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Full Length Article

Monitoring Restoration Impacts to Endemic Plant Communities in Soil Inclusions of Arid Environments

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Abstract

Slickspots are soil inclusions with unique loamy soils that provide habitats for many endemic plants worldwide, including those within sagebrush steppe. Sagebrush-dominated communities are declining and require restoration, but restoration techniques commonly used may impact negatively some intermixed communities found on soil inclusions including those on slickspot soils. Slickspot soils have unique physical and chemical properties that create saline environments with limited plant cover that may include an endangered plant. This study was conducted to yearly variations in slickspot soil areas on sites treated with the herbicide glyphosate and/or seeded with a minimum-till drill relative to control areas. During spring 2004, 2005 and 2006, aerial photography and ground measurements of slickspot areas were taken. Images taken in spring, when vegetation is live and green, can be used to define and measure slickspot soils. Differences among treatments and years of surface area of slickspots were less than 1 m^2 per subplot, out of a possible 780 m^2 per subplot, and were not statistically significant. This implies that there is no effect of minimum-till drill and/or glyphosate on slickspot soil extent and that slickspots are fairly stable over time. Aerial photography provides faster and comparable results to traditional ground-based monitoring, while providing managers with a reliable means of tracking these ecosystems across a landscape. © 2013 Friends Science Publishers

Keywords: Aerial photography; Glyphosate; *Lepidium papilliferum*; Remote sensing; Seed drill; Slickspot extent

Introduction

Vegetation communities are groups of associated plants with similar resource requirements. Generally, they grade from one association into another as either soils or climate grades across a landscape. Discrete community boundaries are often seen when abrupt changes occur between differing soils. Many countries have soil mapping conventions to understand where soils exist and appropriate land uses. Australia uses the Australian Soil Resource Information System (ASRIS, 2011) and generally maps soils to the Land System level, while the United States uses the Cooperative Soil Survey and provides maps to the Map Unit level (USDA NRCS, 2012). These mapping units are often in excess of 4 ha (10 acres). However, not all soils that are important for management can be efficiently and effectively mapped at these scales.

Soil inclusions are taxonomically different soils within soil-mapping units that represent a small portion (<15%) of that unit often forming soil islands with a distinct plant community nested within a more common soil with a different plant community. Plants may evolve endemic relationships with these soils (Romao and Escudero, 2005) and different plant communities may exist. When these inclusions are small and rare they may become the sole habitat for rare plants (Kruckeberg and Rabinowitz, 1985; Sanaullah *et al.*, 2008). These rare habitats and their occupants may create potential problems for restoration practitioners who desire to restore communities on surrounding common soils. They can avoid using potentially harmful practices on these communities or they can determine the impact of restoration practices and then elect to proceed based on the perceived risks and benefits.

In western North America, slickspot soils are characterized by small soil patches (<200 m^2) that, because of their size and their tendency to occur on rangeland environments, have been pedologically undefined. Recent papers have attempted to provide soil profile chemical comparisons to surrounding soils to better understand unique features of slickspots. Slickspot soils are defined by being saline with higher electrical conductivity (EC > 4 vs. < 2 mmho cm^{-1}) and sodium ions (Na^+ 15 to 115 vs. 2 to 23 mmol L^{-1} with depth) than surrounding soils when comparing similar soil horizons from the surface through their common argillic horizons (Fisher *et al.*, 1996). In addition, slickspot soils have lower total C, total N, and

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extractable K, while having higher pH and Na adsorption ratio (Mao *et al*., 2010). Slickspot soils (also known as playettes and natric soils) are an example of a soil inclusion that creates a plant community that is largely devoid of vegetation except for salt-tolerant annuals. These community islands survive within a larger landscape dominated by big sagebrush (*Artemisia tridentata*) grassland communities. In fact, sagebrush steppe is one of the largest semiarid ecosystems in North America (Miller *et al*., 2011), but is restricted to non-saline soils. However, some invasive plants such as cheatgrass (*Bromus tectorum)* that threaten sagebrush-dominated communities, also threaten slickspot communities. Slickspot soils provide habitat for an endemic plant within sagebrush steppe in southwestern Idaho, USA, *Lepidium papilliferum* (slickspot peppergrass) that is listed as threatened under the Endangered Species Act (USFWS, 2009). Potential threats to this plant include wildfires, post-fire rehabilitation activities, and encroachment of non-native plants (Meyer *et al*., 2006; USFWS, 2006).

