MAPPING OVERSTORY STRUCTURE, UNDERGROWTH STRUCTURE, AND SNOW DISTRIBUTION IN SAGEBRUSH HABITATS IN WYOMING.

PHASE I OF II: SELECTION OF FIELD SAMPLING LOCATIONS

A Report to the
Bureau of Land Management, Wyoming State Office

by

George P. Jones, Robert Thurston, Gary P. Beauvais, and Alan Redder
Wyoming Natural Diversity Database, University of Wyoming
and
Ken Driese and William A. Reiners,
Wyoming Geographic Information Sciences Center, University of Wyoming

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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INTRODUCTION

Sagebrush-dominated basins of western North America support several vertebrates of conservation concern (e.g., *Centrocercus urophasianus, Cynomys leucurus, Buteo regalis*), and are subject to increasing resource development and recreational use. In order to integrate wildlife conservation with other land uses, land and wildlife managers need reliable maps of habitat quality for species of concern.

It is becoming increasingly clear that habitat quality for several species depends largely on the overstory and undergrowth structure of sagebrush-dominated vegetation. For example, Connelly *et al.* (2000) reviewed the current state of knowledge of sage grouse (*C. urophasianus*) habitat use in western North America. Based on this summary, they defined productive seasonal habitats in terms of specific heights and canopy densities of sagebrush and the grass/forb layer beneath sagebrush. High-quality habitat for several other species, ranging from passerines to ungulates, can also be expressed in terms of overstory and undergrowth heights and densities.

Although it is relatively straightforward to define habitat in structural terms, it is difficult to extrapolate these definitions across large areas in map form. Also, there is an added degree of complexity when mapping winter habitat: during this season, the height and density of exposed sagebrush is determined by snow depth and distribution as well as vegetation form.

Increased availability of satellite imagery, image processing software, and geographic information systems (GIS) has allowed for the mapping of habitat features directly from remote sensing data. However, to date, remote sensing has proven inadequate for mapping fine-scale structural attributes of sagebrush environments. For example, Black and Goetz (2000) were unable to resolve sagebrush canopy density to the categories specified by Connelly *et al.* (2000). Preliminary findings from a remote sensing project in northeastern Wyoming indicated similar results (B. Jellison, Wyoming Game and Fish Department, personal communication). Furthermore, it is very unlikely that remote sensing will generate any information on sagebrush height, undergrowth height, or undergrowth density. These features may be the most important determinants of habitat quality for sage grouse and other species (Holloran 1999; Schroeder *et al.* 1999; Connelly *et al*. 2000; S. Anderson, University of Wyoming, personal communication).

An alternative to direct mapping of habitat features from satellite images is the modeling of those features based on field data. In this approach, features such as height and canopy density of overstory and undergrowth vegetation are related to physical variables such as elevation, slope angle, slope aspect, and geological substrate. If these relationships can be quantified statistically, with proper validation and strong understanding of the effects of grazing and precipitation history, the resulting models could be extrapolated spatially within a GIS to yield maps of probable vegetation height and density. Combining these probabilistic maps with remotely-sensed maps of sagebrush distribution would produce an integrated map of sagebrush coverage and structure for a given area. Basic GIS manipulations could then be applied to produce a map of habitat quality for a given species of concern; for example, the structural definitions of Connelly *et al.* (2000) could be used as selection criteria to map breeding and brood-rearing habitat for sage grouse. Accurate distribution maps of individual plant (e.g., Fertig and Reiners 2000) and animal (e.g., Beauvais and Smith 2003) species have been produced with this technique, and vegetation types have been successfully mapped with this technique in other states (e.g., Thomas *et al.* 2000).

Similarly, sagebrush habitat structure in winter may be best mapped through modeling. Snow depth and distribution have been successfully modeled in shrub-dominated environments by Liston and Sturm (1998). Their model can be adapted to a given area by parameterization with empirical data on snowfall, wind speed and direction, vegetation, and topography in that area. Once parameterized, model predictions of snow depth can be validated with field data, and model predictions of snow distribution can be validated with satellite images taken during periods of snow cover. Predictions of snow depth and cover can then be combined with predictions of sagebrush height, producing a probabilistic map not only of exposed sagebrush, but also of the height of that exposed sagebrush. An application of this type has already been successfully performed in more complicated terrain and vegetation of the treeline zone in the Medicine Bow Mountains (Hiemstra 1999, Hiemstra *et al.* 2002).

We have proposed to develop and validate a model that predicts four response variables (shrub canopy density and height, and undergrowth density and height) from 7 predictor variables (land cover type, slope, aspect, elevation, geologic substrate, topographic position, and modeled late-winter snow depth). In Phase I of this project, reported herein, we have selected sampling locations. Phase II will consist of collecting data on the response and predictor variables at those locations, and developing and validating the model.

GOAL OF PHASE I

This is the first phase of a two-part project that explores methodological questions about empirically modeling vegetation structure in sagebrush-dominated systems and subsequently mapping the results of those models. For example, what physical variables best predict undergrowth height and density? How much field data are needed to properly parameterize the model? These questions are being investigated in a study area in south-central Wyoming. Testing methodology and feasibility there, in an area of diverse vegetation and physical driving factors, is a prudent first step towards producing accurate maps of sagebrush structure in various parts of the state.

This project, Phase I, is a mapping exercise to develop an approach that can be used where needed around Wyoming. In Phase I, we select a set of sampling locations for Phase II, which will be the actual field data collection and modeling.

The goal of Phase I is to identify an efficient suite of field locations that will sample the range of values of each of 7 stratifying variables, and also adequately sample the unique combinations of values from all 7 variables. Those variables are slope angle, slope azimuth (aspect), elevation, topographic position, geologic substrate, land cover-type, and modeled late-winter snow depth.

We anticipate that Phase II will ultimately measure at least 6 variables in the field to use as predictors of canopy height, canopy density, undergrowth height, and undergrowth density in sagebrush-dominated vegetation. Those 6 variables -- slope angle, slope azimuth (aspect), elevation, topographic position, geologic substrate, and land cover type -- are used as stratifying variables in Phase I. Phase II will also use modeled late-winter snow depth (the 7^{th} stratifying variable from Phase I) as a 7^{th} variable to predict sagebrush structural features; however, because of the logistical problems associated with collecting adequate snow data in the field in late winter, Phase II will proceed with modeled, rather than field-collected, values of snow depth.

There are at least 2 other variables that likely have profound effects on the structure of sagebrush vegetation: spring precipitation and recent grazing intensity. These factors are more variable across space and through time than are any of the 7 variables outlined above, and comprehensive digital layers of these factors are unavailable. Consequently, we elected not to use them in Phase I as variables to help locate sampling sites. We are confident that the site selection method presented in this report results in enough sampling sites, spread widely enough across other major environmental gradients, that meaningful gradients of spring precipitation and grazing intensity will be adequately sampled in future field seasons. We will investigate ways in which recent precipitation and grazing intensity might be included during Phase II in the construction of the vegetation model.

SUMMARY

Details of location selection are described below. In summary, we used available digital layers of biological and physical features to limit the study area to just the lands most likely to be dominated by sagebrush, then mapped each of 7 stratifying variables across those lands. The resulting maps showed the range in values of each stratifying variable, and each range was divided into discrete categories. This allowed the calculation, for every 30 m x 30 m cell, of the combination of values for the 7 variables in the cell. The frequency distribution of variable combinations was used as a population from which we selected a representative sample that efficiently encompassed the range of values of each variable as well as the range of combinations of the 7 variables. The variable combinations to be sampled, and the sampling locations representing them, were then randomly selected.

The digital layers used in this phase included some errors, and we expect that these errors will cause occasional mistakes in our mapping of vegetation types and selection of sampling locations. Therefore, we selected more sampling locations than we think will be needed for constructing a good statistical model. Selection of extra sampling locations will allow field crews in Phase II to bypass mis-mapped locations and replace them with other locations selected to sample the same variable values. Also, we recognize that statistical models are untested hypotheses until validated with independent data. Therefore, we selected enough field sampling locations so that we can use some for model construction and retain some as an independent set of validation data.

METHODS

SELECTION OF STUDY AREAS

We selected two areas in south-central Wyoming in which to perform this project (Figure 1). We selected the size of each area, 60 km x 60 km (37.3 miles x 37.3 miles), to balance the need for a substantial amount of variability in topography, a range in elevation from basins into mountain foothills, and a variety of sagebrush vegetation types on the one hand against the need for a manageable area over which to apply the snow distribution model on the other hand. The snow distribution model uses meteorology, topography, and vegetation variables to predict snow accumulation in each cell of a grid, and we restricted the square grid in each study area to 2,000 cells (each 30 m x 30 m) on a side. The creators of the model indicated that this was an appropriate and manageable size (G. Liston and C. Hiemstra, personal communication).

The location of each area was influenced by our desire to include a high proportion of public land (to give the easiest access to sampling locations in the field), a variety of sagebrush vegetation types and physical environments, and weather stations that give adequate meteorological data for the snow distribution model. Several weather stations or Snotel sites lie within or near each area, but only one station (Rawlins Airport) has a complete record of all of the meteorological variables needed by the snow model. It is reasonable to assume that this paucity of meteorological data is a problem virtually everywhere in Wyoming, and so we wanted to know how the snow distribution model and other aspects of the project will perform under such constraints.

The snow distribution model was run for each of the two areas separately, but the two areas were combined for selection of locations for field sampling. Indeed, although throughout this report we refer to 2 study areas, the analysis and final selection of study locations proceeded as if the 2 areas were simply different subregions within a single study area. If a single contiguous area, of the appropriate size for snow modeling and encompassing all of the necessary vegetative and physical diversity, could have been selected, we would have done so. However, after considering all of the options and constraints, we felt that a single set of sampling locations spread across the 2 separate subregions would ultimately provide better data, and better final models in Phase II.

MASKING OUT PARTS OF THE STUDY AREAS

Parts of each study area were removed from consideration in this project either for biological or logistical reasons. Biological reasons pertained to our goal of considering only the sagebrush-dominated portions of each area as potential sampling locations; logistical reasons primarily pertained to location access by field crews. Four separate "masks" were developed, each to mask out part of the study area for a specific reason, and the four masks were combined and then applied to the study area.

-- Mask #1: non-sagebrush vegetation

In order to reduce the study areas to just that land surface dominated by sagebrush we used a combination of 2 representations of vegetation, the Wyoming Gap Analysis Project's (GAP) land cover layer (Merrill *et al.* 1996), and the National Land Cover Dataset (NLCD) (U.S. Geological Survey 2003). The GAP land cover layer is a polygon coverage with a resolution (minimum mapping unit) of 100 ha (248 acres) for uplands and 40 ha (100 acres) for riparian areas and wetlands. To each polygon, GAP assigned one of 41 land cover types, including 4 sagebrush types (Table 1), as the primary type. For most polygons, GAP also identified the secondary cover type, and a third type was identified in some polygons.

The NLCD, in contrast, is a raster dataset with a resolution of 30 meters. Each 30 m x 30 m cell is mapped as one of 21 cover classes, including only one shrubland class (Table 2). We used the 1992 NLCD.

For each of the two study areas the two vegetation layers were combined into a single vegetation grid that we termed the Wyoming Land Cover Dataset (WYLCD), and that takes advantage of the strength of each original layer: GAP's recognition of the dominant shrubs in the vegetation, and NLCD's finer mapping resolution. In Arc/Info, three 30-meter grids were produced that showed the GAP primary cover type, the GAP secondary type, and the additional GAP type (if any) for the polygon in which each cell was located. For each cell, the cover class value in the NLCD grid was compared successively to the cover type value in each of the GAP grids and, as soon as a corresponding GAP cover type value was encountered, a new combination value was written for that cell into the WYLCD grid. For example, a cell labeled as NLCD shrubland class (code 51) was compared in this manner:

NLCD shrubland, code 51 → GAP primary type: Wyoming big sagebrush, code 32007 → WYLCD type: Shrubland (Wyoming big sagebrush), code 513207

NLCD shrubland, code 51 → GAP primary type not a shrub type
↓
GAP secondary type: Wyoming big sagebrush, code 32007 → WYLCD type: Shrubland (Wyoming big sagebrush), code 513207

Table 3 shows the 56 vegetation cover types in Wyoming that resulted from this method. Note that a number of WYLCD types are named using "Uncategorized"; these types arose from cells that were classified by GAP as land cover types that do not correspond to the NLCD classes for those cells. For example, if NLCD classified a cell as Shrubland, but GAP classified the polygon in which that cell was located as primarily Mixed grass prairie and secondarily as Basin bare rock and soil with no third type, then the resulting WYLCD type was "Shrubland (Uncategorized)".

In 11 cases (denoted by "NLCD class not subdivided" in Table 3), the GAP land cover type was equivalent to a NLCD class or the NLCD used more-detailed classes than the GAP cover type, and the NLCD class and the GAP cover type were combined into a single WYLCD cover type with the same name as the NLCD class. Two NLCD classes, Mixed Forest and Orchards/Vineyards/Other, had no corresponding cover type in the GAP classification.

