

**Accuracy Assessment of Digital Aerial Sketchmapping for
Estimating Size, Placement and Extent of Buffelgrass
(*Pennisetum ciliare* L.) Infestations in Saguaro National Park**

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Abstract

The assessment summarizes the accuracy of the mappers who used digital aerial sketch mapping (DASM) to map buffelgrass (*Pennisetum ciliare* L.) in Saguaro National Park during September of 2012. Following the DASM, ground-based mapping was performed in the subsequent three months to evaluate the accuracy and utility of aerial mapping. The assessment demonstrated that mappers who are experienced in the identification of buffelgrass can accurately map buffelgrass with regards to the relative size and location of buffelgrass infestations.

Background and Introduction

Aerial sketchmapping has been used since the early 1900s to monitor the condition of forests (Johnson, 1954), in particular damage occurring from ice (Scarr et al., 2003), and disease and insects (Johnson and Ross, 2008). Within recent years the use of aerial sketchmapping has expanded to other types of monitoring.

Saguaro National Park conducted an aerial survey for buffelgrass in 2008. The findings from that effort were seen as less than adequate for the park's management needs. In 2012, the park contracted a helicopter for three days with the goal of mapping, in a more refined manner, the extent of buffelgrass infestations in both districts of the park especially in areas that are not easily accessible by foot or on very steep terrain. Aerial mapping provides a more efficient and cost effective alternative to ground-based mapping particularly in difficult terrain. The aerially mapped buffelgrass combined with field mapped buffelgrass provides park managers with a comprehensive map of buffelgrass distribution in the park. Flights were constrained to elevations below 5,000 feet as buffelgrass is considered to be intolerant to cold temperatures (Hanselka, 1988). The summary of the aerial surveys can be found in Appendix A. Small grant funding from Friends of Saguaro National Park and Southwest Exotic Plants Management Team was received to conduct the ground surveys to evaluate the accuracy of location, size, and identity of the aerially mapped buffelgrass.

The approach to 2012 DASM differed in several ways from the 2008 aerial survey and thus we suspected the data would be more accurate. Park staff intimately familiar with the identification of buffelgrass as well as the terrain did the mapping. Drainages were used as a guide for flights, allowing the area to be more thoroughly flown than was done in 2008, where the flightlines resembled more of a regular grid pattern (Figure 1). Areas in the park that were easily accessible on foot were not aerially mapped. Mapping priorities were established, with the Rincon Mountain District (RMD) receiving more attention. The Tucson Mountain District (TMD) was less thoroughly covered because of limited flight time remaining. Table 1 summarizes the flight and mapped data.

Figure 1: Flightlines from 2008 and 2012.