Post-fire rehabilitation and restoration within sagebrush steppe commonly include ground-based seed drills and herbicide applications. The physical and chemical properties of slickspot soils that dictate their unique vegetation community cannot be recreated once lost. Since seed drills inherently cut into soil to plant seeds, there is a concern that seed drills will reduce the integrity of argillic horizons and of the soil chemistry that define slickspot soils, thus weakening the ability of these soils to maintain their unique qualities and their unique plant communities. For example, soil disturbances that may potentially impact slickspot integrity, or may promote introductions of seeded or invasive species into slickspots must be avoided (USFWS, 2009). Herbicides may kill vegetation on both slickspot and adjacent sagebrush communities. But since slickspot communities are initially sparse, dominated by annual plants, and appear to maintain an active seed bank (Meyer *et al*., 2006), some contact herbicides that breakdown quickly in the environment may significantly impact live plants, but may not impact seeds in soils. In addition, weedy species such as cheatgrass are thought to threaten the plant community on slickspots so appropriate herbicides may be beneficial in reducing the spread of weeds on slickspot soils.

Sparse vegetation of arid communities and slickspots enhances the potential of using remote sensing techniques to monitor slickspot integrity. Aerial photography was used to compare image processing results to traditional ground-based measures of slickspot soil extent. Determinations were made of whether habitat area for slickspot peppergrass changed when using a minimum-till drill or ground-applied glyphosate herbicide.

Materials and Methods

The study was located on a flat area (0–4% slope) of the Snake River Plain, Idaho USA (43˚ 14' 46"N, 115˚ 53' 58"W). Dominant soils in the study area were mapped as a Lankbush-Jenness association map unit (Elmore Area, Idaho, Soil Survey; http://soildatamart.nrcs.usda.gov accessed 4 February 2013) with inclusions of slickspot soils (Fisher *et al*., 1996). The study area had the Lankbush Map Unit Component that was verified by soil diagnostic textural horizons with a sandy loam surface horizon grading to a sandy clay loam at about 30 cm deep. The Lankbush soil corresponds to a potential plant community dominated by *A. tridentata* ssp. *wyomingensis* (Wyoming big sagebrush), *Pseudoroegnaria spicata* (bluebunch wheatgrass) and *Achnatherum thurberianum* (Thurber's needlegrass) (Noe, 1991). These soils are now often dominated by *B. tectorum* (cheatgrass), an invasive annual grass that also threatens to invade slickspot soils. Slickspot soils are dominated by salt-tolerant annual plants including *L. papilliferum* (slickspot peppergrass) when it exists (Fisher *et al*., 1996).

Mean annual precipitation for the site is 317 mm. Precipitation during spring and summer 2004 was below average during herbicide application, seed germination and seedling establishment. Although the mean annual precipitation was the same in 2005 and 2006, spring 2006 (March, April and May) was drier than spring 2005 (130 compared to 178 mm) (Table 1).

Seeding and herbicide treatments were applied in fall and spring 2004 for a separate project (Allcock *et al*., 2006). For the slickspot soil study, twelve subplots (36.5 × 21.3 m), were assigned randomly into each of four treatments: (1) no treatment (control); (2) glyphosate (0.88 AI l/ha) sprayed in April 2004 using a boom mounted on an all-terrain vehicle; (3) seeded using a minimum-till rangeland drill in October 2004; (4) treated with both herbicide and seeding. Five native and five introduced grasses and one native forb were sown using a Roughrider Rangeland Drill® (Truax Corporation, New Hope, Minnesota, USA). All seeded species are typical of those sown on the Lankbush soil in this climate. The herbicide was intended to control weedy species that dominated the study area before restoration.

Conventional color aerial photographs were taken at 730 m using a 30-cm mapping film camera mounted on a fixed-wing aircraft. A single photograph covered 12 subplots with a ground resolution (pixel size) of 6.72 cm. The image was geo-referenced using ERDAS® (Leica Geosystems, Atlanta GA) and slickspot soils were classified using VegMeasure® software (Oregon State University, Corvallis OR) and slickspot areas were determined in each subplot. Image classification using VegMeasure followed procedures by Louhaichi *et al*. (2010). Furthermore, ground-truthing data were collected for accuracy assessment. Direct measures of surface area on the ground were not made because of the fragility of these sites, but length and width of slickspots (major and minor axes) were measured. Each measurement direction was marked on the aerial photograph so it could be measured on the rectified aerial images and photogrammetrist classified images. These measurements

