NORTHERN ARIZONA UNIVERSITY

Lab of Landscape Ecology and Conservation Biology

FINAL REPORT
(12 February 2015)

For the project entitled:

Implement a Rapid Plot Design across the Kaibab National Forest

USFS-NAU Agreement #14-CS-11030700-006

Submitted to:

The Kaibab National Forest

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Recommended citation:
Horncastle, V.J. and B.G. Dickson. 2015. Implement a rapid plot design across the Kaibab National Forest. Lab of Landscape Ecology and Conservation Biology, Northern Arizona University, Flagstaff, AZ.

Project overview

This report is submitted as partial fulfillment of the terms of a cost reimbursable agreement between the Kaibab National Forest (KNF) and the Lab of Landscape Ecology and Conservation Biology at Northern Arizona University to implement a rapid plot design (Ray et al. 2012) across the Kaibab National Forest. Specifically, our objectives were to field test this design through plots and pilot data, conduct summary analyses on the variables, and refine the methodology and overall plot design. The variables in the rapid plot design were originally selected to represent several of the monitoring components in Chapter 5 of the Kaibab National Forest Plan. We evaluated the majority of these variables by sampling approach and effort and whether the data collected could be used to calibrate and integrate with various remote sensed data. In addition, we discuss issues encountered in the field, quality of the data, and provide recommendations for future rapid plot sampling efforts.

From June 2 to August 15, 2014, all 3 Kaibab National Forest Ranger Districts were visited and a total of 291 rapid plots were sampled (Williams = 118, Tusayan = 71, North Kaibab = 102) (Figures 1 and 2). The Tusayan Ranger District was 90% completed with only 8 plots not visited due to issues with access (e.g., due to closed or impassable roads). We completed 80% of the Williams Ranger District and 65% of the North Kaibab Ranger District. The majority of plots not visited in the Williams Ranger District were because of closures due to the Sitgreaves Complex fire and other road closure types, causing the sampling of some plots to be impractical or impossible.

There were about 10-15 occasions when prospective plots needed to be moved because they were either located on a road or were located where slopes were > 15% (as designated in the sampling protocol). Plots were always relocated within the same vegetation type and only moved the minimum distance necessary to locate the plot away from an open road (typically, 20-30 m).

Although there were only 6 vegetation categories identified on the original data sheet, dominant vegetation type(s) observed at each plot were placed into 13 unique categories (Table 1). We added sagebrush and scrub types, and the majority of other new classifications were due to some plots having a ~ 50/50 mix of two dominant vegetation types. In these cases, the two types were lumped into a new single category (e.g., 'ponderosa pine, oak'). For future syntheses and analyses, these 13 categories could easily be reduced to a smaller set, as needed.

As expected, several rapid plots were located within planned 4FRI treatment areas and other designated treatments throughout the Williams and Tusayan Ranger Districts. Within the Williams Ranger District, there were 29 plots sampled within planned 4FRI treatment areas and 3 plots in other designated treatment areas. In the Tusayan Ranger District, 14 rapid plots were located in 4FRI planned treatment areas and 2 plots were located in other planned treatment areas. By visiting the majority of plots located within planned treatment areas, we will be able to provide pre-treatment data that can be later compared with post-treatment data in a statistically meaningful and rigorous fashion.

The number of rapid plots could easily be increased as new treatment areas come ‘on line,’ or where there is a need to sample in areas recently disturbed by, for example, insects and wildfire. The number of additional rapid plots located in these areas should be determined by the specific questions and hypotheses needing to be addressed and a suitable power analysis or simulation exercise. In our experience and initial assessment, the number of rapid plots measured during the pilot season—and resultant information—should be statistically robust for addressing numerous questions related to forest change and management within the KNF.

Below we briefly summarize specific categories of the rapid plot pilot effort and offer an initial list of recommendations for future rapid plot sampling efforts.

Non-native species

At each plot, the field crew noted the presence or absence of non-native invasive species including cheatgrass, knapweed, thistles, and toadflax. These data were collected in order to address questions 6 and 24 in the Kaibab NF Monitoring Plan. This will allow new populations of invasive species to be detected early, monitored, and treated as soon as possible. Overall, 32% of the plots had non-native invasive species present. The most common invasive species included several different thistle species, followed by cheatgrass, and Russian thistle (Figure 3). Invasive species were most common in the North Kaibab Ranger District (42% of all plots), followed by the Williams Ranger District (34%) and the Tusayan Ranger District (14%). Although no inferential statistics have yet been generated, we did not observe a strong correlation between plots with invasive species and plots that have experienced vegetation treatments or other types of disturbance.

Soil disturbance

Soil disturbance areas > 0.5 m^2 in size were recorded as either burned, compacted, displaced, or other. Across the Kaibab National Forest, we observed a total of 30 plots (10%) with signs of soil compaction, and the majority of these were on old logging roads or other closed roads that ran through the plot. Compaction was also due to game trails and camp sites. The ‘burning’ category on the data sheet was only checked on 12 occasions; however, signs of fire were noted on 41 occasions under ‘evidence of disturbance.' Overall, soil disturbance due to fires was observed at 42 plots (14%).

