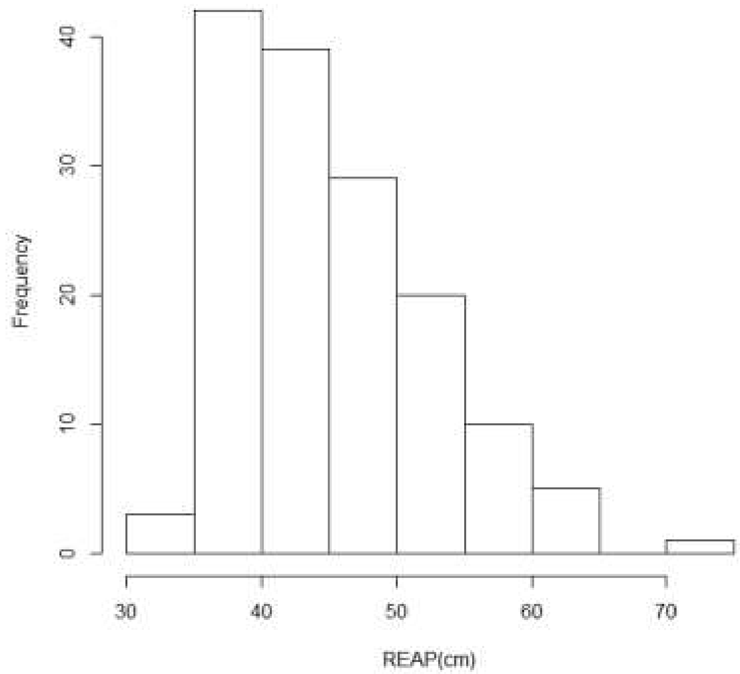

Figure 2. REAP values histogram for the sample sites related to bluebunch wheatgrass, Idaho fescue or rough fescue at the National Bison Range, Moiese, MT.

REAP Model Validation

The REAP model was tested comparing the actual dominant species from the vegetation assessments (“1970”, “2010”, and “2011”) against the predicted target species defined by the REAP_Model_ S (Table A5 on Appendix A). Similar validation was done for the REAP_Model_G to assess the target group model. These tests were done only with the validation set of the sample sites. The mean and the confidence interval for the probability of the model to accurately predict the target species and the target group were determined using a normal approximation of the binomial distribution.

REAP Values for Forests x REAP Values for Grasslands

The comparison between the two major vegetation cover type started by randomly selecting 50 sample sites from coniferous areas and grassland areas respectively, then the REAP values for the sample sites within the forest were compared against the REAP values within the grasslands using t-test.

RESULTS AND DISCUSSION

REAP Values for Grassland Communities

The Kruskal-Wallis test indicated that there is a difference ($P< 0.001$) between the REAP value distribution for the target species at the National Bison Range. However, this test does not specify which species was different so, species separation was accomplished with the Wilcoxon Rank Sum test (Table 3).

Table 3. Results from the Wilcoxon Rank Sum test.

Species Comparison	*P* - value	Result
bluebunch wheatgrass/ Idaho fescue	<0.001	Different
bluebunch wheatgrass/ rough fescue	<0.001	Different
Idaho fescue/ rough fescue	0.989	No Different

Based on these results, the first hypothesis was rejected and the conclusion drawn that the REAP values from sites where bluebunch wheatgrass is the dominant target species are lower than REAP values on sites related to Idaho fescue and rough fescue ($P < 0.001$).

Figure 3 reveal four outliers from sample sites dominated by bluebunch wheatgrass. Two of these sample sites were from the “2011” assessment: “UP Random 3” and “UP Random 1” (Table A3 on Appendix A). Both sample sites are located within the grazing preferred zone identified in a co-related study (Guffey 2011). The outlier “C10T2ST” (Table A1 on Appendix A) belongs to the “1970” assessment, it was located close (98m) to a fence. So, all three of these sample sites occurred in highly disturbed areas where grazing and trampling may have changed species dominance in the plant communities. Interestingly, the fourth sample site identified as “12” belongs to the “2010” assessment (Table A2 on Appendix A) and there is no apparent reason for this site to appear as an outlier.

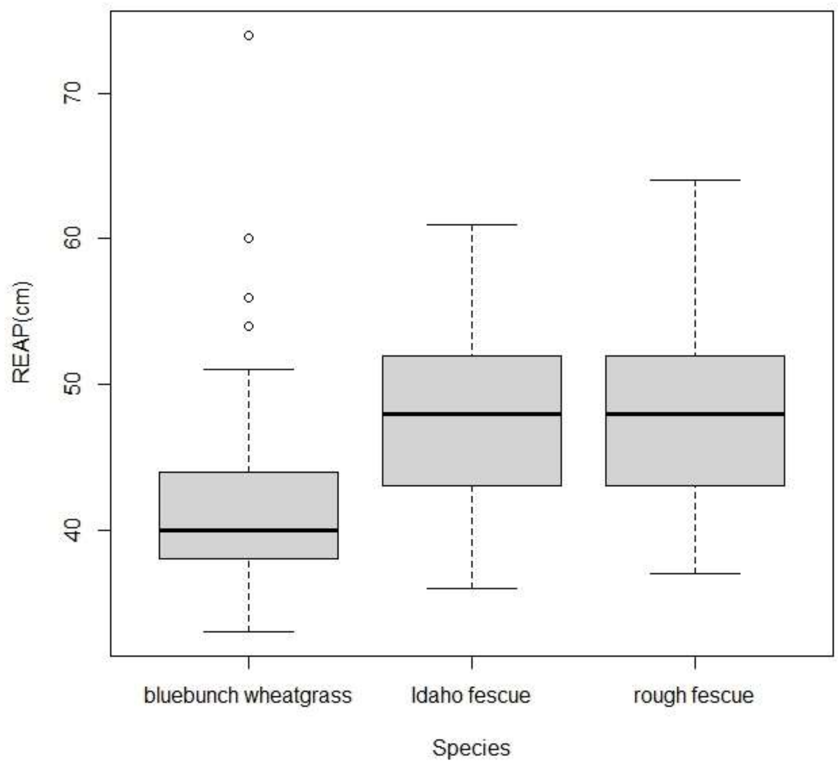

Figure 3. REAP values for each target grass species on the National Bison Range, Moiese, MT.

While there are no references in the literature to the utility of the REAP indicator for predicting species occurrence, absence, or abundance, there are other studies using some form of environmental variables to predict grass dominance. For example, Peters

Table 4. REAP Intervals associated with target grassland species on the National Bison Range, Moiese, MT.

REAP (cm)	Predicted Target Species
< 44	bluebunch wheatgrass
44 - 62	Idaho fescue
> 62	rough fescue

(2002) used simulation modelling to study what climate changes would affect the dominance of certain grass species. Her conclusion was that the Chihuahuan desert grass black grama (*Bouteloua eripoda* [Torr.]), would dominate during periods of uniform precipitation throughout the year while precipitation shifting to the winter period would favor blue grama (*Bouteloua gracillis* [H.B.K. Lag]). This supports our results of an apparent that shift in dominance being dictated by environmental conditions like water availability. The agreement reinforces water availability as being the key process driving grass species dominance dynamics, especially in semi-arid or arid environments (Noy-Meyer 1973, Peters 2002).

Validation of REAP Model for Target Species

The outcome of the re-classification effort is shown in Table 4, Figure 4 and Table A5 on Appendix A.

Out of 45 total sample sites within the validation set, 18 were dominated by bluebunch wheatgrass. The REAP_Model_S correctly predicted 9 sample sites as being related to the target species. Idaho fescue dominance was found on 23 sample sites and the REAP_Model_S correctly predicted 13 of the sites. The species with the richest fit was rough fescue, dominating on only four sites, the REAP_Model_S correctly predicting three of them (Table 5).

The casual probability of the REAP_Model_S to correctly determine the target species at sites within the NBR is 0.33 because all the sample sites, considered on this study, had one of the three target species as dominant. From the results of the normal approximation to binomial distribution, the probability mean of the REAP_Model_S to accurately predict the target species was 0.55 with confidence interval between 0.41 and 0.71. The second hypothesis states that the probability of the REAP indicator to correctly determine the dominant species on landforms within the NBR area is not greater than 0.33(casual probability). Therefore, with the above results the second hypothesis was rejected.

Table 5. Results from the validation of REAP model for species.

Dominant Species	Actual Dominance	Correctly Prediction	Correct %
bluebunch wheatgrass	18	9	50.00
Idaho fescue	23	13	56.52
rough fescue	4	3	75.00

The probability mean, of the REAP_Model_S to accurately predict the dominant species, achieved a satisfactory value (0.55) when compared to the casual probability. This is important because the objective of this study was not to identify suitable habitat but the identification of areas within NBR where each of the target species should be the dominant.

