

Quantifying Habitat Fragmentation in the Big Desert, Idaho

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ABSTRACT

Aerial imagery acquired in 1954, 1992, 2004, and 2009 for the Big Desert in southeast Idaho were used to quantify change in total area of irrigated agriculture for this region. Polygon feature classes were digitized for each year and stored in a personal geodatabase. Area was calculated and compared between years. Total area was determined after applying a 6.9 km buffer around the polygons to account for potential movements of human-subsidized (synanthropic) predation. The imagery for 1954 represented the state of sagebrush-steppe rangelands surrounding the Big Desert prior to significant conversion to irrigated agriculture, and thus was the basis for comparison between 1954 and 2009. Results indicate the Big Desert has seen an increase (>50%) in irrigated agriculture between 1954 and 2009, most of which occurred between 1954 and 1992(~50%).

KEYWORDS: Sage-grouse, agriculture, cropland, irrigated, center pivot, GIS, aerial imagery

INTRODUCTION

The Greater Sage-Grouse (*Centrocercus urophasianus*) is a sagebrush obligate species with annual home ranges that can exceed 2700 km² (Dalke et al. 1963, Schroeder et al. 1999, Leonard et al. 2000, Knick and Connelly, 2011). Historically, sage-grouse distribution was estimated to have extended through regions of 13 US states and 3 Canadian provinces (Schroeder et al. 2004, Connelly et al. 2004). Presently, sage-grouse occupy approximately half of their estimated pre-settlement distribution (Schroeder et al. 2004). Forecasting models of potential for sage-grouse persistence indicate that 75 percent of sage-grouse populations across are likely to decline below minimum viable population of 500 individuals within 100 years if current conditions and trends persist (Garton et al. 2000).

For sage-grouse, nesting and early brood-rearing periods may be considered the bottleneck for persistence of the species as predation of adult sage-grouse is at its highest frequency during the nesting and early brood-rearing period (Connelly et al. 2000a, Naugle et al. 2004, Moynahan et al. 2006, Hagen 2011). Sage-grouse exhibit strong fidelity to previous years' nest sites even if habitat within that site is no longer viable (Fischer et al. 1993, Connelly et al., 2000, Connelly et al. 2004). The minimum recommended distance of human development from sage-grouse lekking sites is 5km for non-migratory populations, and 18km for migratory populations (Connelly et al. 2000). These distances have been recommended due to observed travel distances for population types (non-migratory and migratory), however, they are also recommended with the consideration of potential movements by synanthropic predators such as domestic dogs and cats, red fox, and corvids (Leu et al. 2008, Knick et al. 2011). Nesting hens require diverse vegetation in the form of sagebrush, succulent forbs, tall grasses, and litter, not only for sustenance during prolonged idle periods of nest incubation, but also for shelter from airborne and ground-based predators (Gregg 1991, Schroeder et al. 1999, Connelly et al. 2000^a, Connelly et al. 2004, Aldridge et al. 2008). They require large areas of contiguous habitat because, though hens tend to be less mobile during the nesting period, some have been known to travel distances up to 6.2 km between nest and lek sites (Connelly et al. 2000). Sage-grouse average 51 percent nest success in relatively non-altered habitats and 37 percent in altered habitats (Connelly et al. 2011), with partial clutch loss occurring in ~50 percent of nests. This loss is partially, if not largely, due to predation during nesting and early brood-rearing periods. Predation of adults is less common during this period due to their tendency to abandon nests under predator threat (Patterson 1952, Hagen 2011). However this leaves eggs and recently hatched chicks vulnerable to predation instead. Human development such as irrigated agriculture, infrastructure such as roads, powerlines, and pipelines, and urbanization has fragmented sage-grouse habitat in sagebrush-steppe rangelands, aiding predator movements, particularly those of synanthropic predators (Tewksbury et al. 2002, Knick and Connelly 2011).

Habitat fragmentation refers to permanent or long lasting dissection of natural systems into spatially isolated parts resulting from either anthropogenic or natural influences, where they are impacted such that habitat suitability for a species or community of animals is diminished (Galvin et al. 2008). What are now coined semiarid sagebrush-steppe rangelands were once described as a "sea of sagebrush" in journals of early American explorers such as John C. Frémont and Lewis and Clark (Frémont 1845). Since that time, the "sea of sagebrush" has been divided into several discontinuous "lakes" through human development such as paved roads, fencing, urban centers, residential developments, and large-scale conversion to irrigated agriculture such as center pivot irrigation. For sage-grouse, habitat fragmentation may aid predation (Fichter and Williams 1967, Pasitschniak-Arts et al. 1998, Bunnell 2000, Connelly et al. 2000^a,

Connelly et al. 2004, Leu et al. 2008, Knick et al. 2011), exacerbate the spread of invasive species such as cheatgrass (*Bromus tectorum*) (Vitousek et al. 1997, Smith et al. 2000, Browder et al. 2002, Knick et al. 2003, Connelly et al. 2004, Hansen et al. 2005), or limit the total area of contiguous, undisturbed habitat available to them (Connelly et al. 2004, Aldridge et al. 2008). The underlying cause for population declines across the entire sage-grouse distribution is loss of suitable habitat (Connelly and Braun 1997, Leonard et al. 2000, Aldridge et al. 2008, Knick and Connelly, 2011). Almost all of the Snake River Plain in southern Idaho (Figure 1) that contains deep loamy soils and once supported big sagebrush now has been converted to agriculture (particularly cropland) (Hironaka et al. 1983, Knick et al. 2011). Within this area the first private irrigation projects began on the upper Snake River near Wyoming in the 1870s. Agriculture (mostly cropland) currently covers >230,000 km² (11%) of the entire sage-grouse distribution, which translates to ~1,600,000 km² of total area influenced when a 6.9 km buffer is applied to account for potential movements of synanthropic predators (Leu et al. 2008, Knick et al. 2011). Leonard et al. (2000) correlated declining sage-grouse populations in the upper Snake River Plain of southeast Idaho with cropland area. Within their study area, cropland development was estimated to have increased from 18% to 28% between 1975 and 1985 respectively, and by 1992 reached 31% (Leonard et al. 2000, Knick et al. 2011). Center pivot irrigation (invented by the Mel Brown Company in 1957) visibly represents a large portion of irrigated agricultural development surrounding the Big Desert (Figure 2). No differentiation seems to be made in the current literature as to the impact of center pivot irrigated agriculture on sage-grouse habitat relative to other forms of irrigated agriculture. However, automated center pivot was developed to reduce labor costs, while also distributing water more efficiently and uniformly, which enabled agricultural development of lands that had previously been unsuitable for surface irrigation. This resulted in an increase in the use of center pivot irrigation by 50% from 1986 to 1996 (Evans, 2001).

