AN INVENTORY OF NON-NATIVE PLANT SPECIES ON THE NATIONAL ELK REFUGE

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David T. Barnett[1], Geneva W. Chong[2], and Thomas J. Stohlgren[3]

[1]Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO 80523, barnett@nrel.colostate.edu, 970.491.2302
[2]US Geologic Survey, Northern Rocky Mountain Science Center, Bozeman, MT
US Geologic Survey, National Institute of Invasive Species Science, Fort Collins
[3]Science Center, Fort Collin, CO

INTRODUCTION

Plant invasions occur when species are transported to, and establish in new and often distant ranges (Elton, 1958; Mack et al., 2000). Many of these species, referred to here as weeds, invasive, exotic, and non-native plant species, are implicated in the listing of at least 42% of all species protected by the Endangered Species Act, and pose the second most important threat to biodiversity (Randall, 1996; Wilcove et al., 1998). Non-native plant species directly compete with native species (Westbrooks, 1998) and preferred forage, alter ecological processes such as hydrologic (Mack et al., 2000) and nutrient cycles (Vitousek et al., 1987), and change fire and other disturbance regimes (D'Antonio & Vitousek, 1992; D'Antonio et al., 1999). In short, plant invasions process challenge the Fish and Wildlife Service mission to protect native plant species and wildlife habitat on National Wildlife Refuges across the country.

The National Elk Refuge was created in 1912 as a result of public interest in the survival of the Jackson Elk Herd. Today the Refuge works to, "…provide, preserve, restore, and manage winter habitat for the Jackson Elk Herd, and has expanded

management to include endangered species, birds, fish, and other big game animals… (http://www.fws.gov/nationalelkrefuge/Index.htm)."

Plant invasions alter vegetation composition and the consequences have the potential cascade throughout the Refuge. For example, cheatgrass (*Bromus tectorum*) can invaded historically open space in sage communities, impacting structure crucial to sage grouse habitat and survival. Cheatgrass tends to be more conducive to fire than native sage communities, and it thrives after fire. The combination has the potential to permanently change a diverse perennial shrub vegetation type to one dominated by an annual grass with little forage value.

It may be the ability of non-native plant species to compromise native forage that provides the primary invasive species challenge to Refuge goals. Unpalatable, non-native plant species can displace native diversity and cover essential to wintering elk. Maintaining the existing Jackson Elk Herd currently requires significant supplemental feeding, and further reductions of native forage might necessitate increased feeding. Feeding concentrates elk which promotes the transmission of disease.

The goal of this inventory was to increase the understanding of the composition and distribution of non-native plant species on the National Elk Refuge and to gain insight to the invasion and co-occurrence of native and non-native plant species.

METHODS

In July 2005, we located non-native plant species with mapping techniques, and sampled native and non-native plant species with a plot-based design at the National Elk Refuge.

Plot sampling

The National Elk Refuge vegetation map provided the basis for a stratified-random sampling design. Sixty-three plots (Fig. 1) were placed in five principal of the vegetation types included in the Refuge vegetation map. The majority of the plots were placed according to locations specified by a stratified-random design, while a supplementary purposive sampling design directed the location of other plots. We intended to describe the landscape and pattern of invasion in an unbiased way with the stratified design, and capture additional patches of invasion and extremes in environmental gradients with the purposive sampling.

We sampled with a 168-m^2 circular, multi-scale vegetation plot modified from the National Forest Service Inventory and Analysis Program (Frayer & Furnival, 1999; Fig. 2). Species composition, cover, the average height of each species, and cover of abiotic variables (lichen, litter, moss, poop, rock, soil, standing duff, water, and wood) were recorded to the nearest 1% in each of the three 1-m^2 subplot. The overlap of species accounts for the total percent periodically totaling more than 100. We also collected species composition in the entire 168-m^2 plot. The nature of the multi-scale, nested plot design qualified presence of a species in any of the smaller sub-plots as part of the composition list for the entire plot.

Soil samples were collected at each plot. Soils were collected in the center of the plot and at the inside corner of each 1-m^2 subplots and analyzed for texture and carbon and nitrogen content (texture - % sand, silt, and clay; inorganic C, organic C, total C, and total N). Ancillary data including slope degree and slope aspect were recorded at the location. Other variables including the distance to road, distance to water, LANDSAT

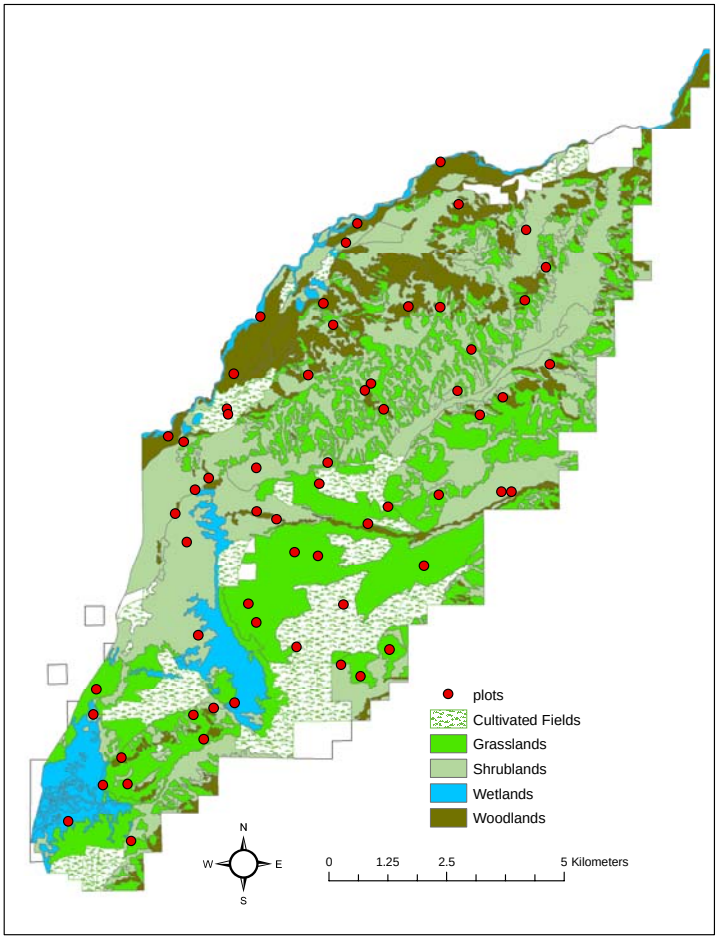

Figure 1. The five principal cover types and plot locations (note: only 62 of 63 plots).

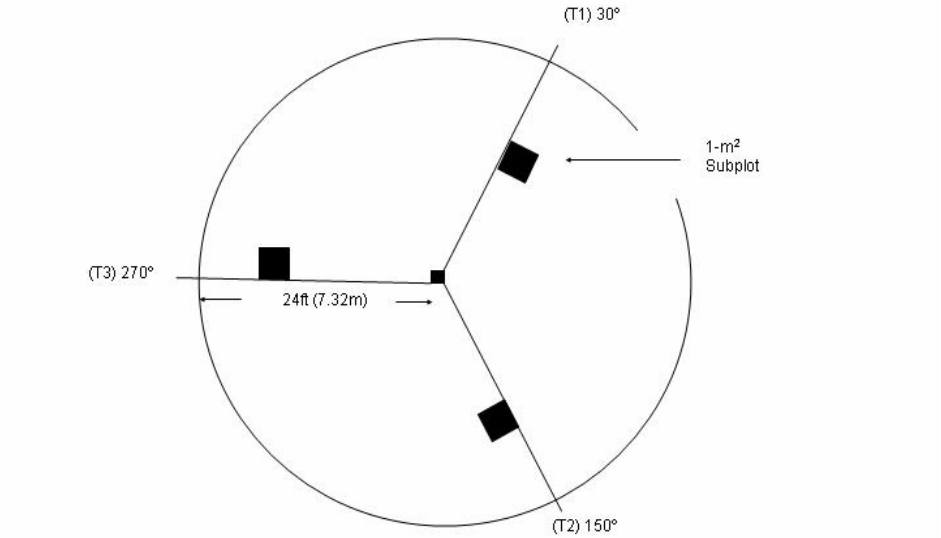

Figure 2. The multi-scale plot design, modified from the Forest Inventory and Analysis Program, used to sample native and non-native vegetation.

remote sensing information (including NDVI and tasselcap (bright, green, wet)), and the slope, aspect, and elevation from a Digital Elevation Model (DEM) were attributed to each plot during analysis.

The sampling locations were recorded but not permanently marked on the ground. This decision reflected concerns for wildlife and the goal of providing distribution information for further inventory. Each plot can be roughly geo-referenced with associated UTM coordinates to place repeat measurements generally 2 to 5-m from the original plot. Repeat sampling should include a search of the area surrounding each plot to account for extant species of concern that the plot may have missed.

Unknown species were collected and/or photographed and subsequently identified by botanists in the Rocky Mountain Herbarium at the University of Wyoming. Data was consolidated in a Microsoft Access database, analyzed with in a Geographic Information System (ESRI, ArcGIS 9.2) and the S Plus and Systat statistical packages.

Non-native plant species mapping

Non-native plant species were mapped using hand-held computers connected to global positioning system (GPS) receivers according to the North American Weed Mapping Association (NAWMA; www.nawma.org, Appendix II, III) standards. We collected species identity, cover, and location in the field, while other required variables were added later. Smaller patches or single individuals were recorded as a single point, and 'gross area' (general area occupied but not entirely covered by the species), 'infested area' (subset of gross area that is occupied by a non-native plant species), and 'cover' (of species in the infested area) were recorded. We recorded larger patches as a polygon by mapping the perimeter of the patch and estimating 'infested area' and 'cover'.

STATISTICAL ANALYSIS

Non-native plant species modeling

Managers must consider entire landscapes, not point locations. Spatial models attempt to describe a variable of interest across an entire landscape based on information gleaned from point-specific sampling. Some models included only plot-based data (variables such as non-native species richness could only be estimated in plots), some incorporated the plot and mapping data. The same independent variables (slope, elevation, absolute aspect (0-180 degrees transformation to make the variable linear and approximate degrees from the driest South slopes), distance to road, distance to water, relative vegetation type moisture (Table 2), and LANDSAT bands 1, 2, 3, 4, 5, 7, NDVI, tassel cap bright, green, and wet) were used for each model and log transformed to approximate assumptions of normality when appropriate. Independent variables were assessed for collinearity, and limited by availability to continuous variables.

‣Trend Surface Models. Working with plot-based data increased our ability to model the variability of non-native plant species. We used multiple regression analysis (OLS; Reich & Davis, 1998) to evaluate coarse-scale variability with a stepwise procedure to select the independent variables to include in the regression models. We then modeled the error (i.e., residuals) from the regression model with a binary regression tree (De'ath & Fabricius, 2000), and avoided over-fitting the model with a 10-fold cross-validation procedure to identify the tree size that minimized the total deviance associated with the tree. We generated grids using model parameter estimates from the regression model. Passing the appropriate independent variables through the regression tree created

another grid representing the error in the regression model. A sum of the two grids amounted to the final surface (Reich et al., 2004).

·Probability Models. We combined data from the plot and mapping methods to create probability models of single-species occurrences. Logistic regression is a type of general linear model (GLM) appropriate for data with a binary distribution such as species presence or absence (McCullagh & Nelder, 1989). Logistic regression used a logit link function that assumed a binomial distribution (Statistical Sciences, 2005). Variables were selected using a stepwise procedure for GLM in S-plus. The probability surface was generated using the predictor variable raster layers with the statistical output from S-plus. The resulting cell values were in the logit scale and were therefore back-transformed to the original scale of the probability surface using:

$$p = \frac{e^{(LP)}}{1 + e^{(LP)}}$$

where p is the probability and LP is the linear predictor. Percent deviance (D^2, similar to an R^2 value) was used to evaluate the model percent deviance explained and measurediscrimination were calculated. Percent deviance explained was calculated as

$$Percentdeviance = \frac{NullDev - \mathrm{Re}\,sDev}{NullDev} X100$$

where NullDev is the null deviance of the evaluation data and ResDev is the residual deviance of the evaluation data in relation to probabilities predicted by the model. This measurement is of overall goodness of fit of the model to the known observations.

RESULTS

Plot sampling

In the plot-based survey, we identified a total of 332 species in the sixty-three 168-m^2 plots. The NRCS PLANTS Database (USDA, 2005) listed sixty-six (Table 1) of these as non-native plant species (Introduced to the U.S. and Native and Introduced; see Appendix 1). While the sampling effort was not equitable across each vegetation type (Table 2), we found the highest cumulative non-native species in the woodland vegetation, and the highest number of non-native species per plot in the woodland, wetland, and cultivated vegetation types (Table 2). A plot in the woodland vegetation type contained the most non-native species (17 non-native species), followed closely by two wetland plots (16 non-native species).

Table 1. The non-native plant species, frequency (Freq.) and average cover by plot and mapping techniques. Standard errors appear in parenthesis where appropriate.