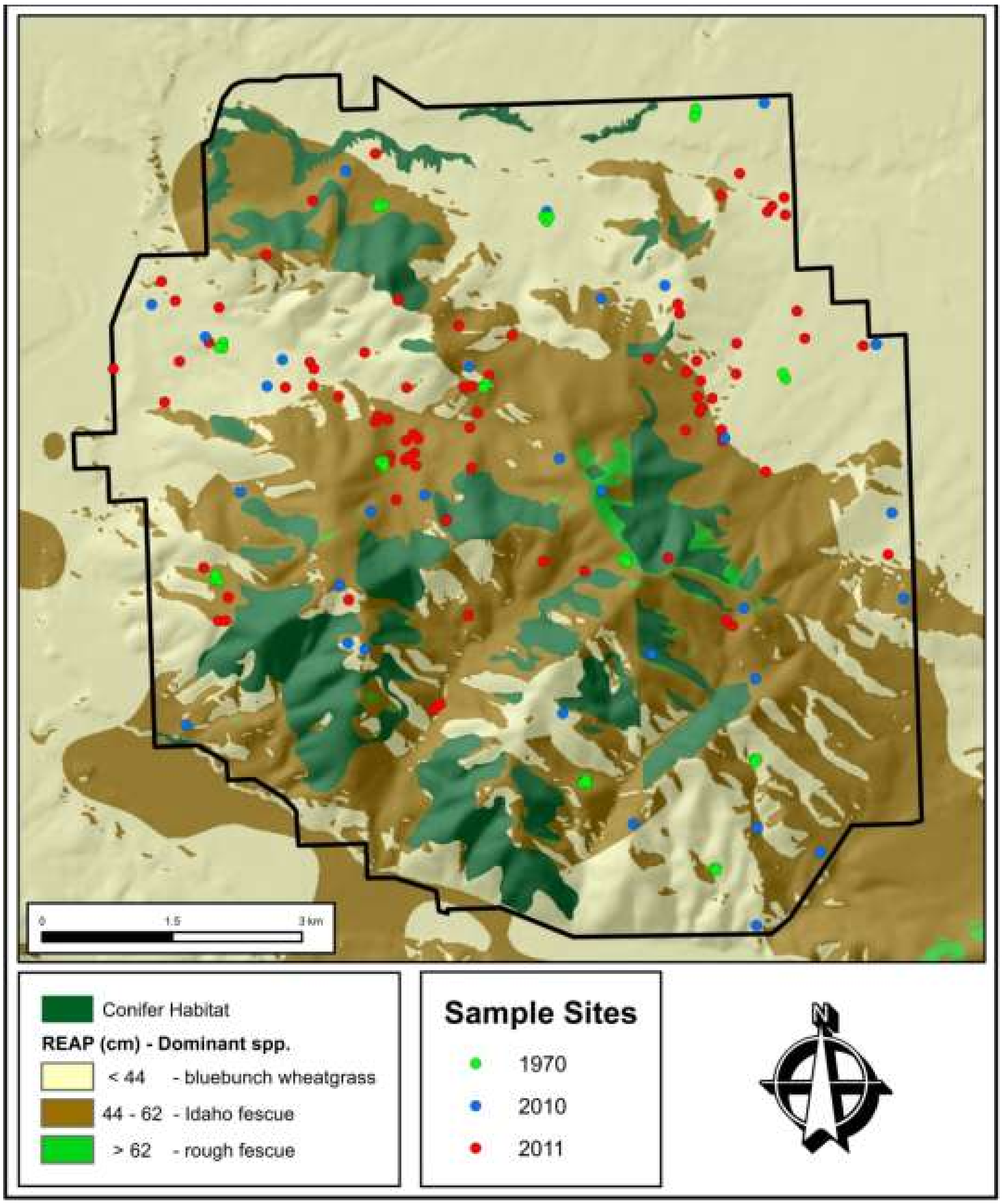

Figure 4. Predicted areas for target grass species on the National Bison Range, Moiese, MT.

Validation of REAP Model for Target Group

The outcome of REAP re-classification for groups of similar target species are shown in Table 6, Figure 5 and Table A6 on Appendix A.

Table 6. REAP Intervals associated with grassland target groups on the National Bison Range, Moiese, MT.

REAP (cm)	Predicted Dominant Species Group
≤ 42	bluebunch group
> 42	fescue group

Out of 45 total sample sites within the validation set, 18 were related to the bluebunch group. The REAP_Model_G correctly predicted 10 sample sites as being related to this group. The fescue group dominance was found on 27 sample sites and the REAP_Model_G correctly predicted on 19 sample sites (Table 7).

Table 7. Validation of the REAP model for target group.

Target Group	Actual Dominance	Correctly Prediction	Correct %
bluebunch group	18	10	55.55
fescue group	27	19	70.37

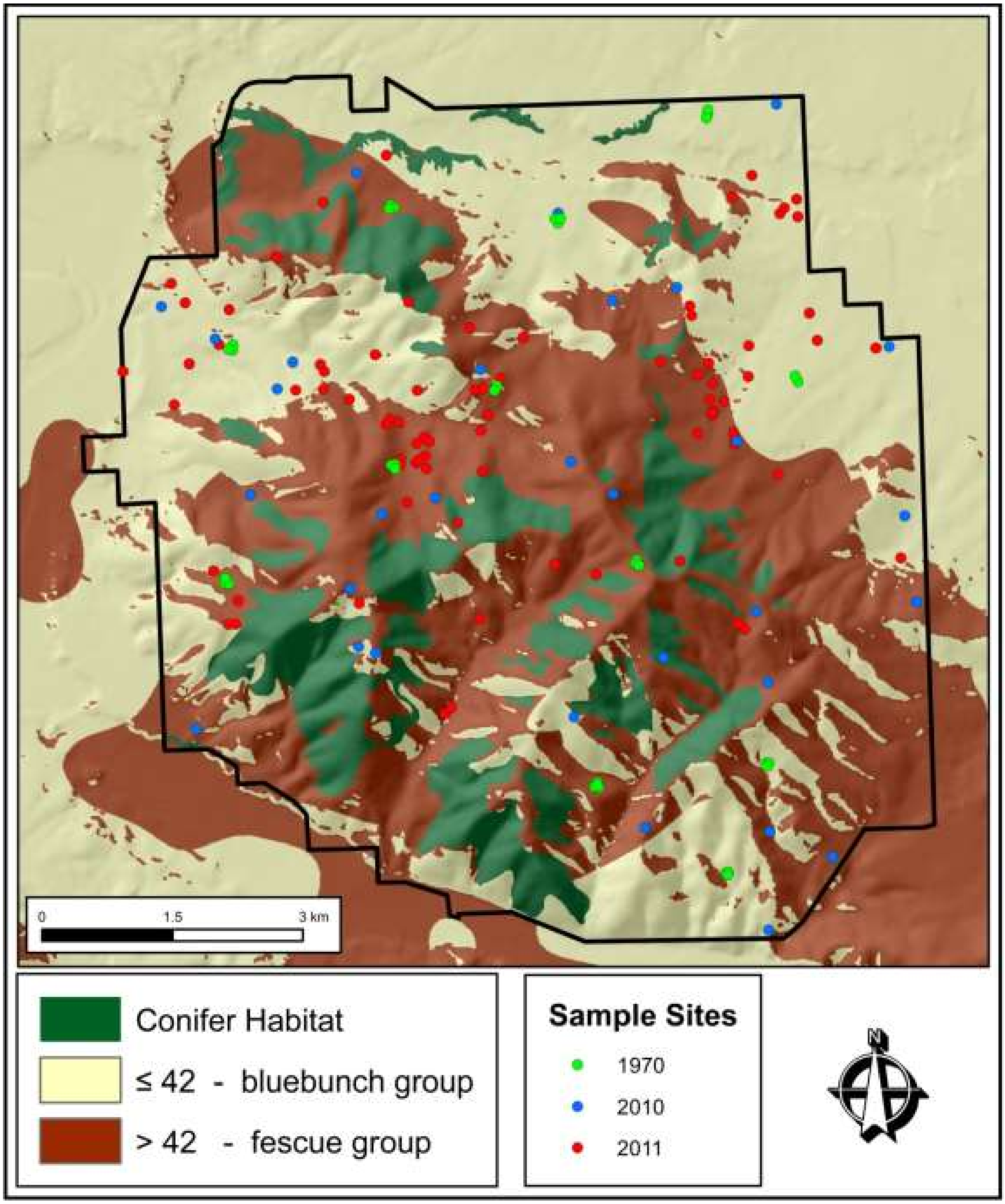

Figure 5. Predictive areas for target group on the National Bison Rage, Moiese, MT.

The development of a different model (REAP_Model_G) by grouping the two species of the genus *Festuca*, improved the probability of the model to correctly determine the plant community dominance.

From the results of the normal approximation to binomial distribution, the probability mean of the REAP_Model_G to accurately predict the target group was estimated as 0.64 with a confidence interval between 0.50 and 0.78. Therefore, the REAP value for the bluebunch group is lower than the REAP value for the fescue group (Figure 6). It is important to point out that the outliers are the same as discussed previously, since the bluebunch group holds only the bluebunch wheatgrass species.

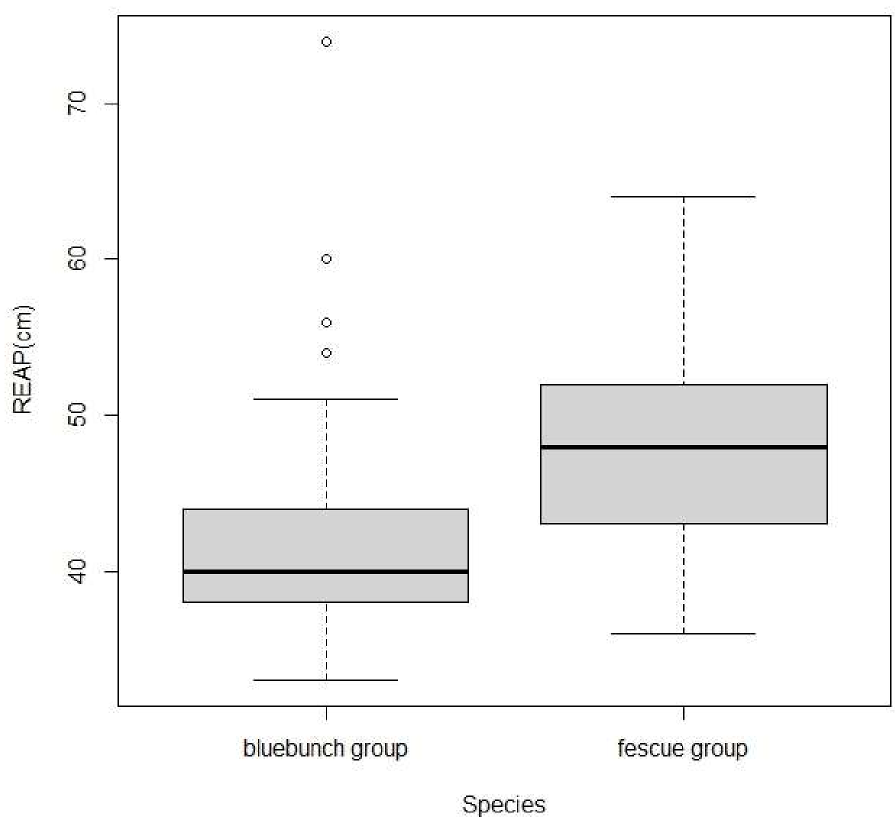

Figure 6. REAP values for each target group on the National Bison Range, Moiese, MT.