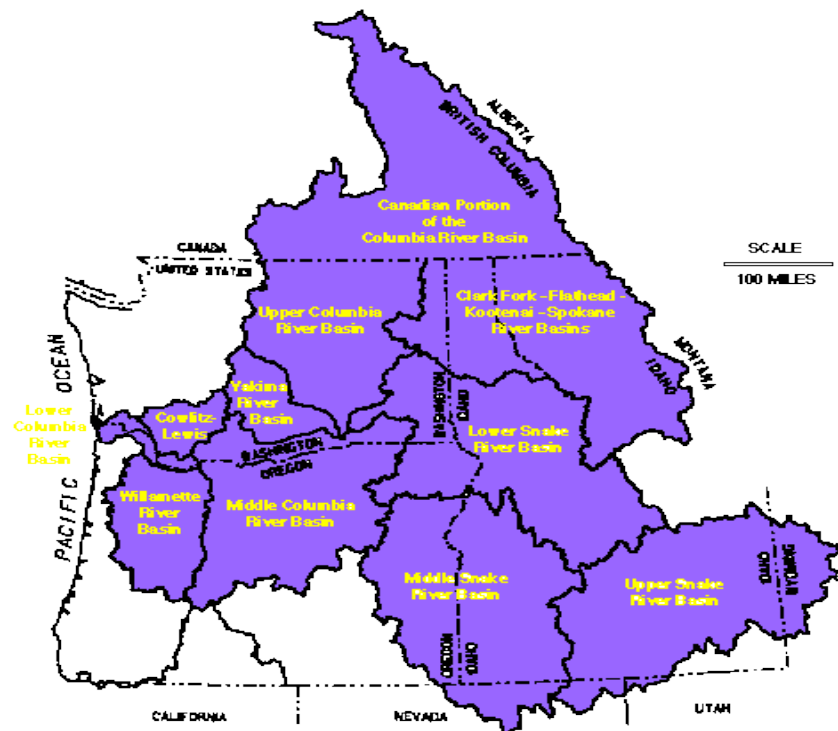


Figure 1. A map of the Columbia River Basin. The Upper Snake River plain is shown in gray (or red, or yellow) (source: US Army Corps of Engineers, North Pacific Division, CRT 69).

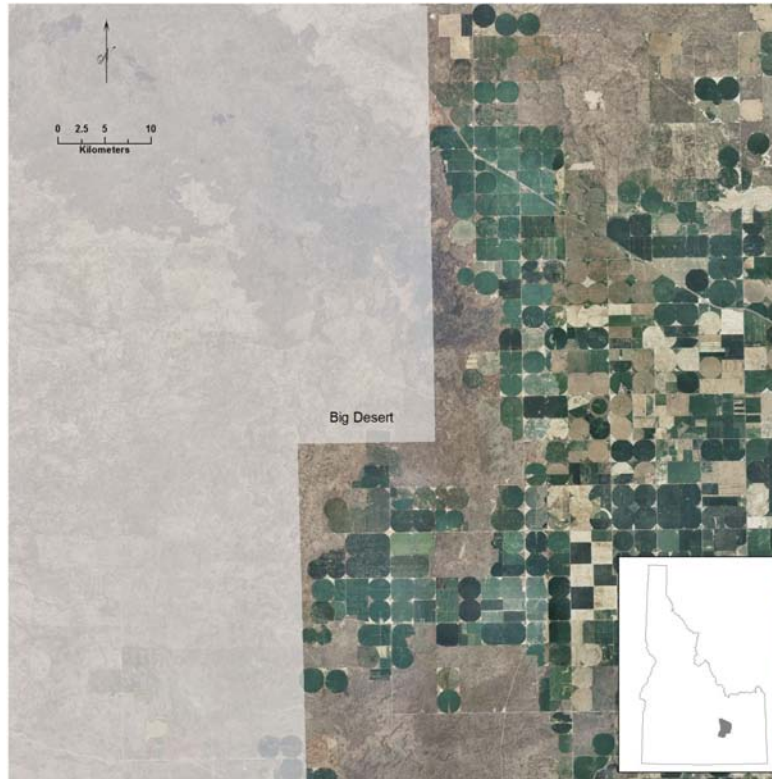


Figure 2. Irrigated agricultural development for the Big Desert, southeast Idaho. This image was generated to highlight the extent of center pivot irrigation as part of a multitemporal analysis of habitat fragmentation of sage-grouse habitat in the form sagebrush-steppe rangeland conversion to agriculture.

This paper attempts to examine habitat fragmentation in the form of irrigated agricultural development surrounding a known sage-grouse stronghold in southeast Idaho – the Big Desert. It describes the techniques used to analyze aerial image data of the Big Desert for four separate years. Image data were used to generate a multitemporal analysis of irrigated agricultural development surrounding the study area.