Evidence of treatment or disturbance

Across all plots, only 17% of the plot locations were associated with evidence of treatments. Treatments were marked as either commercial, lop and scatter, thin and burn, or just thinned if more specifics were not identifiable. Whenever possible, treatments were classified as either 'recent' or 'old.' Fourteen plots were classified as lop and scatter, 15 as commercial, 2 as burn treatments, 1 as thinned and burned, and the other 18 plots showed evidence of thinning, but could not be classified as a particular type of treatment. Sixteen percent of the plots had evidence of some type of disturbance. Disturbances were indicated as low intensity burns (9 plots; likely due to treatment activities), hot burns (6), wildfires in general (25), wind throw (3), heavy grazing (1), or heavy erosion (1).

Species and tree counts

At each plot, all trees and snags ≥ 10cm in dbh were identified to species, counted, and assigned to size classes in dbh of 10-20 cm, 20-30 cm, and > 40 cm. Trees ≥ 40 cm dbh had precise measurements of dbh taken and the number of those trees that meet the Keen description of 'over mature' were counted. These data can be used to address questions 1, 7, and 9 in monitoring plan. There were a few tree species that the field crew had some difficulties identifying, especially a few pines in the North Kaibab Ranger District. There were also some issues with the identification of Keen classes. These issues are further explained in the recommendation section of this report. Eight different tree species were identified in the North Kaibab Ranger District, with aspen and ponderosa pine being the two most common species (Table 2). The majority of trees were in the class 1 and class 2 DBH categories. There were only a total of 36 snags (DBH > 45) across all plots in the district and the average number of snags in each plot was 0.90 (SD = 0.34). The average DBH for trees in class 4 was 51.7. Averages and total counts for each individual species detected in the North Kaibab Ranger District are presented in Table 2.

Five different tree species were identified in the Tusayan Ranger District, with pinyon pine and ponderosa pine being the two most common species (Table 3). The majority of trees were in class 1 and class 2 DBH categories. There were only a total of 8 snags (> 45 dbh) across all plots in the district and the average number of snags in each plot was 1.2 (SD = 1.09). The average DBH for trees in the class 4 was 47.5. Averages and total counts for each individual species measured in the Tusayan Ranger District are presented in Table 3.

Ten different tree species were identified in the Williams Ranger District with ponderosa pine, Utah juniper, and Gambel oak being the most common species (Table 4). The majority of trees were in class 1 and class 2 DBH categories. There were only a total of 15 snags (> 45 dbh) across all plots in the district and the average number of snags in each plot was 0.9 (SD = 0.06). The average DBH for trees in the class 4 was 55.7. Averages and total counts for each individual species detected in the Williams Ranger District are presented in Table 4.

Woody debris

Coarse woody debris was measured using an adaptation of the line intersect method for forest fuels (van Wagner 1968) using the two main transects in the plot. All logs > 8cm diameter were measured at the point they intersected the transects. Length measurements, diameter, and decay class were noted for each log. This information can be used to address questions 1 and 2 of the Kaibab monitoring plan. Across the Kaibab National Forest, woody debris occurred in 55% of the plots sampled. The maximum amount of woody debris in a plot was 39 logs. The average was 5.7 logs per plot (SD = 6.6, mode = 1.0). North Kaibab plots exhibited the largest amount of woody debris (70.6% of all plots), while the Williams (47.5%) and Tusayan (46.5%) Ranger Districts were similar in the proportion of plots with down logs. Plots with the highest amounts of woody debris typically occurred in the aspen or mixed conifer dominated vegetation type categories.

Photo plots and fuels analysis

At each plot, a photo of the plot was taken from the southern end of the north-south transect. Additionally, photos of 1m^2 quadrants were taken 2.5 m from the plot center along each of the 4 transect lines. These photos can be used for estimating fine fuels at each plot using the PHOTOLOAD technique (Keane and Dickson 2007). Although it was beyond the scope of this project to analyze these photos, it only took about 30 seconds to take all 5 pictures at each plot. Continuing the collection of these photos should allow for quick estimates of fuel loadings with little time spent out in the field. The PHOTOLOAD data along with coarse woody debris and litter and duff depths can provide a comprehensive depiction of fuel loading within the plot and relates directly to question 8 in the monitoring plan.

