Canyonlands National Park
Survey Design and Site Selection Report

Defining the Upland Resources for Monitoring

Discussions with Canyonlands National Park (CANY) resource management staff identified upland grasslands and shrublands as the major resource of concern for long-term monitoring. These communities dominate the vegetative portion of the park landscape, are sensitive to soil erosion resulting from unauthorized social trailing by park visitors. Monitoring these areas would provide indication of natural variability as well as provide early warning of system degradation due to human disturbances.

CANY consists of three administrative units – Needles, Island in the Sky (ISKY), and the Maze. Due to logistical reasons, only the Needles and ISKY districts were initially selected for Upland Vegetation and Soils monitoring. Monitoring effort in the Maze district will be determined in the future.

Accessibility

Steep slopes ($\geq$ 50%) and areas isolated due to steep slopes (e.g., mesa tops) have been deemed to be inaccessible for NCPN upland monitoring. In addition to slope steepness, areas only accessible by river travel were also eliminated due to costs of access. Accessibility in CANY was derived using the NCPN Landscape Accessibility Model. The resulting accessibility data layer was clipped to the two districts in further processing (described below).

Delineating the Target Population

Target Ecological Site Types

The Canyonlands Area soil survey map (SCS 1991) and corresponding Ecological Site Descriptions were used to identify the types of ecological sites which potentially supported herbaceous (Table 1) and shrubland (Table 2) vegetation. Based on perceived costs of upland monitoring, the three most spatially extensive ecological site types supporting herbaceous or shrubland communities were selected for further consideration, for a total of six target ecological sites (Table 3, Fig. 1).

Table 1. Area (ha) of ecological sites (ecosites) supporting herbaceous communities in the Needles and ISKY districts of CANY. Estimates of spatial extent exclude inaccessible areas. Bold type indicates the three most spatially extensive site types that were selected for monitoring.

Ecosite #	Ecosite Description	Estimated area of ecosite (ha)	% of total land area	% of total herbaceous land area
R035XY118UT	**Desert Sandy Loam (Four-wing Saltbush)**	**2617.9**	**4.2**	**19.5**
R035XY015UT	Sandy Bottom (Fourwing Saltbush)	1638.5	2.6	12.2
R035XY212UT	**Semidesert Sand (Fourwing Saltbush)**	**4467.7**	**7.3**	**33.3**
R035XY215UT	**Semidesert Sandy Loam (Four-Wing Saltbush)**	**4090.9**	**6.7**	**30.5**
R035XY230UT	Semidesert Shallow Sandy Loam (Shadscale)	562.2	0.9	4.2
Total land area = 61048.2 ha Total herbaceous land = 13377.4 ha				