Fifty-six WYLCD classes were produced when the NLCD and the GAP coverages were combined for all of Wyoming (Table 3). Forty-six of those occur in the two study areas (Table 4). Because we are interested only in vegetation with a substantial amount of sagebrush, only six of those WYLCD cover types were used for selecting sampling locations; the other types were masked out from the analysis. Of the 6 types selected, all belong to the NLCD shrubland class, and 5 belong to a GAP cover type where a substantial amount of sagebrush is stipulated or strongly suggested (Merrill *et al.* 1996b): Bitterbrush shrub-steppe, Mountain big sagebrush, Wyoming big sagebrush, Black sagebrush steppe, and Basin big sagebrush. The sixth belongs to a GAP cover type (Vegetated dunes) that often contains a substantial amount of sagebrush in southern Wyoming (Wyoming Natural Diversity Database, unpublished data).

-- Mask #2: riparian areas and wetlands

In riparian areas and wetlands, the surface or sub-surface water available to plants largely overcomes the influence of slope, aspect, and geologic substrate on vegetation structure. Consequently, we eliminated riparian areas from consideration in this project.

Masking out non-sagebrush vegetation types in the WYLCD layer (Mask #1) eliminated most large wetlands and riparian areas. To assure that small riparian and wetland zones were also removed, we applied a mask created from the riparian and aquatic model developed by Fertig and Thurston (2003). Whereas they buffered all hydrographic features on the 1:100,000-scale enhanced hydrography digital line graphs for Wyoming, in this project we buffered only the perennial hydrographic features. Buffer widths (Table 5) were those used by the Wyoming Gap Analysis Project (Merrill *et al.* 1996a), and were intended to represent the general zone of riparian influence around hydrographic features.

-- Mask #3: private and state lands

Collecting the field data necessary for building and validating the model will require that crews visit a large number of sampling locations throughout both study areas. To simplify access to those locations, we restricted potential sampling locations to federally managed public lands. Using maps of land ownership from the Wyoming Gap Analysis Project (Merrill *et al.* 1996a; available from the Wyoming Natural Resources Data Clearinghouse <http:\\www.sdvc. uwyo.edu/clearinghouse>; described in Table 6), we eliminated all other land management types. Most of the land surface eliminated was private land and State of Wyoming land.

-- Mask #4: minor geologic categories

To characterize the geological substrates of the study areas, we adopted a classification of bedrock stratigraphy units developed by Fertig and Thurston (2003). In that classification, the 213 stratigraphic units from the 1:500,000-scale geologic map of Wyoming (Love and Christiansen 1985, Green and Drouillard 1994) were combined by age and major rock type into 26 categories that approximate those used in regional geologic maps (Table 7). Fourteen of those categories occur in at least one of the two study areas (Table 8).

Study area 1 contained five categories that together accounted for < 5% of the land area, and study area 2 contained six types that together accounted for < 5% of that area. To help reduce the number of unique combinations of stratifying variables that must be considered in the selection of sampling locations, we excluded those rare substrate categories. Because of their rarity in the study areas, we are confident that their exclusion will have no substantial affect on the accuracy or utility of the ultimate models of vegetation structure.

The 4 masks applied together reduced the area under consideration in study area 1 to 141,810 ha (39.39% of the original area) and in study area 2 to 54,413 ha (15.13% of the original area) (Table 9).

TREATMENT OF STRATIFYING VARIABLES

The GIS-based models that we propose to develop in Phase II of this project will use 7 environmental variables -- land cover type, elevation, geologic substrate, aspect, slope, topographic position, and modeled late-winter snow depth -- to predict canopy height and density of both the overstory and undergrowth layers in stands of sagebrush. Those predictive models will be based on data collected in the field for 6 of those variables (land cover type, elevation, geologic substrate, aspect slope, and topographic position), and modeled values of the 7th variable (late-winter snow depth) so field sampling must occur across a range of values of each variable and in many of the combinations of variables. The pre-requisite step to be accomplished in the present project (Phase I), therefore, is to construct digital layers of those variables and combine those layers in a way that allows selection of a set of sampling locations that efficiently encompasses within- and between-variable variation.

Land Cover Type

The six WYLCD categories that contain substantial amounts of sagebrush (Table 10) were included for selection of sampling locations.

Elevation

Elevation data were taken from a 30-meter digital elevation model derived from the National Elevation Dataset (Gesch *et al.* 2002). The elevations of the six WYLCD cover types of interest span 722 m in study area 1 (from 1,774 m to 2,496 m) and 865 m in study area 2 (from 1,910 m to 2,775 m). Because an important consideration of this project is to develop a modeling approach that can be applied state-wide, we sought to divide the elevation ranges of the two study areas into intervals that make sense for sagebrush vegetation elsewhere in Wyoming. Across the state, the six GAP cover types that may include substantial amounts of sagebrush span an elevation range of 2,536 m, from a low of 1,025 m for Wyoming big sagebrush up to 3,561 m for Mountain big sagebrush (Table 11). We divided this elevation range into 300-meter intervals, nine of which are needed to encompass the six cover types throughout the state and five of which occur in the two study areas (Table 12).

Geologic Substrate

Geologic substrate categories were taken from Fertig's and Thurston's (2003) re-classification of the Wyoming geologic map units, described above.

Aspect

Slope aspect (azimuth), in degrees, was ascertained from the 30-meter digital elevation model. This continuous variable was converted to a categorical variable for selecting sampling locations, by dividing the 360^o-aspect range into five categories (Figure 4): 0^o - 90^o, 90^o - 180^o, 180^o - 270^o, 270^o - 360^o, and flat (no aspect).

Slope

Slope, in degrees from horizontal, was calculated from the 30-meter digital elevation model. The range in slopes was divided into five intervals for use in selecting sampling locations (Table 13).

Topographic Position

For expressing topographic position, we are using the scheme of Fels and Matson (1996) for classifying the landscape into four landtypes: ridge, side slope, flat, and swale. Each 30 m x 30 m cell was placed into one of those four landtypes depending on its landscape position and slope. The landscape position value (LPOS) of a cell is the distance-weighted average of the difference in elevation between that cell and each cell in a 9-cell by 9-cell neighborhood and is calculated with the formula

$$LPOS = \sum_{i=1}^{n} [(E_n - E_0)/d]/n$$

where E_0 = elevation of the cell being evaluated, E_n = elevation of another cell in the neighborhood, d = horizontal distance between the two cells, and n = number of cells in the neighborhood less one (n = 80). The resulting values ranged from -1.011 to 0.685. Ridges had LPOS $\leq$ -0.035, side slopes and flats had LPOS from -0.035 to 0.030, and swales had LPOS > 0.030. Side slopes and flats were separated by slope (> 1^o for side slopes, $\leq 1^o$ for flats). Each cell was then classified using the decision tree shown in Figure 5.

Snow Depth

Late-winter snow depth is of interest in this project for two reasons. First, melting snow recharges soil water and promotes plant growth, so areas with shallow snow offer relatively little water to plants, while areas of deep snow have more moisture and allow for greater plant growth. Second, late-winter snow depth and vegetation height together determine how much food and cover are available to animals in this crucial season. In south-central Wyoming, late-winter snow depth varies greatly across the landscape as a result of the area's strong and frequent winter winds. Distribution of snow across the landscape is a function of wind direction and speed, snowfall, topography, and vegetation height and density.

Snow depth and vegetation structure influence each other: tall, dense vegetation traps more snow and therefore causes deeper snow cover, and deeper snow provides more soil moisture that (up to a point) promotes taller, denser vegetation. As part of the predictive model of vegetation structure, we intend to quantify the relationship between snow depth and vegetation height and density. In this stage of the project, though, in which we are developing a method for selecting sampling locations to collect data for building and validating the model, we are interested just in choosing locations that span the range of potential snow depths encountered in the study areas. Categories of snow depth (such as shallow, intermediate, or deep) matter more for this purpose than do numerical estimates of depth.

Direct measurements of late-winter snow depth spanning the study areas are unavailable, so we are relying on a snow distribution model, SnowTran-3D (Liston and Sturm 1998), to predict end-of-season snow depth over both study areas. SnowTran-3D uses vegetation snow-holding capacity, topography, daily average air temperature, daily average relative humidity, daily precipitation, daily average wind speed, and daily resultant wind direction as input variables to model accumulation and loss of snow in each cell in the model domain. In this case, each cell measured 30 m x 30 m, and the domain of each study area measured 2000 cells east-to-west x 2000 cells north-to-south. The model was run for the period October through March. Meteorological data for the model were obtained from four weather stations for study area 1 and from four weather stations and two Snotel sites for study area 2 (Figure 6, Table 14). Data for each input variable were obtained from the following sources. Weather station data are from National Climatic Data Center (2004), and Snotel site data are from USDA Natural Resources Conservation Service (2004).

-- Vegetation snow-holding capacity.

This number, in meters, approximately equals the height of the vegetation and expresses the depth of snow that accumulates and is held against the wind. Each of the WYLCD cover types in the study areas was assigned a snow-holding capacity (Table 4), based on the authors' previous experience observing and measuring different vegetation types in Wyoming in general and the 2 study areas in particular.

-- Topography

Topography (i.e., aspect, slope, and elevation) was taken from the 30-meter digital elevation model.

-- Daily average air temperature

Temperature records were readily available for both study areas. For study area 1, this parameter was calculated for the Jeffrey City, Muddy Gap, and Rawlins Municipal Airport weather stations from the daily maximum and minimum air temperatures. For study area 2, it was provided for the Divide Peak and Sandstone Ranger Station Snotel sites and calculated from daily average maxima and minima for the Rawlins Municipal Airport, Wamsutter, Baggs, and Saratoga weather stations.

-- Daily average relative humidity

Data for this parameter were available only from the Rawlins Municipal Airport weather station. The values for October 2001 - March 2002 were used for the model runs for both study areas.

-- Daily precipitation

Precipitation data were readily available. For all of the weather stations except Muddy Gap (study area 1), the National Climatic Data Center provided daily precipitation. For the two Snotel sites at study area 2, the data available were accumulated precipitation received from October 1 through each date, and the daily amounts were calculated from those data.

To gain some appreciation for the snow distribution patterns that the model predicted, we ran the model 3 separate times using data simulating (1) a dry winter, (2) a winter of intermediate precipitation, and (3) a wet winter.

For each winter from 1982-83 through 2002-03, we averaged the precipitation values from all of the weather stations to derive a single value for the entire region, then chose the winters with low, intermediate, and high averages. Unfortunately, the winter of lowest regional average precipitation was indeed the driest winter at some individual stations but was relatively wet at others, and the same incongruity arose with the winters of intermediate and high regional average precipitation. The result was a confusing pattern of snow distribution across the study areas, with deeper snow in some parts of the study area in the regional-average dry winter than in the regional-average wet winter.

To overcome this lack of correspondence among stations, we selected the winter of 2001-02 to provide each day's proportion of the winter's precipitation and, for each station, adjusted the daily absolute amount up or down. (The winter of 2001-02 was chosen to provide the daily proportions because that was one of the few years with complete records for wind and relative humidity, which came from the Rawlins Municipal Airport.). For the simulated dry winter, every day's precipitation amount was decreased so that the daily amounts summed to the total for driest October - March period for that station. For example, consider the data for the dry model winter for Jeffrey City. The driest winter there was that of 1988-89. The precipitation amount for each day at Jeffrey City for the dry model winter was calculated as:

Day's precip. dry model winter = (Day's precip. 2001-02) x [(Total winter precip. 1988-89) / (Total winter precip. 2001-02)]

This same adjustment was made for every day at every station. Thus the data provided to the model do not represent a real winter that occurred in the study area. Rather, they represent the situation that would obtain in the study area if the winter of lowest total precipitation was the same winter at all stations.

The same procedure was used to make datasets for the simulated intermediate and wet winters.

-- Daily average wind speed

Wind speed data were available only from the Rawlins Municipal Airport weather station. The values from October 2001 - March 2002 were used by SnoTran-3D to model the wind speed and direction across the landscape in both study areas. Unfortunately, wind data are not widely available for weather stations in Wyoming.

-- Daily resultant wind direction

The Rawlins Municipal Airport weather station provided the only records of wind direction, and those data were used to model the wind fields over both study areas. As with wind speed data, wind direction data are available for few Wyoming weather stations. This is unfortunate, because Liston and Sturm (1998) noted that inaccuracies in the model are due largely to errors in the simulated wind fields, especially errors in wind direction. Consequently, the paucity of wind data for Wyoming may place an important limitation on the use of the snow transportation model.

-- Air temperature

Average daily air temperature values were available for both of the Snotel sites and for all of the weather stations except Leo 6 SW (study area 1). For the Snotel sites, the average temperature is provided. For the weather stations, average temperatures were calculated from the daily maxima and minima.

SnowTran-3D was run separately for the two study areas, and for each area, it was run for a dry winter, an intermediate winter, and a wet winter, as described above. We selected the results from the model run on the intermediate winter for each study area. Late-winter snow depth was predicted to range from 0.050 m to 1.579 m in study area 1 and from 0.050 m to 8.568 m in study area 2. The combined range (0.050m - 8.568m) was divided into six intervals for use in selecting sampling locations (Table 15).