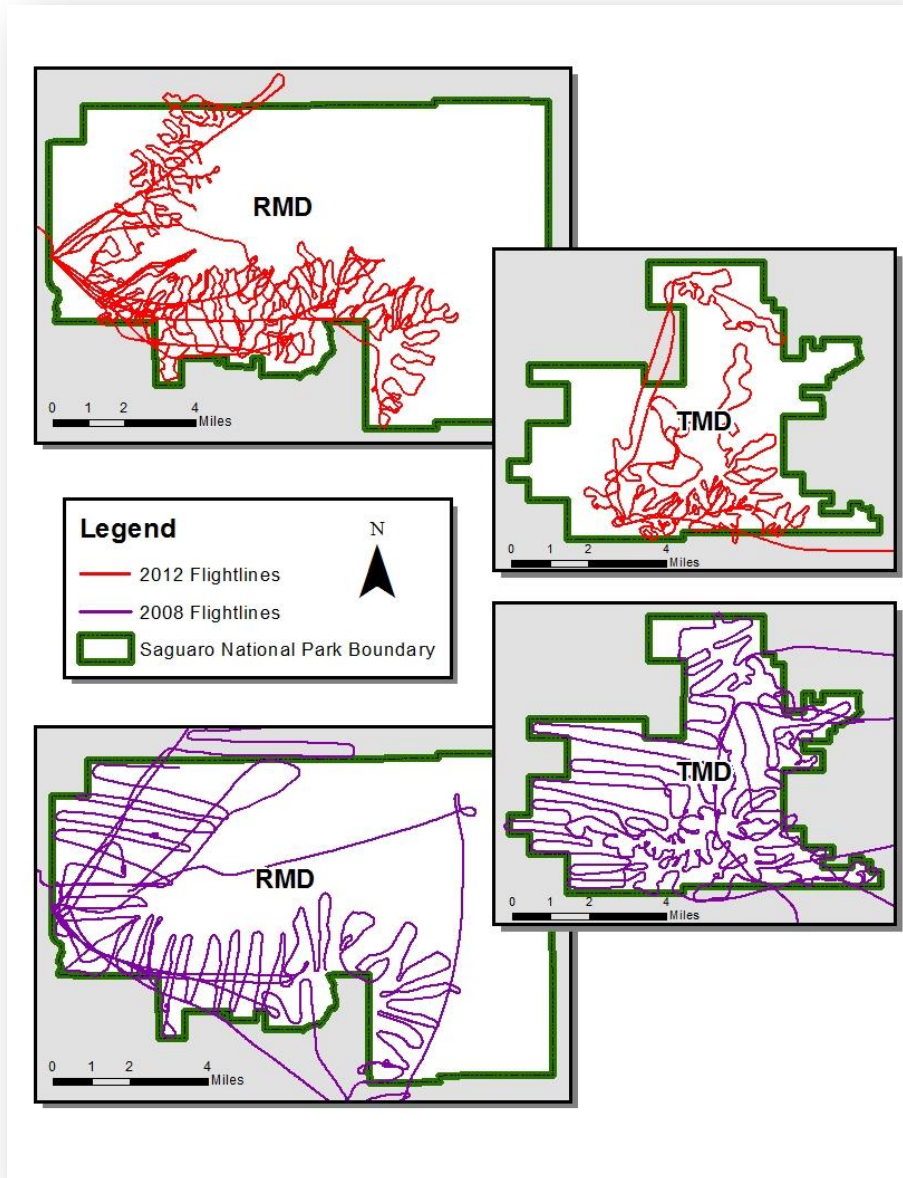


Table 1: Summary of survey results.

	Hours Mapping	Surveyed Area (ac)	Surveyed Area without overlap(ac)*	Miles flown	Buffelgrass Infestation Area (ac)	Number of All Polygons Mapped	Size Range of Mapped Polygons (ac)	Average Size of Mapped Polygons (ac)
RMD	9.7	23,170	190,456	292	780	1,660	0.001-29	0.48
TMD	3.1	9,323	8,855	102	148	465	0.005-9	0.32
Total	12.8	32,494	27,901	395	928	2,125	0.001-29	0.44

Methods

Similar to the 2008 aerial survey, a field-based accuracy assessment occurred after the 2012 aerial survey. In 2008, the aerially mapped polygons were targeted to determine if they were correct in identification, size, and placement. This created several problems both in the field and with the analysis. A different approach was done in 2012 to directly compare the areas mapped from the helicopter to areas mapped on the ground. A systematic approach to mapping buffelgrass on the ground was used. In a grid-like manner, field crews of 2-7 people, spread out at regular intervals (which varied depending upon terrain, visibility, and vegetation density) and systematically walked through a pre-determined area, mapping buffelgrass with handheld computers and GPS. Twenty ground-based survey areas were chosen by accessibility (within a reasonable hiking distance), a high concentration of data collected during the aerial survey, and distributed between the two districts. The data from the aerial survey was not used during the field surveys.

The ground-based data was post-processed in ArcMap 10.1® and compared to the aerial data to determine the amount of buffelgrass mapped at each location and the spatial proximity of ground and aerial polygons.

Results

Twenty sample areas, ranging in size from 0.1 to 239.0 acres, were surveyed totaling roughly 1105 acres or 4% of the total area surveyed by helicopter (27,900 acres). This required 296 person hours (Table 2) compared to the 12.8 hours it took to map from the helicopter. Aerial polygon data was restricted to include only the area that was systematically surveyed on the ground. The total area of buffelgrass infestations mapped on the ground was 190 acres and from the aerial survey 145 acres. Thus, aerial mapping underestimated the amount of buffelgrass on the ground by 34%.