Dibenedetto (1999) and Jensen et al. (2001) stated that identification of grasses are lower than for shrubs and trees, however the probability mean of 0.64 reached on our study is similar to reported inventories of trees and shrubs cover (Da Luz and Crowley 2010, Cho et al. 2012).

REAP Values for Forests x REAP Values for Grasslands

The outcome of the comparison of coniferous forest to grasslands areas can be seen on Figure 4 and Figure 5.

The REAP values for grasslands averaged 44.9 cm. However, for forest patches the average was 50.4cm. Based on the t-test, hypothesis 3 was rejected which means that REAP values for grasslands are significantly different than the REAP values for forest patches (P = 0.0026) (Figure 7). This result is in accordance with the existing ecological knowledge that conifer stands would develop in areas with more available water than grasslands.

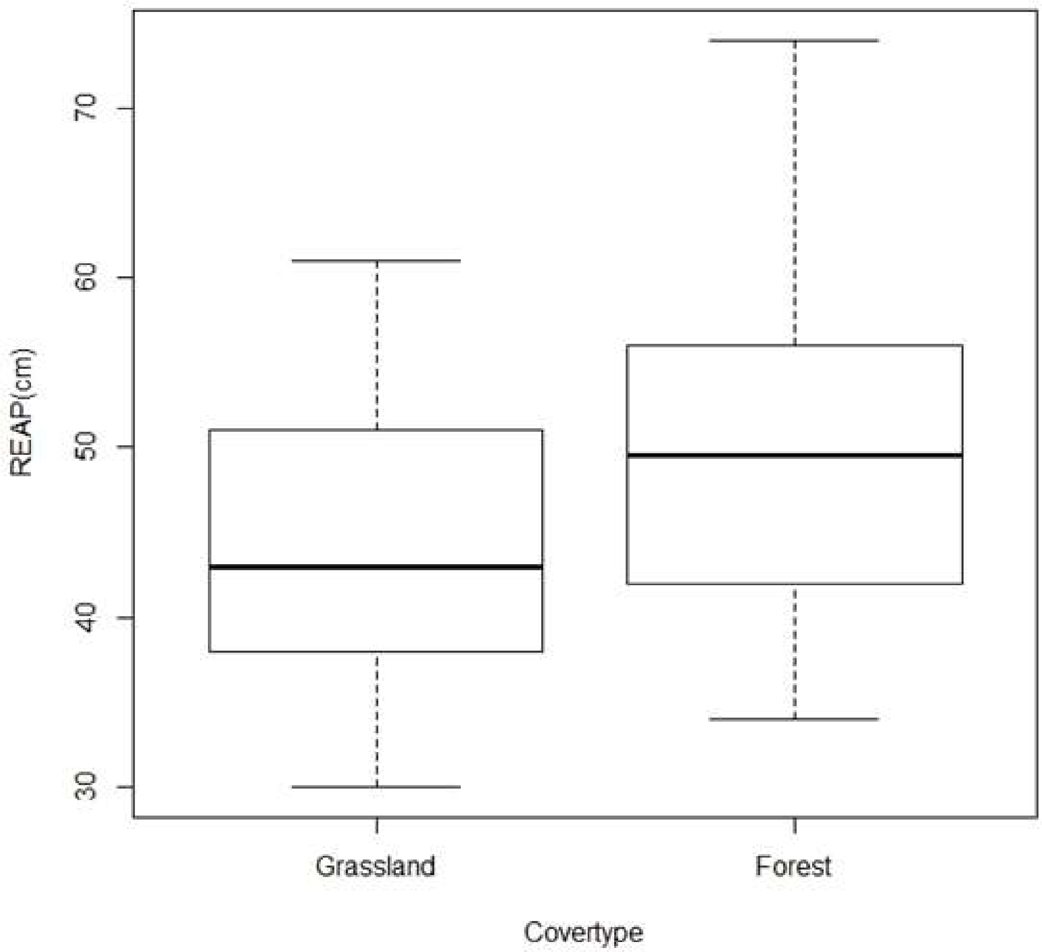

Figure 7. REAP values by major vegetation cover type on the National Bison Range, Moiese, MT.

CONCLUSION

The pristine native vegetation of an area has become a standard reference point for restoration and management of conservation units. Pristine vegetation is expected to persist when a certain plant community is in equilibrium with natural disturbances. The term pristine usually refers to the pre-European settlement condition. However, few and sparse records are available to describe this hypothetical plant community state. For example, in the Palouse Prairie, most of the area has been converted to commercial agriculture, the few remnants restricted to small areas on the border of fields, or rocky slopes which escaped cultivation (Young 1943, Hanson et al. 2008). The scale of this disturbance makes it almost impossible to describe the exact pristine vegetation community, especially within a relatively small area such as the NBR which has a long history of continuous grazing by wild ungulates. An objective description of this prairie community type on the refuge would require fine scale historical information that isn't available. Because of this limitation the NBR managers selected target species most representative of climax grass species on the Palouse Prairie as indicators of pristine conditions. Then they wanted to know where each of the target species would dominate within existing NBR grassland communities. Ideally, earlier habitat descriptions containing these target species could then be used to complete the picture of local climax vegetation community composition.

The habitat type classification scheme assumes that similar environmental conditions support the same specific climax vegetation (Hironaka 1986). However, this requires the availability of undistributed communities to serve as a reference. In areas like the NBR where reference communities no longer exist, the development of a vegetation predictor map based on environmental characteristics and individual species growth requirements would provide an objective means of approximating historic plant communities. The present study is not novel in terms of describing "suitable habitat" for important Palouse Prairie species because habitat characteristics for bluebunch wheatgrass, Idaho fescue, and rough fescue are already known. What this study contributes is a more refined segregation of species dominance in community types than previously reported.

Unlike other remote-sensing based vegetation surveys, this study correctly segregated areas within the NBR where *individual* grass species were mostly likely to dominate. Previous efforts have only differentiated between grass and tree dominated landscapes. To date, REAP cannot discriminate between Idaho fescue and rough fescue dominated communities.

The contradictory results for rough fescue, between the distribution analysis (not different from Idaho fescue, (P =0.989) (Table 3) and the validation (75% correct prediction of areas where rough fescue would dominate) appear to result from the small number of sample sites dominated by this species (only 23 out of 149), and the high REAP value. The relatively low number of sites where rough fescue was actually found to dominate could be related to the fact that it is the most palatable of the three species and very susceptible to overgrazing (Hodgkinson and Young 1973, Willms et al. 1988). We did not evaluate grazing patterns or intensity in this study, but records of overgrazing conditions on NBR go back to the earliest days of the refuge (Lomason and De Nio

1940). It is reasonable to expect that overgrazing may have changed community dominance from rough fescue to Idaho fescue on the highly productive sites demarcated by high REAP values. Importantly, we speculate that the discrimination between the species of *Festuca* (Idaho and rough) on the scale used in this study would require identification of a new set of variables with smaller spatial resolution than now available.

Another challenge is that REAP_Model_S predicted rough fescue sites that overlap with areas predicted to have coniferous forest. There are some sample sites from the most recent surveys (2010 and 2011) within the SSURGO predicted area for coniferous forest which had no forest overstory. This fact leads us to speculate that a soil survey (SSURGO) does not have the spatial resolution to differentiate between species at accurate enough for a local scale study.

To achieve higher prediction results, we suggest developing a more complex model that includes a set of variables with appropriate spatial resolution. Idaho fescue has very few preferences different from rough fescue such as aspect, soil texture, and organic matter (Table 1). The soil data would require a more detailed field survey than what is available at SSURGO. Developing a dataset and overlaying these environmental characteristics with accuracy similar to the REAP raster (10x10m) would make it possible to predict areas where each of the members of genus *Festuca* would dominate. It is important to remember that this fine scale may be necessary to identify degraded phases of fescue dominated communities. However, this modelling effort is beyond the scope and the objectives of this study.

The results indicated the shift of dominance between grass species based on soil water availability, so it could be useful to refine existing climate change simulation models. Because the REAP indicator contains a set of physical parameters that can predict species dominance at the plant community level on the NBR it has the potential to predict species dominance in other non-forested plant communities.

The Relative Effective Annual Precipitation is an indicator of the soil water availability. It is a simple raster layer ready to use, easily extractable using a GIS software package, and available for the entire state. Any user will find the necessary information on the Montana NRCS website (NRCS 2012) and/or with the local NRCS soil specialist. Therefore, the REAP indicator has a tremendous potential for other areas within Montana State.

The map developed for NBR will be useful to identify areas for monitoring and as a baseline for evaluating departure from the target plant composition. Thus, the predictor map will be a guide for grassland restoration projects. The approach may also prove useful when developing rehabilitation targets in areas without reference plant communities. REAP could be used to identify species for abandoned mined lands or Conservation Reserve Program restoration efforts.

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APPENDIX A

SAMPLE SITE CHARACTERISTICS

Table A1. Characteristics of the sample sites from “1970” assessment.