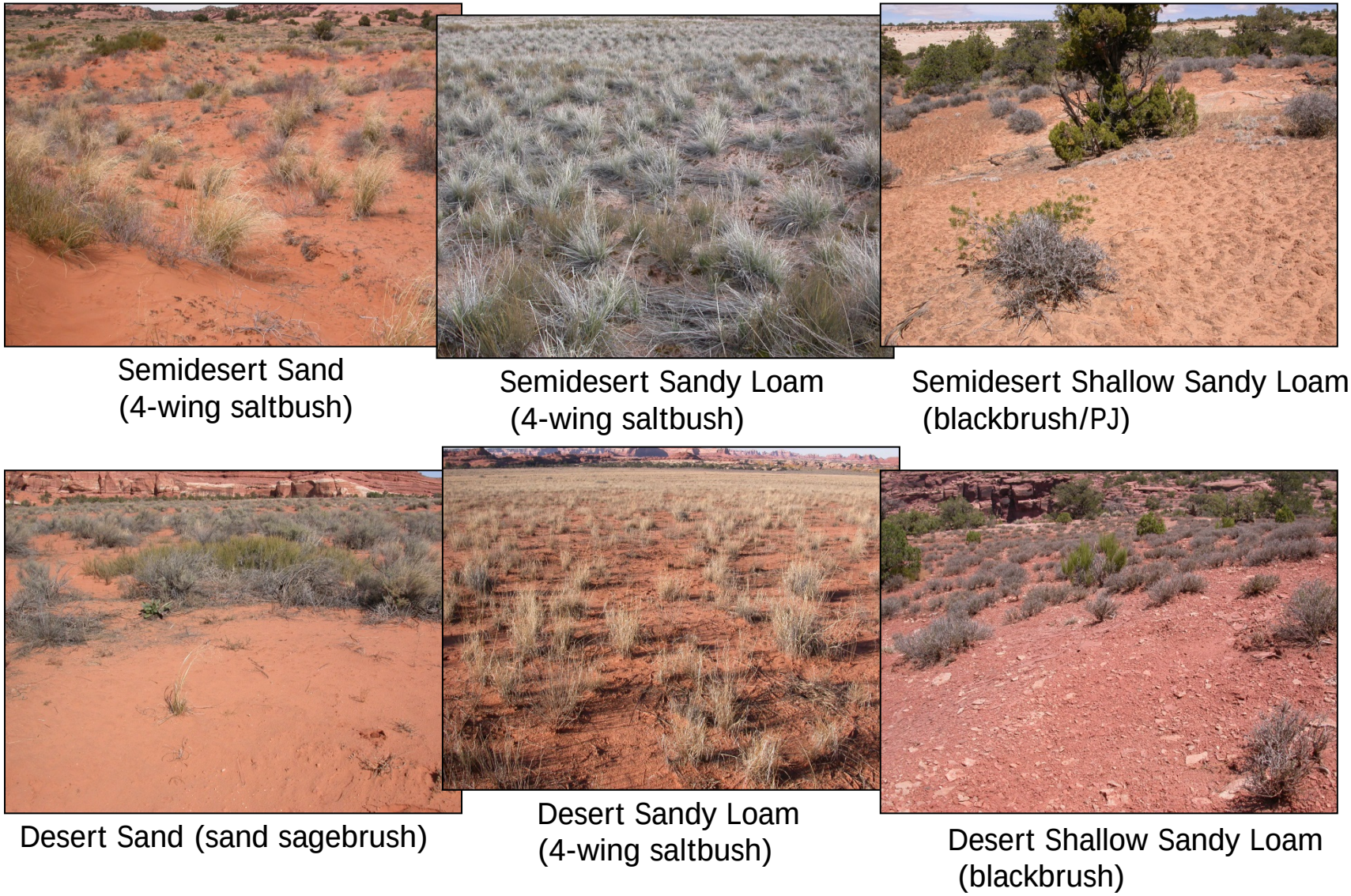
Table 2. Areas (ha) of ecological sites (ecosites) supporting shrub communities in the Needles and ISKY districts of CANY. Estimates of spatial extent exclude inaccessible areas. Bold type indicates the three most spatially extensive site types that were selected for monitoring.

Ecosite #	Ecosite Description	Estimated area of ecosite (ha)	% of total land area	% of total shrubland area
R035XY009UT	Alkali Flat (Greasewood)	286.6	0.5	1.5
R035XY115UT	**Desert Sand (Sand Sagebrush)**	**1848.7**	**3.0**	**9.7**
R035XY121UT	Desert Sandy Loam (Blackbrush)	177.9	0.3	0.9
R035XY130UT	Desert Shallow Sandy Loam (Shadscale)	146.2	0.2	0.8
R035XY133UT	**Desert Shallow Sandy Loam (Blackbrush)**	**9671.9**	**15.8**	**50.5**
R035XY139UT	Desert Stony Loam (Blackbrush)	219.7	0.4	1.1
R035XY011UT	Loamy Bottom (Basin Big Sagebrush)	87.7	0.1	0.5
R035XY218UT	Semidesert Sandy Loam (Blackbrush)	0	0	0
R035XY236UT	**Semidesert Shallow Sandy Loam (Utah Juniper-Pinyon)**	**4741.6**	**7.8**	**24.8**
R035XY243UT	Semidesert Stony Loam (Blackbrush)	391.3	0.6	2.0
R035XY012UT	Semiwet Saline Streambank (Fremont Cottonwood)	62.7	0.1	0.3
R035XY018UT	Talus Slope (Blackbrush-Shadscale)	1184.5	1.9	6.2
R035XY306UT	Upland Loam (Basin Big Sagebrush)	232.2	0.4	1.2
R035XY312UT	Upland Shallow Loam (Black Sagebrush)	93.9	0.2	0.5
Total land area = 61048.2 ha Total shrubland = 19145.0 ha				

Table 3. Description of ecological sites selected for upland monitoring in Canyonlands National Park.