Comparing rapid plots to digitally derived estimates of forest structure

To explore relations between field data and digital data layers used to estimate key forest structure attributes across the Kaibab National Forest (KNF), we used a GIS to intersect each rapid plot location with data layers derived using Forest Inventory and Analysis (FIA) plot data and Landsat imagery acquired in 2010 (see Dickson et al. 2011). Specifically, we intersected rapid plots with layers describing basal area (BA), canopy cover (CC), height, trees per acre (TPA), stand density index (SDI), and quadratic mean diameter (QMD) (Appendix A). For comparison, we used information collected at each rapid plot location to estimate BA, QMD, TPA and SDI. Importantly, canopy cover (i.e., closure) and tree height were not measured at rapid plots so we were unable to compare these metrics. Since individual trees < 40 cm DBH were not measured at rapid plots, we used size classes (as reported on data sheets: 10-20, 20-30, 30-40) to estimate QMD, BA, and SDI. For example, in each size class, we used the average value of the classification range (e.g., a 15 cm DBH was used for a tree in the 10-20 cm DBH class). Notably, a lack of individual tree measurements presented a challenge when trying to make comparisons with the derived data layers, or even FIA data directly. We converted DBH cm to inches before making our calculations. Using the rapid plot data, TPA and SDI were calculated two different ways. The first calculation (TPA_1 and SDI_1) only accounted for trees greater than 3.94” DBH (10 cm DBH), while the second calculation (TPA_2 and SDI_2) included both saplings and seedlings. Data collected in the field combined seedling and sapling counts into one group so we were unable to separate these counts. This led to sometimes very high TPA and SDI values, since some of the plots had > 100 saplings in a plot. The digital structure data, however, included FIA-measured trees > 1” DBH in the calculations. Thus, values for TPA_1 or TPA_2 were consistently lower or higher, respectively, than the derived estimates, especially for rapid plots with a large number of seedlings. We used English units for all calculations.

We used a Pearson correlation coefficient to compare (using English units) the rapid plot and digital structure data for QMD, TPA, BA, and SDI. Correlation coefficients were greater when comparing TPA_1 and SDI_1 to digital data than for TPA_2 and SDI_2. Therefore we used TPA_1 and SDI_1 to evaluate and summarize our results. SDI had the highest correlation coefficient with a value of 0.71, followed by BA (0.69), TPA (0.61), and QMD at 0.44.

For each of the three Ranger Districts (RD) and each of the dominant vegetation types (classified by technicians at each plot), we calculated the mean and standard deviation of TPA, BA, SDI, and QMD using the forest structure data (Tables 5 and 6) and information collected at all rapid plot locations (Tables 7 and 8). For both datasets, mean TPA, BA, and SDI were highest in the North Kaibab RD, followed by the Williams RD and then the Tusayan RD. Mean QMD, however, was highest in the Williams RD and lowest in the North Kaibab RD. The mixed conifer, mixed conifer/aspen, and ponderosa/oak vegetation types tended to have the largest mean values for TPA, BA, SDI, and QMD, based on both the rapid plot data and the digital forest structure data layers.

Time and cost

Our field crew of two averaged about 26-28 plots per week. Each plot, on average, took 45-60 minutes to complete. Grassland-dominated plots were completed the quickest, taking an average of 15-20 minutes, followed by ponderosa pine and oak-dominated plots (30-40 minutes) and mixed conifer plots (30-70 minutes). The amount of down logs at a plot contributed to the wide variability in time to complete a plot, since they added a significant amount of extra time. Due to the variability in time to complete plots and the difference in mileage from Flagstaff to the different Ranger Districts, the cost per plot also varied. An approximate average cost of a plot was about $68. This average was based on a weekly cost divided by the number of plots completed in that week and includes supplies, 2 technician salaries, rental vehicle, gas, and per diem. If a rental vehicle was not needed, the average cost could probably drop to ~ $58/plot.

Considering the aforementioned calculations, comparisons, and challenges, we recommend the following changes be considered in any adjustment to the rapid plot data collection protocols.

Recommendations and clarification for future rapid plot sampling efforts

- *Reevaluate vegetation type categories*
  We increased the number of possible vegetation type categories over the number that was indicated on the original draft data sheet. This was because several plots had a mix of two vegetation types. A total number of meaningful categories should be reconsidered prior to future sampling efforts.
- *Include sagebrush/scrub as a unique vegetation category*
  Several of the plots that were initially listed as grassland in the selection of plots were actually sagebrush or scrub dominated.
- For the point-line intercepts, we classified logs as litter, but this may not be desirable in future sampling efforts.
- MVUM roads should be used in the future for selecting new points along with private land. There were several plots that were not sampled due to private property or closed or non-existent roads.