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant
1967	CO1T1STA	47.340682	-114.179017	Idaho fescue
1967	CO1T2STA	47.341289	-114.179429	Idaho fescue
1967	CO2T1STA	47.333655	-114.240844	Idaho fescue
1967	CO2T2STA	47.333564	-114.241367	Idaho fescue
1967	CO2T3STA	47.333164	-114.240821	bluebunch wheatgrass
1968	CO5T1STA	47.346571	-114.264763	bluebunch wheatgrass
1968	CO5T2STA	47.345987	-114.264810	bluebunch wheatgrass
1968	CO5T3STA	47.346080	-114.265446	bluebunch wheatgrass
1968	CO6T1STA	47.360453	-114.240104	Idaho fescue
1968	CO6T2STA	47.360185	-114.239548	rough fescue
1968	CO6T3STA	47.360066	-114.240289	Idaho fescue
1968	CO7T1STA	47.321934	-114.267327	rough fescue
1968	CO7T2STA	47.321862	-114.266661	rough fescue
1968	CO7T3STA	47.322435	-114.267163	rough fescue
1971	CO9T2STA	47.341360	-114.224854	bluebunch wheatgrass
1971	CO9T3STA	47.340890	-114.225223	bluebunch wheatgrass
1968	CO10T1MID	47.299448	-114.211489	rough fescue
1968	CO10T2STA	47.299708	-114.212087	bluebunch wheatgrass
1968	CO10T3STA	47.299975	-114.211693	Idaho fescue
1968	CO10T4STA	47.299543	-114.212146	rough fescue
1968	CO10T5STA	47.299676	-114.211672	Idaho fescue
1968	CO11T1STA	47.301378	-114.185911	bluebunch wheatgrass
1968	CO11T2STA	47.301382	-114.185529	bluebunch wheatgrass
1968	CO11T3STA	47.301069	-114.185860	bluebunch wheatgrass
1968	CO13T1STA	47.357936	-114.214638	bluebunch wheatgrass
1968	CO13T2STA	47.358433	-114.215106	bluebunch wheatgrass
1968	CO13T3STA	47.358409	-114.214251	bluebunch wheatgrass
1968	CO14T1STA	47.322805	-114.204552	Idaho fescue
1968	CO14T2STA	47.322502	-114.204774	Idaho fescue
1968	CO14T3STA	47.322278	-114.204266	Idaho fescue
1968	CO15T1STA	47.290155	-114.192715	bluebunch wheatgrass
1968	CO15T2MID	47.290251	-114.192331	bluebunch wheatgrass
1968	CO15T3STA	47.289965	-114.192418	bluebunch wheatgrass
1971	CO17T1STA	47.368669	-114.191293	bluebunch wheatgrass
1971	CO17T3STA	47.369078	-114.191263	bluebunch wheatgrass
1971	CO17T4STA	47.368246	-114.191532	bluebunch wheatgrass

[1] Lat/Long Coordinate System, WGS 84

[2] Relative Effective Annual Precipitation, from Montana NRCS.

Table A2. Characteristics of the sample sites from “2010” assessment.

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant
2010	Dsw 6	47.314902	-114.247236	bluebunch wheatgrass
2010	Dup 6	47.328499	-114.243105	Idaho fescue
2010	24	47.284109	-114.1865	bluebunch wheatgrass
2010	23	47.291417	-114.176306	Idaho fescue
2010	Nbr25	47.29424	-114.185767	Idaho fescue
2010	22	47.295115	-114.204737	Idaho fescue
2010	21	47.30971	-114.185271	Idaho fescue
2010	Nbr30	47.306838	-114.21487	Idaho fescue
2010	14	47.317451	-114.162212	rough fescue
2010	Nbr20	47.312673	-114.201018	rough fescue
2010	11	47.317104	-114.186657	Idaho fescue
2010	19	47.306993	-114.272412	bluebunch wheatgrass
2010	18	47.314197	-114.2447	bluebunch wheatgrass
2010	13	47.322345	-114.204221	Idaho fescue
2010	17	47.320908	-114.248257	Idaho fescue
2010	16	47.334743	-114.188648	Idaho fescue
2010	12	47.333259	-114.213968	bluebunch wheatgrass
2010	9	47.329967	-114.234789	Idaho fescue
2010	15	47.343927	-114.164993	bluebunch wheatgrass
2010	10	47.343106	-114.227282	bluebunch wheatgrass
2010	1	47.350838	-114.19696	bluebunch wheatgrass
2010	4	47.347201	-114.267407	bluebunch wheatgrass
2010	3	47.358982	-114.214575	bluebunch wheatgrass
2010	6	47.350759	-114.27546	bluebunch wheatgrass
2010	2	47.36941	-114.180764	bluebunch wheatgrass
2010	7	47.363918	-114.245028	Idaho fescue
2010	5	47.326383	-114.163563	Idaho fescue
2010	2	47.330935	-114.262869	Idaho fescue
2010	3	47.341843	-114.258241	Idaho fescue
2010	4	47.344543	-114.25574	Idaho fescue
2010	6	47.349684	-114.206745	Idaho fescue
2010	Nbr31	47.32976	-114.207684	Idaho fescue

[1] Lat/Long Coordinate System, WGS 84

[2] Relative Effective Annual Precipitation, from Montana NRCS.

Table A3. Characteristics of the sample sites from "2011" assessment.

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant
2011	B 031402	47.317716	-114.266946	Idaho fescue
2011	B 031403	47.3194	-114.246927	Idaho fescue
2011	B 031404	47.322674	-114.217022	Idaho fescue
2011	B 031501	47.317366	-114.228769	Idaho fescue
2011	B 031601	47.323248	-114.268914	Idaho fescue
2011	B 031602	47.317693	-114.26586	rough fescue
2011	B 031603	47.307663	-114.234555	bluebunch wheatgrass
2011	B 031604	47.308275	-114.233537	Idaho fescue
2011	B 031605	47.320076	-114.26532	Idaho fescue
2011	B 042102	47.344188	-114.251555	rough fescue
2011	B 042106	47.36095	-114.250249	Idaho fescue
2011	B 042201	47.350205	-114.265164	rough fescue
2011	B 042202	47.344216	-114.281615	Idaho fescue
2011	B 042203	47.346615	-114.266889	Idaho fescue
2011	B 042204	47.35549	-114.257709	Idaho fescue
2011	B 051301	47.358122	-114.180859	bluebunch wheatgrass
2011	B 051302	47.358699	-114.180152	bluebunch wheatgrass
2011	B 051303	47.357725	-114.178147	bluebunch wheatgrass
2011	B 051902	47.341678	-114.251228	Idaho fescue
2011	B 052002	47.341667	-114.255432	bluebunch wheatgrass
2011	B 052601	47.334474	-114.189052	Idaho fescue
2011	B 052602	47.348887	-114.195105	Idaho fescue
2011	B 052603	47.343303	-114.199858	Idaho fescue
2011	B 060201	47.344997	-114.243152	Idaho fescue
2011	B 060202	47.334344	-114.23614	Idaho fescue
2011	B 060203	47.329604	-114.239169	rough fescue
2011	B 060301	47.34101	-114.228212	Idaho fescue
2011	B 060302	47.341118	-114.226936	Idaho fescue
2011	B 060303	47.332589	-114.227542	Idaho fescue
2011	B 060304	47.333677	-114.237594	Idaho fescue
2011	B 060305	47.33307	-114.236009	Idaho fescue
2011	B 060306	47.340528	-114.247346	rough fescue
2011	B 062301	47.341192	-114.237001	bluebunch wheatgrass
2011	B 062302	47.337934	-114.239953	Idaho fescue
2011	B 062303	47.33833	-114.241433	Idaho fescue
2011	B 062304	47.334129	-114.23992	bluebunch wheatgrass
2011	B 062305	47.336317	-114.236236	Idaho fescue
2011	B 062401	47.333974	-114.23707	Idaho fescue
2011	B 062402	47.34626	-114.220552	Idaho fescue
2011	B 062403	47.337773	-114.241919	Idaho fescue
2011	B 062404	47.335854	-114.235467	Idaho fescue
2011	B 062405	47.33355	-114.240007	bluebunch wheatgrass
2011	B 062901	47.321448	-114.210741	rough fescue
2011	B 062902	47.315308	-114.188467	rough fescue
2011	B 062903	47.335739	-114.194584	Idaho fescue
2011	B 071201	47.337593	-114.19235	bluebunch wheatgrass
2011	B 071202	47.339163	-114.192587	Idaho fescue
2011	B 071203	47.341819	-114.194185	Idaho fescue
2011	B 071204	47.342903	-114.192521	bluebunch wheatgrass
2011	B 071301	47.338002	-114.192037	Idaho fescue
2011	B 071302	47.344546	-114.18632	Idaho fescue
2011	B 071304	47.347889	-114.194874	Idaho fescue
2011	B 071401	47.347689	-114.176903	rough fescue
2011	B 071402	47.344843	-114.175858	rough fescue
2011	B 072101	47.338356	-114.226257	Idaho fescue
2011	B 072102	47.336819	-114.227536	Idaho fescue
2011	B 072103	47.335702	-114.237381	Idaho fescue
2011	B 080301	47.337721	-114.192297	bluebunch wheatgrass
2011	B 080302	47.335085	-114.189003	rough fescue
2011	B 080303	47.3408	-114.192041	rough fescue

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant
2011	B 080304	47.335651	-114.189093	rough fescue
2011	B 080305	47.341394	-114.18656	bluebunch wheatgrass
2011	B 080306	47.338943	-114.19039	rough fescue
2011	B 080401	47.343835	-114.16699	bluebunch wheatgrass
2011	B 080402	47.331134	-114.182569	rough fescue
2011	B 080403	47.365607	-114.240451	Idaho fescue
2011	B 080501	47.362181	-114.18491	Idaho fescue
2011	B 080502	47.359544	-114.178243	bluebunch wheatgrass
2011	B 081101	47.340593	-114.27401	bluebunch wheatgrass
2011	B 081102	47.343497	-114.250991	bluebunch wheatgrass
2011	B 081103	47.353124	-114.273837	Idaho fescue
2011	B 082305	47.360036	-114.187906	rough fescue
2011	HP Random 1	47.322061	-114.1644	bluebunch wheatgrass
2011	HP Random 2	47.315912	-114.189494	bluebunch wheatgrass
2011	HP Random 3	47.322527	-114.197989	bluebunch wheatgrass
2011	LP Random 1	47.344752	-114.271522	bluebunch wheatgrass
2011	LP Random 2	47.350319	-114.237838	bluebunch wheatgrass
2011	LP Random 3	47.351059	-114.271823	bluebunch wheatgrass
2011	UP Random 1	47.342178	-114.224336	bluebunch wheatgrass
2011	UP Random 2	47.347443	-114.228688	Idaho fescue
2011	UP Random 3	47.327298	-114.231603	bluebunch wheatgrass

Table A4. Extracted REAP value for sample sites.