METHODS

Study Area

The Big Desert study area (Figure 3) is located in southeastern Idaho approximately 71 km northwest of Pocatello, Idaho (113° 4' 18.68" W, 43° 14' 27.88" N) (Anderson et al. 2008). The area is largely undeveloped and is characterized as semiarid sagebrush-steppe rangelands bordered by relatively recent lava formations to the west and southwest, and irrigated agricultural lands to the north, south and east (Weber and McMahan, 2003). The study area included irrigated agricultural lands adjacent to the south and east perimeter of USDI BLM Big Desert allotment. The study area is approximately 467,814 ha in size and spreads across portions of four counties including Butte, Blaine, Bingham, and Power Counties. The study area is largely managed by the Bureau of Land Management (BLM) (75 percent). The Department of Energy (DOE) manages approximately eight percent, seven percent is managed by the State of Idaho, and 10 percent is privately owned (Figure 4). Topography is generally flat to gently rolling hills with a mean elevation of 1539 m (range = 1351 m – 2297 m). Soils are comprised mostly of silicic volcanic material and Paleozoic rocks (McBride et al. 1978, Connelly et al. 2000^b). Using precipitation

data relevant for 1992 to 2009, mean annual precipitation was 0.21 m (SE = 0.016 m) with about 48% falling as snow in the winter months (October 1 – March 31). Vegetation type is principally Wyoming big sagebrush (*A. tridentata wyomingensis*)-bluebunch wheatgrass (*Pseudoroegneria spicata*) with other native and non-native species found throughout such as Cheatgrass (*Bromus tectorum*) (McBride et al. 1978, Connelly et al. 1991, Gokhale and Weber, 2010). The Big Desert has a history of continuous low intensity grazing by sheep with a stocking rate of 0.051 animal units per hectare (AU/ha). According to BLM personnel, only approximately 10 percent of available AUs are utilized each year (Weber et al. 2003). In addition, the area has a history of wildfire occurrence (Weber and McMahan, 2003) and over the last 10 years there have been 14 fire occurrences within the Big Desert region.

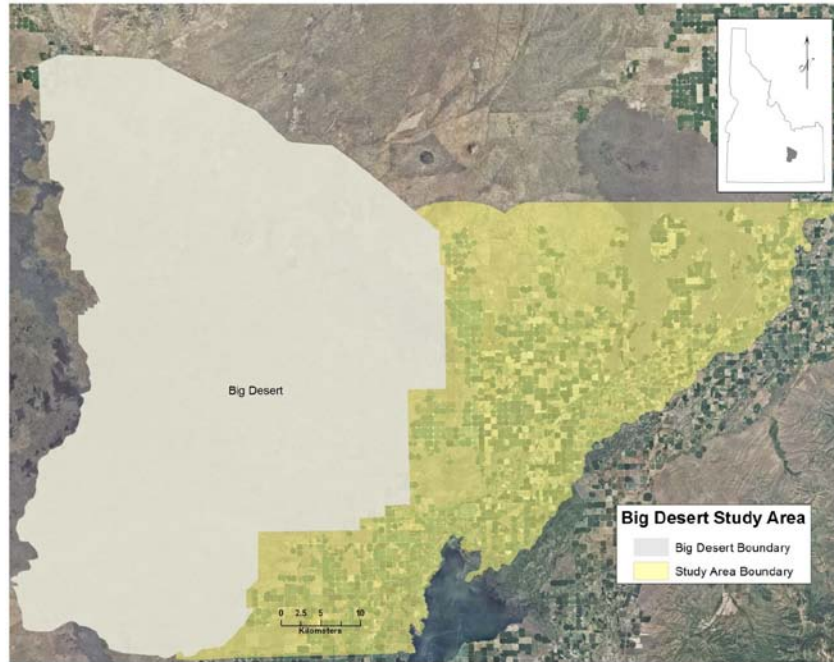


Figure 3. The Big Desert study area in southeast Idaho, ~ 71 km northwest of Pocatello. This site was chosen as the location for a multitemporal analysis of sagebrush-steppe rangeland conversion to irrigated agriculture near a sage-grouse stronghold in southeast Idaho.

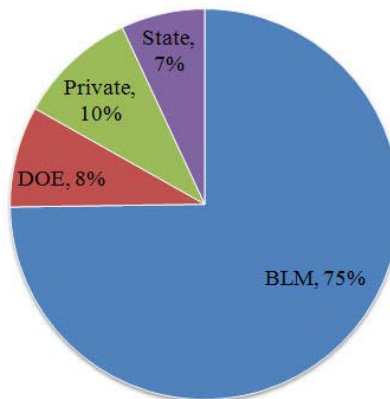


Figure 4. Management delineations for the Big Desert Study area. This study area was chosen as the site for a multi-temporal analysis of sage-grouse habitat fragmentation southeast Idaho.

There are several migratory populations of sage-grouse present in the Big Desert, which remains a region of important habitat in southeast Idaho. Big Desert sage-grouse populations have experienced gradual declines however, due to loss of habitat which has been largely attributed to wildfire (BDSGLWG, 2010). Approximately 70% of the Big Desert has been burned by wildfire since 1995, causing loss of large contiguous areas of sagebrush. Of the 70% burned, 30% has been classified as key sage-grouse habitat (BDSGLWG, 2010). In 2008, the BLM assessed habitat quality for Sage Grouse in Idaho dividing it into four classes: 1) Key delineates areas of prime habitat, 2) R1 delineates areas of perennial native and non-native grasslands with high restoration potential, 3) R2 delineates areas of annual grass dominated areas with low restoration potential, and 4) R3 delineates areas of conifer encroachment with high restoration potential. Of these classes, the Big Desert study area is considered "KEY" (28%) and "R1" (46%) habitat for sage-grouse (Figure 5).