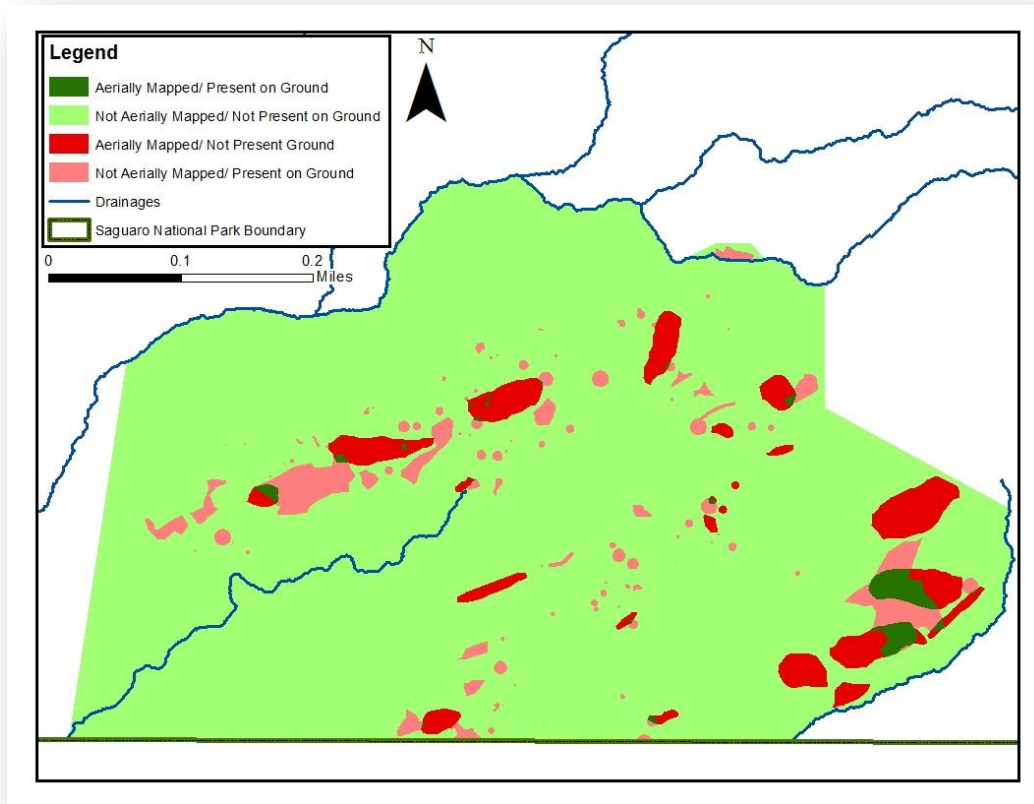
Based on observations from the field crew, the buffelgrass was correctly identified by the aerial sketchmappers, however, there is no way to quantify this using the field mapping approach. Placement and size of the buffelgrass infestation did vary between the two data sets.

Table 2: Summary of ground truthing surveys.

Sample ID	Survey Date	Crew Number	Person Hours	Acres Surveyed
1	10/10/2012	5	32	239.0
2	10/24/2012	2	6	13.2
3	10/24/2012	2	3	5.9
4	10/24/2012	2	3	8.6
5	10/25/2012	4	10	21.7
6	10/25/2012	4	18	89.7
7	10/26/2012	6	36	50.2
8	10/31/2012	2	1.75	3.7
9	10/31/2012	2	0.75	0.9
10	10/31/2012	2	0.25	0.1
11	10/31/2012	2	1.25	2.5
12	11/1/2012	5	17.5	89.7
13	11/3/2012	5	21.25	141.8
14	11/9/2012	4	14	35.0
15	11/9/2012	4	4	19.1
16	11/30/2012	5	25	119.4
17	12/1/2012	4	28	104.9
18	12/5/2012	3	16.5	61.7
19	12/15/2012	7	40	58.0
20	12/19/2012	3	18	40.1
TOTALS			296.25	1105.2

The positive outcomes resulted in the overlap of aerially mapped polygons with actual buffelgrass and the overlap of no aerially mapped polygons with the absence of buffelgrass. The negative outcomes occurred when buffelgrass was mapped from the helicopter but was not present on the ground and when buffelgrass was present on the ground and not mapped from the helicopter. Figure 2 is an example of one sample depicting the four possible outcomes.

Figure 2: An example depicting the four possible outcomes.