Species	NRCS Code	Map Freq.	Average Map Cover	Plot Freq.	Average Plot Cover	Dominance
Achillea millefolium, common yarrow[1]	acmi2			28	2.0 (0.5)	55.03
Acroptilon repens, hardheads	cere6	6	1.5 (0.9)			
Agropyron cristatum, crested wheatgrass	agcr	2	50 (0)	16	16.8 (7.0)	268.44
Alopecurus pratensis, meadow foxtail	alpr3			1		
Alyssum alyssoides, pale madwort	alal3			1		
Alyssum desertorum, desert madwort	alde			21	3.8 (0.9)	79.82
Arabis hirsuta, hairy rockcress[1]	arhi			5	1.8 (1.3)	9.17
Berteroa incana, hoary alyssum	bein2	5	7.8 (3.0)			
Bromopsis inermis[1]	brin7			12	30.8 (14.3)	369.43
Bromus inermis leyss. ssp. inermis	brini			3	10.00	30.00

Bromus inermis, smooth brome	brin2	1	40 (0)	6	27.8 (7.1)	166.60
Bromus japonicus, japanese brome	brja	2	10 (0)	5	0.5 (0)	2.50
Bromus tectorum, cheatgrass	brte	438	28.9 (1.4)	10	29.9 (11.3)	298.69
Camelina microcarpa, littlepod falseflax	cami2	6	33.3 (11.6)	6	0.5 (0)	3.00
Cardaria chalapensis	cach10			2	2.5 (1.8)	5.08
Cardaria draba, whitetop	cadr	60	4.6 (1.3)			
Carduus nutans, nodding plumeless thistle	canu4	545	9.4 (0.5)	4	4.00	16.00
Centaurea diffusa, white knapweed	cedi3	48	0.2 (0.1)	1	2.50	2.50
Centaurea maculosa, spotted knapweed	cema4	56	8.8 (1.0)	1		
Centaurea scabiosa, greater knapweed	cesc2	41	6.8 (1.4)			
Cerastium fontanum baumg. ssp. vulgare	cefov2			1	1.25	1.25
Chenopodium album, lambsquarters[1]	chal7			1		
Chorispora tenella, crossflower	chte2			1		
Cirsium arvense, canadian thistle	ciar4	260	7.7 (0.4)	9	12.8 (4.3)	115.25
Cirsium vulgare, bull thistle	civu	23	6.4 (1.4)	2	1.50	3.00
Crepis tectorum, narrowleaf hawksbeard	crte3			2		
Descurainia sophia, herb sophia	deso2	63	23.4 (2.7)	3	42.00	126.00
Elaeagnus angustifolia, Russian olive	elan	1	1.00			
Elymus junceus	elju			1		
Heracleum sphondylium	hesp6			1		
Hieracium cynoglossoides, houndstongue	hicy	46	2.0 (0.4)			

hawkweed						
Hyoscyamus niger, black henbane	hyni	6	1.7 (0.8)			
Lactuca serriola, prickly lettuce	lase	18	13.6 (1.8)	12	1.6 (0.6)	19.50
Lappula redowskii	lare	22	15.4 (3.7)			
Lappula squarrosa, european stickseed	lasq			1	0.50	0.50
Lepidium latifolium, broadleaved pepperweed	lela2	14	20.6 (2.4)	1		
Lepidium perfoliatum, clasping pepperweed	lepe2	2	25 (0)			
Leucanthemum vulgare, oxeye daisy	levu	1	2.00			
Linaria dalmatica, dalmatian toadflax	lida	52	4.8 (1.5)			
Linaria vulgaris, butter and eggs	livu2	9	10 (4.9)			
Medicago lupulina, black medick	melu	27	26.5 (3.4)	11	15.2 (7.7)	167.10
Medicago sativa, alfalfa	mesa			8	11.6 (7.1)	92.44
Melilotus albus	meal2	2	80.00	8	9.2 (8.0)	73.33
Melilotus officinalis, yellow sweetclover	meof	17	28.5 (7.5)	11	6.4 (3.8)	69.97
Phleum pratense, timothy	phpr3			10	2.9 (1.2)	28.75
Poa annua, annual bluegrass	poan			2	38.00	76.00
Poa bulbosa	pobu			2	1.75	3.50
Poa pratensis, kentucky bluegrass[1]	popr			40	14.36	574.34
Poa trivialis	potr2			1	0.50	0.50
Potentilla recta, sulphur cinquefoil	pore5	1	1.00			
Rumex aquaticus, western dock	ruaq	21	6.00			
Sisymbrium altissimum, tall tumblemustard	sial2	48	26.3 (2.7)	5	11.8 (7.1)	59.17
Sonchus arvensis, field sowthistle	soar2	5	32 (11.1)	1		

Sonchus uliginosus	soul5	11	46.8 (11.9)			
Tanacetum vulgare, common tansy	tavu	9	1.7 (0.4)			
Taraxacum laevigatum, rock dandelion	tala2			2	7 (5)	14.00
Taraxacum officinale, common dandelion[1]	taof	7	14.6 (3.5)	41	1.8 (0.4)	72.64
Thlaspi arvense, field pennycress	thar5	33	13.2 (2.2)	9	0.8 (0.1)	6.75
Tragopogon dubius, yellow salsify	trdu	23	12.7 (3.9)	44	1.3 (0.2)	55.92
Trifolium hybridum, alsike clover	trhy			6	3 (0)	18.00
Trifolium pratense, red clover	trpr2			3		
Trifolium repens, white clover	trre3			3	1.00	3.00
Triticum aestivum, common wheat	trae			1		
Urtica dioica, stinging nettle[1]	urdi			2		
Verbascum thapsus, common mullein	veth	9	2 (0.4)			
Veronica biloba l.	vebi2			2	0.50	1.00

Yellow salsify (*Tragopogon dubius*) occurred with the highest frequency (44 plots). Other species occurring with high rates of frequency include common dandelion (*Taraxacum officinale*, 41 plots), and kentucky bluegrass (*Poa pratensis,* 40 plots). Fourteen non-native species occurred on only one plot (Table 1).

Thirteen non-native species only occurred on the large plot (Fig. 1) and do not have cover values. Of the twenty-eight non-native species occurring in subplots, *Bromopsis inermis* had the highest average cover, followed closely by cheatgrass and smooth brome (*Bromus inermis*). Average cover values for a single plot for these species frequently reached the values of sixty percent and greater, especially in the shrub, wood,

and grassland vegetation types. On the other end of the spectrum, a majority of the non-native species had cover values less than five percent.

Table 2. The number of plots, cumulative species richness, average species richness per plot and average of total cover per plot by vegetation type and species nativity.

Vegetation Type	Number of Plots	Nativity	Cumulative Species Richness	Average Number of Species/Plot	Average Cover/Plot
cultivated	5	native	40	8	30.00
cultivated	5	non-native	16	3	43.42
grassland	26	native	138	5	67.60
grassland	26	non-native	29	1	22.38
shrubland	14	native	138	10	97.73
shrubland	14	non-native	24	2	39.17
wetland	8	native	91	11	75.62
wetland	8	non-native	24	3	38.29
woodland	10	native	120	12	96.66
woodland	10	non-native	31	3	41.56

Non-native plant species mapping

The mapping data from this effort was combined with non-native plant species mapping data conducted by the National Elk Refuge at the same time. While Refuge mapping methods differed from this study, combining the datasets made sense to display distribution data collected in the same time frame. The two datasets were evaluated for overlap and invasive species mapped by the Refuge were given precedence when locations overlapped and all mapped data from the USGS and Colorado State University inventory were modified to the format of the Refuge data.

The combined effort mapped non-native plant species at 1975 locations and recorded 38 non-native plant species. Nodding plumeless thistle (or musk thistle, *Carduus nutans*) was the most frequently mapped species (545 locations, often single

individuals or small and dispersed patches) followed closely by cheatgrass (438, dense patches and variety sizes).

Spatial Modeling

The modeling resulted in single species models of the probability of occurrence and cover, and a model of the cover of non-native species (Figures 3-15). The environmental variables used in the models were limited to those variables that existed as continuous surfaces across the entire Refuge (Table 3).

DISSICUSSION

There are numerous ways that this inventory can contribute to the understanding of invasive species at the National Elk Refuge. A simple risk analysis can be used to evaluate the vulnerability of habitats to invasion and prioritize the current invaders according to threat. Spatial models can be used to estimate the actual and potential distribution of non-native species richness, cover, and the probability of occurrence. And, in addition to directing Refuge and Teton County staff to locations vulnerable to invasion across the Refuge, these models provide an indication of how environmental variables contribute to these distributions, and can also be useful for directing control and assessing impact to natural resource assets and management objectives.

Non-spatial Assessment

Vegetation types with larger non-native plant species accumulations and higher numbers of non-native species per plot provide an indication of vegetation types that are more vulnerable to invasion (Table 2). Vegetation types with higher non-native species

richness and cover should be inventoried more rigorously in the future to evaluate the spread of existing non-natives and for the detection of new invaders.

Table 5. The relationship of significant independent variables and the amount of variability explained in models of species distributions.

Modeled Variable	Model	R^2 contribution	Total Variability Explained	Fig.
Non-native plant species cover - plot data	trend surface = -6.7 – 19.1 * lvegmoist – 7.4 * lstrmdist – 0.7 * sqrtrddist + 0.5 * tm4	0.21	$R^2 = 0.78$	3
	fine-scale = regression tree	0.57		
Probability of cheatgrass - plot and mapping data	probability = -10.4 + 0.0085 * elev – 0.04 * sqrtstrmdist – 0.09 * NDVI – 0.03 * wet	N/A	$D^2 = 0.21$	4
Cover of cheatgrass - plot and mapping data	trend surface = 276.7 – 0.11 * elev + 0.3 * sqrtstrmdist – 0.8 * sqrtrddist + 0.6 * vegmoisture + 0.2 * tm4 – 0.8 * NDVI	0.18	$R^2 = 0.51$	5
	fine-scale = regression tree	0.33		
Probability of bull thistle - plot and mapping data	probability = 80.7 – 2.3 * lslope + 0.4 * tm4 – 0.75 * NDVI – 0.2 * bright	N/A	$D^2 = 0.50$	6, 7
Cover of Canada thistle - plot and mapping data	trend surface = 1.2 + 0.02 * absasp + 0.1 * sqrtrddist – 4.1 * lslope + 0.05 * tm1 + 0.05 * wet	0.20	$R^2 = 0.38$	8
	fine-scale = regression tree	0.18		
Probability of Canada thistle – plot and mapping data	probability = 21.5 – 0.05 * vegmoisture – 0.01 * elev – 0.03 * sqrtstrmdist – 0.05 * sqrtrddist – 1.2 * lslope + 0.03 * wet	N/A	$D^2 = 0.32$	9, 10
Probability of nodding plumeless thistle - plot and mapping data	probability = 67.6 – 0.05 * sqrtrddist – 0.7 * lslope – 0.12 * vegmoisture – 0.2 * tm3 + 0.2 * tm4 – 0.7 * NDVI	N/A	$D^2 = 0.12$	11
Probability of perennial pepperweed - plot and mapping data	probability = -470.9 + 0.05 * absasp 152 * elev – 18.3 * lslope + 0.2 * tm4 – 0.6 * NDVI + 0.1 * wet	N/A	$D^2 = 0.24$	12

Probability of spotted knapweed - plot and mapping data	probability = 30.8 – 4.1 * lslope – 0.1 * sqrtrddist – 0.2 * NDVI + 0.05 * wet	N/A	$D^2 = 0.53$	13
Cover of spotted knapweed	trend surface = -345 + 106.7 * lelev – 6 * lslope – 0.2 * vegmoist + 0.06 * tm3 + 0.07 * wet	0.50	$R^2 = 0.75$	14
pepperweed - plot and mapping data	fine-scale = regression tree	0.25		
Probability of whitetop - plot and mapping data	Large-scale, probability = -13.5 + 0.02 * absasp – 0.1 * sqrtrddist – 4.1 * lslope – 0.2 * vegmoisture – 0.1 * tm1 + 0.3 * tm5 + 0.1 * wet	$D^2 = 0.53$		15
	fine-scale = regression tree	PRE = 0.66		

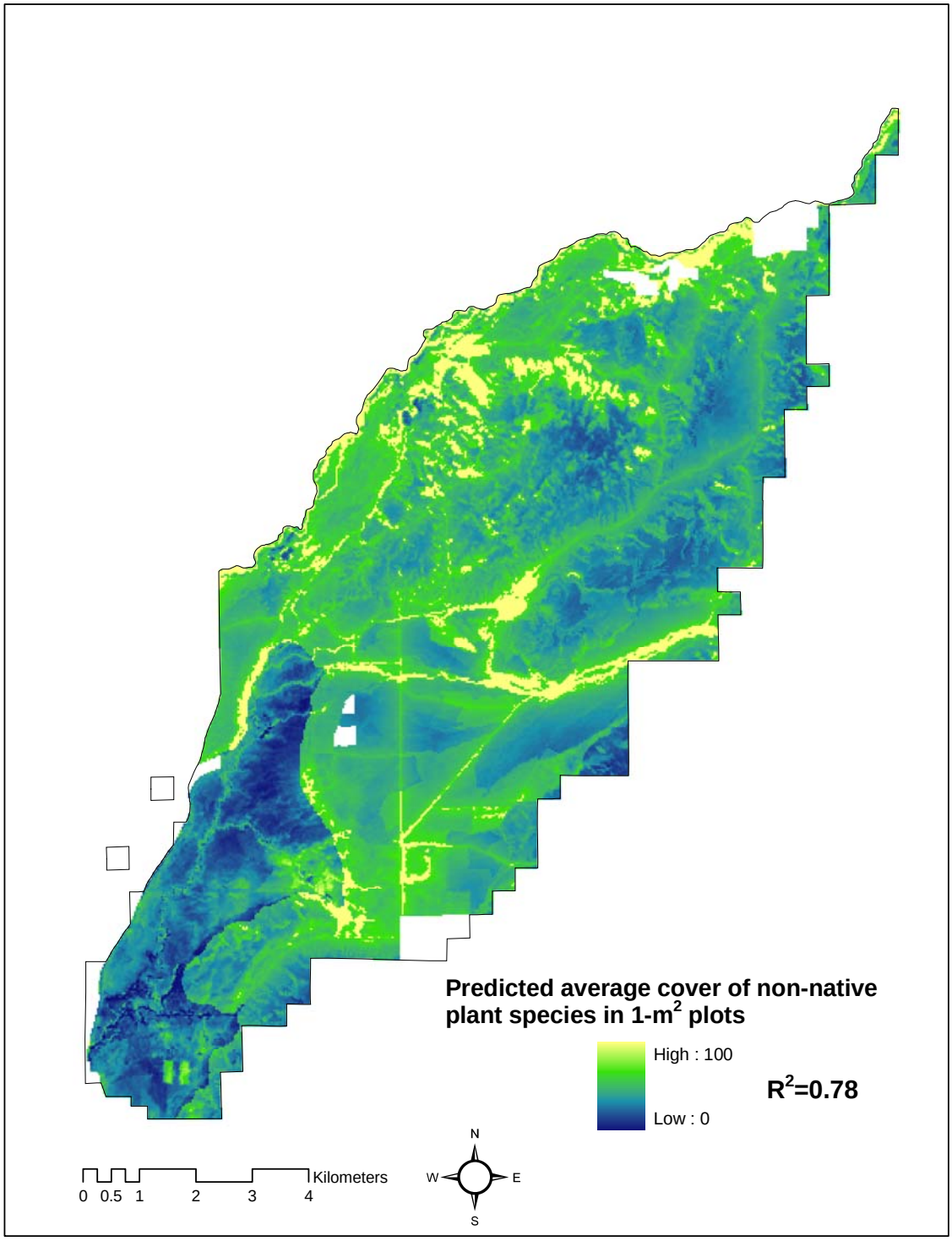

Figure 3. The cover of non-native species (Table 1) based on plot data.