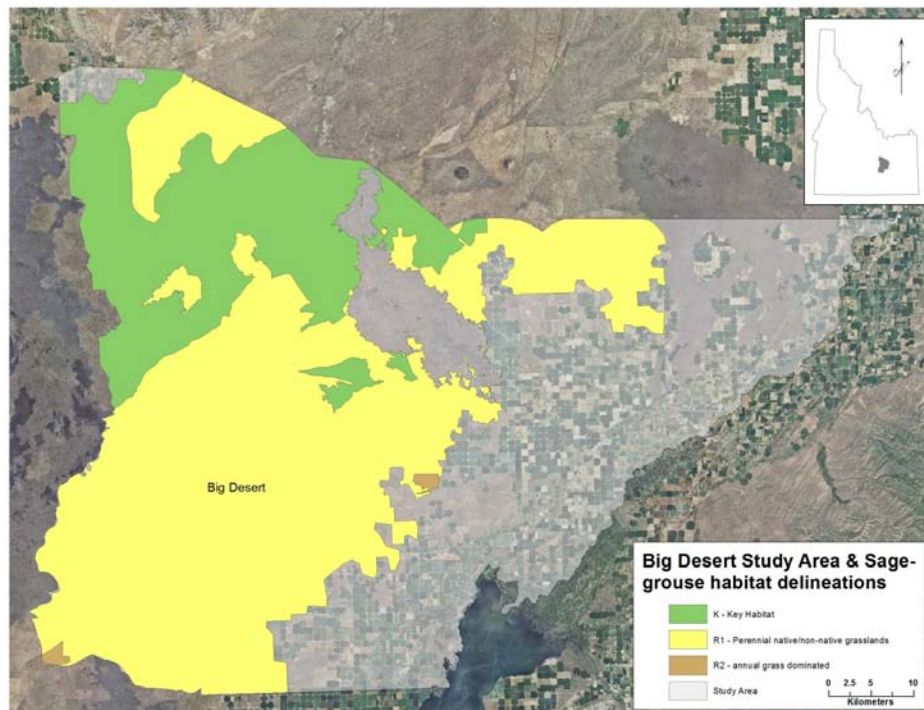


Figure 5. Greater Sage-Grouse habitat quality classes as developed by the Bureau of Land Management within the Big Desert, Idaho. Habitat quality class are: 1)K, which delineates areas of prime habitat, 2) R1, which delineates areas of perennial native and non-native grasslands with high restoration potential, and 3) R2, which delineates areas of annual grass dominated areas with low restoration potential.

In 2006 the Crystal fire burned approximately 89,000 ha of the Big Desert study area (31%). Ypsilantis (BLM) indicated this area coincided with nesting and winter habitat for sage-grouse (Figure 6).

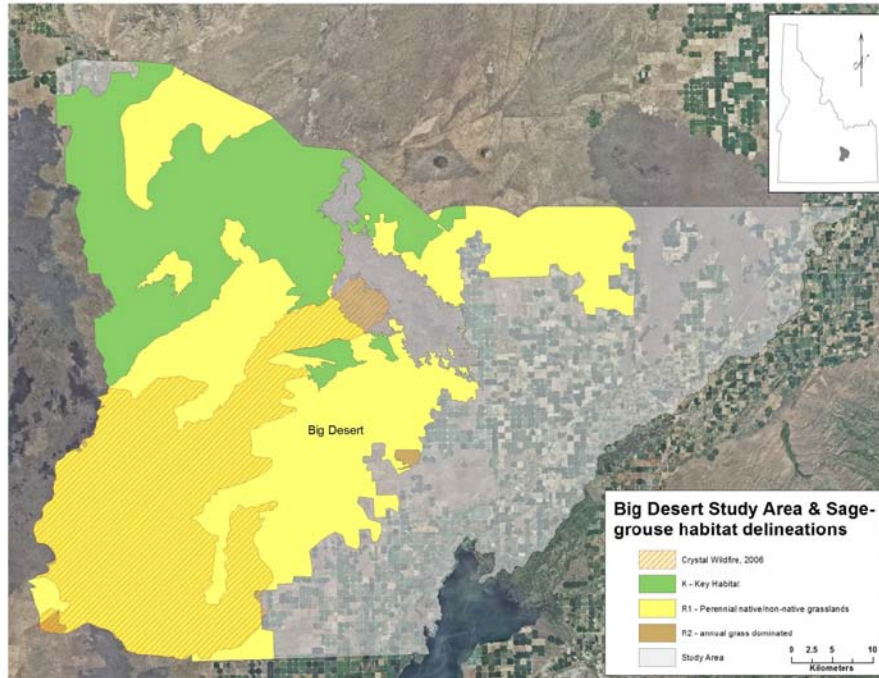


Figure 6. Greater Sage-Grouse habitat quality classes as developed by the Bureau of Land Management within the Big Desert, Idaho superimposed with the 2006 Crystal Fire boundary. Habitat quality classes are: 1)K, which delineates areas of prime habitat, 2) R1, which delineates areas of perennial native and non-native grasslands with high restoration potential, and 3) R2, which delineates areas of annual grass dominated areas with low restoration potential.

While wildfire has fragmented sage-grouse habitat within the Big Desert, conversion of sagebrush-steppe rangelands to cultivated agriculture on private lands (10% of the total study area) along the southern edge of the study area further fragments sage-grouse habitat. Though wildfire has an obvious impact on sage-grouse habitat in the Big Desert, it is part of the sagebrush-steppe rangeland ecosystem, and therefore does not have the same impact as fragmentation caused by anthropogenic influences such as irrigated cropland development. Habitat fragmentation of this form often permanently transforms sagebrush-steppe landscapes. Connelly et al. (2000) reported a recovery rate of approximately 14 years before a wildfire-disturbed landscape was once again considered viable for sage-grouse.