SELECTION OF SAMPLING LOCATIONS

For the unmasked portion of each study area, a single grid was produced showing the combination of the 7 stratifying variables in each cell. Each combination was represented by a 10-digit value calculated from the values for the individual stratifying variables, as follows:

Combination Value = 10^9 + 10^7(Land cover category) + 10^5(Geology category) + 10^4(Elevation interval) + 10^3(Slope interval) + 10^2(Aspect interval) + 10(Snow depth interval) + (Landtype category)

For example, a cell with a 10-digit value of 1291041413 represents the following set of values for the 7 stratifying variables:

Stratifying Variable	Digits	Variable Value	Description
	1		Not used.
Land cover	2 and 3	29	Shrubland (Wyoming big sagebrush)
Geology	4 and 5	10	Miocene/Pliocene (MiPl)
Elevation	6	4	2101-2400 m
Slope	7	1	3^o-10^o
Aspect	8	4	180^o-270^o
Snow depth	9	1	201-400 mm
Landtype	10	3	Side slope

The two grids (one for each study area) were combined into a single grid that contained all of the variable combinations for the two study areas. This grid was converted into a polygon coverage and all polygons <8100 m^2 in area (<9 contiguous grid cells) were removed because they would be too small to contain sampling transects and plots. Application of this 8100 m^2 minimum mapping unit removed 69,479 ha from study area 1 and 29,063 ha from study area 2 (Table 9). The resulting polygon coverage contained all polygons ≥8100 m^2, and also some smaller inclusions of masked-out land surface (i.e., islands of masked out surface within larger polygons of retained surface). This coverage of 39,298 polygons representing 1,634 unique variable combinations constituted the population from which we selected the potential sampling locations.

Slightly fewer than 250 (15%) of the most common variable combinations accounted for 90% of the land in the study areas; most of the 1,634 combinations were very rare (Figure 7). We assume that during Phase II data will be collected from at least 400 locations during one field season, and will be divided into one subset used for building the model and another for validating it. Even with this ambitious field-sampling program, Phase 2 field crews will be able to collect data from locations representing only a minority of the variable combinations.

To select sampling locations in a manner that best captures the range of variable combinations, from the rarest combinations to the most common, we first divided the range of combinations into 12 strata based on the number of polygons in each combination. Then we randomly selected for sampling a percentage of the combinations within each stratum that was proportional to the percentage of all 1,634 combinations contained in that stratum (Table 16). In strata 1 through 10, the combinations to be sampled were selected randomly with the "Random Sample" function (specifying sampling without replacement) in the S-Plus statistical package (Insightful Corporation 2003). Sample size for the strata numbers 9 through 12, encompassing the largest areas (each >15% of the study area), was increased to a minimum of 16 to insure adequate sampling compared to the very small sample sizes that resulted from our algorithm. Strata 11 and 12 each contained so few combinations that every combination could be sampled with replicate polygons. Thus, the rarest variable combinations (i.e., those with the fewest polygons and covering the smallest proportions of the study area) were selected relatively frequently, and common combinations (i.e., those with the most polygons, and hence covering the largest proportions of the study area) were selected less frequently. This method of stratification was chosen because, although we lack data on the variability of sagebrush vegetation structure (the obvious criterion for determining strata [Krebs 1999]), we suspect that the many rare combinations will, as a group, display the largest variability in vegetation structure while those few combinations represented by many polygons and large areas will be relatively homogeneous, thus deserving of less sampling effort.

The polygons (that is, the potential sampling locations) from which the data for each variable combination will be collected were also randomly selected. We constructed a list of initial sampling locations, consisting of a single polygon for each variable combination selected in strata 1-10 and multiple polygons (selected without replacement) for each of the combinations in strata 11 and 12. Selection was performed in ArcInfo using an Arc Macro Language (AML) program. In an effort to cluster the sampling locations and thereby reduce travel time between them, we used a focal variety dataset in selecting the locations. In that dataset, each cell was assigned a value equal to the number of unique combinations within a square neighborhood the size of a township (6 mi by 6 mi or 9.6 km by 9.6 km). Several parts of the study areas had neighborhoods with many combinations (Figure 8), and sampling locations were selected in those high-combination neighborhoods when possible, using an algorithm that tried to randomly select a point within a neighborhood in the highest focal variety range (values of 186-206). If no point occurred within that range, the algorithm then tried to randomly select a point within a neighborhood in the next-lower range (156-185), and so on until a point was selected.

A list of alternate sampling locations also was chosen to replace the initial locations where the field crews discover that the actual values of the 6 variables to be measured in the field differ from the values obtained from the GIS datasets, that is, where the locations fail to represent the variable categories that they were selected to represent. Because each variable combination in stratum 1 is represented by only one polygon, there are no alternate polygons for those combinations, and the alternate list contains the other variable combinations in stratum 1 that can be randomly selected and used as an alternate sampling location when needed. For strata 2 through 12, the alternate set of sampling locations was randomly selected in the same manner as the initial sampling locations using the same list of variable combinations. Consequently, for strata 2 through 12, if the initial sampling location for a given variable combination is rejected, there is an alternate location available for that same combination.

RESULTS AND DISCUSSION

The combined study area over which the predictive model of vegetation structure will be developed (that is, the unmasked portion) consists of 196,223 ha (484,671 acres, or 757 square miles) of upland sagebrush vegetation on federally-managed, public lands. Of that area, 97,681 ha (242,249 acres, or 378 square miles) are included in polygons covering at least 8100 m^2 and so are eligible for field sampling (Table 9, Figure 3).

Four-hundred thirty variable combinations were selected for sampling out of the 1,634 possible combinations. Our goal was to have the variable categories present in the same percentages among those 430 selected combinations as they were among all 1,634 combinations identified in the study area, and the target number of combinations for each variable category was calculated from that percentage (Table 17). With a few exceptions, we met that goal. For only 7 of the 37 variable categories did the selected number of combinations fall below 75% of the target number. Most of those large shortfalls were for categories of land cover type. Discrepancies were more numerous and larger when the selected combinations were compared to the targets on the basis of the areas they occupy (calculated from the number of 900 m^2 cells occupied by each category).

Four-hundred fifty initial locations for sampling land cover type, aspect, slope, elevation, geologic substrate, and landtype were chosen to represent the 430 selected variable combinations (Figure 9), one location for each combination selected from strata 1 through 10, two locations for each combination selected from stratum 11, and four locations for each combination selected from stratum 12. The variable combinations and variable classes represented by each of these initial locations, and the UTM coordinates, are shown in Appendix A, Table A1. When the field crews discover that an initial location fails to represent the variable categories that it was chosen to represent, it will be replaced with another location drawn from alternate list 1 for combinations in stratum 1 (each represented by only 1 polygon) (Appendix A, Table A2) or alternate list 2 for combinations in strata 2 - 12 (with at least 2 polygons each) (Appendix A, Table A3).

The data from the sampling locations will be split into two datasets, one for building the model and the other for validating it. The exact manner in which we'll split the data will depend in part on the sample size and the variability in the data, but we anticipate using data from 80% of the sampling locations (360 of 450 locations) for building the model and the data from the other 20% of the locations (90 of 450 locations) for validation.

Lacking information about the variation present in the habitat structure variables to be measured, we cannot conduct a standard power analysis to determine adequate sample size. Because of the multivariate nature of this study, with 4 response variables to be recorded, sample size should be as large as possible. A minimum sample size of 400 to 500 is recommended for many multivariate techniques with 4 response variables (Tabachnick and Fidell 1996), although a smaller sample could be used, but at the increased risk of lack of power of the resulting model and inadequate representation of the total sample. A sample of 400 would constitute less than 25% of the possible variable combinations and only 1% of the possible sampling areas and should be considered the minimum acceptable sample size for this project.

The final sample size, though, will be determined by the number and sizes of the field crews employed, and hence, by the amount of funding that can be devoted to sampling. We estimate that sampling at 450 locations will require the effort of five 2-person crews working for 45 days. This level of effort will entail a substantial cost, but we believe that it will be necessary to yield the data needed to for a model that can adequately predict vegetation structure and for useful information about the effect of each predictor variable on vegetation structure. That information on vegetation/ environment relationships will be presented in the form of descriptive statistics for each response variable summarized by each predictor variable category, and from ANOVA tests examining significant differences between response variables by predictor variable category.

Because of the lack of data on the variation in vegetation structure across variable combinations, and because knowledge of that variation will increase as field sampling progresses, we recommend that Phase II workers consider the set of sampling locations identified here as a best initial estimate and implement an adaptive sampling regime (Thompson and Seber 1996). Such a regime is based on performing power analyses periodically during the field season that will indicate when sampling for a particular variable category can be stopped and the remaining sampling effort can be concentrated on those variable combinations that have so far received insufficient sampling effort. A consistent “stopping rule” will help ensure that all variable categories and combinations are evenly-sampled; for example, when variability reaches +/- 20% of the category mean, sampling for that category will stop and sampling in other categories will continue until the stopping rule is again reached, and so on. This technique will increase the efficiency of sampling in Phase II.

We have not proposed to measure late-winter snow depth, the 7th stratifying (and, in Phase II, predictor) variable, in the field during Phase II, because of the enormous logistical problems that such sampling would entail. Snow depth must be sampled during a brief period at the end of the winter, instead of at the end of the growing season when data for the other 6 variables will be collected. This constraint precludes measurement of snow depth at all of the sampling locations selected for the other variables. SnowTran-3D has predicted that snow depth will vary but little across most of the study area, so a program to measure snow depth would need to concentrate on widely scattered locations, some of them in the least accessible parts of the study area. Consequently, while we propose to treat late-winter snow depth as a stratifying variable in Phase I and a predictor variable in Phase II, we will always use modeled snow depth.

We alluded earlier to the importance of including spring precipitation and recent grazing intensity as predictors of vegetation structure in Phase II models. At present it is unclear how we might do this most effectively, largely because high-resolution spatial layers of these variables are unavailable. We are aware of several sources of modeled average monthly or annual precipitation; although those sources do not provide data on recent precipitation, they may ultimately have to serve as predictor datasets. We intend to investigate the availability of finer-scale data (e.g., data from rain gauges maintained by the BLM throughout the Rawlins Field Office, monthly precipitation measurements from the weather stations throughout the study area) prior to any Phase II work.

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FIGURES

Figure 1. Locations of the two study areas within the state of Wyoming.

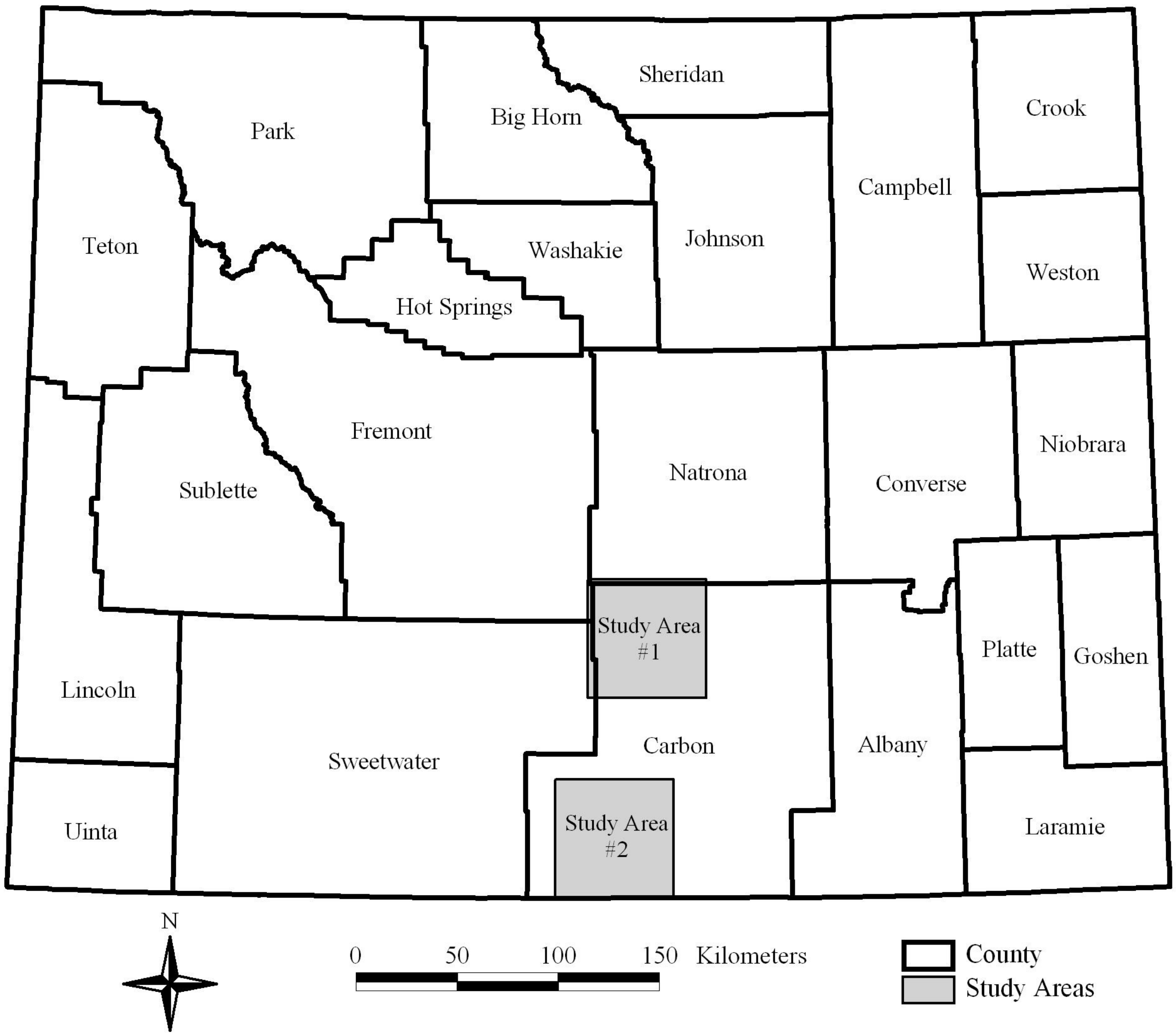


Figure 2. Cover types within the Wyoming Land Cover Dataset with substantial amounts of sagebrush in the two study areas, south-central Wyoming.