Ecological Site Name/ **notation/ No.**	Physiognomic type	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Semidesert Sand (four-wing saltbush) / **SDS212 / 212**	herbaceous	deep sands on dunes and sand sheets	eolian deposits derived from sandstone	dominated by Indian ricegrass, four-wing saltbush, and Mormon tea	Decreased bunchgrass and saltbush and increased snakeweed, prickly pear, juniper, and sand sage. Russian thistle may invade.
Semidesert Sandy Loam (four -wing saltbush) / **SDSL215 / 215**	herbaceous	deep sandy loams on mesas and valleys	alluvium and eolian deposits derived mainly from sandstone	dominated by Indian ricegrass, needle and thread, four-wing saltbush, and Mormon tea	Decreased bunchgrass and increased snakeweed, Mormon tea, and prickly pear. Cheatgrass and Russian thistle may invade.
Semidesert Shallow Sandy Loam (blackbrush) / **SDSSL236 / 236**	shrubland	shallow sandy loams on benches and mesas	residuum and/or eolian deposits from sandstone	dominated by blackbrush, juniper, and pinyon pine	Decreased bunchgrass and increased juniper, blackbrush, and prickly pear. Cheatgrass and annual forbs may invade.
Desert Sandy Loam (four -wing saltbush) / **DSL118 / 118**	herbaceous	deep sandy loams on mesas, stream terraces, and broad valleys	alluvium and/or eolian deposits derived from sandstone	dominated by Indian ricegrass, galleta, dropseeds, and four-wing saltbush	Decreased Indian ricegrass and saltbush and increased snakeweed and Mormon tea. Cheatgrass and Russian thistle may invade.
Desert Shallow Sandy Loam (blackbrush) / **DSSL133 / 133**	shrubland	shallow sandy loams on structural benches and ledges on escarpments	residuum and eolian deposits from sandstone, limestone, and shale	dominated by blackbrush	Decreased bunchgrasses and Mormon tea and increased blackbrush and snakeweed. Cheatgrass and Russian thistle may invade.
Desert Sand (sand sagebrush) / **DS115 / 115**	shrubland/ herbaceous	find sands on dunes and sand sheets	eolian deposits derived from sandstone	dominated by Indian ricegrass, dropseed species, sand sagebrush	Decreased Indian ricegrass, needle and thread, dropseeds, and increased sand sagebrush, broom snakeweed, and low rabbitbrush

Figure 1. Examples of the ecological sites initially selected for upland monitoring in Needles and ISKY districts of CANY. See Table 3 for descriptions.



Soil map units corresponding to the selected ecological site types were evaluated based on the reported percentages of site types within a map unit, and the spatial extent of map units. Based on this evaluation, 17 soil map units were selected for further consideration (Table 4). After the initial filtering of inaccessible areas, and of unsuitable soil map units, the remaining area (shown in Fig. 2 as target areas) was included in field-based investigations of ecological site types.

Table 4. List of soil map units by selected ecological site. Bold, italicized map units were deleted from consideration due to limited amounts of target ecological sites within the map unit or the limited spatial extent of the map unit.

Vegetation community – target ecological site no. (name)	**Soil map units with ≥35% of target ecological site**	**Soil map units with <35% of target ecological site**
SHRUBS – 133 (DesertShallowSandyLoam (Bl. Brush))	1, 56, 57	11, ***20, 40,*** 51, ***58***, 71, 73, ***75***, 76, 80, 99
SHRUBS – 236 (SemidesertShallowSandyLoam (PJ))	71	42, ***55, 71***,75, 76
SHRUBS – 115 (DesertSand (Sand Sagebrush))	80	1, 57, 58, 73
HERB – 212 (SemidesertSand (4-wing Saltbush))	51, 76	7, ***8***, 10, ***41***, 42, ***55, 63, 70,*** 71, ***74***, 75
HERB – 215 (SemidesertSandyLoam (4-wing Saltbush))	7, 10, 42, 66, 67	***6***, 51, ***63***, 71
HERB – 118 (DesertSandyLoam (4-wing Saltbush))	11, 58, 88	1, ***20***, 56, ***61***, 73, 80, ***89, 95***