- *Development of better field guides (plant identification, Keen class descriptions, invasive species)*
  The field crew did have some problems distinguishing between Utah and one-seed juniper species, and between white fir and subalpine fir. For these and other similar species, we recommend having better field guides/plant identification guides available for field crews to keep while out in the field.
  The categories that indicated maturity (platy, yellow, furrowed, or sloughing bark of old trees and Keen Class 4 trees) were rarely marked on the data sheet. This was probably due to some confusion about what these categories actually mean. It would be a good idea to provide more information on these categories and how these data will be used so future crews have a better understanding of how to apply the categorization. A reference sheet with color photos showing trees that would be classified as Keen/Dunning (play yellow bark, etc.) and larger older trees that do not fit into the Keen/Dunning classification would be more useful than just having the line drawings. The 2014 crew was also unsure about whether these data should be collected only in the ponderosa pine-dominated vegetation type, or in other conifer species as well.
- *Provide maps with known treatment areas and wildfire locations*
  It was difficult to distinguish between burning treatment and wildfires unless it was a very hot burn or a very recent thin and burn treatment. Thus, most fire evidence was noted in the 'disturbance' category even if it appeared to be a light burn. Noting fire presence in the field is useful but it would probably be wise to compare these observations to maps of known treatment areas and wildfire locations.
- *Provide better clarification on overtopping and encroachment*
  Overtopping and encroachment were only noted at two plots. Glancing through the raw data it appears that this was actually occurring more often than was documented. For example, if there were a lot of new young trees invading what was a grassland or aspen stand, then this pattern should be reflected in the belt transects and in some of the tree count data. Reviewing the data in this way, however, will take longer than just having it properly marked on the data sheets. For future field efforts, clarification should be provided for these categories, as well as noting to the field crew the importance of encroachment.
- *Reevaluate the inclusion of canopy closure measurements*
  Forest canopy greatly influences microhabitat within the forest by affecting plant growth and survival. Collecting this information would provide additional vegetation and wildlife habitat

information and would also allow for additional comparisons and calibrations to other data sets, such as FIA data or digital data layers that estimate canopy condition. Since, the addition of a canopy closure measurement to the rapid plot protocol would add several minutes to the time spent per plot, the KNF might consider using ‘off the shelf’ estimates of canopy cover (e.g., obtained from the LANDFIRE program or the National Land Cover Database).

- *Separate out sapling counts by > 1” DBH and those < 1” DBH*

  If the KNF is interested in more precise comparisons between rapid plot data and FIA data or digital data layers, we recommend separating out sapling and seedlings by using a 1” DBH cut point. This distinction between saplings and seedlings would probably add an additional 2 minutes to the time spent per plot. To offset the additional time it would take to separate counts by these two size classes, the number of transects could potentially be cut in half (2 transects instead of 4), and we recommend testing this option in the field.
- *Measure all trees > 4” DBH and do not use size classes*

  A precise DBH measurement of all individual trees within rapid plots > 4" DBH would allow for more reasonable, integrated measurements of forest structure attributes, such as stand BA or QMD. More precise measurements would also allow for better calibration of the remotely sensed data. The additional time for these measurements would vary greatly by plot and vegetation type, but shouldn’t take more than 5 minutes. Since this approach would be more time consuming, another option would be to measure all trees > 8” DBH and place smaller trees into bin categories. This would reduce the amount of time in the field but still provide more precise measurements since the larger trees contribute more to basal area calculations. Future work might involve conducting a sensitivity analysis to determine which cutoff size produces more accurate results, without adding too much additional time to full implementation of the rapid plot protocol.

Table 1. Number of rapid plots sampled during the 2014 field season in each of the 13 dominant vegetation type categories we considered, and across the three Kaibab National Forest Ranger Districts. PJ = pinyon-juniper.

Vegetation type	North Kaibab	Tusayan	Williams	Grand Total
Aspen	5	0	2	**7**
Aspen, Mixed Conifer	6	0	0	**6**
Grassland	10	7	22	**39**
Grassland, PJ	0	2	1	**3**
Mixed Conifer	28	0	2	**30**
Oak	8	0	1	**9**
PJ	14	34	37	**85**
PJ, Sagebrush	3	3	0	**6**
Ponderosa	21	22	46	**89**
Ponderosa, Grassland	0	1	1	**2**
Ponderosa, Oak	0	0	5	**5**
Sagebrush	4	2	0	**6**
Scrub	3	0	1	**4**
Grand Total	**102**	**71**	**118**	**291**

Table 2. Total count and average number of trees and snags in each of the DBH classes measured at all rapid plots in the North Kaibab Ranger District in 2014. * indicates trees that could only be identified to the *Pinus* genera.