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant	REAP[2](cm)
1970	CO1T1STA	47.340682	-114.179017	Idaho fescue	40
1970	CO1T2STA	47.341289	-114.179429	Idaho fescue	40
1970	CO2T1STA	47.333655	-114.240844	Idaho fescue	48
1970	CO2T2STA	47.333564	-114.241367	Idaho fescue	48
1970	CO2T3STA	47.333164	-114.240821	bluebunch wheatgrass	48
1970	CO5T1STA	47.346571	-114.264763	bluebunch wheatgrass	38
1970	CO5T2STA	47.345987	-114.264810	bluebunch wheatgrass	38
1970	CO5T3STA	47.346080	-114.265446	bluebunch wheatgrass	38
1970	CO6T1STA	47.360453	-114.240104	Idaho fescue	50
1970	CO6T2STA	47.360185	-114.239548	rough fescue	50
1970	CO6T3STA	47.360066	-114.240289	Idaho fescue	51
1970	CO7T1STA	47.321934	-114.267327	rough fescue	49
1970	CO7T2STA	47.321862	-114.266661	rough fescue	50
1970	CO7T3STA	47.322435	-114.267163	rough fescue	49
1970	CO9T2STA	47.341360	-114.224854	bluebunch wheatgrass	40
1970	CO9T3STA	47.340890	-114.225223	bluebunch wheatgrass	44
1970	CO10T1MID	47.299448	-114.211489	rough fescue	60
1970	CO10T2STA	47.299708	-114.212087	bluebunch wheatgrass	60
1970	CO10T3STA	47.299975	-114.211693	Idaho fescue	56
1970	CO10T4STA	47.299543	-114.212146	rough fescue	60
1970	CO10T5STA	47.299676	-114.211672	Idaho fescue	60
1970	CO11T1STA	47.301378	-114.185911	bluebunch wheatgrass	37
1970	CO11T2STA	47.301382	-114.185529	bluebunch wheatgrass	41
1970	CO11T3STA	47.301069	-114.185860	bluebunch wheatgrass	37
1970	CO13T1STA	47.357936	-114.214638	bluebunch wheatgrass	41
1970	CO13T2STA	47.358433	-114.215106	bluebunch wheatgrass	42
1970	CO13T3STA	47.358409	-114.214251	bluebunch wheatgrass	42
1970	CO14T1STA	47.322805	-114.204552	Idaho fescue	61
1970	CO14T2STA	47.322502	-114.204774	Idaho fescue	61
1970	CO14T3STA	47.322278	-114.204266	Idaho fescue	61
1970	CO15T1STA	47.290155	-114.192715	bluebunch wheatgrass	33
1970	CO15T2MID	47.290251	-114.192331	bluebunch wheatgrass	33
1970	CO15T3STA	47.289965	-114.192418	bluebunch wheatgrass	33
1970	CO17T1STA	47.368669	-114.191293	bluebunch wheatgrass	37
1970	CO17T3STA	47.369078	-114.191263	bluebunch wheatgrass	37
1970	CO17T4STA	47.368246	-114.191532	bluebunch wheatgrass	38
2010	Dsw 6	47.314902	-114.247236	bluebunch wheatgrass	39
2010	Dup 6	47.328499	-114.243105	Idaho fescue	59
2010	24	47.284109	-114.186500	bluebunch wheatgrass	39
2010	23	47.291417	-114.176306	Idaho fescue	50
2010	Nbr25	47.294240	-114.185767	Idaho fescue	44
2010	22	47.295115	-114.204737	Idaho fescue	53
2010	21	47.309710	-114.185271	Idaho fescue	53
2010	Nbr30	47.306838	-114.214870	Idaho fescue	42
2010	14	47.317451	-114.162212	rough fescue	51
2010	Nbr20	47.312673	-114.201018	rough fescue	64
2010	11	47.317104	-114.186657	Idaho fescue	53
2010	19	47.306993	-114.272412	bluebunch wheatgrass	48
2010	18	47.314197	-114.244700	bluebunch wheatgrass	40
2010	13	47.322345	-114.204221	Idaho fescue	61
2010	17	47.320908	-114.248257	Idaho fescue	48
2010	16	47.334743	-114.188648	Idaho fescue	43
2010	12	47.333259	-114.213968	bluebunch wheatgrass	51
2010	9	47.329967	-114.234789	Idaho fescue	53
2010	15	47.343927	-114.164993	bluebunch wheatgrass	38
2010	10	47.343106	-114.227282	bluebunch wheatgrass	37
2010	1	47.350838	-114.196960	bluebunch wheatgrass	43
2010	4	47.347201	-114.267407	bluebunch wheatgrass	38
2010	3	47.358982	-114.214575	bluebunch wheatgrass	42
2010	6	47.350759	-114.275460	bluebunch wheatgrass	39
2010	2	47.369410	-114.180764	bluebunch wheatgrass	38

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant	REAP[2](cm)
2010	7	47.363918	-114.245028	Idaho fescue	55
2010	005	47.326383	-114.163563	Idaho fescue	40
2010	002	47.330935	-114.262869	Idaho fescue	48
2010	003	47.341843	-114.258241	Idaho fescue	37
2010	004	47.344543	-114.255740	Idaho fescue	36
2010	006	47.349684	-114.206745	Idaho fescue	45
2010	Nbr31	47.329760	-114.207684	Idaho fescue	59
2011	B 031402	47.317716	-114.266946	Idaho fescue	45
2011	B 031403	47.3194	-114.246927	Idaho fescue	37
2011	B 031404	47.322674	-114.217022	Idaho fescue	52
2011	B 031501	47.317366	-114.228769	Idaho fescue	44
2011	B 031601	47.323248	-114.268914	Idaho fescue	39
2011	B 031602	47.317693	-114.26586	rough fescue	46
2011	B 031603	47.307663	-114.234555	bluebunch wheatgrass	45
2011	B 031604	47.308275	-114.233537	Idaho fescue	45
2011	B 031605	47.320076	-114.26532	Idaho fescue	51
2011	B 042102	47.344188	-114.251555	rough fescue	37
2011	B 042106	47.36095	-114.250249	Idaho fescue	53
2011	B 042201	47.350205	-114.265164	rough fescue	42
2011	B 042202	47.344216	-114.281615	Idaho fescue	36
2011	B 042203	47.346615	-114.266889	Idaho fescue	38
2011	B 042204	47.35549	-114.257709	Idaho fescue	50
2011	B 051301	47.358122	-114.180859	bluebunch wheatgrass	38
2011	B 051302	47.358699	-114.180152	bluebunch wheatgrass	38
2011	B 051303	47.357725	-114.178147	bluebunch wheatgrass	37
2011	B 051902	47.341678	-114.251228	Idaho fescue	43
2011	B 052002	47.341667	-114.255432	bluebunch wheatgrass	38
2011	B 052601	47.334474	-114.189052	Idaho fescue	44
2011	B 052602	47.348887	-114.195105	Idaho fescue	42
2011	B 052603	47.343303	-114.199858	Idaho fescue	45
2011	B 060201	47.344997	-114.243152	Idaho fescue	43
2011	B 060202	47.334344	-114.23614	Idaho fescue	48
2011	B 060203	47.329604	-114.239169	rough fescue	53
2011	B 060301	47.34101	-114.228212	Idaho fescue	52
2011	B 060302	47.341118	-114.226936	Idaho fescue	48
2011	B 060303	47.332589	-114.227542	Idaho fescue	54
2011	B 060304	47.333677	-114.237594	Idaho fescue	48
2011	B 060305	47.33307	-114.236009	Idaho fescue	52
2011	B 060306	47.340528	-114.247346	rough fescue	41
2011	B 062301	47.341192	-114.237001	bluebunch wheatgrass	41
2011	B 062302	47.337934	-114.239953	Idaho fescue	49
2011	B 062303	47.33833	-114.241433	Idaho fescue	48
2011	B 062304	47.334129	-114.23992	bluebunch wheatgrass	51
2011	B 062305	47.336317	-114.236236	Idaho fescue	52
2011	B 062401	47.333974	-114.23707	Idaho fescue	48
2011	B 062402	47.34626	-114.220552	Idaho fescue	44
2011	B 062403	47.337773	-114.241919	Idaho fescue	48
2011	B 062404	47.335854	-114.235467	Idaho fescue	52
2011	B 062405	47.33355	-114.240007	bluebunch wheatgrass	48
2011	B 062901	47.321448	-114.210741	rough fescue	56
2011	B 062902	47.315308	-114.188467	rough fescue	54
2011	B 062903	47.335739	-114.194584	Idaho fescue	47
2011	B 071201	47.337593	-114.19235	bluebunch wheatgrass	45
2011	B 071202	47.339163	-114.192587	Idaho fescue	44
2011	B 071203	47.341819	-114.194185	Idaho fescue	44
2011	B 071204	47.342903	-114.192521	bluebunch wheatgrass	43
2011	B 071301	47.338002	-114.192037	Idaho fescue	44
2011	B 071302	47.344546	-114.18632	Idaho fescue	39
2011	B 071304	47.347889	-114.194874	Idaho fescue	42
2011	B 071401	47.347689	-114.176903	rough fescue	38
2011	B 071402	47.344843	-114.175858	rough fescue	38
2011	B 072101	47.338356	-114.226257	Idaho fescue	50