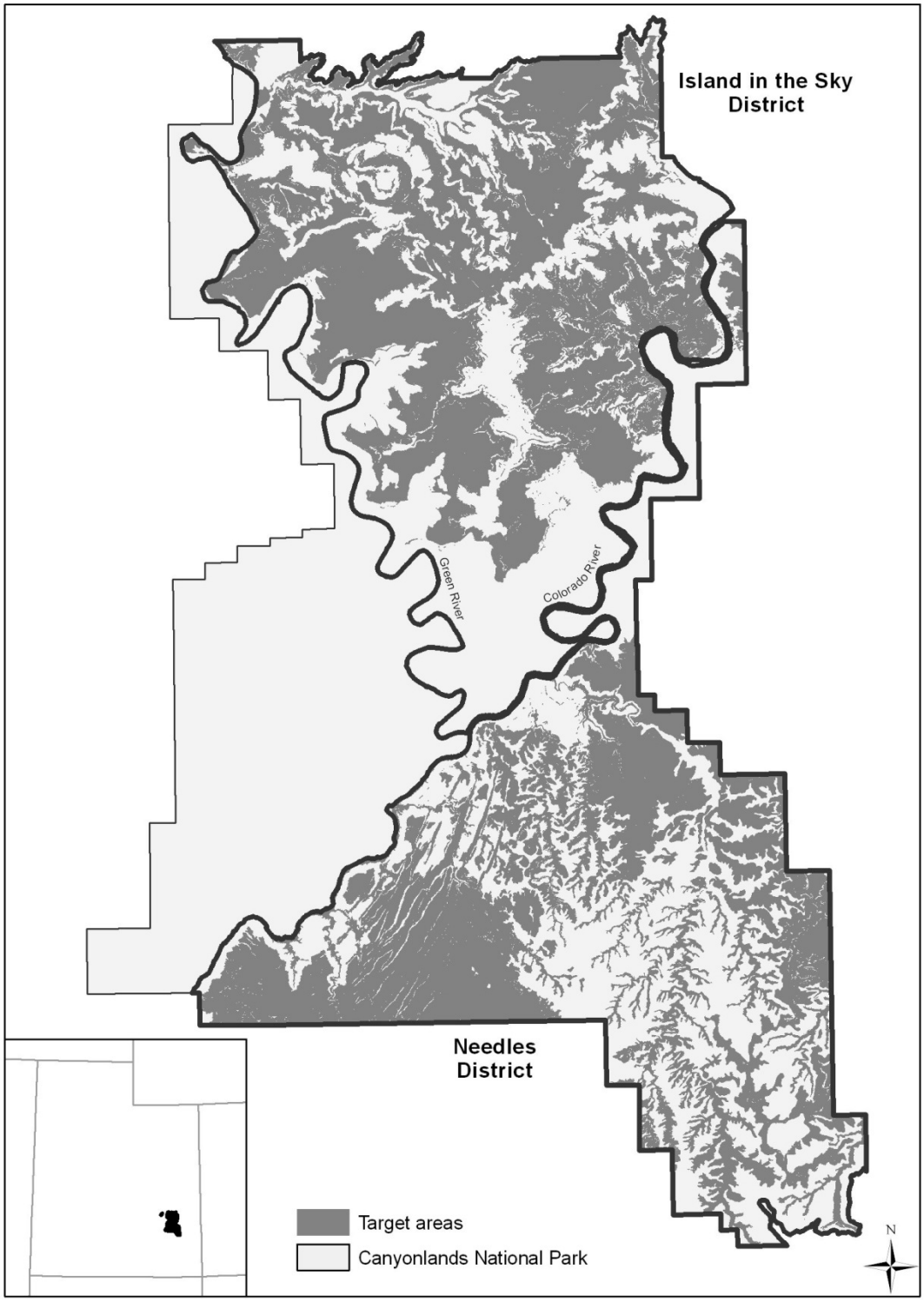


Figure 2. Location of the districts selected for initial Upland Vegetation and Soils monitoring in CANY, and the resulting portion (target areas) of these districts considered in field investigations of ecological sites.

Training Samples for Predictive Mapping

Mapping of ecological sites was required since the soil components which define ecological sites are not explicitly mapped in soil surveys. Predictive mapping requires the use of training sites. Training sites for predictive mapping were acquired in 2006 by sampling 376 locations across the soil map units listed in Table 4. Additionally, 85 samples were contributed by a contemporary study conducted in the Salt Creek drainage (Miller pers. comm.). At each location, the dominant ecological site type was determined using ecological site descriptions (SCS 1991), and aerial extent of the site type was estimated. After eliminating non-target site types and small areas (<1 ha), 178 samples were available for the six target site types. Additionally, 41 large rock outcroppings were hand digitized from color DOQQs and served as training sites for these landscape features.