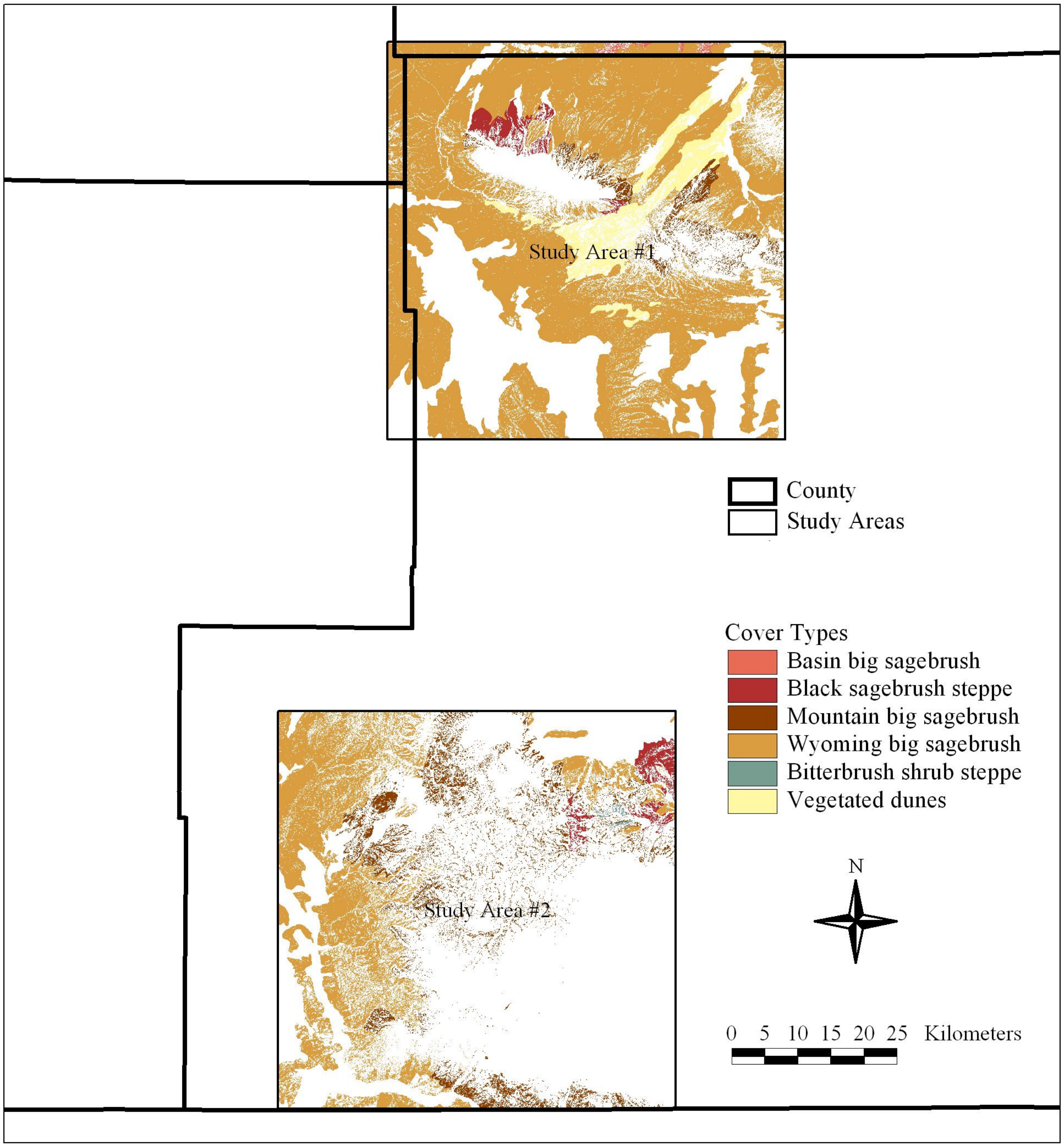


Figure 3. Portions of the two study areas in south-central Wyoming removed by masks and the minimum mapping unit requirement (dark), and remaining portions eligible for field sampling (white).

Figure 4. Aspect categories used for selecting sampling locations.

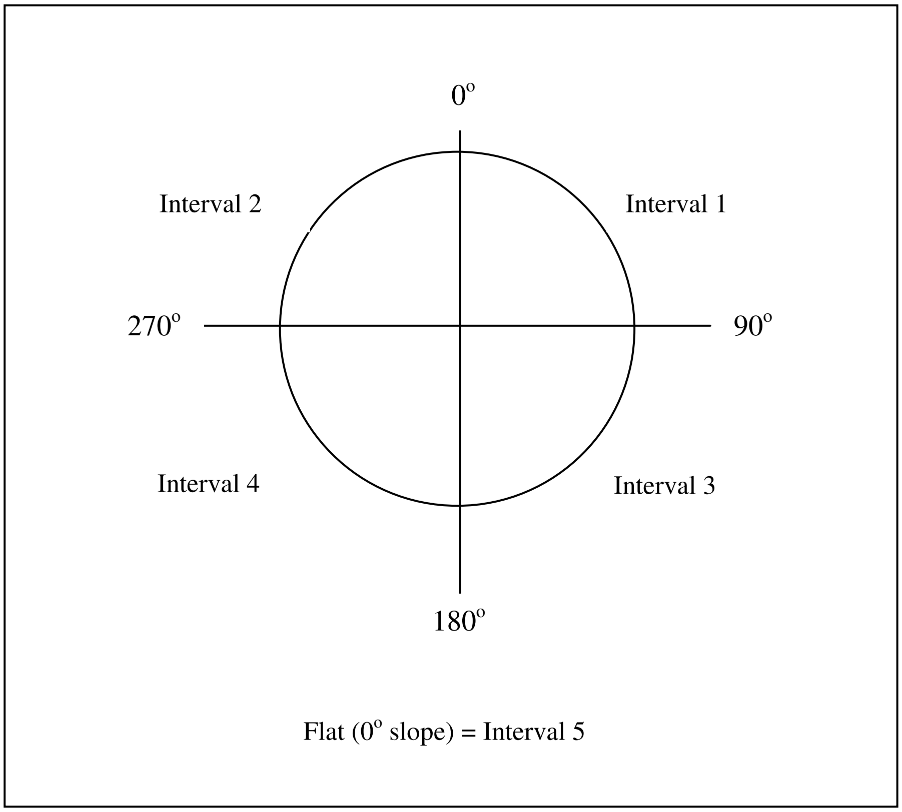


Figure 5. Decision tree for identifying landtypes in the two study areas.
LPOS (landscape position) is calculated for each cell and expresses the elevation of the cell relative to other cells in the 9-cell x 9-cell neighborhood. (See on page 6.) The thresholds for ridge and swale were determined empirically.

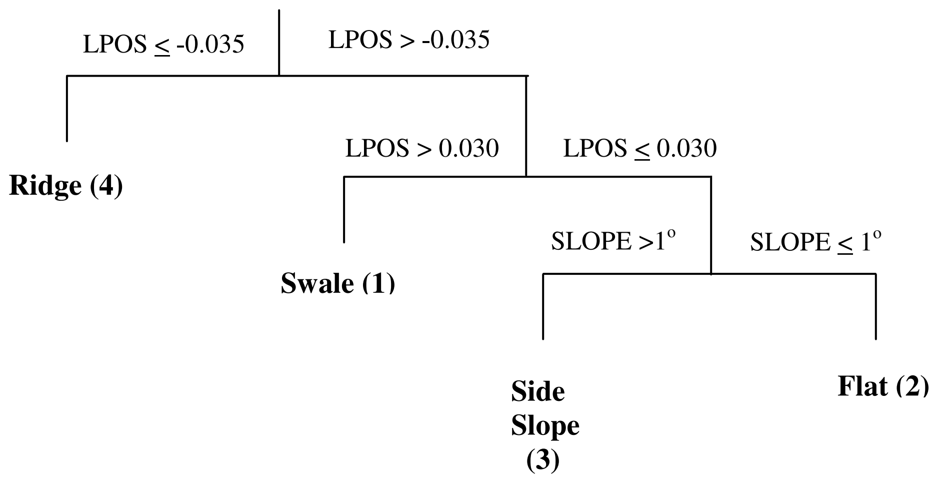


Figure 6. Weather stations and Snotel sites used for meteorological data for the snow distribution model, southcentral Wyoming.

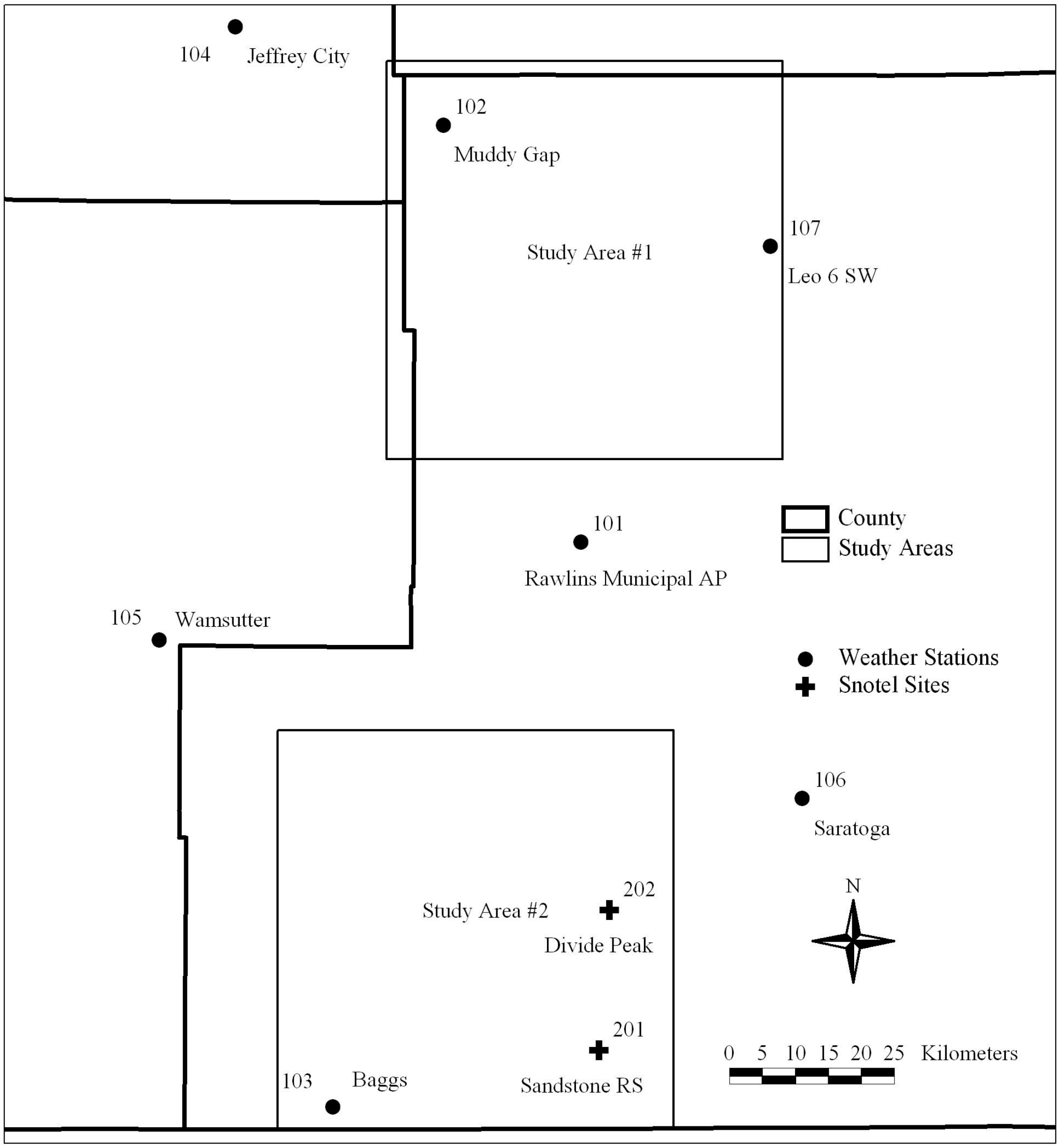


Figure 7. Cumulative percent of the combined study areas occupied by unique combinations of the 7 stratifying variables.