Table 1: Precipitation (mm) data from 2004, 2005, and 2006 for Cinder Cone Butte

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	"Total
2004	39.9	46.8	9.5	13.8	38.7	5.4	5.6	12.3	8.4	38.4	22.3	57.1	298.2
2005	10.5	8.2	33.8	31.2	112.9	21.0	3.3	2.0	6.4	12.0	52.0	87.3	380.6
2006	81.2	12.8	45.1	56.1	29.2	25.3	8.4	0.5	6.7	14.8	46.8	53.8	380.7

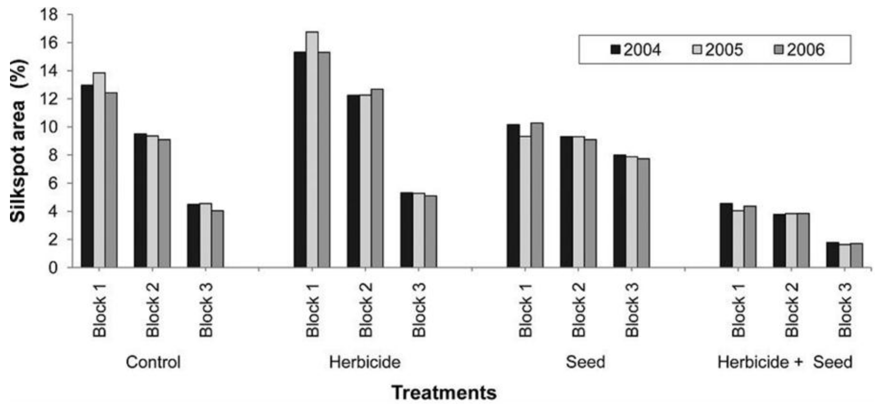

Fig. 1: Variation in slickspot area (%) over time per plot and per treatment based on the on-screen digitizing of the color aerial photography

were compared to corresponding slickspot measurements in control subplots (N = 3) by digitizing on screen for each of the three image resolutions to determine which resolution has the least error.

To determine if slickspot size changed significantly among years, the slope of the linear regression line of slickspot area by year for control subplots was compared to determine if it differed from zero (Kleinbaum *et al*., 1998). Provided this area did not change, an analysis of variance (ANOVA) without accounting for annual variation in slickspot size could be conducted to determine if herbicide application or drilling seed affected slickspot size. A simple model with year and treatments as factors was used.

Results

The mean total area of control slickspot soils within the study site based on photo interpretation and digitizing manually over years 2004 to 2006 was 189.5 m^2 with 2.4 m^2 variation. The change from year-to-year was less than 1% (Fig. 1) and regression lines had slopes not significantly different from zero (P = 0.69). Observations indicated this was within normal variations associated with the effects of parallax, camera distortion, and rubber sheeting distortion or confusion over animal disturbances (Fig. 2). There was no significant difference in slickspot surface area between year 1 (prior to treatment) and either successive year (year 2 p=0.19; year 3 p = 0.70). In addition, no significant differences in slickspot areas due to herbicide or seed drill application (year 1 vs. 2 p = 0.27; year 1 vs. 3 p = 0.69) were detected. Commercial aerial photos provided an acceptable resolution (pixel size = 6.72 cm). The image processing technique classified slickspot area within nearly 2% of the 8.2% determined by a photogrammetrist (range=6.0% and 9.4%) for the 780 m^2 of the experimental control subplots.

Discussion

Restoration and rehabilitation of plant communities on common soils when those communities have unique edaphic communities nested within their present boundaries challenge land managers with developing cost-effective practices for treating broad-scale environments without harming these finer-scale systems nested within. In the case of slickspot habitats nested within potential sagebrush habitats, land managers are faced with the need to restore and rehabilitate large tracts of land (USFWS, 2006). The majority of this area has the potential to support a sagebrush-steppe community. The invasion and dominance of cheatgrass in this region has led to an increase in wildfires and to a conversion to annual grasslands (Miller *et al*., 2011). Typical restoration emphasizes the use of techniques such as herbicides and seed drills to control invasive species and to insure that seeds imbibe, germinate, and establish (Monsen and Stevens, 2004). These techniques may negatively impact edaphic communities found on soil inclusions nested within these larger communities by killing vegetation, introducing inappropriate plants, or physically changing the unique soils in the edaphic community.

Two concerns relating to the survival of slickspot peppergrass are applications of herbicides and seeding treatments to enhance restoration and rehabilitation of sagebrush steppe (Meyer *et al*., 2006; USFWS, 2006).