For the final set of training sites used in predictive mapping, point locations were converted to circles or other geometric shapes based on field-estimated shape and dimensions of the extent of the described site type. This spatial representation is necessary for the predictive mapping method described below.

Predictive Mapping of Ecological Sites on the Landscape

The Feature Analyst (FA) package (VLS 2002) was used for predictive mapping of ecological site types. FA employs inductive machine-learning algorithms to develop pattern recognition rules from the spectral, spatial, and ancillary information of training sites classified to a feature class type. The minimum spatial structure of a feature class is specified by a pattern template (contextual classifier), which is used in evaluating the contextual signal of a feature. Contrasts in the pattern of spectral and related information among feature classes are the basis of the extraction rules. Once rules are developed, they are used to generate a predicted map of feature classes. The use of contextual features and machine learning is increasingly used in predictive mapping, and noticeably has been applied to mapping soils (Zhu et al. 2001) and landforms (MacMillan et al. 2007).

An overview of the procedures for predictive mapping of ecological sites in Canyonlands NP is provided in Garman et al. (2010). The training samples plus color DOQQs, elevation, and geology were used to generate feature-extraction rules. The spatial extent of each training site defined the context of vegetative properties (provided by the three color bands of the DOQQs), elevation, and bedrock geology. FA automatically applied the internally generated pattern rules to the input landscape which was defined by soil map units known or suspected to contain target ecological sites. The output from FA was a predicted map of target ecological sites.

Two predictive maps were generated using different options and input combinations of data layers (Table 5). Assessments of both maps indicated differential success in mapping site types, based on overlays with the training sites. The second FA prediction had the greatest agreement with the training sites with the exception of certain areas which were confounded by shadows on the input DOQQs. These areas corresponded to soil map unit #99. The area corresponding to this soil map unit was masked-out to produce the final predictive map of ecological site types. This final predictive map (see figures 3 and 4) contains predicted ecological site numbers (described in Table 3).

Table 5. Feature Analyst (FA) parameters and options used in predictive mapping of ecological site types.

Name of FA predicted map	Contextual classifier*	Resampling (no. of pixels)		Histogram status*	Minimum patch size in output shape file (no. of pixels)	Wall to wall classification*	Input data layers	Exclusions from input data layers
		Input data layers	Internal to FA*					
FA_map1	13 pixel Manhattan	2	2	off	150	off	elevation (10-m grain), bedrock geology (10-m grain)	Removed areas around paved roads (10-m buffer), around gravel roads (8-m buffer)
FA_map2	13 pixel Manhattan	2	2	off	250	on	elevation (10-m grain), bedrock geology (10-m grain)	Removed areas around paved roads (10-m buffer), around gravel roads (8-m buffer)

* see VSL (2002) for description.