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant	REAP[2](cm)
2011	B 072102	47.336819	-114.227536	Idaho fescue	50
2011	B 072103	47.335702	-114.237381	Idaho fescue	47
2011	B 080301	47.337721	-114.192297	bluebunch wheatgrass	44
2011	B 080302	47.335085	-114.189003	rough fescue	43
2011	B 080303	47.3408	-114.192041	rough fescue	44
2011	B 080304	47.335651	-114.189093	rough fescue	43
2011	B 080305	47.341394	-114.18656	bluebunch wheatgrass	40
2011	B 080306	47.338943	-114.19039	rough fescue	43
2011	B 080401	47.343835	-114.16699	bluebunch wheatgrass	38
2011	B 080402	47.331134	-114.182569	rough fescue	43
2011	B 080403	47.365607	-114.240451	Idaho fescue	41
2011	B 080501	47.362181	-114.18491	Idaho fescue	39
2011	B 080502	47.359544	-114.178243	bluebunch wheatgrass	38
2011	B 081101	47.340593	-114.27401	bluebunch wheatgrass	37
2011	B 081102	47.343497	-114.250991	bluebunch wheatgrass	38
2011	B 081103	47.353124	-114.273837	Idaho fescue	41
2011	B 082305	47.360036	-114.187906	rough fescue	48
2011	HP Random 1	47.322061	-114.1644	bluebunch wheatgrass	42
2011	HP Random 2	47.315912	-114.189494	bluebunch wheatgrass	56
2011	HP Random 3	47.322527	-114.197989	bluebunch wheatgrass	74
2011	LP Random 1	47.344752	-114.271522	bluebunch wheatgrass	37
2011	LP Random 2	47.350319	-114.237838	bluebunch wheatgrass	48
2011	LP Random 3	47.351059	-114.271823	bluebunch wheatgrass	40
2011	UP Random 1	47.342178	-114.224336	bluebunch wheatgrass	54
2011	UP Random 2	47.347443	-114.228688	Idaho fescue	49
2011	UP Random 3	47.327298	-114.231603	bluebunch wheatgrass	56

[1] Lat/Long Coordinate System, WGS 84
[2] Relative Effective Annual Precipitation, from Montana NRCS.

Table A5. Predicted target species for the sample sites.

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant	REAP[2] (cm)	Target Species
1970	CO1T1STA	47.340682	-114.179017	Idaho fescue	40	bluebunch wheatgrass
1970	CO1T2STA	47.341289	-114.179429	Idaho fescue	40	bluebunch wheatgrass
1970	CO2T1STA	47.333655	-114.240844	Idaho fescue	48	Idaho fescue
1970	CO2T2STA	47.333564	-114.241367	Idaho fescue	48	Idaho fescue
1970	CO2T3STA	47.333164	-114.240821	bluebunch wheatgrass	48	Idaho fescue
1970	CO5T1STA	47.346571	-114.264763	bluebunch wheatgrass	38	bluebunch wheatgrass
1970	CO5T2STA	47.345987	-114.264810	bluebunch wheatgrass	38	bluebunch wheatgrass
1970	CO5T3STA	47.346080	-114.265446	bluebunch wheatgrass	38	bluebunch wheatgrass
1970	CO6T1STA	47.360453	-114.240104	Idaho fescue	50	Idaho fescue
1970	CO6T2STA	47.360185	-114.239548	rough fescue	50	Idaho fescue
1970	CO6T3STA	47.360066	-114.240289	Idaho fescue	51	Idaho fescue
1970	CO7T1STA	47.321934	-114.267327	rough fescue	49	Idaho fescue
1970	CO7T2STA	47.321862	-114.266661	rough fescue	50	Idaho fescue
1970	CO7T3STA	47.322435	-114.267163	rough fescue	49	Idaho fescue
1970	CO9T2STA	47.341360	-114.224854	bluebunch wheatgrass	40	bluebunch wheatgrass
1970	CO9T3STA	47.340890	-114.225223	bluebunch wheatgrass	44	Idaho fescue
1970	CO10T1MID	47.299448	-114.211489	rough fescue	60	Idaho fescue
1970	CO10T2STA	47.299708	-114.212087	bluebunch wheatgrass	60	Idaho fescue
1970	CO10T3STA	47.299975	-114.211693	Idaho fescue	56	Idaho fescue
1970	CO10T4STA	47.299543	-114.212146	rough fescue	60	Idaho fescue
1970	CO10T5STA	47.299676	-114.211672	Idaho fescue	60	Idaho fescue
1970	CO11T1STA	47.301378	-114.185911	bluebunch wheatgrass	37	bluebunch wheatgrass
1970	CO11T2STA	47.301382	-114.185529	bluebunch wheatgrass	41	bluebunch wheatgrass
1970	CO11T3STA	47.301069	-114.185860	bluebunch wheatgrass	37	bluebunch wheatgrass
1970	CO13T1STA	47.357936	-114.214638	bluebunch wheatgrass	41	bluebunch wheatgrass
1970	CO13T2STA	47.358433	-114.215106	bluebunch wheatgrass	42	bluebunch wheatgrass
1970	CO13T3STA	47.358409	-114.214251	bluebunch wheatgrass	42	bluebunch wheatgrass
1970	CO14T1STA	47.322805	-114.204552	Idaho fescue	61	Idaho fescue
1970	CO14T2STA	47.322502	-114.204774	Idaho fescue	61	Idaho fescue
1970	CO14T3STA	47.322278	-114.204266	Idaho fescue	61	Idaho fescue
1970	CO15T1STA	47.290155	-114.192715	bluebunch wheatgrass	33	bluebunch wheatgrass
1970	CO15T2MID	47.290251	-114.192331	bluebunch wheatgrass	33	bluebunch wheatgrass
1970	CO15T3STA	47.289965	-114.192418	bluebunch wheatgrass	33	bluebunch wheatgrass
1970	CO17T1STA	47.368669	-114.191293	bluebunch wheatgrass	37	bluebunch wheatgrass
1970	CO17T3STA	47.369078	-114.191263	bluebunch wheatgrass	37	bluebunch wheatgrass
1970	CO17T4STA	47.368246	-114.191532	bluebunch wheatgrass	38	bluebunch wheatgrass
2010	Dsw 6	47.314902	-114.247236	bluebunch wheatgrass	39	bluebunch wheatgrass
2010	Dup 6	47.328499	-114.243105	Idaho fescue	59	Idaho fescue
2010	24	47.284109	-114.186500	bluebunch wheatgrass	39	bluebunch wheatgrass
2010	23	47.291417	-114.176306	Idaho fescue	50	Idaho fescue
2010	Nbr25	47.294240	-114.185767	Idaho fescue	44	Idaho fescue
2010	22	47.295115	-114.204737	Idaho fescue	53	Idaho fescue
2010	21	47.309710	-114.185271	Idaho fescue	53	Idaho fescue
2010	Nbr30	47.306838	-114.214870	Idaho fescue	42	bluebunch wheatgrass
2010	14	47.317451	-114.162212	rough fescue	51	Idaho fescue
2010	Nbr20	47.312673	-114.201018	rough fescue	64	rough fescue
2010	11	47.317104	-114.186657	Idaho fescue	53	Idaho fescue
2010	19	47.306993	-114.272412	bluebunch wheatgrass	48	Idaho fescue
2010	18	47.314197	-114.244700	bluebunch wheatgrass	40	bluebunch wheatgrass
2010	13	47.322345	-114.204221	Idaho fescue	61	Idaho fescue
2010	17	47.320908	-114.248257	Idaho fescue	48	Idaho fescue
2010	16	47.334743	-114.188648	Idaho fescue	43	Idaho fescue
2010	12	47.333259	-114.213968	bluebunch wheatgrass	51	Idaho fescue
2010	9	47.329967	-114.234789	Idaho fescue	53	Idaho fescue
2010	15	47.343927	-114.164993	bluebunch wheatgrass	38	bluebunch wheatgrass
2010	10	47.343106	-114.227282	bluebunch wheatgrass	37	bluebunch wheatgrass
2010	1	47.350838	-114.196960	bluebunch wheatgrass	43	Idaho fescue
2010	4	47.347201	-114.267407	bluebunch wheatgrass	38	bluebunch wheatgrass
2010	3	47.358982	-114.214575	bluebunch wheatgrass	42	bluebunch wheatgrass
2010	6	47.350759	-114.275460	bluebunch wheatgrass	39	bluebunch wheatgrass