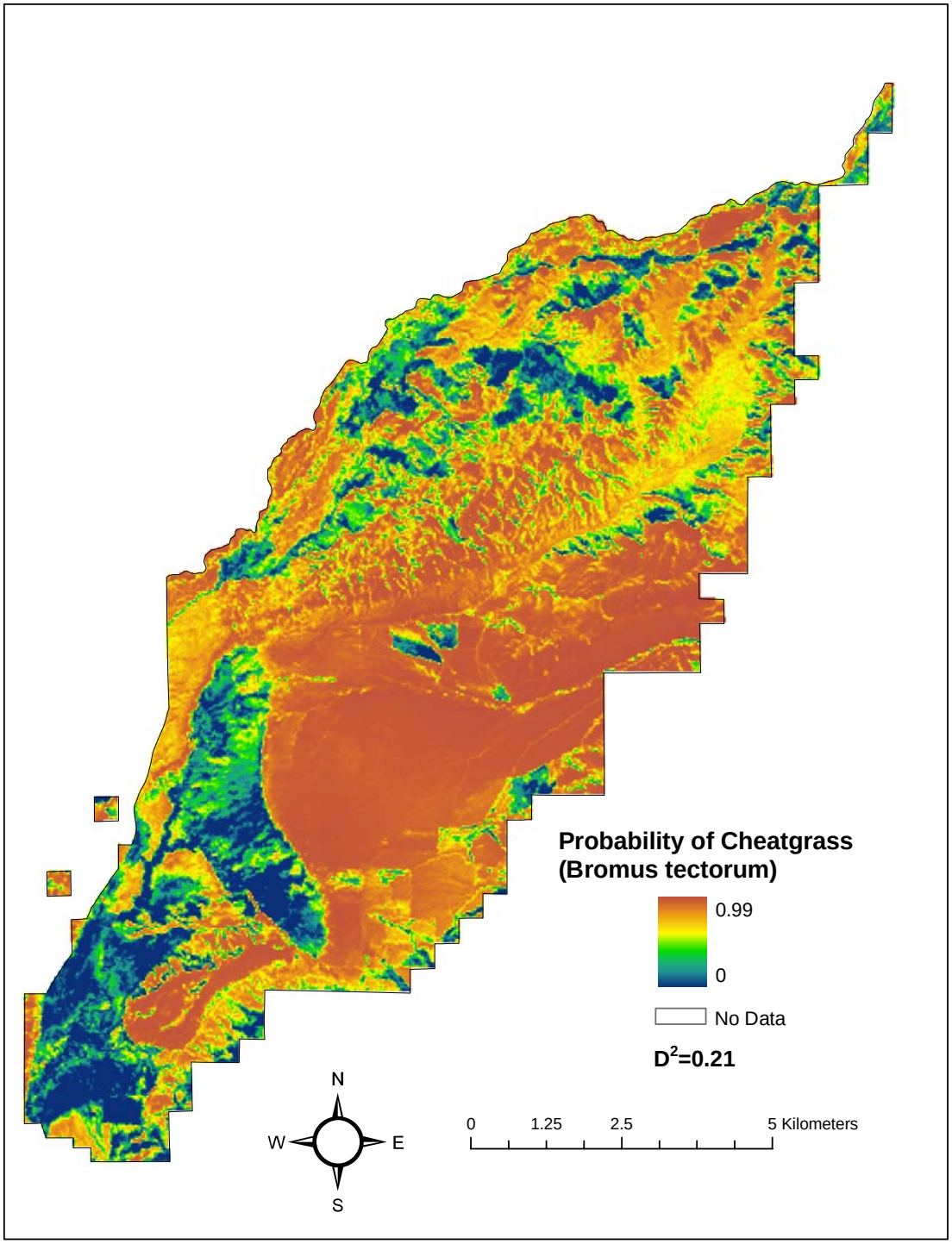

Figure 4. The probability of occurrence of cheatgrass.

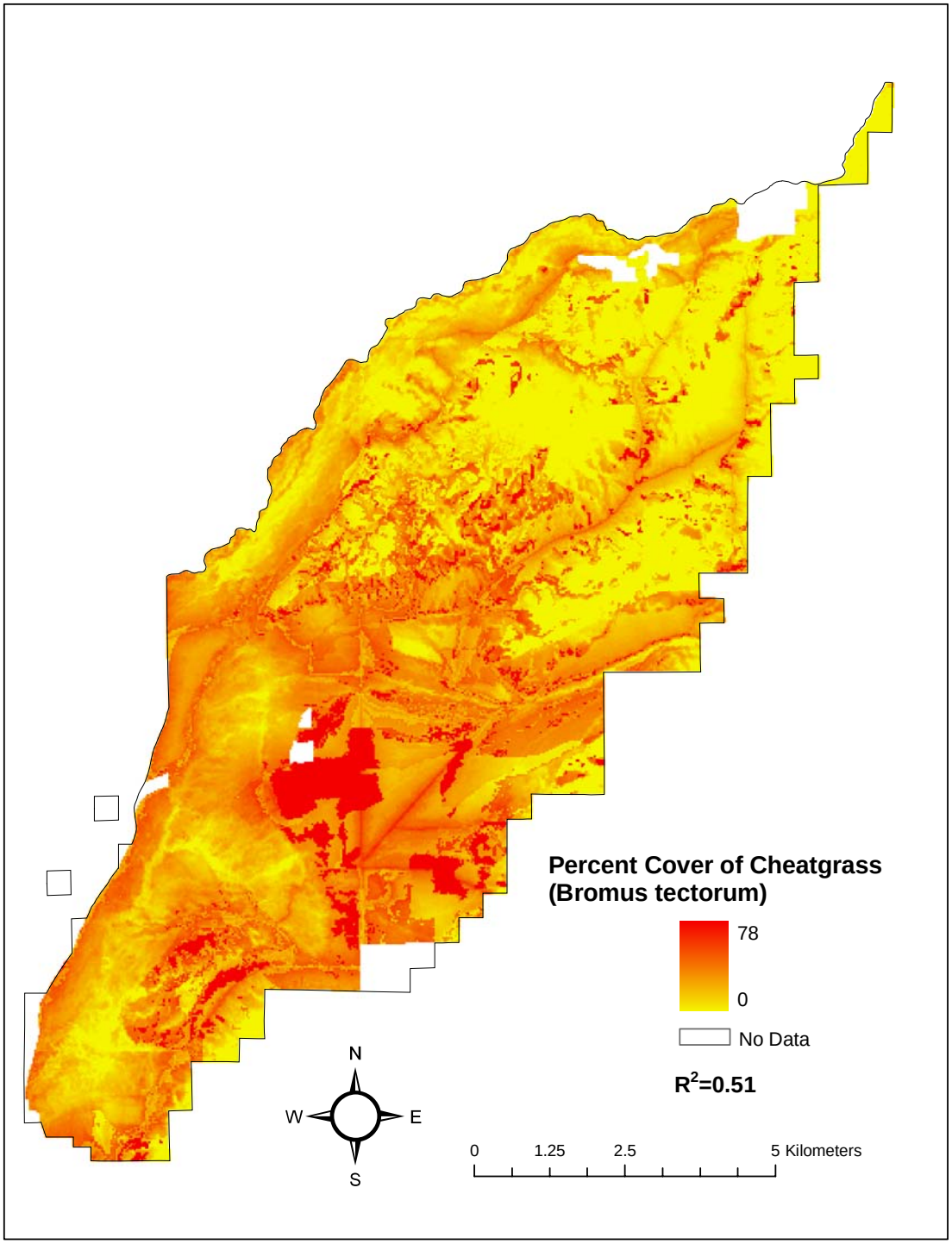

Figure 5. The predicted cover of cheatgrass.

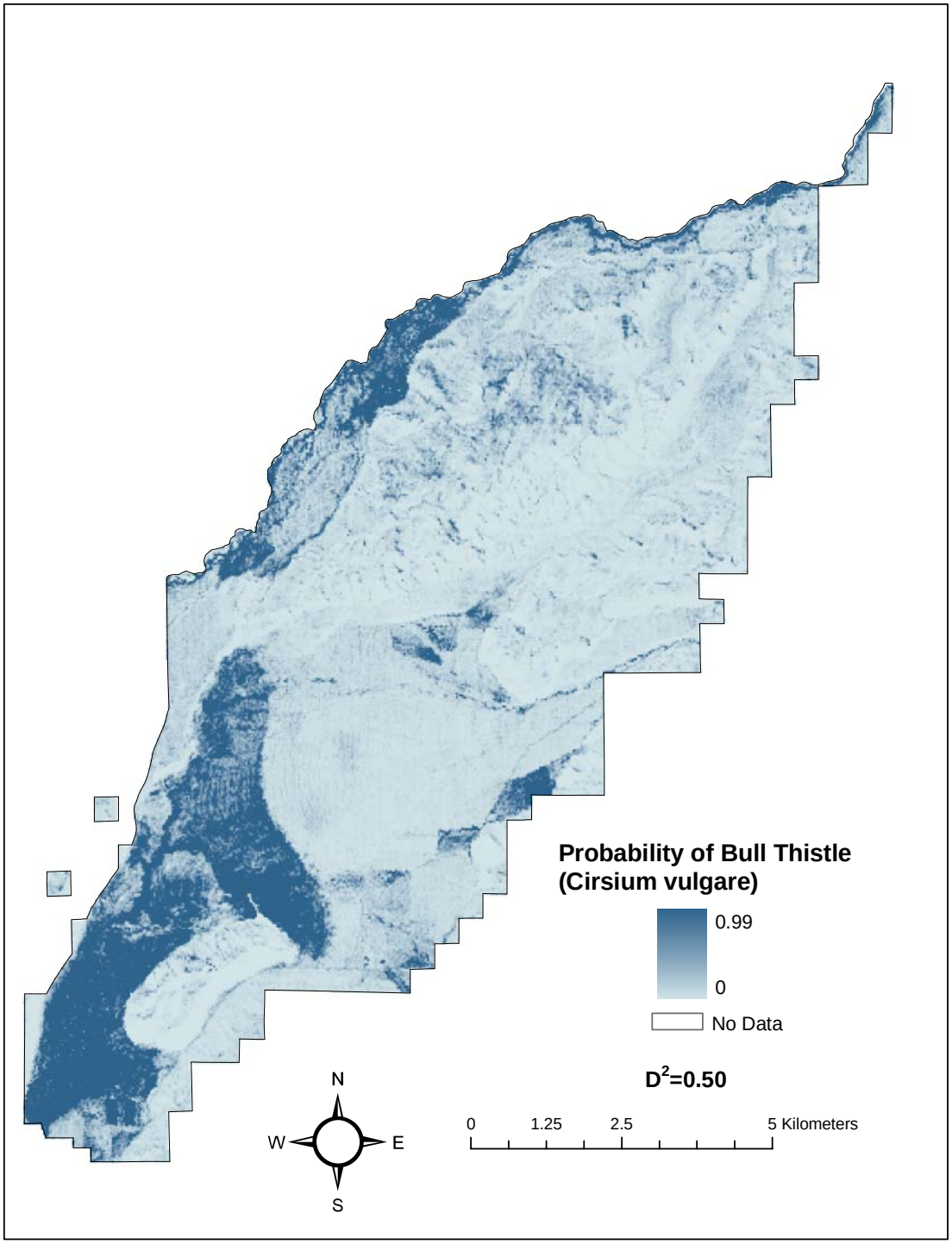

Figure 6. The probability of occurrence of bull thistle.

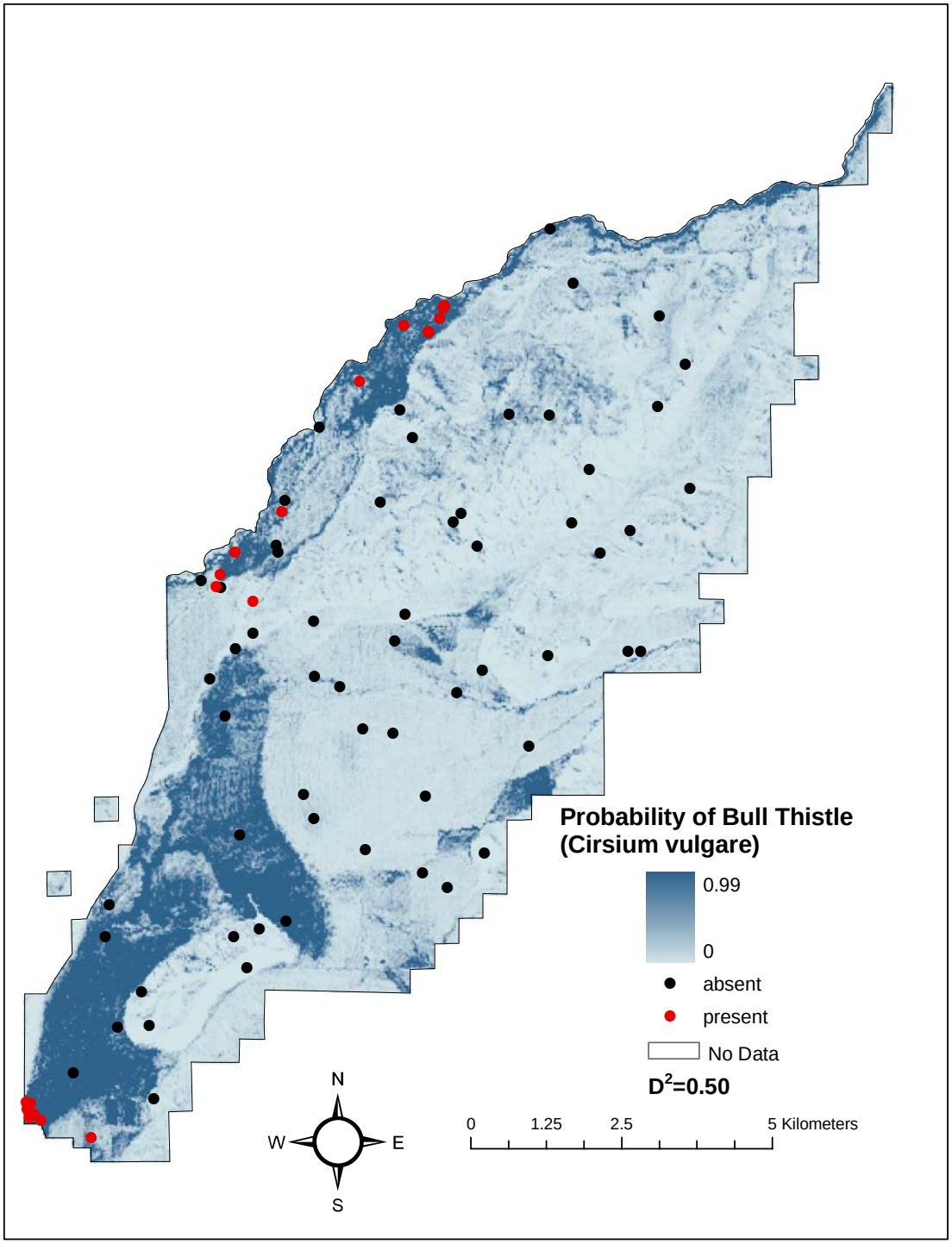

Figure 7. The probability of occurrence of bull thistle and presence and absence points based on mapping and plot data.