Image Acquisition and processing

Aerial imagery of the study area was collected for four separate years including 1954, 1992, 2004, and 2009. Imagery collected in 2004 and 2009 were produced through the National Agricultural Imagery Program (NAIP) (1m x 1m spatial resolution) (horizontal positional accuracy ± 5 m). Imagery collected in 1992 was a mosaic of several 3.75 minute Digital Orthophoto Quarter Quadrant (DOQQs) tiles originating from the U.S. Geological Survey (USGS) (1m x 1m spatial resolution). The imagery collected in 1954 was a mosaic of several aerial image tiles produced by the Army Map Service. Images were taken at an altitude of 8,991 m. Individual frames were arranged together manually and then scanned to a tagged image file format (TIFF) (10m x 10m spatial resolution) (Figure 7). To the author's knowledge, this aerial mosaic is the best available representation of the Big Desert prior to significant conversion of sagebrush-steppe rangelands to center pivot irrigation, and therefore served as a foundation for comparison.



Figure 7. 1954 still frame mosaic of the Big Desert study area in southeast Idaho.

To cover the entire study area, several tiles were mosaicked together to create a single cohesive image for each year (1954, 1992 and 2004) using LizardTech GeoExpress ver 7.0 software. NAIP imagery for 2009 covered the entire state of Idaho and was streamed into the project via the Idaho State University (ISU) GIS Training and Research Center (GIS TReC) website image service, removing the mosaic process for this image year. The imagery from 1954 was image to image co-registered to the 2004 NAIP imagery (the “gold standard” image for this study), using the ArcGIS 10.0 georectify tool. The “gold standard” image was the aerial image with the lowest root mean square error (RMSE) of horizontal positional accuracy. The remaining imagery (1992 and 2009) was tested for co-registration. Co-registration is the process by which the pixels of one image are aligned with the pixels of another so that specific geographic features appear within the correct, representative pixel. A final rectification permanently aligns the pixels of the images to the gold standard image. A first-order, or affine, transformation using nearest neighbor resampling was used as it reduces the likelihood that pixel values will change once the images are georectified. Higher order transformations may further reduce horizontal error but may also change the pixel values. Higher order transformations are typically used with images having inconsistent XY extent where greater warp/rubber sheeting is necessary for proper pixel alignment and reduced horizontal error. This process ensured good relative accuracy between images. Relative accuracy refers to the level of precision by which pixels of images are aligned relative to the “gold standard” image. Images for the later years (1992 and 2009) were tested for co-registration against the gold standard imagery (RMSE 0.03 and 0.22 respectively) and a final rectification was not necessary.

Table 1. Root mean square error (RMSE) of all co-registered and co-registration tested imagery of the Big Desert, southeast Idaho for years 1954, 1992, 2009

<u>Image Date</u>	<u>RMSE</u>
1954	17.3 m ^A
1992	0.03 m ^B
2009	0.22 m ^B

A- imagery was rectified using nearest neighbor resampling

B- imagery was tested for co-registration but not rectified as the current level of co-registration was acceptable.

Laboratory and statistical analysis

Heads-up digitizing was used with ArcGIS 10.0 software to create polygons around visible agricultural fields within each of the images. Polygon extents were limited to those areas visible in all images. For precise digitizing, 1992, 2004, and 2009 imagery were zoomed to an extent of 1:2,000 (where 1cm on the image is equivalent to 20m on the ground). The imagery from 1954 was digitized while zoomed to an extent of 1:60,000 (where 1cm on the image is equivalent to 600 m on the ground). The zoomed extents used (1:2,000 and 1:60,000) were chosen because they represent the extent before which imagery became too pixelated for precise digitizing while also optimizing visibility of the targets being digitized. Polygons were digitized for each year beginning with 2009 and working backward to 1954. The 2009 imagery was digitized first because it was hypothesized that, of all the imagery used for this study, it would have the greatest total area of irrigated agriculture.

Working chronologically backwards with the 2009 polygon feature class, polygons that were not fragmented in the previous year imagery (e.g., 2004) were removed so that each representative polygon layer accurately reflected irrigated agriculture present in that year. Moving backwards in time, there were instances that polygons were added rather than removed (as with the 1954 imagery) because the boundaries had faded so greatly that they were not previously visible in imagery for the more recent years (2004 and 2009). The goal for digitizing was to capture all visible boundaries within the imagery for irrigated agricultural lands, as it has been suggested that once an area has been converted from sagebrush-steppe rangelands to something else, it can never return to its original state (Seastedt et al. 2008). Polygon data were stored as feature classes in a personal geodatabase. If agricultural fields shared boundaries with neighboring fields (i.e., were only separated by a road), a single polygon was created around the outside perimeter of those fields. Patches of unconverted habitat within the extent of larger polygons were only accounted for if the area was consistent with the recommended minimum distance (≥ 18 km) from lekking sites for migratory species of sage-grouse, such as those populations in the Big Desert study area (Connelly et al. 2000).

Polygons were digitized to extend only from the southeast to the east edge of the Big Desert (Figure 8), as preliminary visual analysis of the imagery suggested that the majority of conversion to irrigated agriculture surrounding the Big Desert occurred in this area. Polygons extended to the Snake River, as the purpose of the study was to examine agricultural development immediately surrounding the Big Desert.