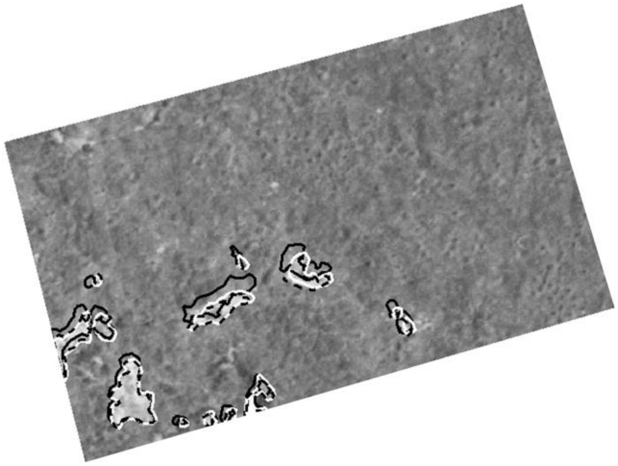

Fig. 2: Solid black, solid white and dashed black polygon's color boundaries represent the change of slickspots in 2004, 2005, and 2006 respectively for subplot number 7. The effect of parallax, camera distortion and rubber sheeting distortion can be seen in the outlined position of the slickspots between years

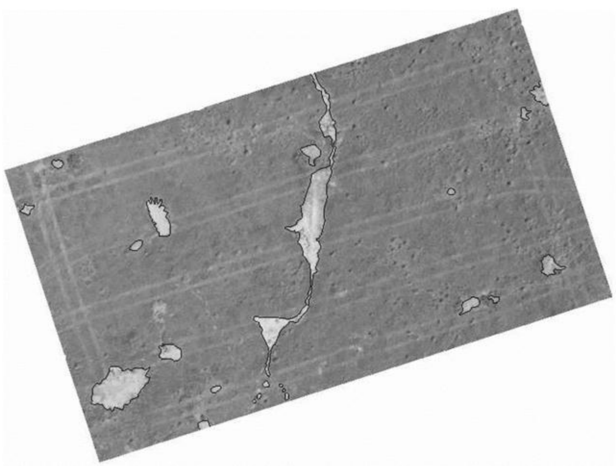

Fig. 3: Example of slickspots that have been identified by a photogrammetrist and digitized on a computer screen

This study provided no evidence of changes in slickspot soil area when either the herbicide glyphosate was applied in the spring to reduce cheatgrass cover or when a minimum-till drill was used to seed native grasses and forbs. Since slickspot soils are small inclusions (< 200 m^2) within these larger sagebrush-steppe environments, it is impractical to avoid them during revegetation projects. Our findings indicate that plants surrounding and those seeded into the slickspots did not invade or establish and grow in slickspots after these treatments were applied. If slickspot areas had declined then someone would need to determine if it was due to invading vegetation or due to increases in slickspot vegetation.

Previous studies showed mixed results regarding the success of seeded species to survive in slickspots. Documented growth of seeded introduced plants from seed drills pulled through slickspots was reported (USFWS, 2006). These used traditional rangeland drills that opened a furrow to seeds. Scholten (2000), similar to our study, found no evidence for survival of seeded species on slickspots.

In conclusion, remote sensing techniques offer advantages of rapid data acquisition with generally short turnaround time and procedures that are considerably less costly than ground surveys (Everitt *et al*., 1995). Slickspot soil areas can be mapped accurately using low-level aerial photography. The brightness characteristics of slickspots made spectral classification relatively easy (Fig. 3); nevertheless, some confusion may arise from animal activities, such as badger or ant mounds, that can add to classification errors requiring initial field visits for identification. However, using fixed-wing aerial photography with large-format mapping cameras allows the coverage of large areas in high resolution, single images that are well suited for inventorying and monitoring landscapes. This technique can provide an easy method for initial inventories of these unique soil habitats, may identify new potential habitat for rare endemic plants such as slickspot peppergrass, and may provide an accurate monitoring technique for tracking potential changes in slickspot area.