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant	REAP[2] (cm)	Target Species
2010	2	47.369410	-114.180764	bluebunch wheatgrass	38	bluebunch wheatgrass
2010	7	47.363918	-114.245028	Idaho fescue	55	Idaho fescue
2010	005	47.326383	-114.163563	Idaho fescue	40	bluebunch wheatgrass
2010	002	47.330935	-114.262869	Idaho fescue	48	Idaho fescue
2010	003	47.341843	-114.258241	Idaho fescue	37	bluebunch wheatgrass
2010	004	47.344543	-114.255740	Idaho fescue	36	bluebunch wheatgrass
2010	006	47.349684	-114.206745	Idaho fescue	45	Idaho fescue
2010	Nbr31	47.329760	-114.207684	Idaho fescue	59	Idaho fescue
2011	B 031402	47.317716	-114.266946	Idaho fescue	45	Idaho fescue
2011	B 031403	47.3194	-114.246927	Idaho fescue	37	bluebunch wheatgrass
2011	B 031404	47.322674	-114.217022	Idaho fescue	52	Idaho fescue
2011	B 031501	47.317366	-114.228769	Idaho fescue	44	Idaho fescue
2011	B 031601	47.323248	-114.268914	Idaho fescue	39	bluebunch wheatgrass
2011	B 031602	47.317693	-114.26586	rough fescue	46	Idaho fescue
2011	B 031603	47.307663	-114.234555	bluebunch wheatgrass	45	Idaho fescue
2011	B 031604	47.308275	-114.233537	Idaho fescue	45	Idaho fescue
2011	B 031605	47.320076	-114.26532	Idaho fescue	51	Idaho fescue
2011	B 042102	47.344188	-114.251555	rough fescue	37	bluebunch wheatgrass
2011	B 042106	47.36095	-114.250249	Idaho fescue	53	Idaho fescue
2011	B 042201	47.350205	-114.265164	rough fescue	42	bluebunch wheatgrass
2011	B 042202	47.344216	-114.281615	Idaho fescue	36	bluebunch wheatgrass
2011	B 042203	47.346615	-114.266889	Idaho fescue	38	bluebunch wheatgrass
2011	B 042204	47.35549	-114.257709	Idaho fescue	50	Idaho fescue
2011	B 051301	47.358122	-114.180859	bluebunch wheatgrass	38	bluebunch wheatgrass
2011	B 051302	47.358699	-114.180152	bluebunch wheatgrass	38	bluebunch wheatgrass
2011	B 051303	47.357725	-114.178147	bluebunch wheatgrass	37	bluebunch wheatgrass
2011	B 051902	47.341678	-114.251228	Idaho fescue	43	Idaho fescue
2011	B 052002	47.341667	-114.255432	bluebunch wheatgrass	38	bluebunch wheatgrass
2011	B 052601	47.334474	-114.189052	Idaho fescue	44	Idaho fescue
2011	B 052602	47.348887	-114.195105	Idaho fescue	42	bluebunch wheatgrass
2011	B 052603	47.343303	-114.199858	Idaho fescue	45	Idaho fescue
2011	B 060201	47.344997	-114.243152	Idaho fescue	43	Idaho fescue
2011	B 060202	47.334344	-114.23614	Idaho fescue	48	Idaho fescue
2011	B 060203	47.329604	-114.239169	rough fescue	53	Idaho fescue
2011	B 060301	47.34101	-114.228212	Idaho fescue	52	Idaho fescue
2011	B 060302	47.341118	-114.226936	Idaho fescue	48	Idaho fescue
2011	B 060303	47.332589	-114.227542	Idaho fescue	54	Idaho fescue
2011	B 060304	47.333677	-114.237594	Idaho fescue	48	Idaho fescue
2011	B 060305	47.33307	-114.236009	Idaho fescue	52	Idaho fescue
2011	B 060306	47.340528	-114.247346	rough fescue	41	bluebunch wheatgrass
2011	B 062301	47.341192	-114.237001	bluebunch wheatgrass	41	bluebunch wheatgrass
2011	B 062302	47.337934	-114.239953	Idaho fescue	49	Idaho fescue
2011	B 062303	47.33833	-114.241433	Idaho fescue	48	Idaho fescue
2011	B 062304	47.334129	-114.23992	bluebunch wheatgrass	51	Idaho fescue
2011	B 062305	47.336317	-114.236236	Idaho fescue	52	Idaho fescue
2011	B 062401	47.333974	-114.23707	Idaho fescue	48	Idaho fescue
2011	B 062402	47.34626	-114.220552	Idaho fescue	44	Idaho fescue
2011	B 062403	47.337773	-114.241919	Idaho fescue	48	Idaho fescue
2011	B 062404	47.335854	-114.235467	Idaho fescue	52	Idaho fescue
2011	B 062405	47.33355	-114.240007	bluebunch wheatgrass	48	Idaho fescue
2011	B 062901	47.321448	-114.210741	rough fescue	56	Idaho fescue
2011	B 062902	47.315308	-114.188467	rough fescue	54	Idaho fescue
2011	B 062903	47.335739	-114.194584	Idaho fescue	47	Idaho fescue
2011	B 071201	47.337593	-114.19235	bluebunch wheatgrass	45	Idaho fescue
2011	B 071202	47.339163	-114.192587	Idaho fescue	44	Idaho fescue
2011	B 071203	47.341819	-114.194185	Idaho fescue	44	Idaho fescue
2011	B 071204	47.342903	-114.192521	bluebunch wheatgrass	43	Idaho fescue
2011	B 071301	47.338002	-114.192037	Idaho fescue	44	Idaho fescue
2011	B 071302	47.344546	-114.18632	Idaho fescue	39	bluebunch wheatgrass
2011	B 071304	47.347889	-114.194874	Idaho fescue	42	bluebunch wheatgrass
2011	B 071401	47.347689	-114.176903	rough fescue	38	bluebunch wheatgrass

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Dominant	REAP[2] (cm)	Target Species
2011	B 071402	47.344843	-114.175858	rough fescue	38	bluebunch wheatgrass
2011	B 072101	47.338356	-114.226257	Idaho fescue	50	Idaho fescue
2011	B 072102	47.336819	-114.227536	Idaho fescue	50	Idaho fescue
2011	B 072103	47.335702	-114.237381	Idaho fescue	47	Idaho fescue
2011	B 080301	47.337721	-114.192297	bluebunch wheatgrass	44	Idaho fescue
2011	B 080302	47.335085	-114.189003	rough fescue	43	Idaho fescue
2011	B 080303	47.3408	-114.192041	rough fescue	44	Idaho fescue
2011	B 080304	47.335651	-114.189093	rough fescue	43	Idaho fescue
2011	B 080305	47.341394	-114.18656	bluebunch wheatgrass	40	bluebunch wheatgrass
2011	B 080306	47.338943	-114.19039	rough fescue	43	Idaho fescue
2011	B 080401	47.343835	-114.16699	bluebunch wheatgrass	38	bluebunch wheatgrass
2011	B 080402	47.331134	-114.182569	rough fescue	43	Idaho fescue
2011	B 080403	47.365607	-114.240451	Idaho fescue	41	bluebunch wheatgrass
2011	B 080501	47.362181	-114.18491	Idaho fescue	39	bluebunch wheatgrass
2011	B 080502	47.359544	-114.178243	bluebunch wheatgrass	38	bluebunch wheatgrass
2011	B 081101	47.340593	-114.27401	bluebunch wheatgrass	37	bluebunch wheatgrass
2011	B 081102	47.343497	-114.250991	bluebunch wheatgrass	38	bluebunch wheatgrass
2011	B 081103	47.353124	-114.273837	Idaho fescue	41	bluebunch wheatgrass
2011	B 082305	47.360036	-114.187906	rough fescue	48	Idaho fescue
2011	HP Random 1	47.322061	-114.1644	bluebunch wheatgrass	42	bluebunch wheatgrass
2011	HP Random 2	47.315912	-114.189494	bluebunch wheatgrass	56	Idaho fescue
2011	HP Random 3	47.322527	-114.197989	bluebunch wheatgrass	74	rough fescue
2011	LP Random 1	47.344752	-114.271522	bluebunch wheatgrass	37	bluebunch wheatgrass
2011	LP Random 2	47.350319	-114.237838	bluebunch wheatgrass	48	Idaho fescue
2011	LP Random 3	47.351059	-114.271823	bluebunch wheatgrass	40	bluebunch wheatgrass
2011	UP Random 1	47.342178	-114.224336	bluebunch wheatgrass	54	Idaho fescue
2011	UP Random 2	47.347443	-114.228688	Idaho fescue	49	Idaho fescue
2011	UP Random 3	47.327298	-114.231603	bluebunch wheatgrass	56	Idaho fescue

[1] Lat/Long Coordinate System, WGS 84
[2] Relative Effective Annual Precipitation, from Montana NRCS.

Table A6. Predicted target group for the sample sites

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Group Dom	REAP[2](cm)	Target Group
1970	CO1T1STA	47.340682	-114.179017	fescue group	40	bluebunch group
1970	CO1T2STA	47.341289	-114.179429	fescue group	40	bluebunch group
1970	CO2T1STA	47.333655	-114.240844	fescue group	48	fescue group
1970	CO2T2STA	47.333564	-114.241367	fescue group	48	fescue group
1970	CO2T3STA	47.333164	-114.240821	bluebunch group	48	fescue group
1970	CO5T1STA	47.346571	-114.264763	bluebunch group	38	bluebunch group
1970	CO5T2STA	47.345987	-114.264810	bluebunch group	38	bluebunch group
1970	CO5T3STA	47.346080	-114.265446	bluebunch group	38	bluebunch group
1970	CO6T1STA	47.360453	-114.240104	fescue group	50	fescue group
1970	CO6T2STA	47.360185	-114.239548	fescue group	50	fescue group
1970	CO6T3STA	47.360066	-114.240289	fescue group	51	fescue group
1970	CO7T1STA	47.321934	-114.267327	fescue group	49	fescue group
1970	CO7T2STA	47.321862	-114.266661	fescue group	50	fescue group
1970	CO7T3STA	47.322435	-114.267163	fescue group	49	fescue group
1970	CO9T2STA	47.341360	-114.224854	bluebunch group	40	bluebunch group
1970	CO9T3STA	47.340890	-114.225223	bluebunch group	44	fescue group
1970	CO10T1MID	47.299448	-114.211489	fescue group	60	fescue group
1970	CO10T2STA	47.299708	-114.212087	bluebunch group	60	fescue group
1970	CO10T3STA	47.299975	-114.211693	fescue group	56	fescue group
1970	CO10T4STA	47.299543	-114.212146	fescue group	60	fescue group
1970	CO10T5STA	47.299676	-114.211672	fescue group	60	fescue group
1970	CO11T1STA	47.301378	-114.185911	bluebunch group	37	bluebunch group
1970	CO11T2STA	47.301382	-114.185529	bluebunch group	41	bluebunch group
1970	CO11T3STA	47.301069	-114.185860	bluebunch group	37	bluebunch group
1970	CO13T1STA	47.357936	-114.214638	bluebunch group	41	bluebunch group
1970	CO13T2STA	47.358433	-114.215106	bluebunch group	42	bluebunch group
1970	CO13T3STA	47.358409	-114.214251	bluebunch group	42	bluebunch group
1970	CO14T1STA	47.322805	-114.204552	fescue group	61	fescue group
1970	CO14T2STA	47.322502	-114.204774	fescue group	61	fescue group
1970	CO14T3STA	47.322278	-114.204266	fescue group	61	fescue group
1970	CO15T1STA	47.290155	-114.192715	bluebunch group	33	bluebunch group
1970	CO15T2MID	47.290251	-114.192331	bluebunch group	33	bluebunch group
1970	CO15T3STA	47.289965	-114.192418	bluebunch group	33	bluebunch group
1970	CO17T1STA	47.368669	-114.191293	bluebunch group	37	bluebunch group
1970	CO17T3STA	47.369078	-114.191263	bluebunch group	37	bluebunch group
1970	CO17T4STA	47.368246	-114.191532	bluebunch group	38	bluebunch group
2010	Dsw 6	47.314902	-114.247236	bluebunch group	39	bluebunch group
2010	Dup 6	47.328499	-114.243105	fescue group	59	fescue group
2010	24	47.284109	-114.186500	bluebunch group	39	bluebunch group
2010	23	47.291417	-114.176306	fescue group	50	fescue group
2010	Nbr25	47.294240	-114.185767	fescue group	44	fescue group
2010	22	47.295115	-114.204737	fescue group	53	fescue group
2010	21	47.309710	-114.185271	fescue group	53	fescue group
2010	Nbr30	47.306838	-114.214870	fescue group	42	bluebunch group
2010	14	47.317451	-114.162212	fescue group	51	fescue group
2010	Nbr20	47.312673	-114.201018	fescue group	64	fescue group
2010	11	47.317104	-114.186657	fescue group	53	fescue group
2010	19	47.306993	-114.272412	bluebunch group	48	fescue group
2010	18	47.314197	-114.244700	bluebunch group	40	bluebunch group
2010	13	47.322345	-114.204221	fescue group	61	fescue group
2010	17	47.320908	-114.248257	fescue group	48	fescue group
2010	16	47.334743	-114.188648	fescue group	43	fescue group
2010	12	47.333259	-114.213968	bluebunch group	51	fescue group
2010	9	47.329967	-114.234789	fescue group	53	fescue group
2010	15	47.343927	-114.164993	bluebunch group	38	bluebunch group
2010	10	47.343106	-114.227282	bluebunch group	37	bluebunch group
2010	1	47.350838	-114.196960	bluebunch group	43	fescue group
2010	4	47.347201	-114.267407	bluebunch group	38	bluebunch group
2010	3	47.358982	-114.214575	bluebunch group	42	bluebunch group
2010	6	47.350759	-114.275460	bluebunch group	39	bluebunch group