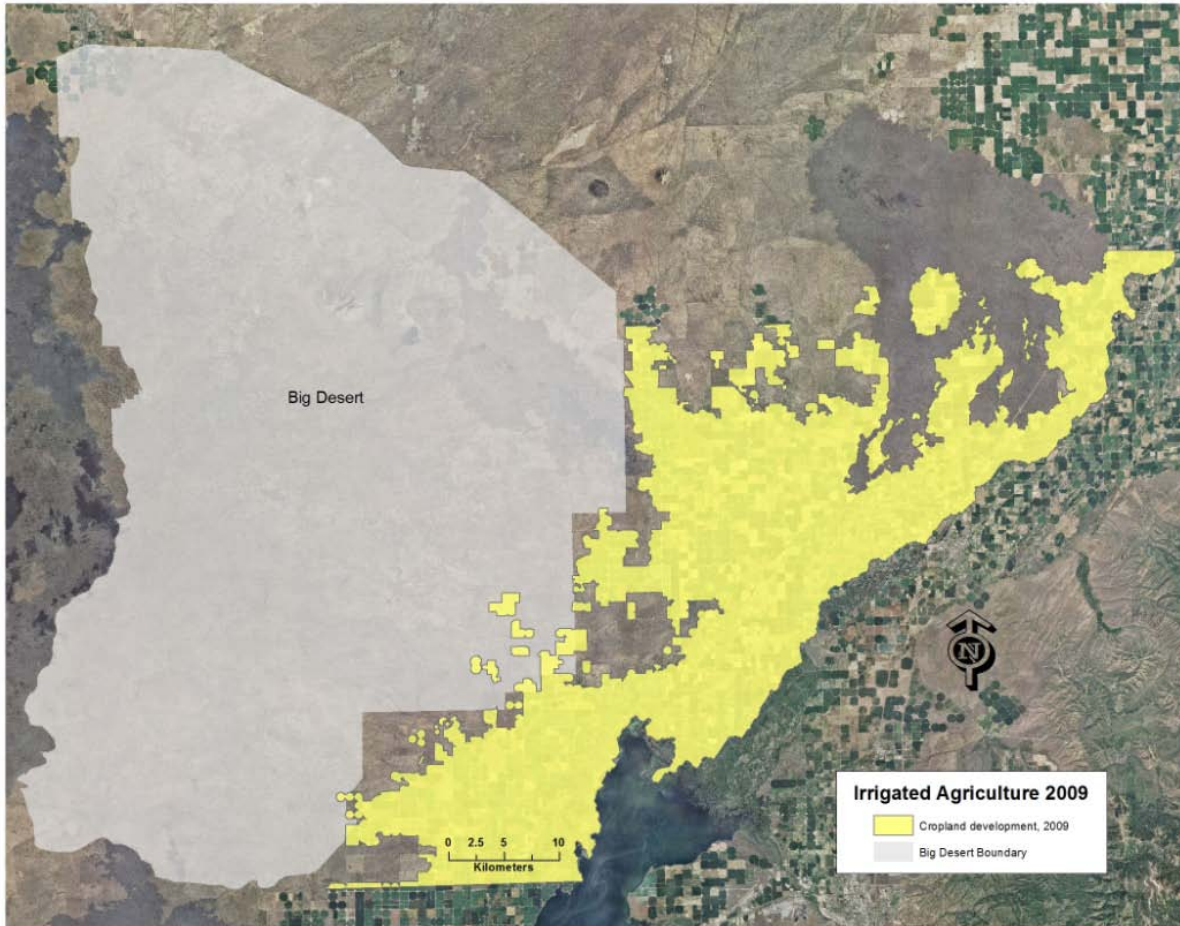


Figure 8. Polygons of cropland development near the Big Desert, ID in 2009, extending as far north and south as the southeast boundary of the Big Desert, and to the Snake River.

Geoprocessing

A 6.9 km buffer was created around polygon extents for each year (1954, 1992, 2004, 2009) to allow for potential movements away from agricultural fields by synanthropic predators (domestic dogs and cats, red fox, and corvids) (Leu et al. 2008, Connelly et al. 2004, Knick and Connelly, 2011). Total area was calculated and compared for each year (1954, 1992, 2004, and 2009) for buffered and non-buffered polygon extents. Conversion to agriculture was recorded in hectares as well as a percent of overall change from 1954 as well as between years. Geoprocessing tasks (buffers) were documented and performed within the Model Builder application of ArcGIS 10.0 (Figure 9).