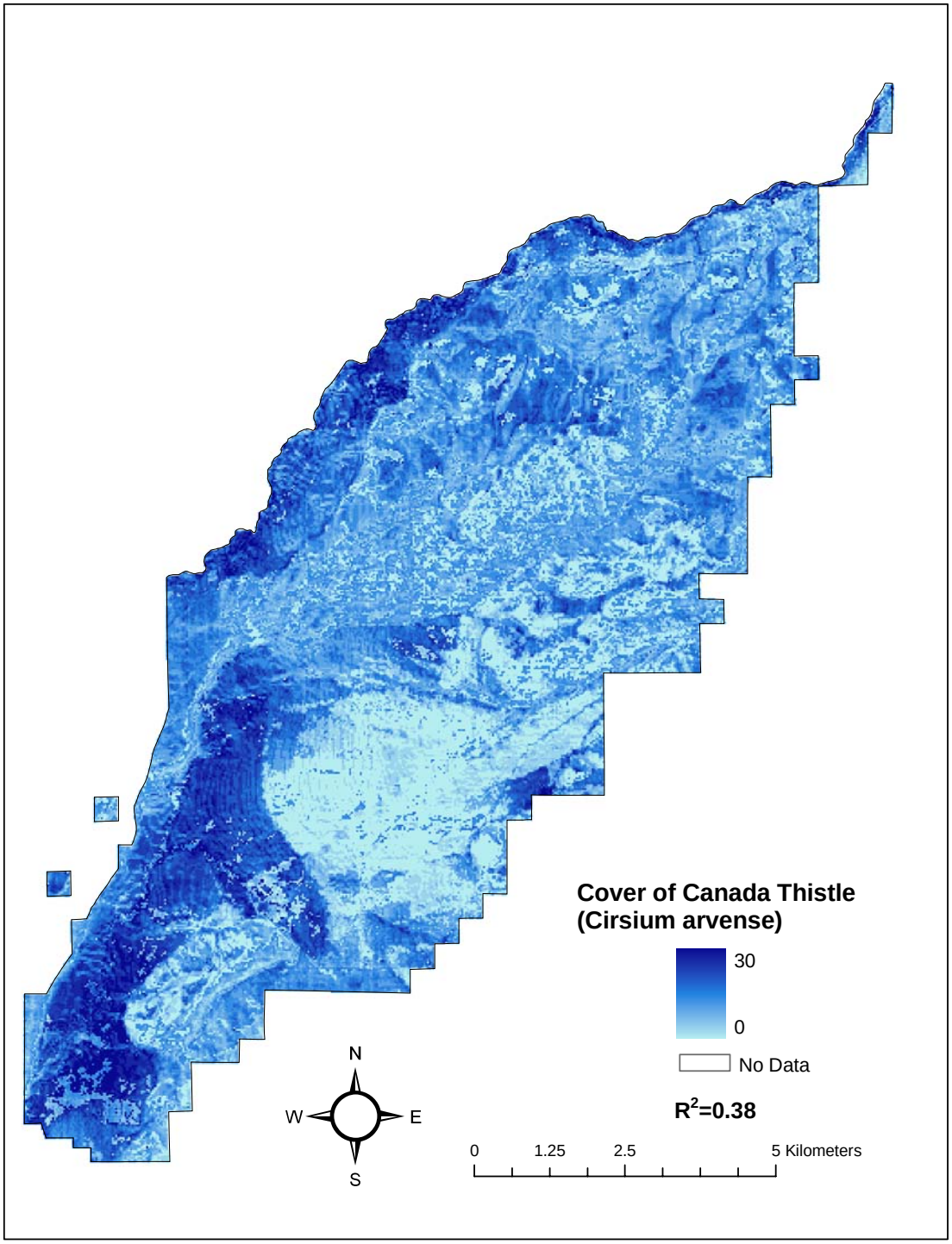

Figure 8. The predicted cover of Canada thistle.

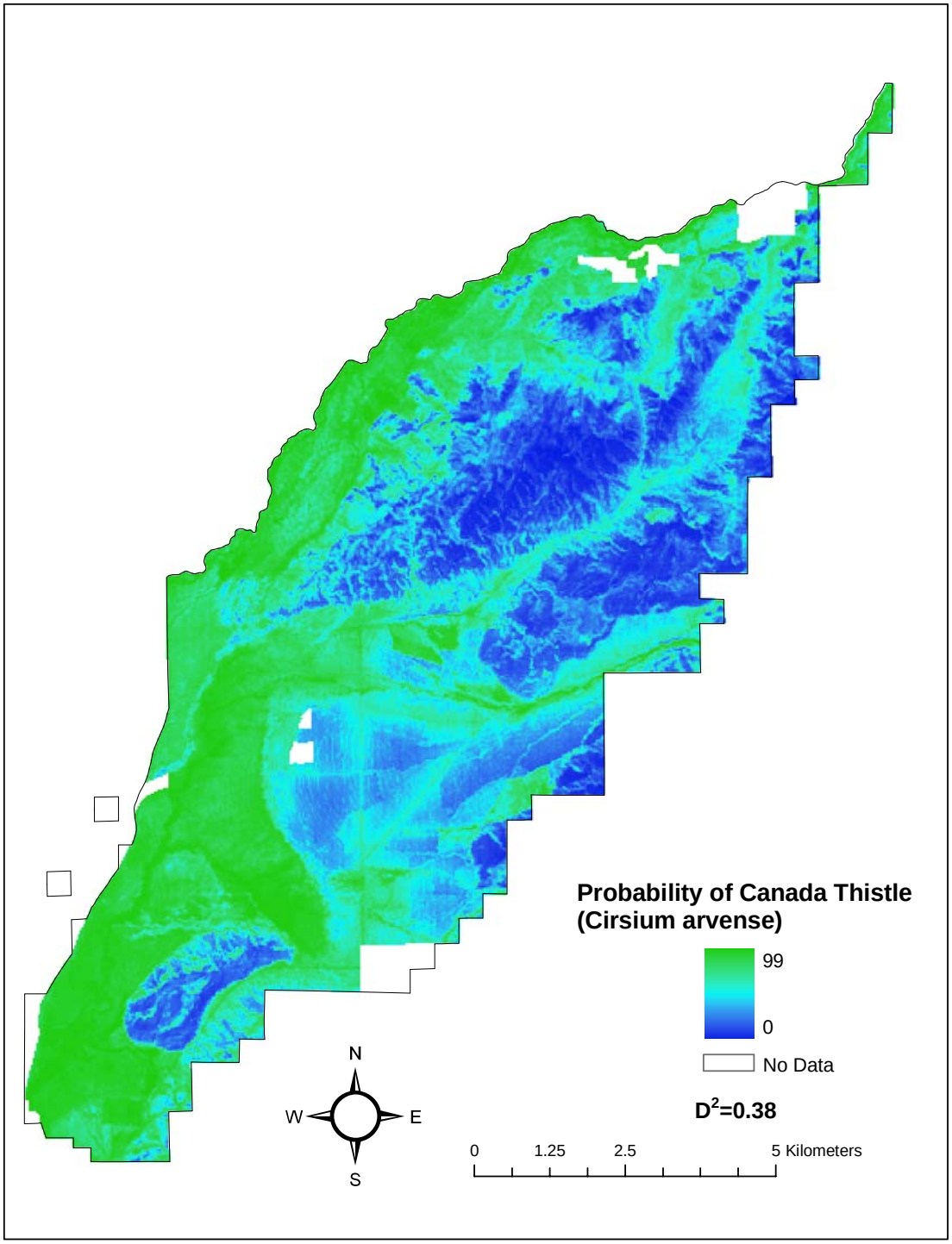

Figure 9. The probability of Canada thistle occurrence.

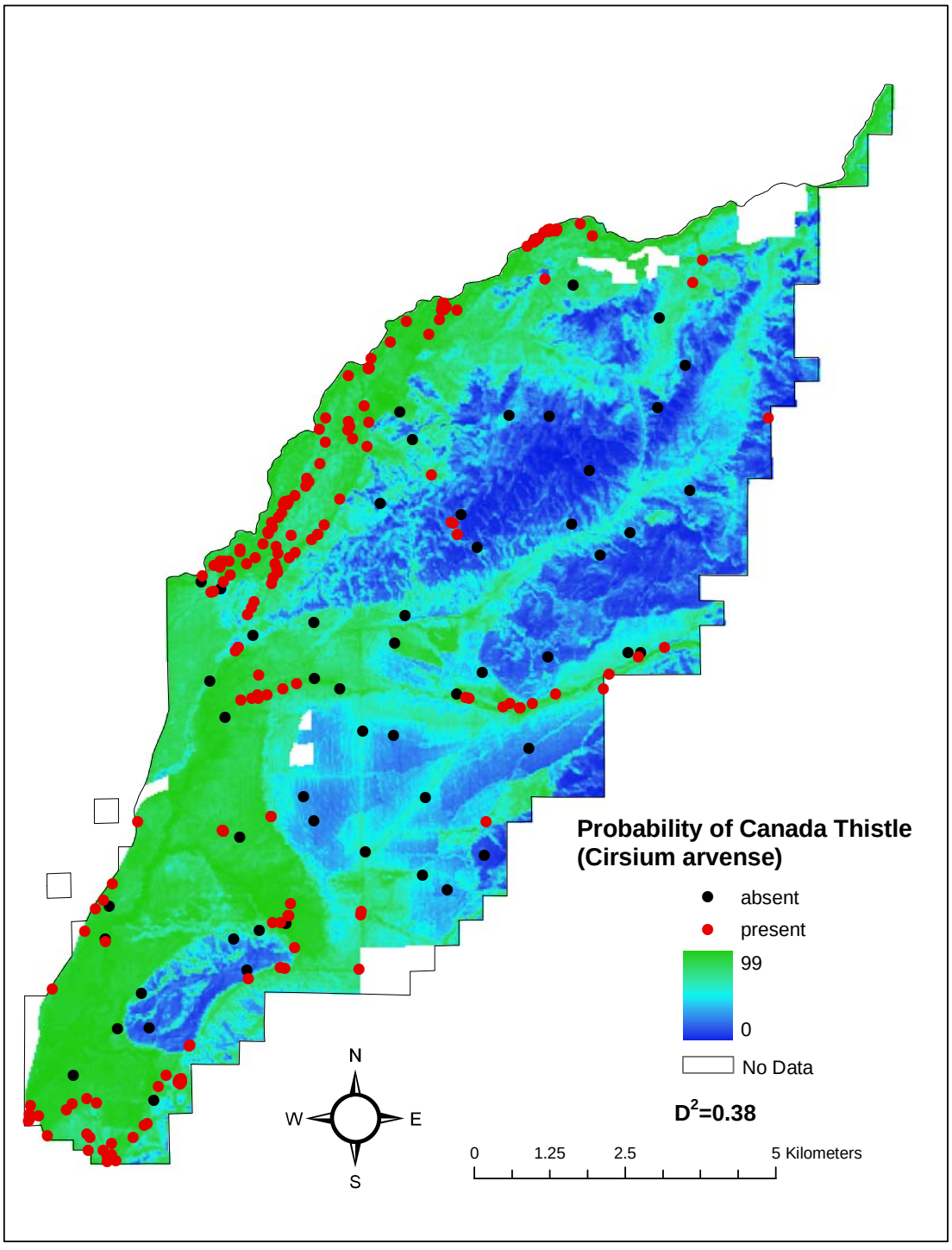

Figure 10. The probability of Canada thistle occurrence and present and absent locations based on mapping and plot data.