		DBH class					
Tree Species		**1 (10-20)**	**2 (20-30)**	**3 (30-40)**	**4 (>40)**	**Snag (>45)**	**Avg. DBH (class 4)**
Subalpine fir	Total count	48	21	12	2	2	NA
	Average (SD)	4 (2.86)	2.6 (1.99)	2 (1.09)	1 (0.00)	1 (0.00)	48.2 (0.98)
White fir	Total count	84	13	11	6	0	NA
	Average (SD)	4.2 (4.6)	1.4 (0.73)	1.8 (1.6)	1.5 (1.0)	0	50.5 (2.35)
Utah juniper	Total count	30	22	28	25	3	NA
Douglas fir	Total count	105	63	55	38	5	NA
	Average (SD)	4.2 (4.28)	2.7 (2.45)	2.6 (1.98)	2.0 (1.00)	1 (0.00)	51.4 (5.82)
	Average (SD)	2.7 (1.95)	2 (1.0)	2.2 (1.28)	2.5 (1.35)	1 (0.00)	59 (8.21)
Pinyon pine	Total count	103	35	11	2	0	NA
	Average (SD)	8.6 (10.66)	4.4 (3.46)	1.8 (1.17)	1 (0.0)	0	44.6 (0.57)
Ponderosa pine	Total count	190	88	60	100	15	NA
	Average (SD)	6.5 (8.3)	3.8 (4.42)	2.5 (1.77)	2.9 (2.2)	1.4 (0.67)	55.9 (7.73)
Pinus spp.*	Total count	99	29	28	17	3	NA
	Average (SD)	3.5 (3.14)	1.8 (1.32)	2.3 (2.02)	1.4 (0.51)	1.5 (0.71)	53.8 (5.27)
Aspen	Total count	345	77	35	12	8	NA
	Average (SD)	10.5 (12.34)	2.9 (2.29)	2.1 (1.02)	2 (2.00)	1.6 (1.34)	50.2 (4.23)
Gambel oak	Total count	8	1	0	0	0	NA
	Average (SD)	8 (0.00)	1 (0.00)	0	0	0	0
Total	**Total count**	**1012**	**349**	**240**	**202**	**36**	**NA**
	Average (SD)	**5.5 (6.01)**	**2.7 (2.21)**	**2.2 (1.49)**	**1.8 (1.00)**	**0.9 (0.34)**	**51.7 (4.39)**

Table 3. Total count and average number of trees and snags in each of the DBH classes measured at all rapid plots in the Tusayan Ranger District in 2014.

		DBH class					
Tree Species		**1 (10-20)**	**2 (20-30)**	**3 (30-40)**	**4 (>40)**	**Snag (>45)**	**Avg DBH (class 4)**
One-seed juniper	Total count	16	18	13	8	1	NA
	Average (SD)	2.3 (2.36)	2 (1.22)	1.6 (0.92)	1.3 (0.52)	1 (0.00)	72.6 (21.73)
Utah juniper	Total count	60	47	36	40	2	NA
	Average (SD)	2.6 (2.15)	2.1 (1.49)	1.9 (1.37)	2.1 (1.41)	1 (0.00)	59.8 (12.64)
Pinyon pine	Total count	270	122	33	5	2	NA
	Average (SD)	7.1 (4.73)	3.5 (2.58)	2.1 (0.99)	1 (0.00)	1 (0.00)	48.08 (3.02)
Ponderosa pine	Total count	149	93	55	24	3	NA
	Average (SD)	7.5 (6.24)	4.4 (4.85)	2.8 (1.41)	1.7 (0.99)	3 (0.00)	56.8 (4.97)
Gambel oak	Total count	80	7	2	0	0	NA
	Average (SD)	11.4 (9.25)	1.8 (0.96)	1 (0.00)	0	0	0
Total	**Total count**	**575**	**287**	**139**	**77**	**8**	**NA**
	Average (SD)	**6.18 (4.94)**	**2.8 (2.22)**	**1.9 (0.94)**	**1.2 (0.58)**	**1.2 (1.09)**	**47.5 (8.47)**

Table 4. Total count and average number of trees and snags in each of the DBH classes measured at all rapid plots in the Williams Ranger District in 2014.

		DBH class					
Tree Species		**1 (10-20)**	**2 (20-30)**	**3 (30-40)**	**4 (>40)**	**Snag (>45)**	**Avg DBH (class 4)**
White fir	Total count	0	0	2	1	0	NA
	Average (SD)	0	0	2 (0.00)	1 (0.00)	0	56
Douglas fir	Total count	11	8	5	4	5	NA
	Average (SD)	5.5 (0.71)	4 (1.41)	2.5 (0.71)	2 (1.41)	5 (0.00)	51.4 (3.51)
Alligator juniper	Total count	68	32	26	31	0	NA
	Average (SD)	3.1 (2.74)	1.8 (0.94)	1.6 (0.96)	2.1 (1.53)	0	65.6 (16.97)
One-seed juniper	Total count	22	26	23	26	0	NA
	Average (SD)	2.8 (1.75)	2.6 (2.8)	2.3 (2.31)	3.7 (2.69)	0	55.8 (9.89)
Utah juniper	Total count	105	72	68	46	2	NA
	Average (SD)	4.0 (3.17)	3.3 (2.33)	2.6 (2.10)	2.4 (1.54)	1 (0.00)	61.3 (13.56)
Pinyon pine	Total count	41	19	8	0	1	NA
	Average (SD)	2.6 (1.86)	1.6 (1.24)	1.3 (0.82)	0	1 (0.00)	0
Ponderosa pine	Total count	252	198	160	104	7	NA
	Average (SD)	5.4 (4.79)	4.2 (4.5)	3.6 (2.59)	2.4 (1.65)	1.2 (0.41)	48.9 (5.85)
White pine	Total count	7	1	2	3	0	NA
	Average (SD)	7 (0.00)	1 (0.00)	2 (0.00)	3 (0.00)	0	44.9 (2.38)
Aspen	Total count	36	4	2	0	0	NA
	Average (SD)	18 (12.73)	2 (1.41)	2 (0.00)	0	0	0
Gambel oak	Total count	162	89	22	18	0	NA
	Average (SD)	7.7 (7.01)	4.7 (4.23)	2.4 (2.51)	2.3 (1.58)	0	50.9 (9.99)
Total	**Total count**	**704**	**449**	**318**	**233**	**15**	**NA**
	Average (SD)	**5.4 (4.34)**	**2.7 (2.35)**	**2.3 (1.49)**	**1.8 (1.49)**	**0.9 (0.06)**	**55.7 (9.96)**