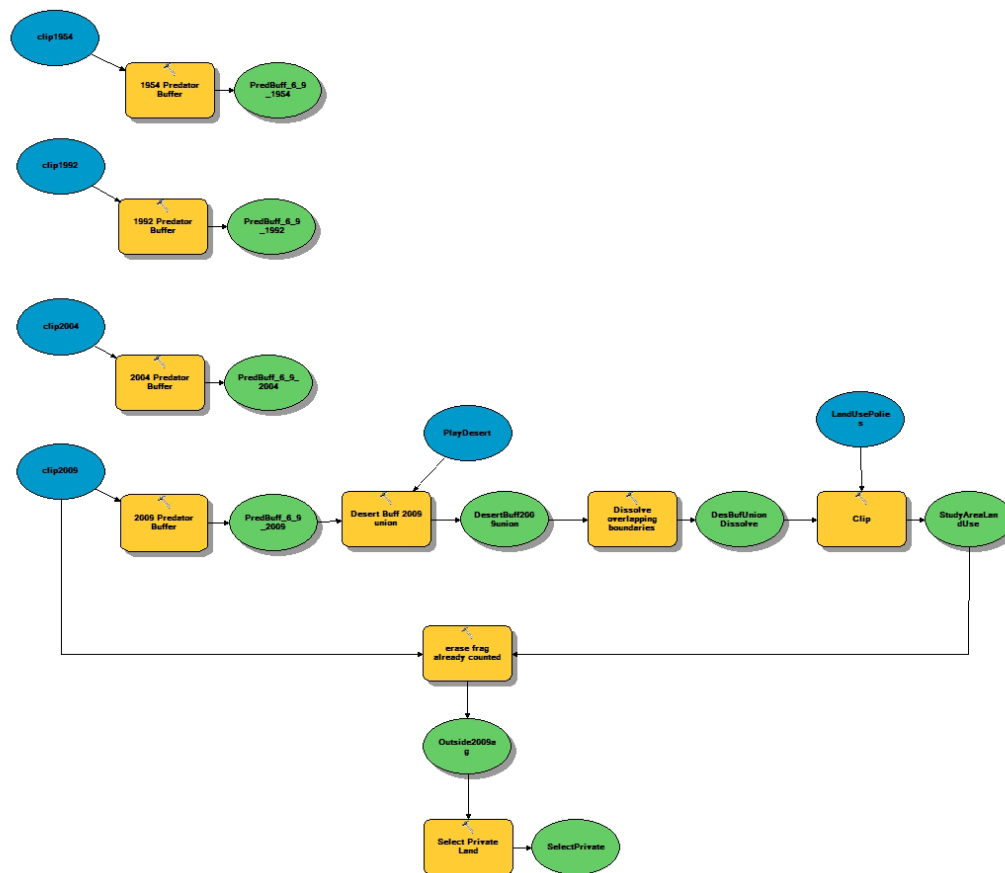


Figure 9. Model Builder flow chart documenting geoprocessing performed in ArcGIS 10.0 to analyze total area of change between polygons representing cropland development in the Big Desert, Idaho between 1954 and 2009.

A union was performed with the buffered polygon extent for 2009 and the Big Desert. Surface Management Agency (SMA) polygons (GIS data obtained at www.insideidaho.org) describing land ownership were clipped to the extent of the Big Desert study area. An erase function was performed to display those land ownership parcels within the Big Desert study area that had not been converted to irrigated agriculture as of 2009. A select function was then performed to display privately owned parcels that could be converted to irrigated agriculture. Visual analysis of the 2009 imagery was used to remove those polygons within the study area where conversion had already begun, but were not included in the study. These geoprocessing tasks were performed to indicate the potential for future habitat fragmentation through rangeland conversion to irrigated agriculture.

RESULTS AND DISCUSSION

The year estimated to have the greatest total digitized area of irrigated agriculture was 2009 (95,210 ha or 20% of the study area). Estimated total area converted between 1954 and 2009 was 35,862 ha (Table 2), or a 60% increase from the total area present in 1954. A comparison of calculated areas between years suggested that the majority of conversion after 1954 occurred between 1954 and 1992 (51%), and much smaller percent increases from 1992 to 2004 (4%), and 2004 to 2009 (2%) equating to an approximate total increase of 6% between 1992 and 2009.

Table 2: Total area of change in agricultural development in an area immediately adjacent to the south and east perimeter of the Big Desert, Idaho between 1954, 1992, 2004, and 2009.

Imagery	Total area in irrigated agriculture (ha)	Change in irrigated agriculture (ha)	Percent change relative to 1954	Total Estimated since 1954 (ha)
1954	59374	59374	n/a	
1992	89409	30062	50 %	
2004	93152	3743	4 %	
2009	95210	2057	2 %	35862

When the 6.9 km synanthropic predation buffer was included around digitized polygon extents for each year (1954, 1992, 2004, and 2009), total area of estimated irrigated agricultural development between 1954 and 2009 increased from 35,862 ha to 42,311 ha (Table 4). This indicates that the area actually influenced is 15% greater than the area of irrigated agricultural development.

Table 3: Total area of change in agricultural development in an area immediately adjacent to the south and east perimeter of the Big Desert, Idaho between 1954, 1992, 2004, and 2009 with a 6.9 km synanthropic predation buffer representing total area of influence.

Imagery	Total Area Hectares	Change in irrigated agriculture (ha)	Percent of total where total is 1954 imagery	Total estimated growth since 1954 (Hectares)
1954	77305	77305	n/a	
1992	113660	36355	47 %	
2004	117511	3851	3 %	
2009	119616	2105	2 %	42311

To measure the potential for future fragmentation of sage-grouse habitat near the Big Desert, land use polygons were analyzed indicating an additional 27,781 ha of privately owned land could be converted to irrigated agriculture. With the current level of irrigated agricultural development, Big Desert sage-grouse populations can still use some centralized areas that are greater than 18 km away from the total area of influence (Figure 10). However, there are private lands within the study area that were not accounted for, as well as some areas that have not yet been developed (Figure 11).

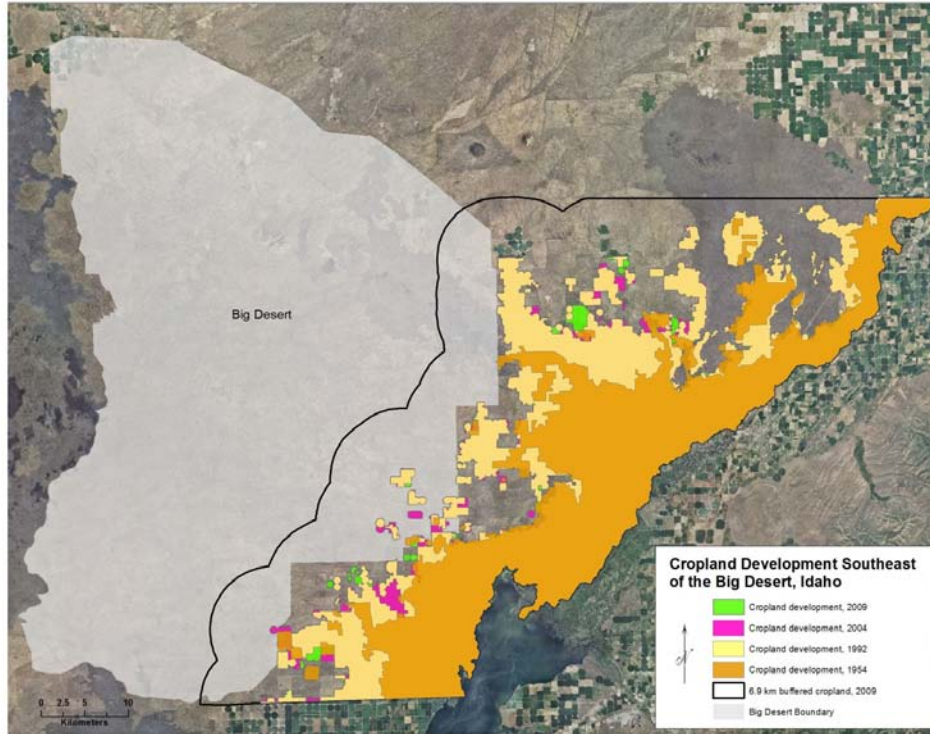


Figure 10. Irrigated agricultural development near the Big Desert, Idaho including a synanthropic predation buffer (6.9 km) showing total impact of agriculture on sage-grouse habitat.