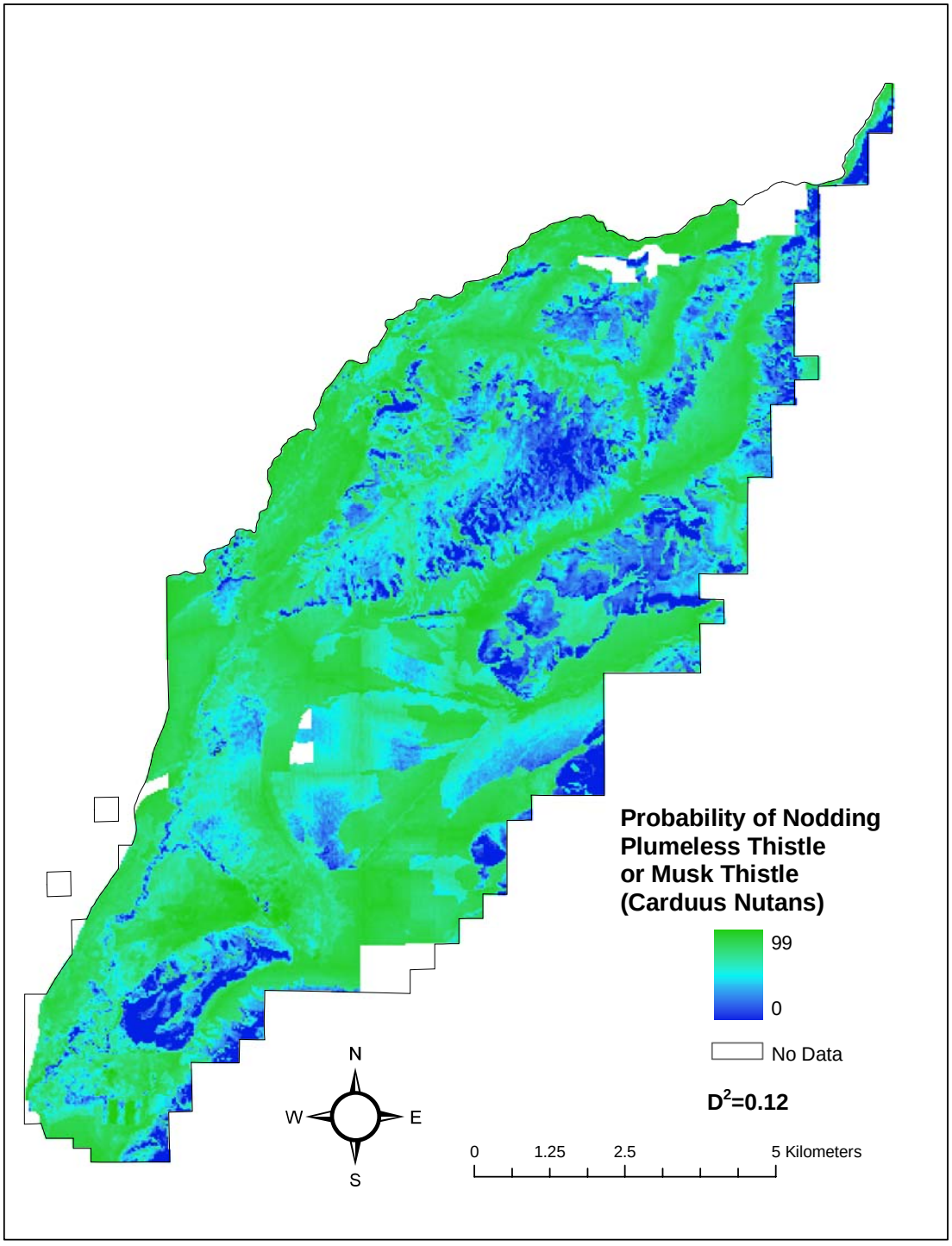

Figure 11. The probability of nodding plumeless thistle (musk thistle) occurrence.

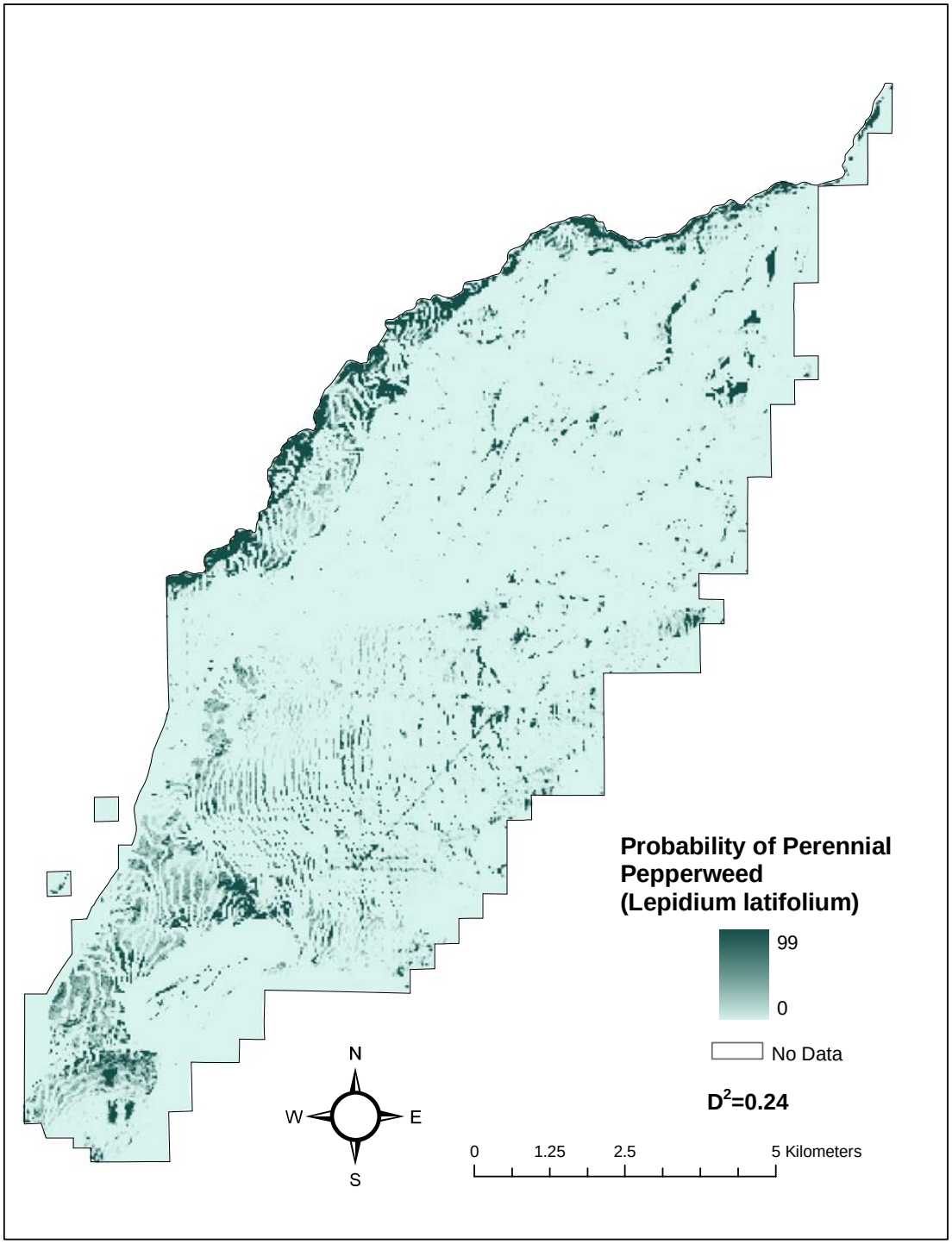

Figure 12. The probability of perennial pepperweed occurrence.

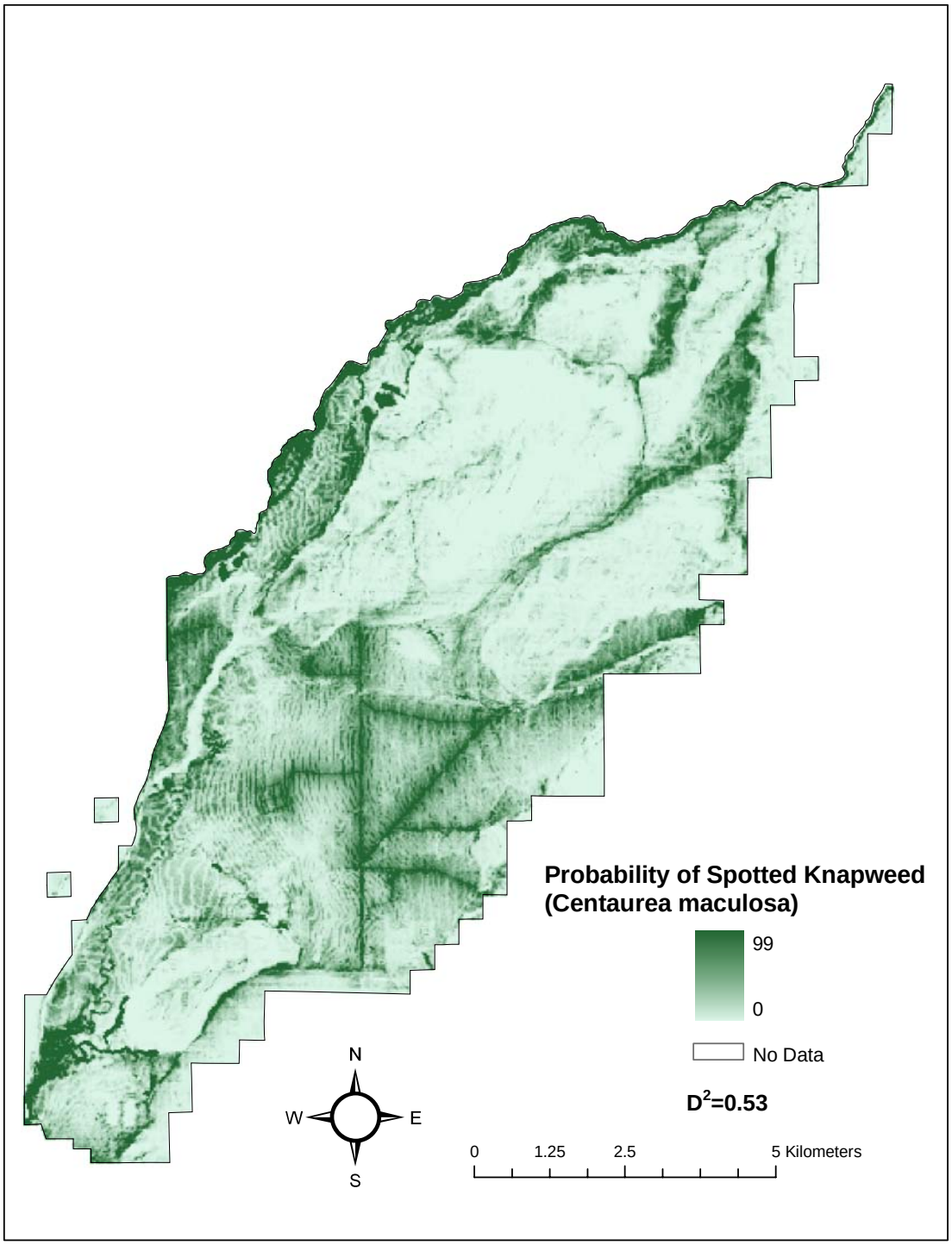

Figure 13. The probability of spotted knapweed occurrence.

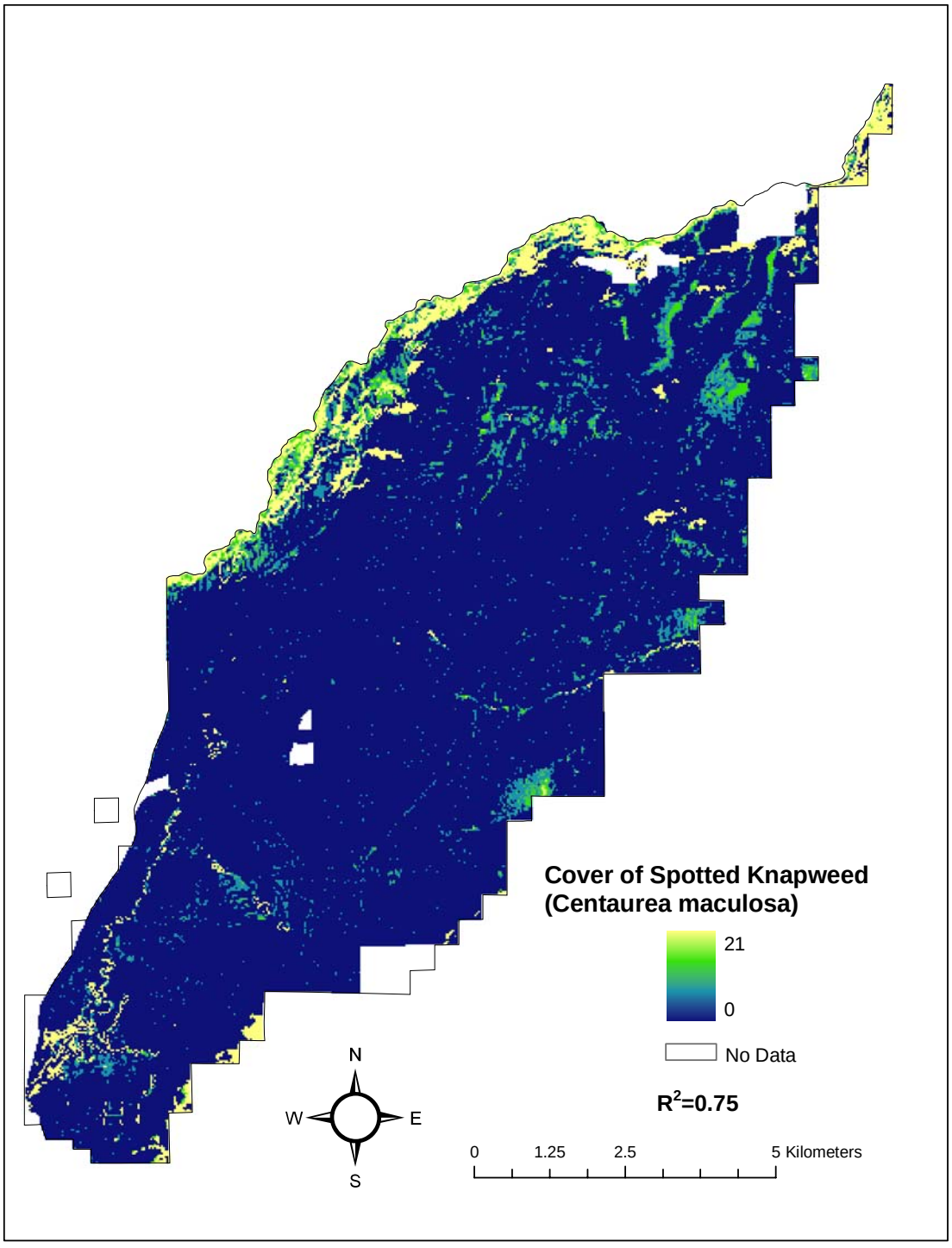

Figure 14. The predicted cover of spotted knapweed.