The positive and negative outcome analysis used all 20 sample locations and without one sample (Sample 1). This was done because Sample 1 was so heavily infested with buffelgrass that the data could skew the analysis, resulting in more positive outcomes (Table 3).

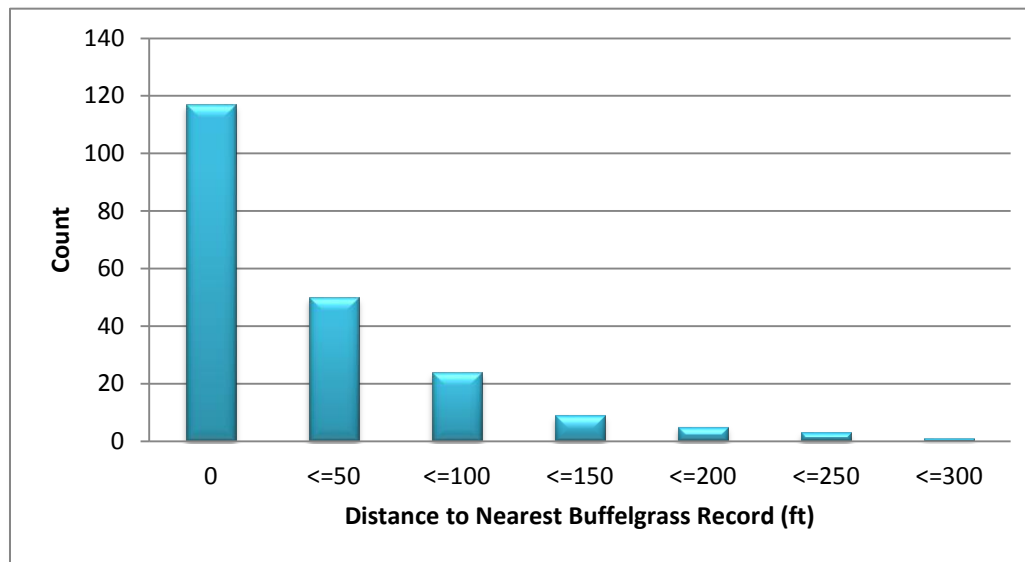
The percentage of the polygons aerially mapped that overlapped with infestations on the ground was low (7.1% and 3.7% without Sample 1). The absence of aerially mapped polygons and infestations on the ground was high (76.7% and 89.1% without Sample 1). The overall positive outcomes were 83.8% and 90.3%, with and without Sample 1 respectively.

Table 3: Positive and negative outcomes.

		All Locations Aerially Mapped		Without Sample 1 Aerially Mapped	
		Yes	No	Yes	No
Present on Ground & Percent Overlap	Yes	78.97 ac (7.1%)	111.86 ac (10.1%)	10.35 ac (1.2%)	31.85 ac (3.7%)
	No	66.37 ac (6%)	847.89 ac (76.7%)	52.37 ac (6.0%)	771.33 ac (89.1%)

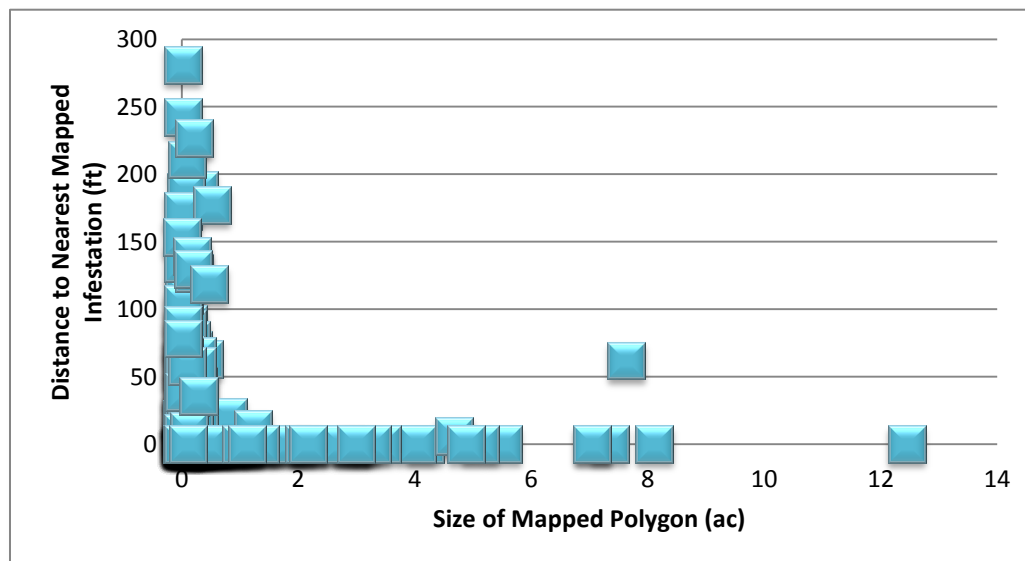
To evaluate spatial placement, a nearest neighbor analysis was done. The average distance from any aerially mapped polygon to the nearest buffelgrass infestation recorded on the ground was approximately 29 feet. Figure 3 shows the frequency distribution of the distances to the nearest buffelgrass infestation mapped from the ground. Over 50% of the polygons overlapped (classified as 0 feet for distance to nearest buffelgrass record) a ground mapped buffelgrass record.