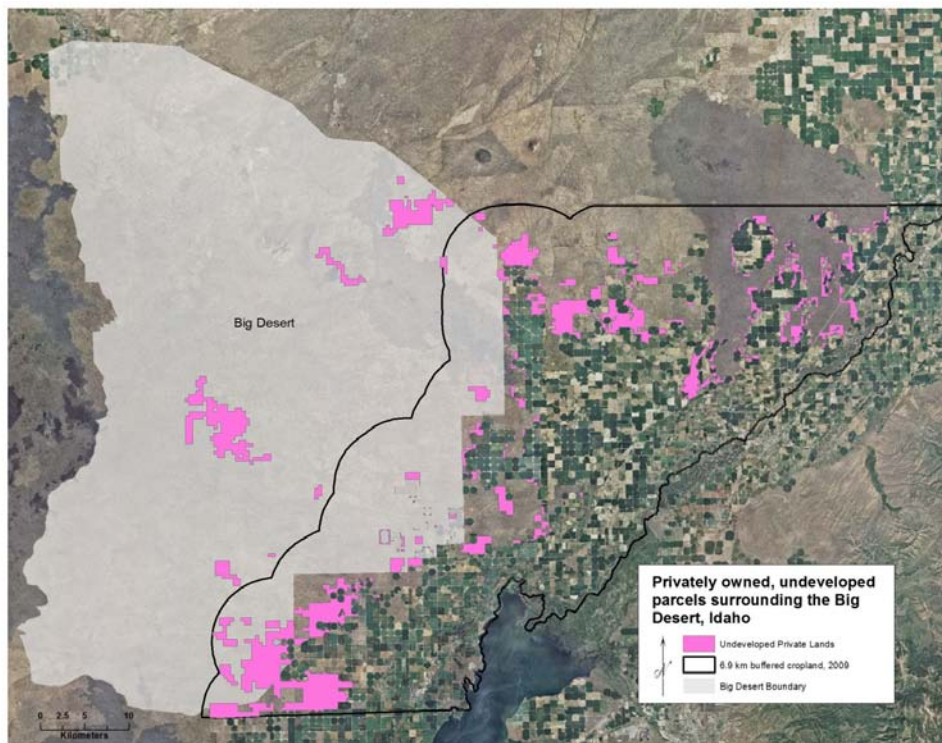


Figure 11. Potential irrigated agricultural development near the Big Desert, Idaho based on 2010 land ownership parcels (www.insideidaho.org) displaying privately owned lands that have not yet been converted to irrigated agriculture.

CONCLUSION

The results of this study indicate the total area of land that has been converted from sagebrush-steppe rangelands to agriculture has increased since 1954. Comparison of converted areas from each year (1954, 1992, 2004, and 2009) indicate the majority of conversion occurred between 1954 and 1992 (~50%) with smaller increases in more recent years. These results correlate with agricultural development patterns along the Snake River Plain reported by Leonard et al. (2000) indicating a 10% increase in irrigated agriculture along the Snake River Plain between 1975 and 1985. Johnson et al. (2011) argued the majority of conversion of sagebrush-steppe rangelands to irrigated agriculture occurred during the first half of the 20th century. This could mean that even imagery as early as 1954 may not accurately reflect the study area prior to significant sagebrush-steppe rangeland conversion to irrigated agriculture.

Though the Big Desert Sage-Grouse Local Working Group (BDSGLWG) believes there is a limited possibility of converting sagebrush-steppe to agricultural production, there is presently an additional 27,781 ha of undeveloped, privately owned land within the Big Desert study area that, if developed, could further fragment sage-grouse habitat (Connelly et al. 2000). Current conservation measures seem to revolve around restoring sage-grouse habitat through sagebrush restoration programs such as the Conservation Reserve Program (CRP). The CRP program allows agricultural lands that have been converted from sagebrush-steppe to be planted with perennial grasses, forbs, and sagebrush (Schroeder and Vander Haegan 2011, BDSGLWG 2010, Pyke 2011). As a result, Schroeder et al. (2011) reported success in sage-grouse response to CRP lands in Washington with increases in observed nesting sites. Conclusions cannot be drawn from the results presented in this research as to the effect CRP land has had on Big Desert sage-grouse populations. However, results indicate that presently, Big Desert sage-grouse populations still have use of some centralized areas that are greater than 18 km away from the total area influenced by irrigated agricultural development.

ACKNOWLEDGEMENTS

This study was made possible by a grant from the National Aeronautics and Space Administration Goddard Space Flight Center (NNX08AO90G). Idaho State University would also like to acknowledge the Idaho Delegation for their assistance in obtaining this grant.

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Recommended citation style:

Hanson, D. and K. T. Weber, 2011. Quantifying Habitat Fragmentation in the Big Desert, Idaho. Pages 235-252 in K. T. Weber and K. Davis (Eds.), Final Report: Assessing Post-Fire Recovery of Sagebrush-Steppe Rangelands in Southeastern Idaho. 252 pp.