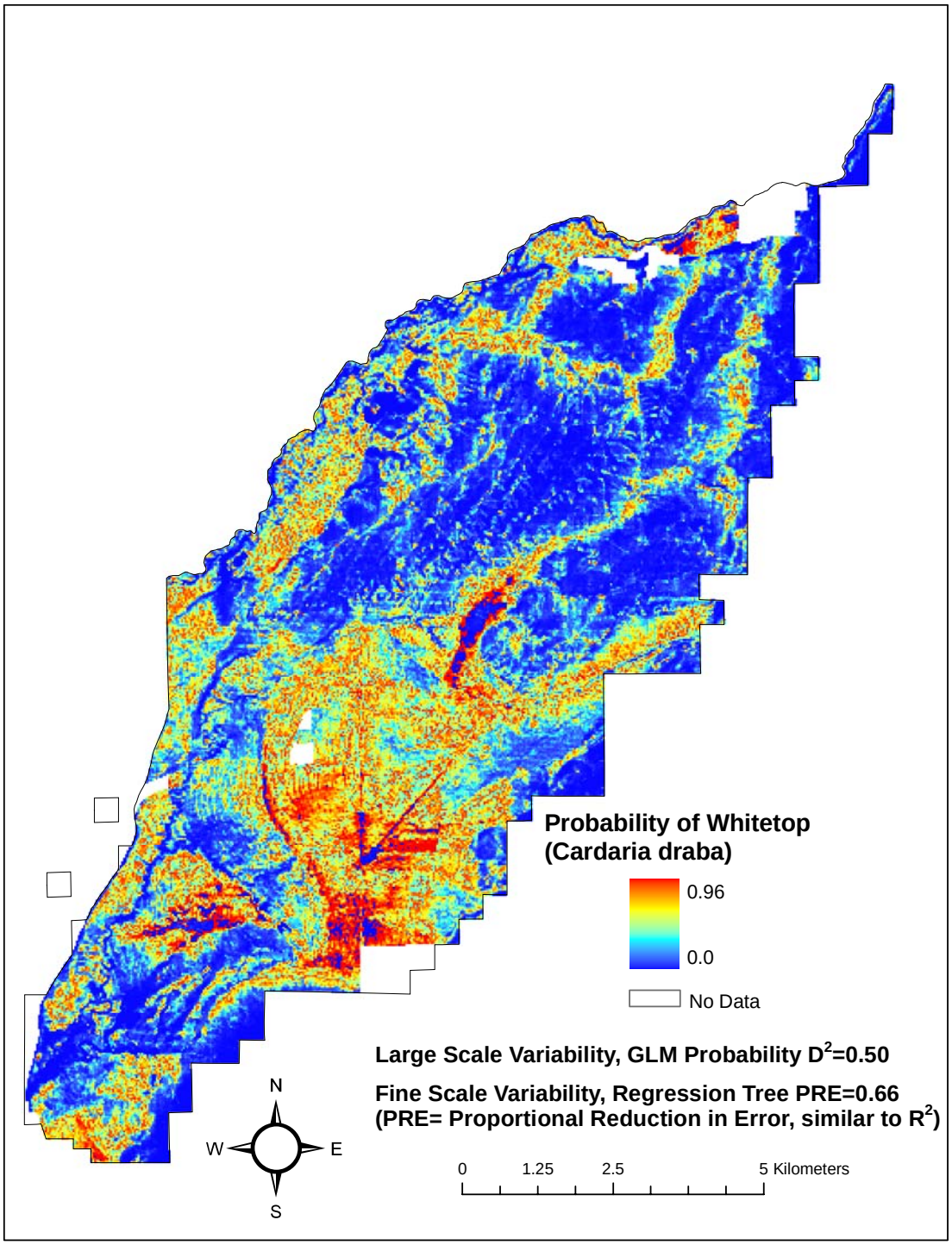

Figure 15. The probability of whitetop occurrence.

A habitat analysis can be useful for determining vulnerability, but species identity matters in invasion biology. Some species wreak havoc on natural systems while others seem to be additive, existing at low levels that do not disrupt native species. Most of the detrimental-invasive-plant species undergo a lag phase, existing at low, background numbers and densities for some time before spreading across the landscape. The difficulty of differentiating between relatively harmless invasive species and the next big invader drives our rational for including all NRCS non-native plant species in the analysis.

A species-specific approach that examines frequency of occurrence and cover of these species can provide an estimate of how prevalent these species are on the landscape (Table 1). Dominance (cover x frequency) combines these two metrics to provide another way to assess the relative importance of species across the landscape. The relatively high dominance score of Kentucky bluegrass, the *Bromopsis inermis* variety of smooth brome, and crested wheatgrass (*Agropyron cristatum*) reflects pervasiveness (Table 1). Many species had low dominance scores, and some of these despite moderately high frequencies (e.g. prickly lettuce (*Lactuca serriola*) dandelion (*Taraxacum officinale*), and yellow salsify.). These species may not threaten native plant species as they are not taking up a lot of space or resources. Annual bluegrass (*Poa annua*) and herb sophia (*Descurainia sophia*) had relatively high dominance scores despite occurring in only one plot. These species should be continuously evaluated and monitored as they may have the ability to spread and have a significant impact on native plant species.

Combining Plot and Mapping Data

A combination of mapping and plot data might be the best way to efficiently understand the composition, distribution, abundance, and impact of invading non-native plant species on a landscape (Parker et al., 1999). Mapping techniques only tell half the story. While they

effectively describe the general distribution of non-native plant species, and, with strategic searching, function as a valuable contribution to the early detection of new and rare invaders on the landscape (Stohlgren & Schnase, 2005), the metrics may not be repeatable and they ignore native species and important ancillary data for predictive spatial models. Plot sampling may miss rare species and fail to capture the fine scale distribution of invasive plant species, but it can describe conditions with accurate and repeatable methods, and record native species information and ancillary data. The two techniques compliment each other.

Sampling sixty-three plots we detected forty-nine non-native plant species. Mapping at 1957 locations detected thirty-eight non-native plant species. While mapping detected ten fewer species, it did capture some species missed by plot sampling. Twenty-eight of the non-native plant species found in plots were not detected with mapping techniques, and seventeen of the thirty-eight mapped non-native species were not captured with plot sampling. A total of sixty-six non-native species were captured with the combination of the two methods. Like rare plant surveys, searching with mapping techniques located rare non-native species on the landscape. Of the seventeen species unique to mapping, three of these were mapped three or fewer times. However, stratified-random plot sampling reached locations and detected rare non-native species that may have otherwise gone unsampled. Of the twenty-eight non-native species unique to plots, ten occurred in only one plot (Table 1).

Invasive Species and Native Forage

One of the greatest values of plot sampling is that it recorded the presence of non-native and native plant species. Information on the co-occurrence of species can be useful for understanding the relationship between native and non-native species, and in this case,

evaluating the impact of non-native species on native forage species. Comparing the cover of non-native and native species provides a means for evaluating impact of plant invasions. At the plot scale, forty-six of sixty-three plots had higher cover of native species than non-native species, but some plots were heavily weighted towards non-native species cover (ner007: 58% non-native, 3.3% native; Table 4). Grass utilization is tracked on the Refuge, and seems to be the most valuable growth for forage and the same pattern holds (46 of 63 plots higher native cover; Table 5).

Table 4. The average cover of three 1-m2 plots of native and introduced species by plot.

Plot Visit ID	Plot Name	Native % Cover	Introduced % Cover
120	ner001	16.04	
121	ner002	10.33	0.50
155	ner100	26.08	2.25
156	ner101	13.42	23.17
177	ner003	17.08	4.13
178	ner004	21.13	16.88
179	ner005	6.50	37.00
180	ner006	37.56	20.50
218	ner102	11.33	34.00
219	ner103	9.52	27.58
220	ner007	3.33	58.25
221	ner008	21.54	4.71
222	ner009	19.96	0.50
223	ner010	27.96	0.50
277	ner104	22.80	12.92
278	ner105	19.25	10.25
279	ner106	30.03	35.92
289	ner107	29.08	13.25
290	ner108	17.25	
291	ner109	16.10	2.75
292	ner011	15.31	5.25
293	ner012	24.61	3.00
300	ner013	17.08	
301	ner014	39.67	
302	ner015	35.33	5.67
313	ner109B	67.38	
314	ner110	42.97	
347	ner111	28.17	7.13
348	ner112	31.30	12.67

366	ner016	17.71	3.00
367	ner017	18.92	30.58
379	ner112b	15.88	73.63
380	ner113	15.35	
381	ner113b	27.64	25.25
382	ner114	11.94	56.21
430	ner018	20.88	2.83
431	ner019	6.19	2.00
437	ner115	21.21	
438	ner116	21.70	4.83
439	ner020	15.58	24.58
440	ner021	18.45	8.92
466	ner117	17.88	
467	ner118	19.52	20.92
486	ner022	20.27	6.00
487	ner023	32.42	20.42
488	ner024	17.42	
489	ner119	44.67	7.83
490	ner120	26.18	7.75
491	ner121	15.72	8.67
521	ner122	33.64	27.04
522	ner123	6.67	35.72
523	ner124	7.03	16.42
544	ner125	41.67	1.00
545	ner126	27.75	46.50
580	ner127	15.06	21.08
581	ner128	30.00	25.38
582	ner129	10.98	12.75
583	ner130	12.75	41.00
602	ner131	24.40	13.00
603	ner132	22.80	25.00
604	ner133	10.77	4.25
611	ner134	15.40	2.50
612	ner135	30.22	2.83

Table 5. Average cover of native and non-native grass species by plot.

Plot Visit ID	Plot Name	Native % Cover	Non-native % Cover
120	ner001	14.88	
121	ner002	14.50	
155	ner100	39.00	
156	ner101	4.00	66.00
177	ner003	25.17	0.50
178	ner004	34.00	24.50
179	ner005		44.33
180	ner006	64.00	34.00
218	ner102	8.00	34.00
219	ner103	12.33	24.50
220	ner007		115.50
221	ner008	49.25	1.75
222	ner009	53.67	
223	ner010	35.50	
277	ner104	41.25	25.33
278	ner105	23.83	
279	ner106	71.50	62.00
289	ner107	15.33	25.50
290	ner108	26.83	
291	ner109	37.42	4.00
292	ner011	20.83	10.00
293	ner012	61.33	3.00
300	ner013	26.50	
301	ner014	78.33	
302	ner015	58.50	
313	ner109B	88.67	
314	ner110	116.00	
347	ner111	16.50	11.00
348	ner112	17.67	23.33
366	ner016	37.00	
367	ner017	12.00	14.67
379	ner112b	14.50	143.00
380	ner113	27.67	
381	ner113b	6.00	0.50
382	ner114	17.00	35.33
430	ner018	60.50	0.50
431	ner019	4.25	0.50
437	ner115	39.00	
438	ner116	46.67	7.67
439	ner020	16.00	34.67
440	ner021	6.92	3.00
466	ner117	31.33	

467	ner118	23.33	32.17
486	ner022	32.83	
487	ner023	36.00	34.33
488	ner024	20.75	
489	ner119	85.83	7.00
490	ner120	65.17	15.00
491	ner121	27.67	16.33
521	ner122	27.17	30.25
522	ner123	6.67	71.67
523	ner124	7.58	28.33
544	ner125	50.75	
545	ner126	5.00	38.50
580	ner127	16.67	23.33
581	ner128	30.00	26.33
582	ner129	19.17	14.50
583	ner130	25.00	71.67
602	ner131	44.00	13.00
603	ner132	52.33	25.00
604	ner133	9.50	
611	ner134	31.00	
612	ner135	76.67	4.67

The importance of dominance was already discussed in relation to non-native plant species. When the dominance of native and non-native plant species is compared across all plots, two of the top three species are non-native species (Table 6). That two of these species are a variety of smooth brome (*Bromopsis inermis*) and crested wheatgrass will come as no surprise to Refuge staff. But, that cheatgrass is the second most dominant grass species on the Refuge may be a surprise and should be of concern.

Spatial Assessments

Spatial models describe species distributions that can be used to direct early detection and control. The models reflect statistically derived relationships that approximate extant distributions or potential distributions based on the

Table 6. Dominance scores for the 15 most dominant grasses.

Species	NRCS Code	Nativity	Dominance
Bromopsis inermis	brin7	Native and Introduced to U.S.	369.43
Poa secunda, sandberg bluegrass	pose	Native to U.S.	362.76
Bromus tectorum, cheatgrass	brte	Introduced to U.S.	298.69
Agropyron cristatum, crested wheatgrass	agcr	Introduced to U.S.	268.44
Hesperostipa comata	heco26	Native to U.S.	204.64
Carex utriculata	caut	Native to U.S.	201.17
Elymus spicatus	elsp3	Native to U.S.	176.19
Elymus lanceolatus, streambank wheatgrass	ella3	Native to U.S.	161.70
Stipa comata	stco4	Native to U.S.	128.50
Festuca idahoensis, idaho fescue	feid	Native to U.S.	106.25
Calamagrostis rubescens	caru	Native to U.S.	95.50
Poa nevadensis	pone3	Native to U.S.	89.45
Poa annua, annual bluegrass	poan	Introduced to U.S.	76.00
Koeleria macrantha, prairie junegrass	koma	Native to U.S.	73.65
Juncus balticus, baltic rush	juba	Native to U.S.	68.75

field sampling effort. Assessing the accuracy of spatial models that describe spreading organisms is difficult; this effort simply relied on the percent of variability explained (R^2 or D^2). The statistical accuracy and representation of actual distributions can be improved with the addition of more data, fine tuning spatial layers, and computer power that prevented successful kriging of residuals to explain fine-scale variability.