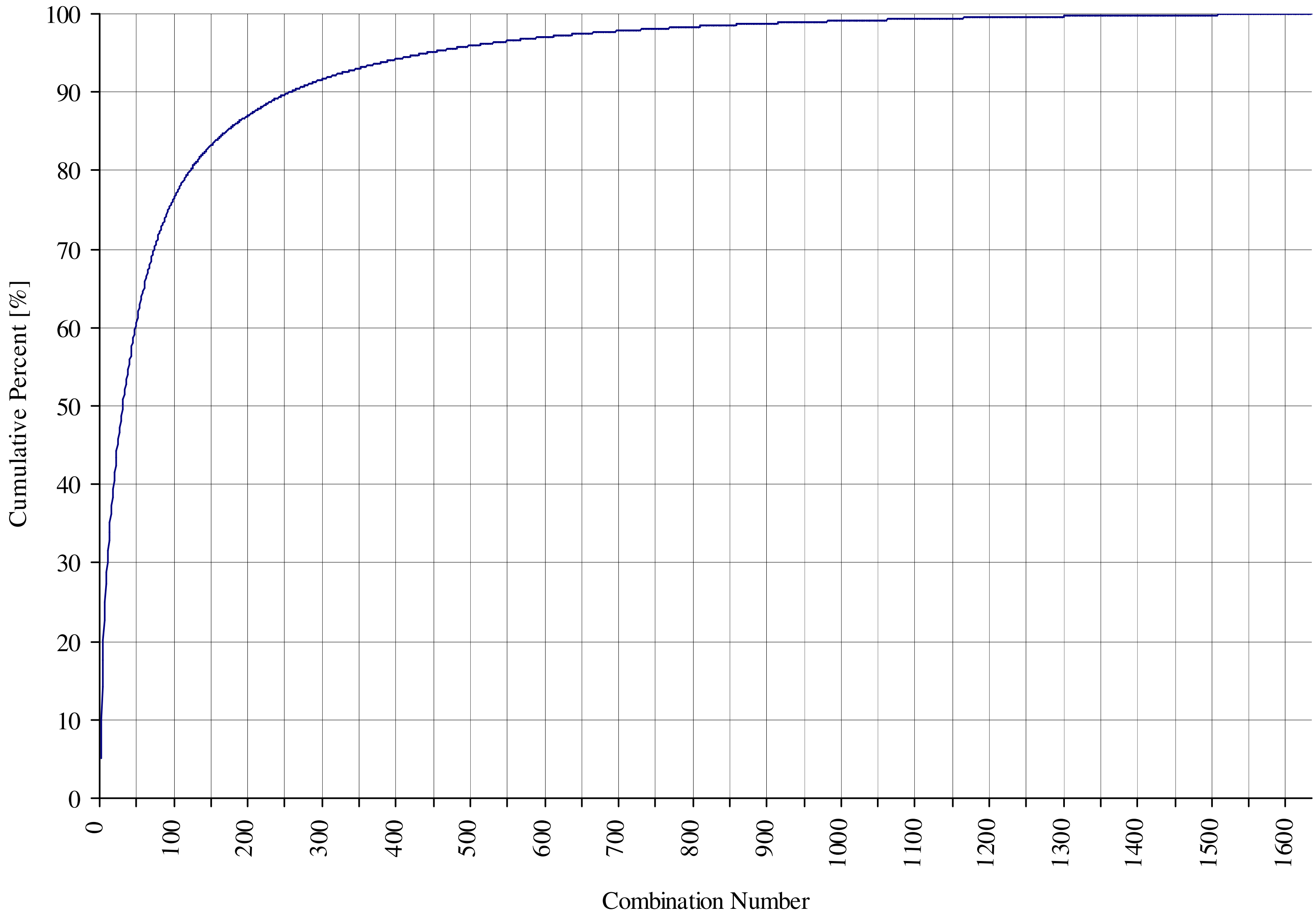


Figure 8. The number of unique variable combinations within each square neighborhood the size of a township (6 mi by 6 mi or 9.6 km by 9.6 km).
Darker shades indicate more combinations.

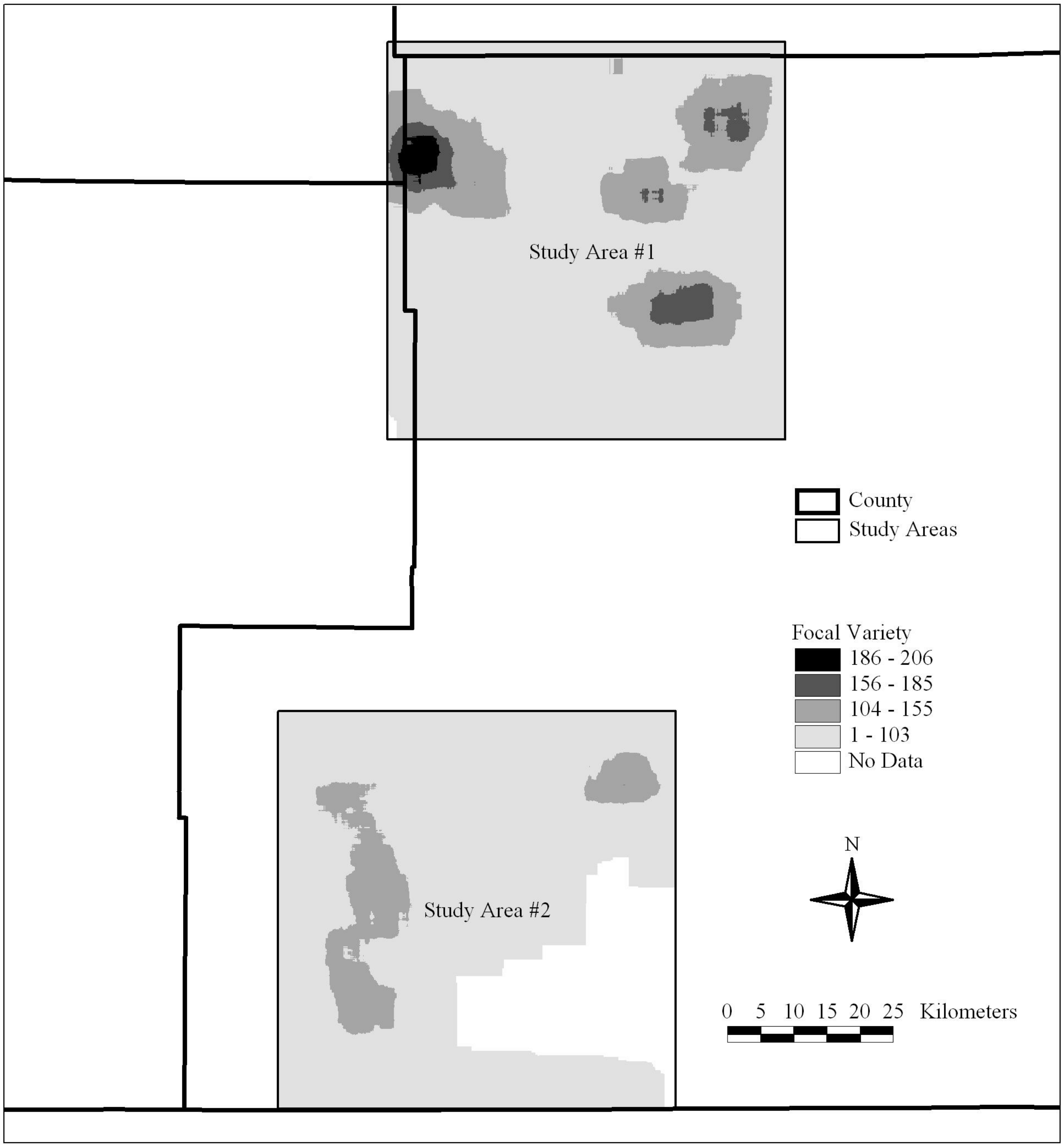
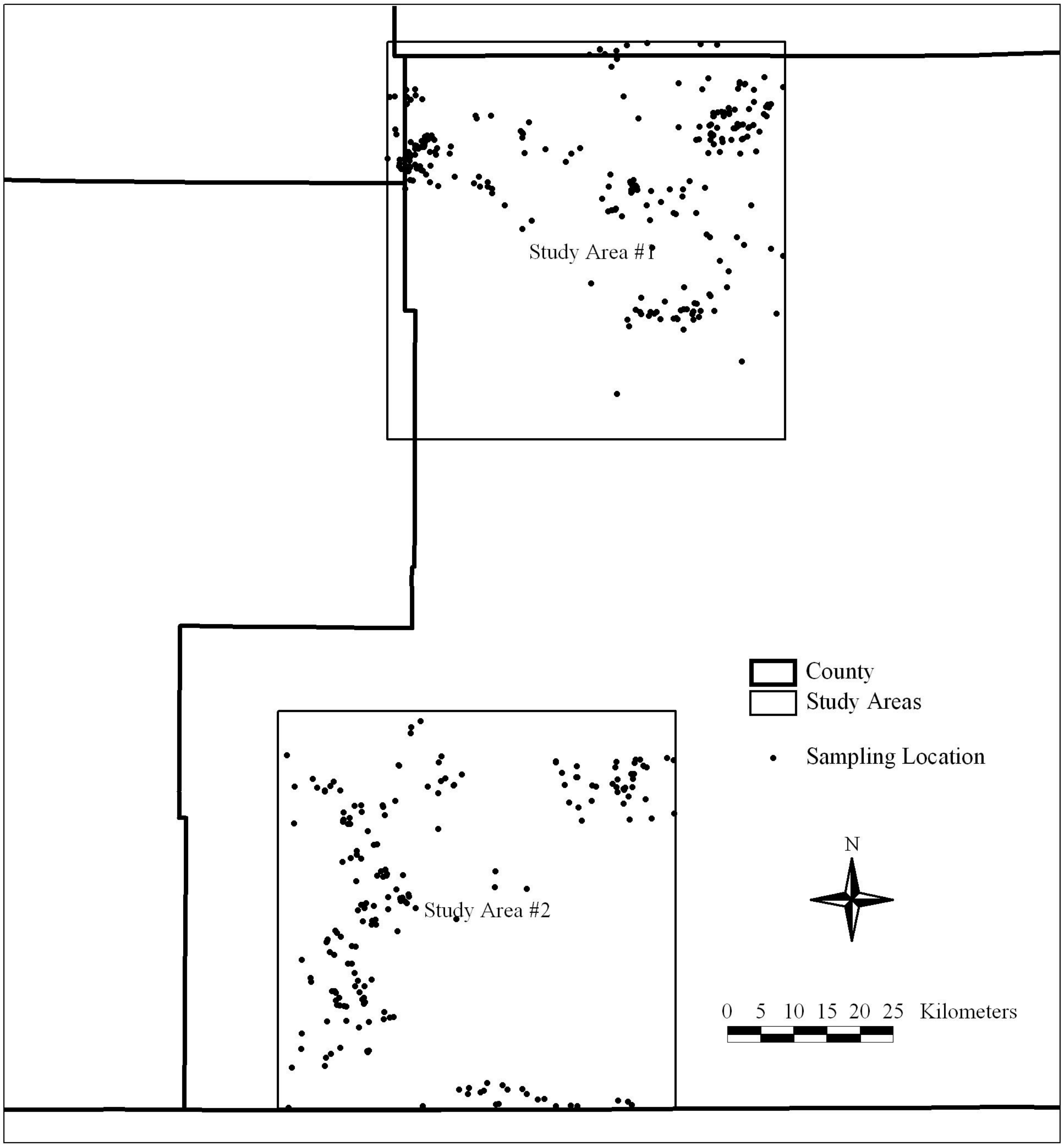


Figure 9. The 450 initial sampling locations.



TABLES

Table 1. Names and codes of Wyoming Gap Analysis Project land cover types (Merrill *et al*. 1996).

Code	Name
11001	Human settlements
21001	Dry-land crops
21002	Irrigated crops
31001	Mixed grass prairie
31002	Short grass prairie
31003	Great Basin foothills grassland
32001	Mesic upland shrub
32002	Xeric upland shrub
32005	Bitterbrush shrub steppe
32006	Mountain big sagebrush
32007	Wyoming big sagebrush
32008	Black sagebrush Steppe
32009	Basin big sagebrush
32010	Desert shrub
32011	Saltbush fans and flats
32012	Greasewood fans and flats
32013	Vegetated dunes
41001	Aspen forest
41002	Bur oak woodland
42001	Spruce-fir
42003	Douglas fir
42004	Lodgepole pine
42007	Clearcut conifer
42008	Whitebark pine
42009	Limber pine woodland and scrub
42010	Ponderosa pine
42015	Juniper woodland
42016	Burned conifer
52001	Open water
61001	Forest-dominated riparian
62001	Shrub-dominated riparian
62002	Grass-dominated wetland
62003	Grass-dominated riparian
71001	Unvegetated playa
73001	Active Sand dunes
74001	Basin bare rock and soil
74002	Alpine bare rock and soil
75001	Mining operations
82001	Alpine tundra
82002	Subalpine meadow
91001	Permanent snow

Table 2. Names and codes of cover classes from the National Land Cover Dataset (U.S. Geological Survey 2003).