Table 5. Mean (and SD) values for digital forest structure data (2010) derived within each of the three Ranger Districts on the Kaibab National Forest. These estimates include all trees > 1" DBH. TPA = trees per acre, QMD = quadratic mean diameter, BA = basal area, SDI = stand density index, CC = canopy cover

District	TPA	QMD (in)	BA (ft^2/acre)	SDI	CC (%)	Height (ft)
North Kaibab	1049.8 (912.4)	3.5 (2.4)	69.4 (53.6)	184.9 (149.8)	34.2 (26.9)	34.8 (28.8)
Tusayan	351.5 (324.4)	4.0 (2.7)	48.9 (35.8)	113.2 (84.5)	23.0 (15.9)	17.9 (14.2)
Williams	473.4 (432.9)	4.3 (3.2)	61.6 (49.1)	140.8 (111.4)	24.9 (18.5)	24.1 (20.7)

Table 6. Mean (and SD) values for digital forest structure data (2010) derived within each of the dominant vegetation types on the Kaibab National Forest. These estimates include all trees > 1" DBH. TPA = trees per acre, QMD = quadratic mean diameter, BA = basal area, SDI = stand density index, CC = canopy cover

Vegetation type	TPA	QMD (in)	BA (ft^2/acre)	SDI	CC (%)	Height (ft)
Aspen	1319.5 (467.3)	5.3 (1.0)	95.4 (28.9)	243.2 (80.8)	40.5 (14.7)	49.3 (17.6)
Grassland	61.9 (213.5)	0.4 (1.0)	5.9 (19.1)	15.7 (55.1)	2.9 (9.6)	2.8 (10.3)
Grassland/PJ	51.7 (89.6)	0.8 (1.4)	10.7 (18.6)	23.7 (41.1)	5.2 (9.0)	3.1 (5.3)
Mixed Conifer	1965 (455.4)	5.1 (0.6)	117.7 (27.2)	322.8 (78.4)	59.6 (13.1)	60.3 (12.7)
Mixed Conifer/Aspen	2361.5 (280.2)	5.4 (0.3)	122.1 (8.1)	367.1 (27.8)	68.2 (4.1)	65.3 (1.4)
Oak	383.1 (343.8)	1.5 (1.9)	30.8 (36.8)	73.5 (82.2)	13.4 (12.4)	9.8 (14.9)
Pinyon-Juniper (PJ)	259.9 (246.8)	3.8 (2.7)	41.9 (33.1)	94.1 (77.0)	21 (16.1)	12.4 (10.2)
Pinyon-Juniper/Sagebrush	16.8 (31.5)	0.8 (1.5)	4.5 (8.8)	9.4 (18.4)	2.9 (5.7)	2.4 (4.9)
Ponderosa	782.8 (354.1)	6.0 (1.8)	91 (31.7)	211.6 (70.4)	36.4 (10.8)	39.8 (14.9)
Ponderosa/Grassland	380.9 (437.3)	2.2 (1.5)	33 (29.2)	92.7 (69.9)	15.5 (12.8)	15.9 (10.4)
Ponderosa/Oak	1030.0 (184.4)	6.2 (0.8)	108.9 (18.2)	254.2 (47.3)	42.1 (4.5)	45.3 (7.8)
Sagebrush	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Scrub	20.2 (40.4)	0.5 (0.9)	4 (8.0)	7.6 (15.2)	2 (4.0)	0.8 (1.7)

Table 7. Mean (and SD) values for rapid plot data collected during 2014 within each of the three Ranger Districts on the Kaibab National Forest. QMD and BA were calculated using the mean of the DBH class ranges and TPA_1 and SDI_1 were calculated using trees > 3.94" DBH. TPA = trees per acre, QMD = quadratic mean diameter, BA = basal area, SDI = stand density index

District	**TPA_1**	**QMD (in)**	**BA (ft^2/acre)**	**SDI_1**
North Kaibab	103.2 (92.3)	9.7 (6.5)	68.7 (56.1)	118.4 (95.0)
Tusayan	87.7 (70.4)	9.9 (4.5)	52.5 (40.1)	92.7 (68.3)
Williams	82.8 (72.8)	10.5 (5.3)	65.3 (51.6)	109.6 (85.6)