The models are based on locations were species were found both by mapping and in plots, and absence data defined as plots in which the target species did not exist. The models

essentially evaluate the environmental window of presence or cover and describe similar areas on the landscape. Therefore, they should not be thought of as locations where the target species exists, but locations that it is likely to invade based on locations where it was detected. It is important to note that the model or environmental window could change if the target species that had been missed was found in a new location, or if the species spread to locations outside the perceived window.

REFERENCES

D'Antonio, C.M., Dudley, T.L. and Mack, M.: 1999, 'Disturbance and biological invasions: direct effects and feedbacks', in: L.R.Walker, (ed.), *Ecosystems of Disturbed Ground*, Elsevier, New York, NY, pp. 413-452.

D'Antonio, C.M. and Vitousek, P.M.: 1992, 'Biological invasions by exotic grasses, the grass fire cycle, and global change', *Annual Review of Ecology and Systematics* **23**, 63-87.

De'ath, G. and Fabricius, K.E.: 2000, 'Classification and regression trees: a powerful yet simple technique for ecological data analysis', *Ecology* **81(11)**, 3178-3192.

Elton, C.: 1958, The ecology of invasions by animals and plants, Methuen and Company, LTD, London.

Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M. and Bazzaz, F.: 2000, 'Biotic invasions: causes, epidemiology, global consequences and control', *Issues in Ecology* **5**, 1-19.

McCullagh, P. and Nelder, J.A.: 1989, Generalized linear models, 2nd edition, Chapman and Hall, New York, NY.

Parker, I.M., Simberloff, D., Lonsdale, W.M., Goodell, K., Wonham, P.M., Kareiva, M.H., Von Holle, B., Moyle, P.B., Byers, J.E. and Goldwasser, L.: 1999, 'Impact: toward a framework for understanding the ecological effects of invaders', *Biological Invasions* **1**, 3-19.

Randall, J.M.: 1996, 'Weed control and the preservation of biological diversity', *Weed Technology* **10(2)**, 370-383.

Reich, R.M. and Davis, R.A.: 1998, 'On-line spatial library for the S-Plus statistical software package', Colorado State University, Fort Collins, CO, http://www.warnercnr.colostate.edu/~robin/. October 5, 2005.

Reich, R.M., Lundquist, J.E. and Bravo, V.A.: 2004, 'Spatial models for estimating fuel loads in the Black Hills, South Dakota, USA', *International Journal of Wildland Fire* **13**, 119-129.

Statistical Sciences: 2005, S-PLUS 7.0 for Windows. Insightful Corporation.

Stohlgren, T.J., Chong, G.W., Kalkhan, M.A. and Schell, L.D.: 1997a, 'Multiscale sampling of plant diversity: Effects of minimum mapping unit size', *Ecological Applications* **7(3)**, 1064-1074.

Stohlgren, T.J., Chong, G.W., Kalkhan, M.A. and Schell, L.D.: 1997b, 'Rapid assessment of plant diversity patterns: A methodology for landscapes', *Environmental Monitoring and Assessment* **48(1)**, 25-43.

Stohlgren, T.J., Coughenour, M.B., Chong, G.W., Binkley, D., Kalkhan, M.A., Schell, L.D., Buckley, D.J. and Berry, J.K.: 1997c, 'Landscape analysis of plant diversity', *Landscape Ecology*, **12(3)**, 155-170.

Stohlgren, T.J., Falkner, M.B. and Schell, L.D.: 1995, 'A Modified-Whittaker Nested Vegetation Sampling Method', *Vegetatio* **117(2)**, 113-21.

Stohlgren, T.J. and Schnase, J.L.: 2005, 'Biological hazards: what we need to know about invasive species', *Risk Assessment Journal* (in press).

USDA: 2005, 'The PLANTS Database', version 3.5. USDA, NRCS. Data compiled from various sources by Mark W. Skinner, National Plant Data Center, Baton Rouge, LA 70874-4490 USA. http://plants.usda.gov. October 4, 2005.

Vitousek, P.M., Walker, L.R., Whiteaker, L.D., Mueller-Dombois, D. and Matson, P.A.: 1987, 'Biological invasion by *Myrica faya* alters ecosystem development in Hawaii', *Science* **238**, 802-804.

Westbrooks, R.: 1998, Invasive plants, changing the landscape of America: Fact book, Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICNMEW), Washington, D.C.

Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A. and Losos, E.: 1998, 'Quantifying threats to imperiled species in the United States', *BioScience* **48(8)**, 607-615.

Appendix 1. List of native and non-native species located by plot sampling.

NRCS Code	Species	Nativity	Frequency on Plots
brte	bromus tectorum, cheatgrass	Introduced to U.S.	10
canu4	carduus nutans, nodding plumeless thistle	Introduced to U.S.	4
trdu	tragopogon dubius, yellow salsify	Introduced to U.S.	44
deso2	descurainia sophia, herb sophia	Introduced to U.S.	3
taof	taraxacum officinale, common dandelion	Native and Introduced to U.S.	41
ciar4	cirsium arvense, canadian thistle	Introduced to U.S.	9
popr	poa pratensis, kentucky bluegrass	Native and Introduced to U.S.	40
pose	poa secunda, sandberg bluegrass	Native to U.S.	39
lare	lappula redowskii	Native to U.S.	15
sial2	sisymbrium altissimum, tall tumblemustard	Introduced to U.S.	5
elsp3	elymus spicatus	Native to U.S.	32
chvi8	chrysothamnus viscidiflorus, green rabbitbrush	Native to U.S.	30
ella3	elymus lanceolatus, streambank wheatgrass	Native to U.S.	30
acmi2	achillea millefolium, common yarrow	Native and Introduced to U.S.	28
phho	phlox hoodii, spiny phlox	Native to U.S.	26
gusa2	gutierrezia sarothrae, broom snakeweed	Native to U.S.	25
pone3	poa nevadensis	Native to U.S.	24
erum	eriogonum umbellatum, sulphur wildbuckwheat	Native to U.S.	24
meof	melilotus officinalis, yellow sweetclover	Introduced to U.S.	11
thar5	thlaspi arvense, field pennycress	Introduced to U.S.	9
artr2	artemisia tridentata, big sagebrush	Native to U.S.	23
lase	lactuca serriola, prickly lettuce	Introduced to U.S.	12
arso2	arnica sororia, twin arnica	Native to U.S.	21
alde	alyssum desertorum, desert madwort	Introduced to U.S.	21
chna2	chrysothamnus nauseosus	Native to U.S.	21
cafl7	castilleja flava, yellow indian paintbrush	Native to U.S.	20
koma	koeleria macrantha, prairie junegrass	Native to U.S.	20
arfr4	artemisia frigida, fringed sagewort	Native to U.S.	20
heco26	hesperostipa comata	Native to U.S.	18
somi2	solidago missouriensis, missouri goldenrod	Native to U.S.	17
aggl	agoseris glauca, pale agoseris	Native to U.S.	17
agcr	agropyron cristatum, crested wheatgrass	Introduced to U.S.	16
syas3	symphyotrichum ascendens	Native to U.S.	15
melu	medicago lupulina, black medick	Introduced to U.S.	11
basa3	balsamorhiza sagittata, arrowleaf balsamroot	Native to U.S.	14
syor2	symphoricarpos oreophilus, whortleleaf snowberry	Native to U.S.	14
lepu	leptodactylon pungens, granite pricklygilia	Native to U.S.	14

arho2	arabis holboellii, holboell`s rockcress	Native to U.S.	14
kopy	koeleria pyramidata	Native to U.S.	13
copa26	comandra pallida	Native to U.S.	13
caro2	campanula rotundifolia, bluebell bellflower	Native to U.S.	12
ersu2	erigeron subtrinervis, threenerve fleabane	Native to U.S.	12
lotr2	lomatium triternatum, nineleaf biscuitroot	Native to U.S.	12
stco4	stipa comata	Native to U.S.	12
canu3	calochortus nuttallii, sego lily	Native to U.S.	12
asmi9	astragalus miser, timber milkvetch	Native to U.S.	12
oxse	oxytropis sericea, silvery oxytrope	Native to U.S.	12
brin7	bromopsis inermis	Introduced to U.S.	12
erpu2	erigeron pumilus, shaggy fleabane	Native to U.S.	12
anmi3	antennaria microphylla, littleleaf pussytoes	Native to U.S.	12
lofo	lomatium foeniculaceum, desert biscuitroot	Native to U.S.	11
teca2	tetradymia canescens, spineless horsebrush	Native to U.S.	11
acne9	achnatherum nelsonii	Native to U.S.	11
artr4	artemisia tripartita, threetip sagebrush	Native to U.S.	11
arlu	artemisia ludoviciana, louisiana sagewort	Native to U.S.	11
crac2	crepis acuminata, longleaf hawksbeard	Native to U.S.	11
pepr2	penstemon procerus, littleflower penstemon	Native to U.S.	10
meal2	melilotus albus	Introduced to U.S.	8
asmih	astragalus miser var. hylophilus	Native to U.S.	10
amal2	amelanchier alnifolia, saskatoon serviceberry	Native to U.S.	10
asco12	astragalus convallarius	Native to U.S.	10
phpr3	phleum pratense, timothy	Introduced to U.S.	10
gevi2	geranium viscosissimum, sticky geranium	Native to U.S.	10
carex	carex sp.		10
erpup3	erigeron pumilus ssp. pumilus	Native to U.S.	10
tonu	townsendia nuttallii, nuttall`s townsend daisy	Native to U.S.	9
arhop2	arabis holboellii var. pendulocarpa	Native to U.S.	9
rowo	rosa woodsii, woods` rose	Native to U.S.	9
cami2	camelina microcarpa, littlepod falseflax	Introduced to U.S.	6
phlo2	phlox longifolia, longleaf phlox	Native to U.S.	9
mesa	medicago sativa, alfalfa	Introduced to U.S.	8
cema4	centaurea maculosa, spotted knapweed	Introduced to U.S.	1
luar3	lupinus argenteus, silvery lupine	Native to U.S.	8
arco5	arenaria congesta, ballhead sandwort	Native to U.S.	8
anpa4	antennaria parvifolia, smallleaf pussytoes	Native to U.S.	9
frsp	frasera speciosa, showy frasera	Native to U.S.	8
cadu6	carex duriuscula	Native to U.S.	8
gabo2	galium boreale, northern bedstraw	Native to U.S.	8
crmo4	crepis modocensis, siskiyou hawksbeard	Native to U.S.	8
anum	antennaria umbrinella, umber pussytoes	Native to U.S.	7
staca	stenotus acaulis var. acaulis	Native to U.S.	8
luse4	lupinus sericeus, silky lupine	Native to U.S.	8
rosa3	rosa sayi	Native to U.S.	8

cesc2	centaurea scabiosa, greater knapweed	Introduced to U.S.	
gema4	geum macrophyllum, largeleaf avens	Native to U.S.	7
maca2	machaeranthera canescens, hoary aster	Native to U.S.	7
brin2	bromus inermis, smooth brome	Native and Introduced to U.S.	6
caut	carex utriculata	Native to U.S.	7
mast4	maianthemum stellatum, starry false solomon`s seal	Native to U.S.	7
viad	viola adunca, hookedspur violet	Native to U.S.	7
poan3	populus angustifolia, narrowleaf cottonwood	Native to U.S.	7
eltrt	elymus trachycaulus (link) gould ex shinners ssp. trachycaulus	Native to U.S.	7
trhy	trifolium hybridum, alsike clover	Introduced to U.S.	6
aspup7	astragalus purshii var. purshii	Native to U.S.	6
orhy	oryzopsis hymenoides	Native to U.S.	6
cafi	carex filifolia	Native to U.S.	6
depi	descurainia pinnata, western tansymustard	Native to U.S.	6
pupa5	pulsatilla patens, american pasqueflower	Native to U.S.	6
potr5	populus tremuloides, quaking aspen	Native to U.S.	6
lela2	lepidium latifolium, broadleaved pepperweed	Introduced to U.S.	1
brja	bromus japonicus, japanese brome	Introduced to U.S.	5
sest3	senecio streptanthifolius, cleftleaf groundsel	Native to U.S.	6
soca6	solidago canadensis, canada goldenrod	Native to U.S.	6
andi2	antennaria dimorpha, low pussytoes	Native to U.S.	6
caru	calamagrostis rubescens	Native to U.S.	5
liru4	lithospermum ruderale, western gromwell	Native to U.S.	5
juba	juncus balticus, baltic rush	Native to U.S.	5
feid	festuca idahoensis, idaho fescue	Native to U.S.	5
cami7	carex microptera	Native to U.S.	5
haac	haplopappus acaulis	Native to U.S.	5
pefl15	pentaphylloides floribunda, shrubby cinquefoil	Native to U.S.	5
pasm	pascopyrum smithii, western wheatgrass	Native to U.S.	5
vica4	viola canadensis, canadian white violet	Native to U.S.	5
eqla	equisetum laevigatum, smooth horsetail	Native to U.S.	5
cisc2	cirsium scariosum, meadow thistle	Native to U.S.	5
civu	cirsium vulgare, bull thistle	Introduced to U.S.	2
coli2	collomia linearis, narrowleaf mountaintrumpet	Native to U.S.	5
soul5	sonchus uliginosus	Introduced to U.S.	
arhi	arabis hirsuta, hairy rockcress	Native and Introduced to U.S.	5
riin2	ribes inerme, whitestem gooseberry	Native to U.S.	5
sela	sedum lanceolatum, spearleaf stonecrop	Native to U.S.	5
eltra3	elymus trachycaulus (link) gould ex shinners var. andinus (scribn. & j.g. sm.) dorn	Native to U.S	5