Code	Name
11	Open Water
12	Perennial Ice/Snow
21	Low Intensity Residential
22	High Intensity Residential
23	Commercial/Industrial/Transportation
31	Bare Rock/Sand/Clay
32	Quarries/Strip Mines/Gravel Pits
33	Transitional
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
51	Shrubland
61	Orchards/Vineyards/Other
71	Grasslands/Herbaceous
81	Pasture/Hay
82	Row Crops
83	Small Grains
84	Fallow
85	Urban/Recreational Grasses
91	Woody Wetlands
92	Emergent Herbaceous Wetlands

Table 3. Fifty-six Wyoming Land Cover Dataset (WYLCD) land cover types made from combinations of the National Land Cover Dataset (U.S. Geological Survey 2003) and the Wyoming Gap Analysis Project (Merrill *et al.* 1996).

WYLCD Type Code	WYLCD Type Name	NLCD Class Code	NLCD Class Name	GAP Type Code	GAP Type Name
110000	Open Water	11	Open Water	0	NLCD class not subdivided
120000	Perennial Ice/Snow	12	Perennial Ice/Snow	0	NLCD class not subdivided
210000	Low Intensity Residential	21	Low Intensity Residential	0	NLCD class not subdivided
220000	High Intensity Residential	22	High Intensity Residential	0	NLCD class not subdivided
230000	Commercial/Industrial/Transportation	23	Commercial/Industrial/Transportation	0	NLCD class not subdivided
310000	Bare Rock/Sand/Clay (Uncategorized)	31	Bare Rock/Sand/Clay	0	Uncategorized
317101	Bare Rock/Sand/Clay (Unvegetated playa)	31	Bare Rock/Sand/Clay	71001	Unvegetated playa
317301	Bare Rock/Sand/Clay (Active sand dunes)	31	Bare Rock/Sand/Clay	73001	Active sand dunes
317401	Bare Rock/Sand/Clay (Basin exposed rock/soil)	31	Bare Rock/Sand/Clay	74001	Basin exposed rock/soil
317402	Bare Rock/Sand/Clay (Alpine exposed rock/soil)	31	Bare Rock/Sand/Clay	74002	Alpine exposed rock/soil
320000	Quarries/Strip Mines/Gravel Pits	32	Quarries/Strip Mines/Gravel Pits	0	NLCD class not subdivided
330000	Transitional (Uncategorized)	33	Transitional	0	Uncategorized
334207	Transitional (Clearcut conifer)	33	Transitional	42007	Clearcut conifer
334216	Transitional (Burned conifer)	33	Transitional	42016	Burned conifer
410000	Deciduous Forest (Uncategorized)	41	Deciduous Forest	0	Uncategorized
414101	Deciduous Forest (Aspen forest)	41	Deciduous Forest	41001	Aspen forest
414102	Deciduous Forest (Bur oak woodland)	41	Deciduous Forest	41002	Bur oak woodland
420000	Evergreen Forest (Uncategorized)	42	Evergreen Forest	0	Uncategorized
424201	Evergreen Forest (Spruce-fir)	42	Evergreen Forest	42001	Spruce-fir
424203	Evergreen Forest (Douglas fir)	42	Evergreen Forest	42003	Douglas fir
424204	Evergreen Forest (Lodgepole pine)	42	Evergreen Forest	42004	Lodgepole pine
424208	Evergreen Forest (Whitebark pine)	42	Evergreen Forest	42008	Whitebark pine
424209	Evergreen Forest (Limber pine and woodland)	42	Evergreen Forest	42009	Limber pine and woodland
424210	Evergreen Forest (Ponderosa pine)	42	Evergreen Forest	42010	Ponderosa pine
424215	Evergreen Forest (Juniper woodland)	42	Evergreen Forest	42015	Juniper woodland
430000	Mixed Forest	43	Mixed Forest	0	No corresponding Gap type
510000	Shrubland (Uncategorized)	51	Shrubland	0	Uncategorized
513201	Shrubland (Mesic upland shrub)	51	Shrubland	32001	Mesic upland shrub
513202	Shrubland (Xeric upland shrub)	51	Shrubland	32002	Xeric upland shrub

Table 3 (continued).

WYLCD Type Code	WYLCD Type Name	NLCD Class Code	NLCD Class Name	GAP Type Code	GAP Type Name
513205	Shrubland (Bitterbrush shrub steppe)	51	Shrubland	32005	Bitterbrush shrub steppe
513206	Shrubland (Mountain big sagebrush)	51	Shrubland	32006	Mountain big sagebrush
513207	Shrubland (Wyoming big sagebrush)	51	Shrubland	32007	Wyoming big sagebrush
513208	Shrubland (Black sagebrush steppe)	51	Shrubland	32008	Black sagebrush steppe
513209	Shrubland (Basin big sagebrush)	51	Shrubland	32009	Basin big sagebrush
513210	Shrubland (Desert shrub)	51	Shrubland	32010	Desert shrub
513211	Shrubland (Saltbush fans and flats)	51	Shrubland	32011	Saltbush fans and flats
513212	Shrubland (Greasewood fans and flats)	51	Shrubland	32012	Greasewood fans and flats
513213	Shrubland (Vegetated dunes)	51	Shrubland	32013	Vegetated dunes
610000	Orchards/Vineyards/Other	61	Orchards/Vineyards/Other	0	No corresponding Gap type
710000	Grasslands/Herbaceous (Uncategorized)	71	Grasslands/Herbaceous	0	Uncategorized
713101	Grasslands/Herbaceous (Mixed grass prairie)	71	Grasslands/Herbaceous	31001	Mixed grass prairie
713102	Grasslands/Herbaceous (Short grass prairie)	71	Grasslands/Herbaceous	31002	Short grass prairie
713103	Grasslands/Herbaceous (Great Basin foothills grassland)	71	Grasslands/Herbaceous	31003	Great Basin foothills grass
718201	Grasslands/Herbaceous (Meadow tundra)	71	Grasslands/Herbaceous	82001	Meadow tundra
718202	Grasslands/Herbaceous (Subalpine meadow)	71	Grasslands/Herbaceous	82002	Subalpine meadow
810000	Pasture/Hay	81	Pasture/Hay	0	NLCD class not subdivided
820000	Row Crops	82	Row Crops	0	NLCD class not subdivided
830000	Small Grains	83	Small Grains	0	NLCD class not subdivided
840000	Fallow	84	Fallow	0	NLCD class not subdivided
850000	Urban/Recreational Grasses	85	Urban/Recreational Grasses	0	NLCD class not subdivided
910000	Woody Wetlands (Uncategorized)	91	Woody Wetlands	0	Uncategorized
916101	Woody Wetlands (Forest-dominated riparian)	91	Woody Wetlands	61001	Forest-dominated riparian
916201	Woody Wetlands (Shrub-dominated riparian)	91	Woody Wetlands	62001	Shrub-dominated riparian
920000	Emergent Herbaceous Wetlands (Uncategorized)	92	Emergent Herbaceous Wetlands	0	Uncategorized
926202	Emergent Herbaceous Wetlands (Grass-dominated wetland)	92	Emergent Herbaceous Wetlands	62002	Grass-dominated wetland
926203	Emergent Herbaceous Wetlands (Grass-dominated riparian)	92	Emergent Herbaceous Wetlands	62003	Grass-dominated riparian

Table 4. Forty-six Wyoming Land Cover Dataset (WYLCD) land cover types in the two study areas. See Table 3 for details on the WYLCD types. Vegetation in the 6 cover types shown in bold typeface was assumed to be dominated by sagebrush, and these types were mapped as the potential sampling domain in this project. Average canopy height was estimated by the authors based on field experience in the area. Snow-holding capacity class, needed in the snow distribution model, was derived from the height estimates.

WYLCD Name	WYLCD Code	Number of cells		Snow-holding capacity	
		Area 1	Area 2	Avg. Canopy Ht. (m)	class
Open Water	110000	82348	2202	0.05	1
Perennial Ice/Snow	120000	--	55	0.05	1
Low Intensity Residential	210000	6	192	5.00	9
High Intensity Residential	220000	35	93	5.00	9
Commercial/Industrial/Transportation	230000	3067	--	5.00	9
Bare Rock/Sand/Clay (Uncategorized)	310000	19108	1179	0.05	1
Bare Rock/Sand/Clay (Unvegetated playa)	317101	5428	66	0.05	1
Bare Rock/Sand/Clay (Active sand dunes)	317301	15953	--	0.05	1
Bare Rock/Sand/Clay (Basin exposed rock/soil)	317401	138	497	0.05	1
Bare Rock/Sand/Clay (Alpine exposed rock/soil)	317402	--	17	0.05	1
Quarries/Strip Mines/Gravel Pits	320000	3201	123	0.05	1
Transitional (Uncategorized)	330000	712	20523	0.15	3
Transitional (Clearcut conifer)	334207	--	11485	0.15	3
Deciduous Forest (Uncategorized)	410000	688	7845	10.00	10
Deciduous Forest (Aspen forest)	414101	82	115587	10.00	10
Evergreen Forest (Uncategorized)	420000	5520	66567	10.00	10
Evergreen Forest (Spruce-fir)	424201	5645	68271	10.00	10
Evergreen Forest (Lodgepole pine)	424204	42941	322759	10.00	10
Evergreen Forest (Limber pine and woodland)	424209	19643	--	10.00	10
Evergreen Forest (Ponderosa pine)	424210	4573	--	10.00	10
Evergreen Forest (Juniper woodland)	424215	13019	152	4.00	8
Mixed Forest	430000	55	947	10.00	10
Shrubland (Uncategorized)	510000	51773	4996	0.30	5
Shrubland (Mesic upland shrub)	513201	--	13292	1.00	7
Shrubland (Xeric upland shrub)	513202	4917	--	1.00	7
Shrubland (Bitterbrush shrub steppe)	**513205**	**--**	**3604**	**0.30**	**5**
Shrubland (Mountain big sagebrush)	**513206**	**62163**	**221583**	**0.50**	**6**
Shrubland (Wyoming big sagebrush)	**513207**	**2094147**	**676596**	**0.30**	**5**
Shrubland (Black sagebrush steppe)	**513208**	**42238**	**45402**	**0.20**	**4**
Shrubland (Basin big sagebrush)	**513209**	**11591**	**--**	**1.00**	**7**
Shrubland (Desert shrub)	513210	254509	90273	0.30	5
Shrubland (Saltbush fans and flats)	513211	134056	155911	0.10	2
Shrubland (Greasewood fans and flats)	513212	342691	98161	0.50	6
Shrubland (Vegetated dunes)	**513213**	**163687**	**--**	**0.50**	**6**
Grasslands/Herbaceous (Uncategorized)	710000	505964	1789479	0.15	3
Grasslands/Herbaceous (Mixed grass prairie)	713101	78834	168965	0.15	3
Grasslands/Herbaceous (Subalpine meadow)	718202	--	10767	0.20	4
Pasture/Hay	810000	6399	43805	0.50	6

Table 4 (continued).

WYLCD Name	WYLCD Code	Number of cells		Snow-holding capacity	
		Area 1	Area 2	Avg. Canopy Ht. (m)	class
Row Crops	820000	8	8575	0.10	2
Small Grains	830000	346	637	0.10	2
Fallow	840000	84	917	0.05	1
Urban/Recreational Grasses	850000	--	264	0.10	2
Woody Wetlands (Uncategorized)	910000	3885	7327	10.00	10
Woody Wetlands (Forest-dominated riparian)	916101	61	3408	10.00	10
Woody Wetlands (Shrub-dominated riparian)	916201	1124	1078	5.00	9
Emergent Herbaceous Wetlands (Uncategorized)	920000	19361	36400	0.30	5
Number of WYLCD types	46	39	39		

Table 5. Widths of buffers applied to hydrographic features to estimate the width of riparian influence on vegetation (from Fertig and Thurston 2003).
The buffer is applied to each side of streams.

Feature	Strahler Stream Order	Buffer Width (m)
Stream	1	40
	2	40
	3	60
	4	90
	5	120
	6	150
	7	210
Reservoir		90
Lake or Pond		90
Wide River		300
Marsh or Wetland		0
Ephemeral Wash		0

Table 6. Categories of ownership for lands included in and masked out of the analysis. Ownership map was from Merrill *et al*. (1996).