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References

ASRIS (Australian Soil Resource Information System), 2011. *ASRIS – Australian Soil Resource Information System.* CSIRO Land and Water, Canberra, Australia. Available at: http://www.asris.csiro.au/ (Accessed: 4 February 2013)

Allcock, K., R. Nowak, R.R. Blank, T.A. Jones, T.A. Monaco, J. Chambers, R. Tausch, P. Doescher, V. Saytal, J. Tanaka, D. Ogle, L. St John, M. Pellant, D.A. Pyke, E.W. Schupp and C.A. Call, 2006. Integrating weed management and restoration on western rangelands. *Ecol. Restoration*, 24: 199–200

Everitt, J.H., G.L. Anderson, D.E. Escobar, M.R. Davis, N.R. Spencer and R.J. Andrascik, 1995. Use of remote sensing for detecting and mapping leafy spurge (*Euphorbia esula*). *Weed Technol.*, 9: 599–609

Fisher, H., L. Eslick and M. Seyfried, 1996. *Edaphic Factors that Characterize the Distribution of Lepidium papilliferum,* Technical Bulletin 96-6, Bureau of Land Management, Idaho State Office, Boise, Idaho, USA

Kleinbaum, G.D., L.L. Kupper, K.E. Muller and A. Nizam, 1998. *Applied Regression Analysis and other Multivariable Methods.* Duxbury Press, Boston, Massachusetts, USA

Kruckeberg, A.R. and D. Rabinowitz, 1985. Biological aspects of endemism in higher plants. *Annu. Rev. Ecol. Syst*., 16: 447–479

Louhaichi, M., M.D. Johnson, A.L. Woerz, A.W. Jasra and D.E. Johnson, 2010. Digital charting technique for monitoring rangeland vegetation cover at local scale. *Int. J. Agric. Biol.,* 12: 406–410

Mao, J., A.J. Palazzo, D.C. Olk, C.E. Clapp, N. Senesi, T.L. Bashore and X. Cao, 2010. Chemical structure of soil organic matter in slickspots as investigated by advanced solid-state NMR. *Soil Sci.*, 175: 329–338

Meyer, S.E., D. Quinney and J. Weaver, 2006. A stochastic population model for *Lepidium papilliferum* (Brassicaseae), a rare desert ephemeral with a persistent seed bank. *Amer. J. Bot.*, 93: 891–902

Miller, R.F., S.T. Knick, D.A. Pyke, C.W. Meinke, S.E. Hanser, M.J. Wisdom and A.L. Hild, 2011. Characteristics of sagebrush habitats and limitations to long-term conservation. *In*: *Greater Sage-Grouse: Ecology and Conservation of a Landscape Species and its Habitats*, pp: 145–184. Knick, S.T. and J.W. Connelly (eds.). Studies in Avian Biology, University of California Press, Berkeley, California, USA

Monsen, S.B. and R. Stevens, 2004. Seedbed preparation and seeding practices. *In*: *Restoring Western Ranges and Wildlands,* Vol. 1, pp: 121–155. Monsen, S.B., R. Stevens and N.L. Shaw (eds.). General Technical Report RMRS-GTR-136 USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA

Noe, H.R., 1991. *Soil Survey of Elmore County Area, Idaho, Parts of Elmore, Owyhee and Ada Counties*. USDA, Soil Conservation Service, Boise, Idaho, USA

Romao, R.L. and A. Escudero, 2005. Gypsum physical soil crusts and the existence of gypsophytes in semi-arid central Spain. *Plant Ecol.*, 181: 127–137

Sanaullah, M., E. Blagodatskaya, A. Chabbi, C. Rumpel and Y. Kuzyakov, 2008. Drought effects on microbial biomass and enzyme activities in the rhizosphere of grasses depend on plant community composition. *Appl. Soil Ecol.*, 48: 38–44

Scholten, D.M., 2000. *Effects of Rangeland Rehabilitation Practices on Lepidium papilliferum (Henderson) Nelson and McBride*. M.S. Thesis, University of Idaho, Moscow, Idaho, USA

USDA NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service), 2012. *National Soil Survey Handbook*, Title 430-VI. Washington, DC, USA Available at: http://soils.usda.gov/technical/handbook/ (Accessed: 4 February 2013)

USFWS (U.S. Fish and Wildlife Service), 2006. *Draft Best Available Biological Information for Slickspot Peppergrass (Lepidium papilliferum).* U.S. Fish and Wildlife Service, Snake River Fish and Wildlife Office, Boise, Idaho, USA

USFWS (U.S. Fish and Wildlife Service). 2009. Endangered and threatened wildlife and plants; listing *Lepidium papilliferum* (Slickspot Peppergrass) as a threatened species throughout its range; Final Rule. U.S. *Fed. Reg*., 74: 52014–52064

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