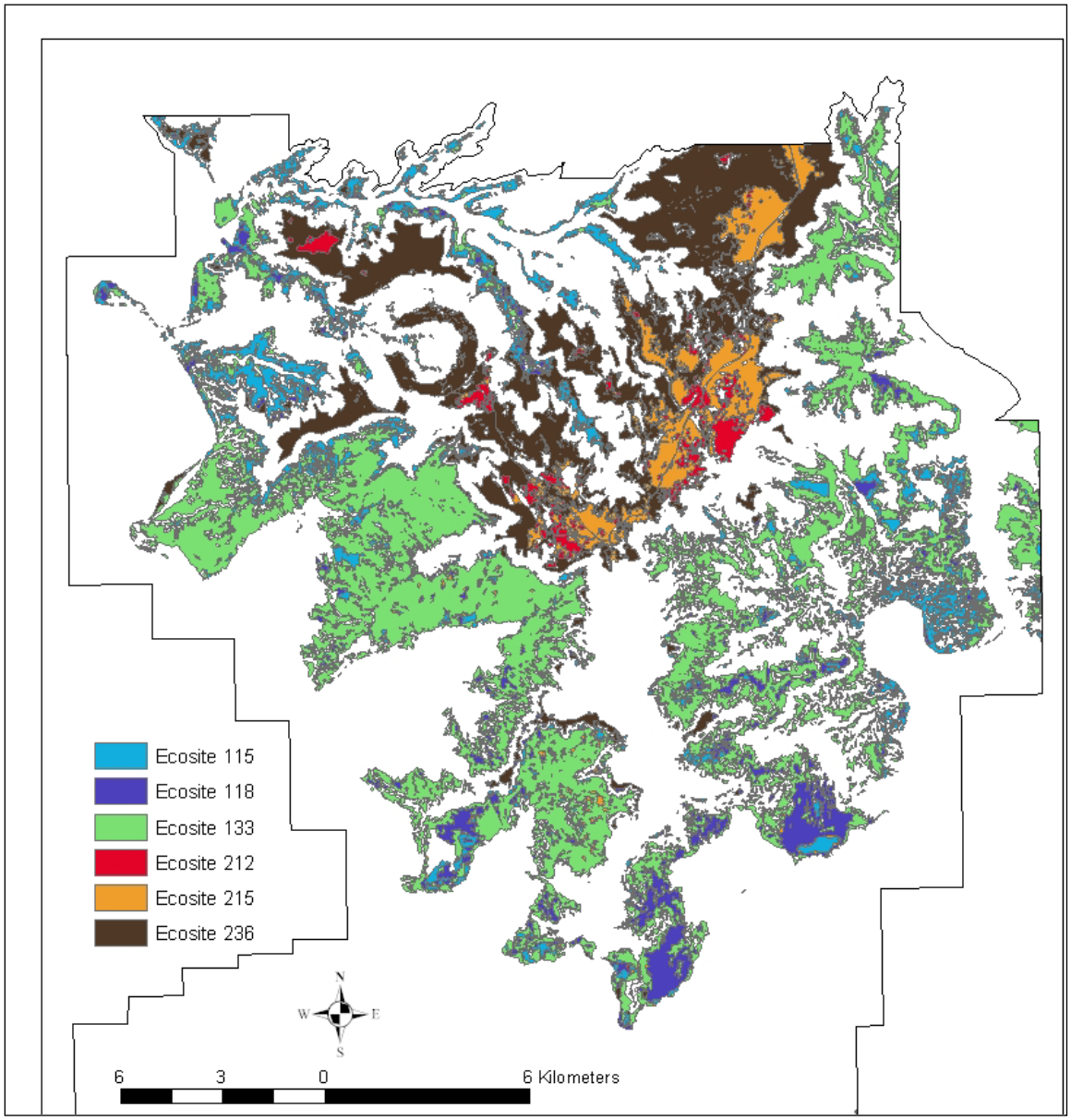


Figure 3. Predicted target ecological sites (ecosites) for the ISKY district of CANY. Ecosite numbers are defined in Table 3.