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Group Dom	REAP[2](cm)	Target Group
2010	2	47.369410	-114.180764	bluebunch group	38	bluebunch group
2010	7	47.363918	-114.245028	fescue group	55	fescue group
2010	005	47.326383	-114.163563	fescue group	40	bluebunch group
2010	002	47.330935	-114.262869	fescue group	48	fescue group
2010	003	47.341843	-114.258241	fescue group	37	bluebunch group
2010	004	47.344543	-114.255740	fescue group	36	bluebunch group
2010	006	47.349684	-114.206745	fescue group	45	fescue group
2010	Nbr31	47.329760	-114.207684	fescue group	59	fescue group
2011	B 031402	47.317716	-114.266946	fescue group	45	fescue group
2011	B 031403	47.3194	-114.246927	fescue group	37	bluebunch group
2011	B 031404	47.322674	-114.217022	fescue group	52	fescue group
2011	B 031501	47.317366	-114.228769	fescue group	44	fescue group
2011	B 031601	47.323248	-114.268914	fescue group	39	bluebunch group
2011	B 031602	47.317693	-114.26586	fescue group	46	fescue group
2011	B 031603	47.307663	-114.234555	bluebunch group	45	fescue group
2011	B 031604	47.308275	-114.233537	fescue group	45	fescue group
2011	B 031605	47.320076	-114.26532	fescue group	51	fescue group
2011	B 042102	47.344188	-114.251555	fescue group	37	bluebunch group
2011	B 042106	47.36095	-114.250249	fescue group	53	fescue group
2011	B 042201	47.350205	-114.265164	fescue group	42	bluebunch group
2011	B 042202	47.344216	-114.281615	fescue group	36	bluebunch group
2011	B 042203	47.346615	-114.266889	fescue group	38	bluebunch group
2011	B 042204	47.35549	-114.257709	fescue group	50	fescue group
2011	B 051301	47.358122	-114.180859	bluebunch group	38	bluebunch group
2011	B 051302	47.358699	-114.180152	bluebunch group	38	bluebunch group
2011	B 051303	47.357725	-114.178147	bluebunch group	37	bluebunch group
2011	B 051902	47.341678	-114.251228	fescue group	43	fescue group
2011	B 052002	47.341667	-114.255432	bluebunch group	38	bluebunch group
2011	B 052601	47.334474	-114.189052	fescue group	44	fescue group
2011	B 052602	47.348887	-114.195105	fescue group	42	bluebunch group
2011	B 052603	47.343303	-114.199858	fescue group	45	fescue group
2011	B 060201	47.344997	-114.243152	fescue group	43	fescue group
2011	B 060202	47.334344	-114.23614	fescue group	48	fescue group
2011	B 060203	47.329604	-114.239169	fescue group	53	fescue group
2011	B 060301	47.34101	-114.228212	fescue group	52	fescue group
2011	B 060302	47.341118	-114.226936	fescue group	48	fescue group
2011	B 060303	47.332589	-114.227542	fescue group	54	fescue group
2011	B 060304	47.333677	-114.237594	fescue group	48	fescue group
2011	B 060305	47.33307	-114.236009	fescue group	52	fescue group
2011	B 060306	47.340528	-114.247346	fescue group	41	bluebunch group
2011	B 062301	47.341192	-114.237001	bluebunch group	41	bluebunch group
2011	B 062302	47.337934	-114.239953	fescue group	49	fescue group
2011	B 062303	47.33833	-114.241433	fescue group	48	fescue group
2011	B 062304	47.334129	-114.23992	bluebunch group	51	fescue group
2011	B 062305	47.336317	-114.236236	fescue group	52	fescue group
2011	B 062401	47.333974	-114.23707	fescue group	48	fescue group
2011	B 062402	47.34626	-114.220552	fescue group	44	fescue group
2011	B 062403	47.337773	-114.241919	fescue group	48	fescue group
2011	B 062404	47.335854	-114.235467	fescue group	52	fescue group
2011	B 062405	47.33355	-114.240007	bluebunch group	48	fescue group
2011	B 062901	47.321448	-114.210741	fescue group	56	fescue group
2011	B 062902	47.315308	-114.188467	fescue group	54	fescue group
2011	B 062903	47.335739	-114.194584	fescue group	47	fescue group
2011	B 071201	47.337593	-114.19235	bluebunch group	45	fescue group
2011	B 071202	47.339163	-114.192587	fescue group	44	fescue group
2011	B 071203	47.341819	-114.194185	fescue group	44	fescue group
2011	B 071204	47.342903	-114.192521	bluebunch group	43	fescue group
2011	B 071301	47.338002	-114.192037	fescue group	44	fescue group
2011	B 071302	47.344546	-114.18632	fescue group	39	bluebunch group
2011	B 071304	47.347889	-114.194874	fescue group	42	bluebunch group
2011	B 071401	47.347689	-114.176903	fescue group	38	bluebunch group

Assessment	Sample Site	Latitude[1]	Longitude[1]	Actual Group Dom	REAP[2](cm)	Target Group
2011	B 071402	47.344843	-114.175858	fescue group	38	bluebunch group
2011	B 072101	47.338356	-114.226257	fescue group	50	fescue group
2011	B 072102	47.336819	-114.227536	fescue group	50	fescue group
2011	B 072103	47.335702	-114.237381	fescue group	47	fescue group
2011	B 080301	47.337721	-114.192297	bluebunch group	44	fescue group
2011	B 080302	47.335085	-114.189003	fescue group	43	fescue group
2011	B 080303	47.3408	-114.192041	fescue group	44	fescue group
2011	B 080304	47.335651	-114.189093	fescue group	43	fescue group
2011	B 080305	47.341394	-114.18656	bluebunch group	40	bluebunch group
2011	B 080306	47.338943	-114.19039	fescue group	43	fescue group
2011	B 080401	47.343835	-114.16699	bluebunch group	38	bluebunch group
2011	B 080402	47.331134	-114.182569	fescue group	43	fescue group
2011	B 080403	47.365607	-114.240451	fescue group	41	bluebunch group
2011	B 080501	47.362181	-114.18491	fescue group	39	bluebunch group
2011	B 080502	47.359544	-114.178243	bluebunch group	38	bluebunch group
2011	B 081101	47.340593	-114.27401	bluebunch group	37	bluebunch group
2011	B 081102	47.343497	-114.250991	bluebunch group	38	bluebunch group
2011	B 081103	47.353124	-114.273837	fescue group	41	bluebunch group
2011	B 082305	47.360036	-114.187906	fescue group	48	fescue group
2011	HP Random 1	47.322061	-114.1644	bluebunch group	42	bluebunch group
2011	HP Random 2	47.315912	-114.189494	bluebunch group	56	fescue group
2011	HP Random 3	47.322527	-114.197989	bluebunch group	74	fescue group
2011	LP Random 1	47.344752	-114.271522	bluebunch group	37	bluebunch group
2011	LP Random 2	47.350319	-114.237838	bluebunch group	48	fescue group
2011	LP Random 3	47.351059	-114.271823	bluebunch group	40	bluebunch group
2011	UP Random 1	47.342178	-114.224336	bluebunch group	54	fescue group
2011	UP Random 2	47.347443	-114.228688	fescue group	49	fescue group
2011	UP Random 3	47.327298	-114.231603	bluebunch group	56	fescue group

[1] Lat/Long Coordinate System, WGS 84 Datum
[2] Relative Effective Annual Precipitation, from Montana NRCS.