Figure 3: Distances of aerially mapped polygons to nearest ground mapped polygons.



The larger the aerially mapped infestation was, the greater the likelihood it would occur close to a ground mapped infestation (Figure 4). Thus, very small infestations or single plants were more likely to be inaccurate in placement.

Figure 4: Relationship of aerially mapped infestation size to the nearest infestation.



To evaluate if the mappers were “lumpers” or “splitters” and which method would be more accurate, percent cover attributed to the polygon was used. Percent cover multiplied by the gross number of acres mapped results in net acres. Table 4 indicates that aerially mapped polygons tend to have an overestimation of percent cover. This was most likely due to a more refined percent cover scale used on the ground surveys, eight cover classes, compared to the four used for aerial mapping.

Table 4: Gross and net acre comparison.

	All Locations		Without Sample #1	
	Gross	Net	Gross	Net
Total acres mapped from helicopter	145.3	88.9	62.7	34.7
Total acres mapped on the ground	190.8	36.0	42.2	16.1

For the aerially mapped features, the percent cover assigned to points (< 16 feet diameter) was defaulted to 87.5% (the median of High cover class). Polygons were attributed with a percent cover class of Trace (0-25%), Low (26-51%), Medium (51-75%) and High (76-100%). Polygons with higher percent cover of buffelgrass were more likely to overlap with buffelgrass that was mapped on the ground (Table 5).

Table 5: Percentage of acres overlap by percent cover category.

Feature and Cover Type	Count	Gross Acres	Gross Acres Overlap	% Gross Acres
Points	38	0.7	0.1	14.3%
Poly- Trace	2	0.6	0.03	5.0%
Poly- Low	70	37.1	12.9	34.8%
Poly-Med	77	77.1	45.0	58.3%
Poly-High	22	29.8	21.0	70.5%

Accuracy was also assessed by the individual mapper. The analysis by mapper only considered the features actually drawn by the mapper. The absence of drawn features (a feature not mapped because buffelgrass was not present) could not be attributed to any single mapper, thus, the comparison could only be made between what was mapped from the helicopter with the overlap of infestations on the ground. There was a wide range (2.7% to 64.6%) of accuracy, based on acres of overlap (Table 6).

Mappers were most likely more accurate because not mapping a polygon where there was no infestation on the ground is also positive result.

Table 6: Acres and accuracy of individual mappers.

Mapper	Count	Gross Acres Mapped	Gross Acres Overlap	Spatial Overlap (% of Acres Mapped)
1	64	28.3	15.0	53.0%
2	12	7.3	0.2	2.7%
3	57	44.0	23.7	53.8%
4	66	60.2	38.9	64.6%
5	10	5.6	1.2	21.4%

Conclusions

The accuracy assessment demonstrated that DASM is a useful tool for mapping infestations of buffelgrass in hard to reach areas of the park. While the amount of overlap of aerial map infestations with actual infestations on the ground was low due to spatial placement errors, the resultant data is the best estimate for the number of acres of buffelgrass infestation. For the intended purposes of this data set, park managers now have a more clear understanding of the general location of infestations, the size and density of the infestations, and the extent of the infestations.