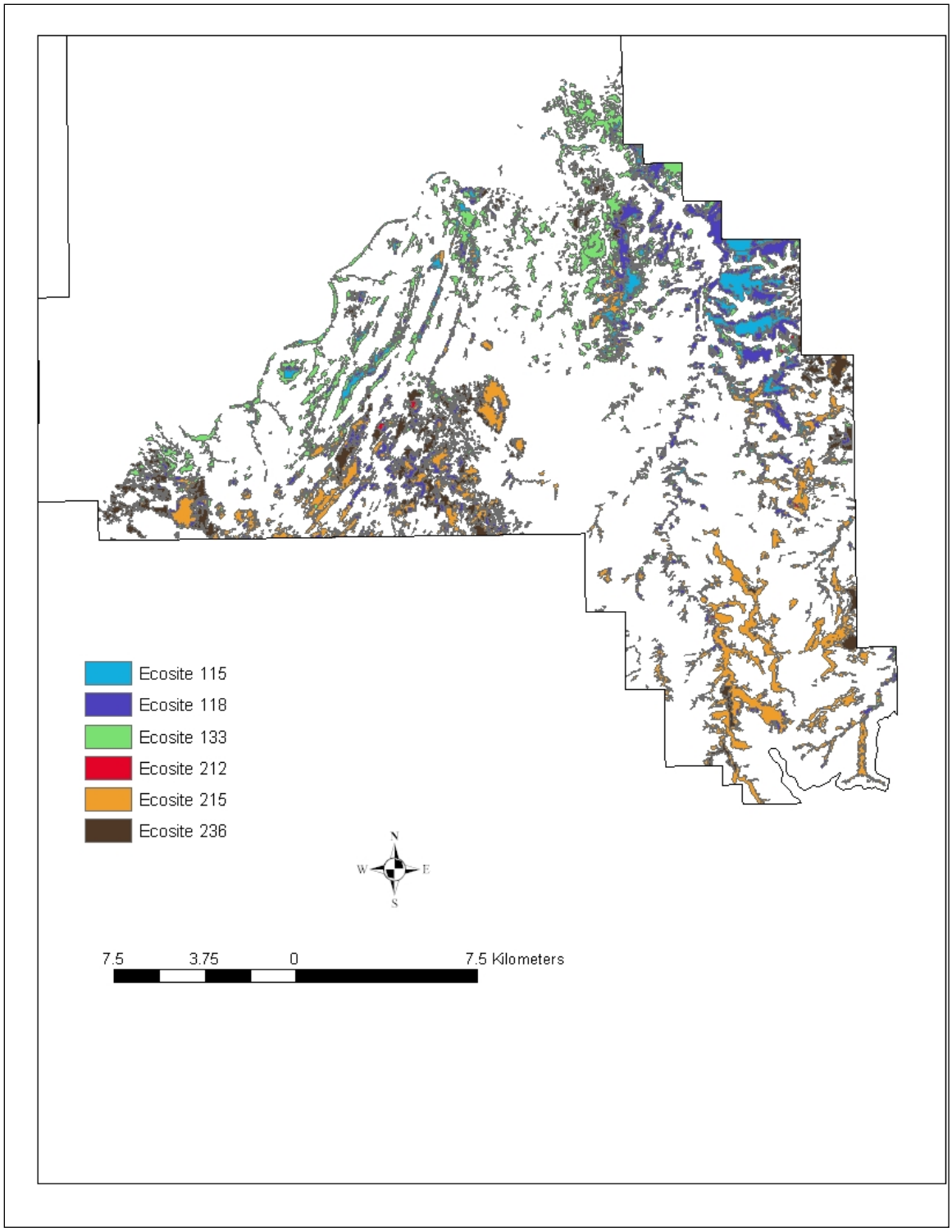


Figure 4. Predicted target ecological sites (ecosites) for the Needles district of CANY. Ecosite numbers are defined in Table 3.

Preparation of the Predicted Ecological Site Map for Monitoring Site Selection

To avoid selection of sites too close to site-type boundaries, polygons of predicted site types were buffered 'inward' by 30 meters. Also, to optimize the use of contextual features in FA, not all inaccessible areas were masked-out in the data layers used in the predictive mapping. In addition to buffering, inaccessible areas were eliminated based on the accessibility results described above. Predicted rock outcroppings also were eliminated. The resulting map was used in the selection of monitoring sites (described in 5.0).

Monitoring Site Selection

Monitoring sites were selected using R-GRTS (Stevens and Olsen 2004). An area-frame was employed for all site types. This simply required the use of an ArcGIS shape file with unique coding for each ecological site. Although 30-60 sites per ecological site type are expected for operational monitoring purposes, an over-sample was selected, for a total of 300 locations per site type. The output from the R-GRTS site-selection procedure is stored as cany_sites.shp, and contains the selected points for each target site type.

Tracking Monitoring Sites

CANY_upland_master.shp, derived from cany_sites.shp, contains all potential monitoring plots and any relevant tracking information (Table 6). The attributes include acceptance or rejections of plots, reasons for rejection, and date of plot establishment. It is used to schedule pre-monitoring evaluation of sites and for the eventual derivation of selection probabilities.

Table 6. Attributes of CANY_upland_master.shp for tracking Canyonlands National Park upland monitoring locations.