Table 8. Mean (and SD) values for rapid plot data collected during 2014 within each of the dominant vegetation types on the Kaibab National Forest. QMD and BA were calculated using the average value of the DBH classification range, and TPA_1 and SDI_1 were calculated using trees > 3.94" DBH. TPA = trees per acre, QMD = quadratic mean diameter, BA = basal area, SDI = stand density index

Vegetation type	**TPA_1**	**QMD (in)**	**BA (ft^2/acre)**	**SDI_1**
Aspen	99.8 (62.6)	11.8 (4.6)	53.6 (18.8)	95.3 (34.6)
Grassland	3.7 (9.3)	2.8 (5.0)	2 (4.3)	3.5 (7.5)
Grassland/Pinyon-Juniper	55.3 (51.3)	9.2 (1.4)	24.4 (20.1)	46.5 (39.4)
Mixed Conifer	172.5 (57.1)	11.1 (1. 8)	114.1 (46.1)	199.7 (72.5)
Mixed Conifer/Aspen	250 (84.5)	8.3 (1.0)	90.6 (20.3)	179.4 (41.0)
Oak	29.9 (62.4)	7.8 (12.6)	16.8 (27.7)	28.1 (50.3)
Pinyon-Juniper	93.2 (59.0)	11.9 (3.9)	72.5 (45.3)	121.1 (71.4)
Pinyon-Juniper/Sagebrush	18.1 (15.1)	9.7 (4.0)	12.9 (15.2)	21.8 (24.6)
Ponderosa	105.4 (67.3)	12.6 (3.5)	77.6 (40.9)	131.8 (67.4)
Ponderosa/Grassland	106.3 (67.5)	12.7 (5.6)	57.2 (20.2)	101.4 (52.2)
Ponderosa/Oak	176.3 (153.8)	11.3 (2.1)	108 (61.6)	191.6 (117.3)
Sagebrush	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Scrub	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