When the infestations had a higher percent cover, the spatial overlap with actual infestations was greater. A couple of reasons for this could be that patches with High percent cover were generally large infestations, spreading across an extensive area, thus, the higher the probability of overlap. Also, many of the High percent cover polygons were near highly identifiable features (large rock outcrops, drainage confluences, etc.) that were displayed on the background reference images.

Overall, gross acres, not net acres, were a better representation of what was actually on the ground. This may be a result of the inability to map at a fine scale from a helicopter, combined with the quick decision time needed to identify a percent cover class. Also, it is possible that the oblique angle at which the infestation was detected may distort the size, shape, and location. In addition, it would certainly be different than the ground perspective.

Another factor that may have caused the accuracy to be low is the Blue Tooth software used to transmit the GPS location to the tablet while the helicopter was moving had some lag time. Thus, when the icon for the helicopter was displayed on the tablet, the helicopter had already moved forward. This was

especially challenging when there were no highly identifiable features on the landscape that could be used for reference.

It would have been very useful if one mapper could see the work of the others. This would help ensure that fewer patches were missed or coincidentally mapped. This issue tended to occur most frequently when a single drainage required several passes to map the infestation.

The configuration of the mappers in the helicopter could have also influenced the outcome of the data. The intention was to have the mapper in the front map what was directly below the helicopter and the two mappers in the back to map the infestations on the sides of the drainages. The mapper in the front and the mapper directly behind that mapper sometimes mapped the same infestation and during the immediate post-flight review of the data, some duplicates were not detected.

Future DASM considerations that could improve the accuracy of the aerial survey could include: (a) connection between tablets to view other mappers work; (b) only two mappers or better define the roles of each mapper; and (c) re-survey areas that are either very infested or have polygons with questionable placement.

Literature cited

Hanselka, C. Wayne. 1988. *Buffelgrass: South Texas Wonder Grass*. Rangelands 10(6): 279-281.

Johnson, Erik W. and Jennifer Ross. 2008. *Quantifying error in aerial survey data*. Australian Forestry 71(3): 216-222.

Johnson, Evert W. 1954. *Role of Aircraft in Forest-Pest Control*. The Scientific Monthly 79(6): 379-391.

Scarr, Taylor A., Anthony A. Hopkin and Gordon M. Howse. 2003. *Aerial sketch-mapping of the 1998 ice storm in eastern Ontario*. The Forestry Chronicle 79(1): 91-98.

APPENDIX A: BUFFELGRASS AERIAL MAPPING USING DASM

Total Flight Time: 15 hours plus 2 hours ferry from Glendale

Total Area Surveyed: 27,900ac w/o overlap (32,493ac total)

Total Flight Length for surveying: 395 miles

Number of polygons mapped: 2125

Total Area of Buffelgrass Infestations Mapped: 919.4 acres

Total Area of other species Infestations Mapped: 8.9 acres

Total Helicopter Cost: \$29,078

Cost/Acre: \$1.04

Total Project Cost = \$36,800

Salary (non-base): \$1,640

Equipment (Hardware, software, camera and accessories): \$6,092

	RMD	hours mapping	acres surveyed	Acres surveyed without overlap	miles flew	acres mapped	# polygons
09.11.12	Flight 1 Day 1	2	4396		63.6	80.3	410
09.12.12	Flight 1 Day 2	2.5	4546.9		59.6	312.4	575
09.12.12	Flight 2 Day 2	2.1	6422.2		69	260.6	430
09.12.12	Flight 3 Day 2	2.1	5647.8		67.04	105	165
09.13.12	Flight 1 Day 3 (resurvey)	1	2157.5		33.2	21.6	80
	sub total	9.7	23170.4	19045.7	292.44	779.9	1660
	TMD						
09.13.12	Flight 2 Day 3	2.5	7538		76.1	68.6	380
09.13.12	Flight 3 Day 3	0.6	1785.4		26.3	79.8	85
	sub total	3.1	9323.4	8855.0	102.4	148.4	465
	Grand Total	12.8	32493.8	27900.7	394.84	928.3	2125

Hours mapping does not include ferry time, training flights, to/from helibase, or flight across Tucson.

Area surveyed was calculated by adding a 200m buffer around each flight line.

Data calculated before ground trothing.