frat	fritillaria atropurpurea, spotted missionbells	Native to U.S.	4
ruaq	rumex aquaticus, western dock	Native to U.S.	2
salix	salix sp.		4
liin2	lithospermum incisum, narrowleaf gromwell	Native to U.S.	4
dece	deschampsia cespitosa, tufted hairgrass	Native to U.S.	4
anse4	androsace septentrionalis, pygmyflower rockjasmine	Native to U.S.	4
anro2	antennaria rosea, rosy pussytoes	Native to U.S.	4
krla2	krascheninnikovia lanata, winterfat	Native to U.S.	4
lile3	linum lewisii, prairie flax	Native to U.S.	4
jubam	juncus balticus var. montanus	Native to U.S.	4
somim	solidago missouriensis var. missouriensis	Native to U.S.	4
cisu	cirsium subniveum, jackson hole thistle	Native to U.S.	2
anpu	antennaria pulcherrima, showy pussytoes	Native to U.S.	4
eqar	equisetum arvense, field horsetail	Native to U.S.	4
hepa11	heuchera parvifolia, littleleaf alumroot	Native to U.S.	4
casti3	calamagrostis stricta ssp. inexpansa	Native to U.S.	4
popa2	poa palustris, fowl bluegrass	Native to U.S.	4
coum	comandra umbellata, bastard toadflax	Native to U.S.	3
crru3	crepis runcinata, fiddleleaf hawksbeard	Native to U.S.	3
scli	schoenocrambe linifolia, flaxleaf plainsmustard	Native to U.S.	3
epan2	epilobium angustifolium, fireweed	Native to U.S.	3
orlu2	orthocarpus luteus, yellow owlclover	Native to U.S.	3
plma2	plantago major, common plantain	Native to U.S.	3
chpr5	chenopodium pratericola, desert goosefoot	Native to U.S.	3
merte	mertensia sp.		3
sybo2	aster borealis	Native to U.S.	3
cast36	calamagrostis stricta	Native to U.S.	3
trpr2	trifolium pratense, red clover	Introduced to U.S.	3
agst2	agrostis stolonifera, creeping bentgrass	Native to U.S.	3
trre3	trifolium repens, white clover	Introduced to U.S.	3
erco5	erigeron corymbosus	Native to U.S.	3
vaede	valeriana edulis nutt. ex torr. & gray var. edulis	Native to U.S.	3
hafl2	hackelia floribunda, manyflower stickseed	Native to U.S.	3
phfr	phacelia franklinii, franklin`s phacelia	Native to U.S.	3
erca8	eriogonum caespitosum, matted buckwheat	Native to U.S.	3
caca4	calamagrostis canadensis	Native to U.S.	3
saps	salix pseudomonticola	Native to U.S.	3
putr2	purshia tridentata, antelope bitterbrush	Native to U.S.	3
mear4	mentha arvensis	Native to U.S.	
prvu	prunella vulgaris, common selfheal	Native to U.S.	3
elel5	elymus elymoides, bottlebrush squirreltail	Native to U.S.	3
prvi	prunus virginiana, common chokecherry	Native to U.S.	3
deoc	delphinium ×occidentale	Native to U.S.	3

ardr4	artemisia dracunculus, tarragon	Native to U.S.	3
sehy2	senecio hydrophilus nutt.	Native to U.S.	3
casi2	carex simulata	Native to U.S.	3
oppo	opuntia polyacantha, plains pricklypear	Native to U.S.	3
brini	bromus inermis leyss. ssp. inermis	Introduced to U.S.	3
posee	poa secunda j. presl var. elongata (vasey) dorn	Native to U.S.	3
eleoc	eleocharis sp.		2
dain	danthonia intermedia	Native to U.S.	2
drne	draba nemorosa, woodland whitlowgrass	Native to U.S.	2
crat	crepis atribarba	Native to U.S.	2
epsa	epilobium saximontanum	Native to U.S.	2
cora5	cordylanthus ramosus, bushy bird`s beak	Native to U.S.	2
crte3	crepis tectorum, narrowleaf hawksbeard	Introduced to U.S.	2
eltr7	elymus trachycaulus, slender wheatgrass	Native to U.S.	2
chdo	chaenactis douglasii, douglas` dustymaiden	Native to U.S.	2
frve	fragaria vesca, woodland strawberry	Native to U.S.	2
erco24	eremogone congesta	Native to U.S.	2
dopu	dodecatheon pulchellum	Native to U.S.	2
scta2	schoenoplectus tabernaemontani	Native to U.S.	2
plel	plantago elongata, longleaf plantain	Native to U.S.	2
poan	poa annua, annual bluegrass	Introduced to U.S.	2
pobu	poa bulbosa	Introduced to U.S.	2
pogr9	potentilla gracilis, northwest cinquefoil	Native to U.S.	2
pogrf2	potentilla gracilis dougl. ex hook. var. fastigiata (nutt.) s. wats.	Native to U.S.	2
hahy3	habenaria hyperborea	Native to U.S.	2
ardr	arabis drummondii, drummond`s rockcress	Native to U.S.	2
arco9	arnica cordifolia, heartleaf arnica	Native to U.S.	2
racy	ranunculus cymbalaria, alkali buttercup	Native to U.S.	2
arco24	arabis confinis	Native to U.S.	2
sabo2	salix boothii	Native to U.S.	2
phal2	phleum alpinum, alpine timothy	Native to U.S.	2
saex	salix exigua	Native to U.S.	2
prin	primula incana	Native to U.S.	2
soar2	sonchus arvensis, field sowthistle	Introduced to U.S.	1
solid	solidago sp.		2
stcr	stellaria crassifolia, fleshy starwort	Native to U.S.	2
stri2	stipa richardsonii	Native to U.S.	2
syal	symphoricarpos albus, common snowberry	Native to U.S.	2
syspi	aster occidentalis	Native to U.S.	2
syspi	aster occidentalis	Native to U.S.	2
tala2	taraxacum laevigatum, rock dandelion	Introduced to U.S.	2
trma4	triglochin maritimum, seaside arrowgrass	Native to U.S.	2
urdi	urtica dioica, stinging nettle	Native and Introduced to U.S.	2

vaoc2	valeriana occidentalis, western valerian	Native to U.S.	2
vebi2	veronica biloba l.	Introduced to U.S.	2
saca4	salix candida, sageleaf willow	Native to U.S.	2
muri	muhlenbergia richardsonis, mat muhly	Native to U.S.	2
leca10	lesquerella carinata, idaho bladderpod	Native to U.S.	2
bran	bromus anomalus rupr. ex fourn.	Native to U.S.	2
cach10	cardaria chalapensis	Introduced to U.S.	2
hysc5	hypericum scouleri, scouler`s st. johnswort	Native to U.S.	2
brca5	bromus carinatus, california brome	Native to U.S.	2
havi3	halimolobos virgata	Native to U.S.	2
ascab	astragalus canadensis var. brevidens	Native to U.S.	2
hevid	heterotheca villosa (pursh) shinners var. depressa	Native to U.S.	2
zive	zigadenus venenosus, meadow deathcamas	Native to U.S.	2
osde	osmorhiza depauperata, bluntseed sweetroot	Native to U.S.	2
caho5	carex hoodii	Native to U.S.	1
caaq	carex aquatilis, water sedge	Native to U.S.	1
anma	anaphalis margaritacea, western pearlyeverlasting	Native to U.S.	1
caau3	carex aurea	Native to U.S.	1
alpr3	alopecurus pratensis, meadow foxtail	Introduced to U.S.	1
cabr6	cardamine breweri, brewer`s bittercress	Native to U.S.	1
anpi2	angelica pinnata	Native to U.S.	1
alge	allium geyeri, geyer`s onion	Native to U.S.	1
alal3	alyssum alyssoides, pale madwort	Introduced to U.S.	1
capr7	carex praticola	Native to U.S.	1
chte2	chorispora tenella, crossflower	Introduced to U.S.	1
chal7	chenopodium album, lambsquarters	Native and Introduced to U.S.	1
asar4	astragalus argophyllus	Native to U.S.	1
cedi3	centaurea diffusa, white knapweed	Introduced to U.S.	1
aste9	astragalus terminalis	Native to U.S.	1
aster	aster sp.		1
anten	antennaria sp.		1
arca13	artemisia cana, silver sagebrush	Native to U.S.	1
cefov2	cerastium fontanum baumg. ssp. vulgare	Introduced to U.S.	1
arabi2	arabis sp.		1
chan9	chamerion angustifolium	Native to U.S.	1
beoc2	betula occidentalis, water birch	Native to U.S.	1
artrt2	artemisia tripartita rydb. ssp. tripartita	Native to U.S.	1
chbez	chenopodium berlandieri moq. var. zschackii (j. murr) j. murr ex aschers.	Native to U.S.	1
cifo	cirsium foliosum, elk thistle	Native to U.S.	1
pera2	penstemon radicosus, matroot penstemon	Native to U.S.	1
pssps	pseudoroegneria spicata (pursh) a. löve ssp. spicata	Native to U.S.	1

psme	pseudotsuga menziesii, douglas fir	Native to U.S.	1
potr2	poa trivialis	Introduced to U.S.	1
pope8	potentilla pensylvanica, pennsylvania cinquefoil	Native to U.S.	1
pope23	potentilla pectinisecta	Native to U.S.	1
ponei2	poa nemoralis l. ssp. interior (rydb.) w.a. weber	Native to U.S.	1
polyg4	polygonum sp.		1
pofe	poa fendleriana	Native to U.S.	1
pobi10	potentilla bipinnatifida	Native to U.S.	1
orco5	orobanche corymbosa, flattop broomrape	Native to U.S.	1
phmu3	phlox multiflora, flowery phlox	Native to U.S.	1
riox	ribes oxyacanthoides, canadian gooseberry	Native to U.S.	1
peprp	penstemon procerus dougl. ex graham var. procerus	Native to U.S.	1
pehu	penstemon humilis, low penstemon	Native to U.S.	1
pegr2	pedicularis groenlandica, elephanthead lousewort	Native to U.S.	1
pecy2	penstemon cyananthus hook.	Native to U.S.	1
pecr	pedicularis crenulata, meadow lousewort	Native to U.S.	1
past10	packera streptanthifolia	Native to U.S.	1
papap2	parnassia palustris var. parviflora	Native to U.S.	1
paca15	packera cana	Native to U.S.	1
hesp6	heracleum sphondylium	Introduced to U.S.	1
pifl2	pinus flexilis, limber pine	Native to U.S.	1
vire2	viola renifolia, white violet	Native to U.S.	1
viam	vicia americana, american vetch	Native to U.S.	1
tyla	typha latifolia, broadleaf cattail	Native to U.S.	1
trpu18	trichophorum pumilum	Native to U.S.	1
trma20	triglochin maritima	Native to U.S.	1
trae	triticum aestivum, common wheat	Introduced to U.S.	1
thve	thalictrum venulosum, veiny meadowrue	Native to U.S.	1
stlo2	stellaria longipes	Native to U.S.	1
spro	spiranthes romanzoffiana, hooded ladiestresses	Native to U.S.	1
pylal	pyrrocoma lanceolata var. lanceolata	Native to U.S.	1
spgr	spartina gracilis	Native to U.S.	1
rice	ribes cereum, wax currant	Native to U.S.	1
sogi	solidago gigantea	Native to U.S.	1
sior3	silene oregana, oregon silene	Native to U.S.	1
sime	silene menziesii	Native to U.S.	1
shca	shepherdia canadensis, russet buffaloberry	Native to U.S.	1
sepa5	senecio pauperculus, balsam groundsel	Native to U.S.	1
seca2	senecio canus, woolly groundsel	Native to U.S.	1
rusam	rumex salicifolius weinm. var. mexicanus (meisn.) c.l. hitchc	Native to U.S.	1

rumex	rumex sp.		1
opfr	opuntia fragilis, brittle pricklypear	Native to U.S.	1
spob	sphenopholis obtusata	Native to U.S.	1
elglg	elymus glaucus buckl. ssp. glaucus	Native to U.S.	1
frvi	fragaria virginiana, virginia strawberry	Native to U.S.	1
feidi2	festuca idahoensis elmer ssp. idahoensis	Native to U.S.	1
ersp4	erigeron speciosus	Native to U.S.	1
erovp2	eriogonum ovalifolium nutt. var. purpureum (nutt.) dur.	Native to U.S.	1
erlo	erigeron lonchophyllus	Native to U.S.	1
erige2	erigeron sp.		1
ergl2	erigeron glabellus	Native to U.S.	1
orfa	orobanche fasciculata, clustered broomrape	Native to U.S.	1
elju	elymus junceus	Introduced to U.S.	1
getr	geum triflorum, prairiesmoke	Native to U.S.	1
elco	elaeagnus commutata	Native to U.S.	1
dral4	draba albertina	Native to U.S.	1
debi	delphinium bicolor, little larkspur	Native to U.S.	1
cyof	cynoglossum officinale	Introduced to U.S.	
crmom	crepis modocensis ssp. modocensis	Native to U.S.	1
crdo2	crataegus douglasii	Native to U.S.	1
crco6	crataegus columbiana	Native to U.S.	1
cloc2	clematis occidentalis, western blue virginsbower	Native to U.S.	1
clhih	clematis hirsutissima pursh var. hirsutissima	Native to U.S.	1
ellal	elymus lanceolatus (scribn. & j.g. sm.) gould ssp. lanceolatus	Native to U.S.	1
juarl	juncus arcticus willd. ssp. littoralis	Native to U.S.	1
muhle	muhlenbergia sp.		1
monu	monolepis nuttalliana, nuttall`s povertyweed	Native to U.S.	1
mola6	moehringia lateriflora	Native to U.S.	1
migu	mimulus guttatus, seep monkeyflower	Native to U.S.	1
mare11	mahonia repens, oregongrape	Native to U.S.	1
lida	linaria dalmatica, dalmatian toadflax	Introduced to U.S.	
lepe2	lepidium perfoliatum, clasping pepperweed	Introduced to U.S.	
leci4	leymus cinereus	Native to U.S.	1
gabi	galium bifolium, twinleaf bedstraw	Native to U.S.	1
julol	juncus longistylis torr. var. longistylis	Native to U.S.	1
ipsp	ipomopsis spicata, spiked gilia	Native to U.S.	1
ipco5	ipomopsis congesta, ballhead gilia	Native to U.S.	1
ipag	ipomopsis aggregata, skyrocket gilia	Native to U.S.	1
hiod	hierochloe odorata	Native to U.S.	1
heunu	helianthella uniflora var. uniflora	Native to U.S.	1
heun	helianthella uniflora, oneflower helianthella	Native to U.S.	1
hebo	hedysarum boreale, northern sweetvetch	Native to U.S.	1
lasq	lappula squarrosa, european stickseed	Introduced to U.S.	1