Field	Description
Veg_Type	Vegetation type for upland sampling methods (grassland/shrubland)
EcoType	Predicted vegetation type based on sampling frame (blackbrush=133; grassland=115, 118, 212, or 215; PJ=236)
MasterStrat	Indicates groups for analyzing data (blackbrush, grassland, PJ)
PlotID	The plot number, based on the siteID produced by GRTS
panel	Panel that plot is associated with in the revisit design (1-14, panel=0 for rejected plots)
PanelYear	Year(s) that panel is sampled (1-7)
EvalStatus	Ultimate status of a plot (estab = established; NotEval = not visited; accept = visited and deemed to be acceptable as a monitoring site; reject = rejected, REMOVE=plot that was established but later deemed inappropriate for monitoring)
S_Action	Status of plot determined in the field and recorded on GPS (accept or reject)
EvalReason	Describes why a site was accepted or rejected
Estab_Date	Month, day, and year of plot establishment
Soil_MU	Soil map unit from UT633 associated with the monitoring plot
xcoord	UTM E (NAD83, Zone 12)
ycoord	UTM N (NAD83, Zone 12)
Hike_km	Hiking distance to plot in kilometers
AreaDescr	General area of the park where the plot is located
Comments	Miscellaneous
PredEco	Predicted ecological site number of each plot (133, 236, 115, 212, 215, 118)
siteID	GRTS-assigned ordered unique identifier
stratum	GRTS attribute not used for selection of these sites (None)
mdcaty	Predicted ecological site code used by GRTS (1=133; 2=236; 3=115; 4=212; 5=215; 6=118)
wgt	1/selection probability for each point

Modifications After Pilot Implementation

Target Ecological Site Types

During the first two years of implementation (2006-07), the inability to differentiate 115-Desert Sand (Sand Sagebrush) from 118-Desert Sandy Loam (four-wing saltbush) became apparent. Also, SCS (1991) descriptions of the Desert Sand type did not seem to correspond to the areas reported to contain large amounts of this type (i.e., soil map units dominated by this type). For these reasons, this site type was dropped from the initial pilot monitoring effort. Inclusion of these areas in the operational survey design will be determined after analyzing the pilot data.

Accessibility

The sampling frame area was restricted to a 4 km hiking distance due to the difficulty of the terrain in some sections of CANY.

FA Predictive Mapping

During the pilot implementation of monitoring, errors in the FA predicted map used in site selection became readily apparent. Of special concern was the over-prediction of ecological site number 212 (Semidesert Sand), the under-prediction of site number 215 (Semidesert Sandy Loam), and the inclusion of very rocky areas in predictions of site number 236 (Semidesert Shallow Sandy Loam).

Using the field-visitation information after initial implementation efforts (2006-07), the Hierarchical Learning feature of FA was employed to generate new predictions of ecological site types. The learning process evaluates the contextual properties of locations predicted correctly and incorrectly, and generates new rules for prediction. This learning process is performed separately for each feature of a mapped area. A feature in this case was an ecological site. The learning procedure used the original training sites, the original predicted map, and the GRTS-selected locations which had been visited in the field. For the latter, the field-assigned ecological site was used to determine correct and incorrect predictions in the original FA procedure. Additionally, large well-defined patches of an ecological site were hand-digitized to increase sample size and the contextual representation of these types. New predicted maps were generated for each of the five target ecological site types (No. 115 was eliminated from consideration for reasons described above), and merged.

Literature Cited

Garman, S. L., D. Witwicki, and A. Wight. 2010. Mapping ecological sites for long-term monitoring in national parks. *In* van Riper III, C., B. F. Wakeling, and T. D. Sisk, eds., The Colorado Plateau IV: Shaping conservation through science and management. Tucson: The University of Arizona Press.

MacMillan, R. A., D. E. Moon, and R. A. Coupe. 2007. Automated predictive ecological mapping in a forest region of B.C., Canada, 2001-2005. Geoderma 140:353-373.

SCS (U.S.D.A. Soil Conservation Service). 1991. Soil Survey of Canyonlands area, Utah, Parts of Grand and San Juan Counties. Salt Lake City: U.S. Department of Agriculture, Natural Resources Conservation Service. 293 p.

SRM (Society for Range Management). 1989. Glossary of terms used in range management. 3rd edition, Society for Range Management, Denver.

SRM (Society for Range Management). 1995. New concepts for assessment of rangeland condition. Journal of Range Management 48:271-282.

Stevens, D. L. and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

VSL (Visual Learning Systems). 2002. User Manual, Feature Analyst Extension for ArcView 3.2, Visual Learning Systems, Inc. Missoula, MT.

Zhu, A-Xing, B. Hudson, J. Burt, K. Lubich, and D. Simonson. 2001. Soil mapping using GIS, expert knowledge, and fuzzy logic. Soil Science Society of America Journal 65:1463-1472.