Display	Display Name	Category	Treatment in this project
1	N.P.S. National Park/Monument	Federal	Included
2	N.P.S. National Recreation Area/Historic Site	Federal	Included
3	U.S.F.S. National Forest	Federal	Included
4	U.S.F.S. National Grassland	Federal	Included
5	U.S.F.S. Wilderness Area/Scenic River	Federal	Included
6	U.S.F.S. Research Natural/Special Interest Area	Federal	Included
7	U.S.F.S. National Recreation Area	Federal	Included
8	National Wildlife Refuge	Federal	Included
9	Bureau of Land Management	Federal	Included
10	Department of Defense	Federal	Included
11	Indian Reservation	Private	Masked out
12	Wyoming State Land	State	Masked out
13	State Park	State	Masked out
14	State Wildlife Habitat Management Area	State	Masked out
15	Private Lands	Private	Masked out
16	The Nature Conservancy Preserve	Private	Masked out
17	Open Water	Water	Masked out

Table 7. Re-classification by Fertig and Thurston (2003) of bedrock geology stratigraphic units from Love and Christiansen (1985) into geologic categories based on age and major rock type.
Original stratigraphic units are shown in regular typeface; new geologic categories are shown in bold typeface. Fertig's and Thurston's (2003) re-classification contained 26 categories, of which only the 14 that occur in one of the study areas are shown here.

Symbol	Stratigraphic Unit Name
Qal	**Quaternary alluvium**
Qa	Alluvium and colluvium
Qt	Gravel, pediment, and fan deposits
QTg	Terrace gravel (Pleistocene and/or Pliocene)
Qu	Undivided surficial deposits
Qls	**Quaternary landslide**
Qls	Landslide deposits
Qs	**Quaternary sand**
Qs	Dune sand and loess
MiPl	**Miocene/Pliocene**
Tmo	Lower Miocene and Upper Oligocene Rocks
Tml	Lower Miocene rocks, Bighorn Mountains
Tm	Miocene Rocks
Tu	Post-Eocene Sandstone and Conglomerate
Tmu	Upper Miocene Rocks
Eoe	**Early Eocene**
Tbs	Battle Spring formation
Tgl	Green River formation: Laney member
Tglu	Green River formation: Luman tongue
Tgt	Green River formation: Tipton shale member or tongue
Tgw	Green River formation: Wilkins Peak member
Tim	Indian Meadows formation
Tbw	Transitional unit between Battle Spring and Wasatch formations
Twn	Wasatch formation: Niland tongue
Twc	Wastach Formation: Cathedral Bluffs tongue
Twm	Wastach formation: main body
Twdr	Wind River formation - at base locally includes equivalent of Indian Meadows formation
Ein	**Eocene volcanic intrusive**
Tai	Alkalic intrusive and extrusive rocks
Tbf	Basalt flows and intrusive igneous rocks
Tid	Dacite and quartz latite intrusive and extrusive igneous rocks
Pal	**Paleocene**
Tco	Coalmont formation
TKf	Ferris formation
Tfu	Fort Union formation
Tha	Hanna formation
Kl	Lance formation
Kmb	Medicine Bow formation
Kmix	**Cretaceous mixed sandstone/shale**
Kcf	Code shale and Frontier formation
Kfl	Fox Hills sandstone and Lewis shale
Kf	Frontier formation
Kft	Frontier formation and Mowry and Thermopolis shales
Kml	Meeteetse formation and Lewis shale
Kmv	Mesaverde group

Table 7 (continued).

Symbol	Stratigraphic Unit Name
Ksh	**Cretaceous shale**
Kc	Cody shale
Kle	Lewis shale
Kmt	Mowry and Thermopolis shales
Kn	Niobrara formation
Ks	Steele shale
Ksn	Steele shale and Niobrara formation
Kss	**Cretaceous sandstone**
Kfh	Fox Hills sandstone
PTJ	**Permian/Triassic/Jurassic**
*Tr*cd	Chugwater and Dinwoody formations
*Tr*Pcg	Chugwater and Goose Egg formations
*Tr*c	Chugwater formation or group
KJs	Cloverly, Morrison, and Sundance formations
KJ	Cloverly and Morrison formations
Pfs	Forelle limestone and Satanka shale
*Tr*Pg	Goose egg formation
*Tr*Pjs	Jelm and Chugwater formations, Forelle limestone, and Satanka shale
MzPz	Mesozoic and Paleozoic Rocks
J*Tr*n	Nugget sandstone
Pp	Phosphoria formation and related rocks
Js	Sundance formation
Pze	**Early Paleozoic**
P*Pp*cf	Casper and Fountain formations
P*Pp*c	Casper formation
Pzr	Gallatin Limestone, Gros Ventre Formation and equivalents, and Flathead Sandstone
Mm	Madison limestone or group
Pzr	Madison limestone, Darby formation, Bighorn dolomite, Gallatin Limestone, GrosVentre formation and Flathead sandstone
PM	Ten Sleep sandstone and Amsden formation
P*Pp*M	Wells and Amsden formations
PCf	**Precambrian felsic**
Xdl	Deep Lake Group
Wgn	Granite Gneiss
Xgy	Granitic Rocks of 1,700Ma Age Group
Wg	Granitic Rocks of 2,600Ma Age Group
Xlc	Libby Creek Group
WVsv	Metasedimentary and Metavolcanic Rocks
Xsv	Metasedimentary and Metavolcanic Rocks
Ws	Metasedimentary Rocks
Xqd	Quartz Diorite
Ys	Sherman Granite
PCm	**Precambrian mafic**
Yla	Anorthosite and Norite
!W	Mafic intrusive rocks
Xm	Mafic Intrusive Rocks
Wmu	Metamorphosed Mafic and Ultramafic Rocks
Wp	Peridotite Intrusive Rocks
Yls	Pyroxene and Horneblende Syenite

Table 8. Extent of geologic categories in each study area in south-central Wyoming. The calculations of total area and extent of each geologic category are based on the unmasked portion of each study area. Shading indicates geologic categories that together account for ≤ 5% of a study area and were excluded from the selection of sampling locations.

Study Area 1

Category	Label	Area (ha)	% of Study Area	Cumulative % of Area
Miocene/Pliocene (MiPl)	10	52,035	34.86	100.00
Quaternary sand (Qs)	20	30,511	20.44	65.14
Quaternary alluvium (Qal)	17	19,451	13.03	44.69
Cretaceous mixed sandstone/shale (Kmix)	7	15,686	10.51	31.66
Cretaceous shale (Ksh)	8	11,109	7.44	21.15
Paleocene (Pal)	15	8,160	5.47	13.71
Pre-cambrian felsic (PCf)	12	4,858	3.25	8.24
Early Eocene (Eoe)	3	3,375	2.26	4.99
Permian/Triassic/Jurassic (PTJ)	14	2,333	1.56	2.72
Early Paleozoic (Pze)	16	726	0.49	1.16
Pre-cambrian mafic (PCm)	13	651	0.44	0.67
Cretaceous sandstone (Kss)	9	249	0.17	0.24
Entire Study Area		149,251	100.00	

Study Area 2

Category	Label	Area (ha)	% of Study Area	Cumulative % of Area
Cretaceous shale (Ksh)	8	17,801	32.02	100.00
Paleocene (Pal)	15	12,666	22.79	67.98
Cretaceous mixed sandstone/shale (Kmix)	7	8,147	14.66	45.19
Miocene/Pliocene (MiPl)	10	7,830	14.09	30.53
Early Eocene (Eoe)	3	6,044	10.87	16.45
Quaternary sand (Qs)	20	1,925	3.46	5.57
Quaternary alluvium (Qal)	17	802	1.44	2.11
Quaternary landslide (Qls)	19	237	0.43	0.67
Permian/Triassic/Jurassic (PTJ)	14	84	0.15	0.24
Eocene volcanic intrusive (Ein)	2	25	0.05	0.09
Pre-cambrian felsic (PCf)	12	21	0.04	0.04
Pre-cambrian mafic (PCm)	13	3	0.01	0.01
Entire Study Area		55,585	100.00	

Table 9. Reduction of each study area by successive masks.
Masking was intended to reduce each study area to easily-accessible, sagebrush-dominated patches without riparian influence. Because of overlap among the masks, the areas removed by individual masks do not sum to the area removed by all masks combined.

Area (ha)	Study Area 1	Study Area 2	Combined Study Area
Total	360,000	360,000	720,000
Removed by Vegetation Mask	*146,356*	*274,753*	
Removed by Riparian & Wetland Mask	*20,400*	*8,350*	
Removed by Ownership Mask	*126,561*	*141,521*	
Removed by Geology Mask	*38,463*	*57,488*	
Removed by All Masks	218,190	305,587	523,777
Unmasked (model domain)	141,810	54,413	196,223
Smaller than 8100 m^2 min. mapping unit	69,479	29,063	98,542
Area Remaining & Eligible for Sampling	72,331 (20.09%)	25,350 (7.04%)	97,681 (13.57%)

Table 10. Category labels assigned to the Wyoming Land Cover Dataset (WYLCD) cover types for use in selecting sampling locations.

WYLCD Name	WYLCD Code	Category Label
Shrubland (Bitterbrush shrub steppe)	513205	27
Shrubland (Mountain big sagebrush)	513206	28
Shrubland (Wyoming big sagebrush)	513207	29
Shrubland (Black sagebrush steppe)	513208	30
Shrubland (Basin big sagebrush)	513209	31
Shrubland (Vegetated dunes)	513213	35

Table 11. Elevation ranges state-wide of the 6 Wyoming Gap Analysis land cover types (Merrill *et al.* 1996) that contain large amounts of sagebrush.

GAP cover type	Elevation (m)		
	Min.	Max.	Range
Bitterbrush shrub steppe	1859	2845	986
Mountain big sagebrush	1301	3561	2260
Wyoming big sagebrush	1025	3398	2373
Black sagebrush steppe	1424	2725	1301
Basin big sagebrush	2014	2077	63
Vegetated dunes	1562	2249	687
All Types	1025	3561	2536

Table 12. Elevation intervals used for selecting sampling locations.
All intervals that include the 6 Wyoming Gap Analysis land cover types (Merrill *et al.* 1996) that contain large amounts with sagebrush are shown. The intervals occuring in each study area are indicated.

Interval Label	Elevation Range (m)	Study Area
1	1501 - 1800	1
2	1801 - 2100	1,2
3	2101 - 2400	1,2
4	2401 - 2700	1,2
5	2701 - 3000	2

Table 13. Slope intervals used for selecting sampling locations.

Interval Label	Steepness range (degrees)
0	0 - 3
1	3 - 10
2	10 - 20
3	20 - 45
4	> 45

Table 14. Meteorological data obtained from each weather station or Snotel site in south-central Wyoming.
Stations and sites are shown in Figure 6.

	Pertains to Study Area	Daily Precip.	Ave. Daily Temperature	Ave. Daily Relative Humidity	Ave. Daily Wind Speed	Resultant Wind Direction
Jeffrey City	1	Yes	Calculated*	--	--	--
Muddy Gap	1	--	Calculated*	--	--	--
Leo 6 SW	1	Yes	--	--	--	--
Rawlins Mun. Airport	1 & 2	Yes	Calculated*	Calculated*	Yes	Yes
Wamsutter	2	Yes	Calculated*	--	--	--
Saratoga	2	Yes	Calculated*	--	--	--
Baggs	2	Yes	Calculated*	--	--	--
Divide Peak	2	Calculated**	Yes	--	--	--
Sandstone Ranger Sta.	2	Calculated**	Yes	--	--	--

* Average daily temperatures for these stations and average daily relative humidity for Rawlins were calculated from the daily minimum and maximum values.
** Daily precipitation for the Snotel sites was calculated from the accumulated precipitation

Table 15. Snow depth intervals used for selecting sampling locations.

Interval Number	Snow Depth (mm)
0	0 - 200
1	201 - 400
2	401 - 600
3	601 - 800
4	801 - 1000
5	> 1000

Table 16. Strata used in selecting variable combinations to be sampled.
The range in variable combinations was divided into 12 strata based on the number of polygons in each combination, and combinations were randomly selected for sampling within each stratum.

Stratum ID Number	1	2	3	4	5	6	7	8	9	10	11	12	Totals
No. of Polygons / Combination	1	2	3-4	5-8	9-16	17-32	33-62	63-124	125-250	251-500	501-1000	1000+	
No. of the 1,634 Variable Combinations in Stratum	465	212	229	209	168	149	83	41	47	19	8	4	1634
Pct. of the 1,634 Combinations in Stratum	28.46%	12.97%	14.01%	12.79%	10.28%	9.12%	5.08%	2.51%	2.88%	1.16%	0.49%	0.24%	100.00%
No. of Polygons in Stratum Selected for Sampling	114	52	57	52	42	37	21	11	16	16	16	16	450
Pct. of Combinations in Stratum Represented by Selected Polygons	24.52%	24.53%	24.89%	24.88%	25.00%	24.83%	25.30%	26.83%	34.04%	84.21%	200.00%	400.00%	
Pct. of Study Area Represented by Polygons in Stratum	0.56%	0.53%	1.05%	1.95%	3.28%	6.49%	7.28%	8.49%	22.50%	15.92%	15.43%	16.53%	100.00%

Table 17. Degree to which the set of variable combinations selected for sampling represents the 7 predictor variables.
For each variable category, the target number of combinations (out of 430 selected combinations) was calculated from the proportion of all 1,634 combinations that belonged to that category. The area of each combination is the sum of the 900-m^2 cells coded as belonging to that combination. Boldface type indicates cases where the selection fell below 75% of the target.

Variable and Categories		Number of combinations			Percent of combinations			Percent of Area		
Land Cover Type		Target	Selected	Sel/Tar	Target	Selected	Sel/Tar	Target	Selected	Sel/Tar
27	Shrubland (Bitterbrush shrub steppe)	3	1	**0.333**	0.7%	0.2%	**0.317**	0.0%	0.0%	**0.032**
28	Shrubland (Mountain big sagebrush)	97	92	0.948	22.6%	21.4%	0.945	3.9%	1.6%	**0.410**
29	Shrubland (Wyoming big sagebrush)	240	266	1.108	55.9%	61.9%	1.107	90.4%	95.4%	1.055
30	Shrubland (Black sagebrush steppe)	42	27	**0.643**	9.7%	6.3%	**0.645**	3.1%	1.5%	**0.497**
31	Shrubland (Basin big sagebrush)	13	8	**0.615**	2.9%	1.9%	**0.633**	0.2%	0.0%	**0.182**
35	Shrubland (Vegetated dunes)	35	36	1.029	8.1%	8.4%	1.036	2.3%	1.4%	**0.613**
		430	430	1.000	100.0%	100.0%	1.000	100.0%	100.0%	1.000
Geology Type		Target	Selected	Sel/Tar	Target	Selected	Sel/Tar	Target	Selected	Sel/Tar
3	Early Eocene	17	19	1.118	3.9%	4.4%	1.128	3.9%	2.4%	**0.622**
7	Cretaceous mixed sandstone/shale	72	72	1.000	16.6%	16.7%	1.006	10.1%	5.7%	**0.559**
8	Cretaceous shale	63	69	1.095	14.7%	16.0%	1.093	14.9%	13.3%	0.894
10	Miocene/Pliocene	108	109	1.009	25.2%	25.3%	1.008	35.6%	49.5%	1.390
12	Precambrian felsic	51	42	0.824	11.8%	9.8%	0.831	1.2%	0.4%	**0.359**
15	Paleocene	41	41	1.000	9.5%	9.5%	1.005	11.2%	7.4%	**0.657**
17	Quaternary alluvium	27	21	0.778	6.4%	4.9%	0.767	12.3%	9.1%	**0.742**
20	Quaternary sand	52	57	1.096	12.0%	13.3%	1.105	10.7%	12.2%	1.131
		431	430	0.998	100.0%	100.0%	1.000	100.0%	100.0%	1.000
Elevation		Target	Selected	Sel/Tar	Target	Selected	Sel/Tar	Target	Selected	Sel/Tar
1	1500 m <= Elevation <= 1800 m	9	9	1.000	2.2%	2.1%	0.950	1.1%	0.2%	**0.198**
2	1800 m < Elevation <= 2100 m	188	203	1.080	43.6%	47.2%	1.082	78.2%	88.1%	1.127
3	2100 m < Elevation <= 2400 m	211	202	0.957	49.1%	47.0%	0.957	20.3%	11.6%	**0.573**
4	2400 m < Elevation <= 2700 m	22	16	**0.727**	5.1%	3.7%	**0.733**	0.5%	0.1%	**0.135**
		430	430	1.000	100.0%	100.0%	1.000	100.0%	100.0%	1.000

Table 17 (continued).

Variable and Categories		Number of combinations			Percent of combinations			Percent of Area		
Slope		Target	Selected	Sel/Tar	Target	Selected	Sel/Tar	Target	Selected	Sel/Tar
0	0 deg <= Slope <= 3 deg	93	96	1.032	21.6%	22.3%	1.033	40.6%	45.3%	1.115
1	3 deg < Slope <= 10 deg	165	171	1.036	38.4%	39.8%	1.035	52.8%	52.3%	0.991
2	10 deg < Slope <= 20 deg	129	113	0.876	30.1%	26.3%	0.873	5.7%	1.9%	**0.325**
3	20 deg < Slope <= 45 deg	42	50	1.190	9.9%	11.6%	1.180	0.8%	0.5%	**0.621**
		429	430	1.002	100.0%	100.0%	1.000	100.0%	100.0%	1.000
Aspect		Target	Selected	Sel/Tar	Target	Selected	Sel/Tar	Target	Selected	Sel/Tar
0	Flat (Slope = 0 deg)	2	0	**0.000**	0.4%	0.0%	**0.000**	0.2%	0.0%	0.000
1	NE (0 deg <= Aspect <= 90 deg)	98	94	0.959	22.9%	21.9%	0.955	26.5%	28.0%	1.056
2	NW (270 deg < Aspect <= 360 deg)	102	97	0.951	23.7%	22.6%	0.950	25.9%	28.0%	1.084
3	SE (90 deg < Aspect <= 180 deg)	127	135	1.063	29.6%	31.4%	1.062	29.7%	29.6%	0.996
4	SW (180 deg < Aspect <= 270 deg)	101	104	1.030	23.4%	24.2%	1.035	17.7%	14.4%	0.811
		430	430	1.000	100.0%	100.0%	1.000	100.0%	100.0%	1.000
Snow_Depth		Target	Selected	Sel/Tar	Target	Selected	Sel/Tar	Target	Selected	Sel/Tar
0	0 mm <= Snow_Depth <= 200 mm	1	1	1.000	0.3%	0.2%	0.760	0.0%	0.0%	0.086
1	200 mm < Snow_Depth <= 400 mm	221	226	1.023	51.5%	52.6%	1.021	74.6%	82.2%	1.102
2	400 mm < Snow_Depth <= 600 mm	95	95	1.000	22.1%	22.1%	1.000	20.6%	15.9%	0.772
3	600 mm < Snow_Depth <= 800 mm	67	67	1.000	15.5%	15.6%	1.002	3.0%	1.3%	**0.445**
4	800 mm < Snow_Depth <= 1000 mm	34	34	1.000	8.0%	7.9%	0.994	1.6%	0.5%	**0.303**
5	1000 mm < Snow_Depth	11	7	**0.636**	2.6%	1.6%	**0.619**	0.1%	0.0%	**0.254**
		429	430	1.002	100.0%	100.0%	1.000	100.0%	100.0%	1.000
Landtype		Target	Selected	Sel/Tar	Target	Selected	Sel/Tar	Target	Selected	Sel/Tar
1	Swale	82	89	1.085	19.0%	20.7%	1.091	2.9%	1.7%	0.569
2	Flat	27	18	**0.667**	6.3%	4.2%	**0.664**	8.3%	6.1%	**0.733**
3	Sideslope	211	221	1.047	49.1%	51.4%	1.047	85.6%	91.0%	1.064
4	Ridge	110	102	0.927	25.6%	23.7%	0.925	3.2%	1.2%	**0.383**
		430	430	1.000	100.0%	100.0%	1.000	100.0%	100.0%	1.000

APPENDIX A. DESCRIPTION OF TABLES OF INITIAL AND ALTERNATE SAMPLING LOCATIONS.

Tables A1 through A3 are contained in the spreadsheet, "Sage Model Report Appendix A.xls." Table A1 shows the initial sampling locations for combinations in all strata. Table A2 shows the alternate sampling locations for the variable combinations in stratum 1. Because each combination in this stratum is represented by only one polygon (that is, one sampling location), an initial location from this stratum that is rejected for sampling must be replaced by an alternate location representing a different variable combination. Table A3 show alternate sampling locations for variable combinations in strata 2 - 12. Because each combination in these strata is represented by > 1 polygon, an initial location from these strata that his rejected for sampling can be replaced with another location representing the same variable combination.

For each location, the tables show the variable combinations and variable categories or intervals represented, and the UTM coordinates. Refer to the report text for explanations of the variable categories and intervals.

APPENDIX B. CONTENTS OF COMPANION CD.

The CD that accompanies this report contains a copy of the report in the *Report* directory and the GIS data associated with the project in the *GIS_Data* directory. The contents of the *GIS_Data* directory and its subdirectories are briefly described below. More detailed information can be found in the *ReadMe.txt* files located in most directories.

***GIS_Data* directory**

This directory contains the GIS data associated with phase 1 of the project to map overstory structure, undergrowth structure, and snow distribution in sagebrush habitats in Wyoming.

Subdirectory	Contents
avl	ArcView GIS 3.2 legend files
Base_Layers	datasets that can be used as reference or base layers
Other	other datasets
Sampling_Locations	sampling locations and associated datasets
Strat_Var	stratification variables
Strat_Var_R	stratification variables (reclassified)

File	Description
GIS_Data.apr	ArcView GIS 3.2 project for viewing the GIS datasets

The map projection for the GIS datasets is defined below.

```
Projection                                     LAMBERT
Datum                                            NAD27
Units                                           METERS
Spheroid                                    CLARKE1866
Parameters:
  1st standard parallel               41  0  0.000
  2nd standard parallel               45  0  0.000
  central meridian                  -107 30  0.00
  latitude of projection's origin     41  0  0.000
  false easting (meters)                   0.00000
  false northing (meters)                  0.00000
```

***GIS_Data\\Base_Layers* directory**

This ArcInfo workspace contains datasets that can be used as reference or base layers.

Coverage	Description
clipcov	coverage used to clip selected GIS datasets to an area in south-central Wyoming that includes both study areas
county	Wyoming county boundaries
hydro	hydrography
q_100k	1:100,000 quadrangles
q_24k	1:24,000 quadrangles
road	roads
study_areas	study area boundaries

Grid	Description
hillshade	shaded relief

Info Table	Description
hydro.line	describes the hydrographic line features associated with the MINOR1 arc attribute codes
hydro.poly	describes the hydrographic polygon features associated with the MINOR1 polygon attribute codes
road.classes	defines numerical codes used for 7 road classes

***GIS_Data\Other* directory**

This ArcInfo workspace contains a variety of datasets.

Coverage	Description
landcov	Gap land cover
landown	Gap land ownership and management
ripmod	riparian/aquatic model
snotel_sites	Snotel sites that were considered as sources of meteorological data for the snow depth models
weather_sta	weather stations that were considered as sources of meteorological data for the snow depth models

Grid	Description
mask_b7	composite mask that combines the geology, land cover, land ownership, riparian/aquatic, and study area masks
mask_b7_mmu	composite mask that combines mask_b7 with the minimum mapping unit mask and defines the area from which sampling locations were selected
mask-geol	geology mask
mask-lc	land cover mask
mask-lo	land ownership mask
mask-mmu	minimum mapping unit mask
mask-rip	riparian/aquatic mask
mask-sa	study area mask
nlcd1992	National Land Cover Dataset

Info Table	Description
landcov.name	defines numerical codes used for 41 Gap land cover types
landown.display	defines numerical codes used for 17 Gap land ownership classes
nlcd.classes	defines numerical codes used for 21 National Land Cover Dataset classes
ripmod.types	defines numerical codes used for 14 riparian/aquatic types

***GIS_Data\Sampling_Locatons* directory**

This ArcInfo workspace contains datasets for the initial and alternate sampling locations and datasets associated with their selection.

Coverage	Description
samp_loc	initial set of 450 sampling locations
samp_loc-alt	alternate set of sampling locations
sv_b7_mmu_cov	complete set of potential sampling locations.

Grid	Description
fv_b7_mmu_r90	focal variety grid that indicates the number of unique variable combinations for a neighborhood the size of a township (6 mi X 6 mi (9600 m X 9600 m))
sv_b7_mmu_r	grid version of the sv_b7_mmu_cov polygon coverage.
sv_b7_r	grid that combines the information of the seven reclassified stratification variable grids (wylcd_r, bedgeol_g, elev_r, slope_r, aspect_r, snowdepth_r, landtype)

Info Table	Description
comb.b7_mmu	table with information on the 1634 stratification variable combinations

***GIS_Data\Strat_Var* directory**

This ArcInfo workspace contains datasets for the seven stratification variables.

Coverage	Description
bedgeol	bedrock geology

Grid	Description
aspect	aspect (slope direction)
elev	elevation
landtype	landtype
slope	degree slope
snowdepth	snow depth (modeled)
wylcd	Wyoming Land Cover Dataset

Info Table	Description
bedgeol.reclass	defines the reclassification of the original 213 geologic units to a set of 26 units
bedgeol.units	describes the 26 geologic units
wylcd.types	defines the 56 WYLCD land cover types, which are a combination of NLCD land cover classes and Gap land cover types

***\GIS_Data\Strat_Var_R* directory**

This ArcInfo workspace contains reclassified datasets for the seven stratification variables. These datasets differ from the datasets in the Strat_Var directory in that these datasets all represent categorical variables.

Grid	**Description**
aspect_r	aspect (slope direction)
bedgeol_g	bedrock geology
elev_r	elevation
landtype	landtype
slope_r	degree slope
snowdepth_r	snow depth
wylcd_r	Wyoming Land Cover Dataset