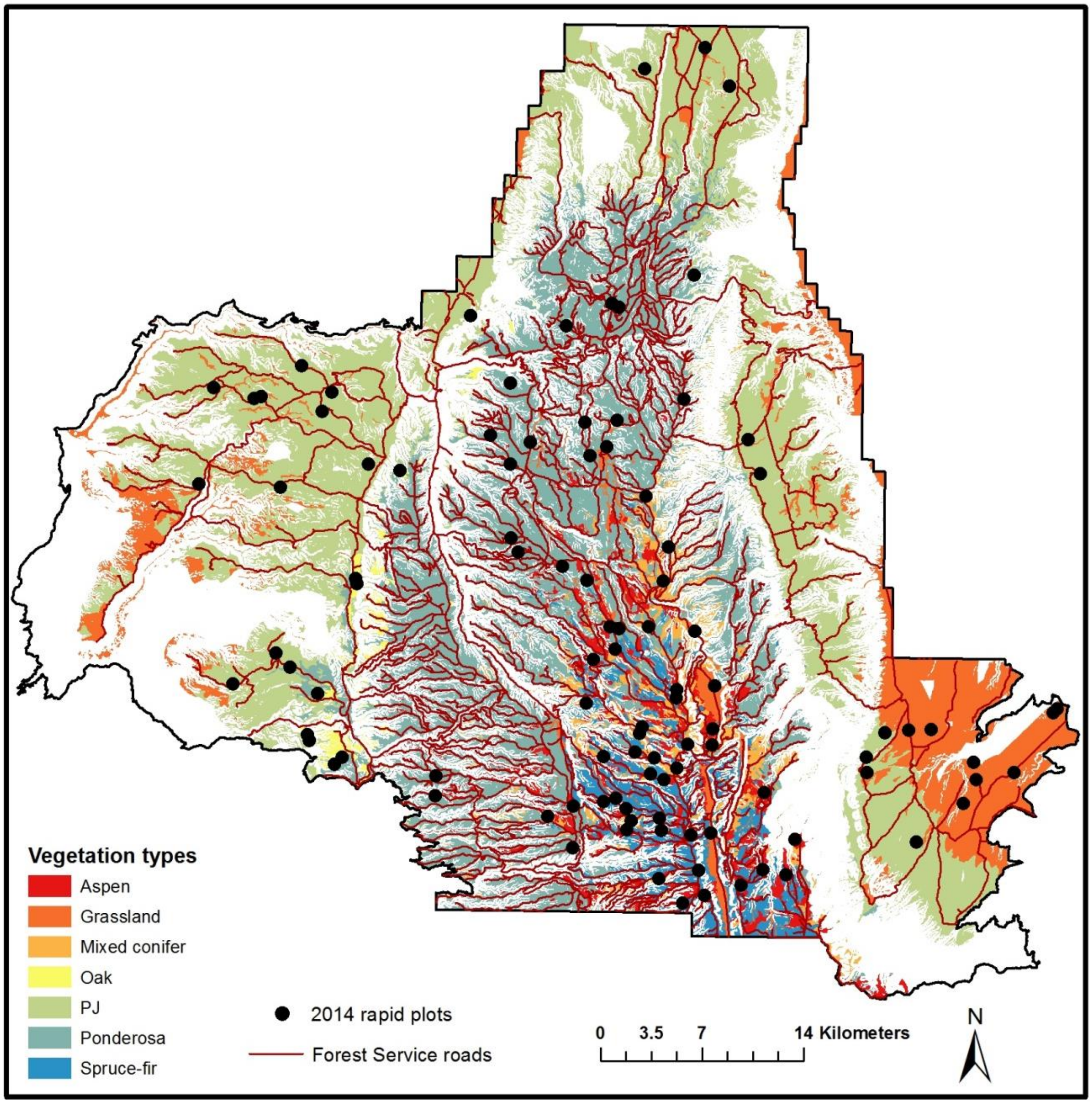

Figure 1. Locations of rapid plots surveyed during the 2014 pilot field season in the North Kaibab Ranger District.

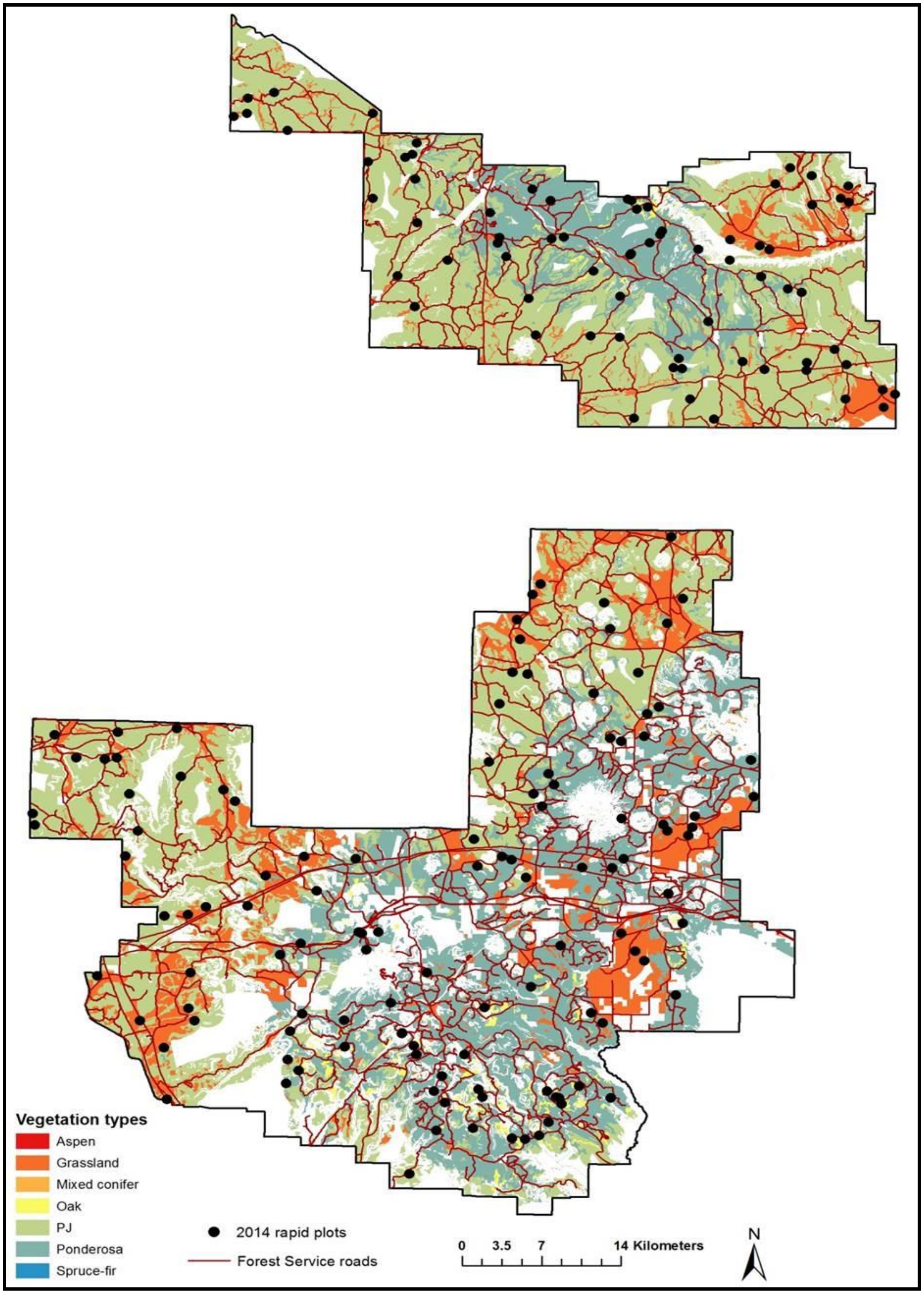

Figure 2. Locations of rapid plots surveyed during the 2014 pilot field season in the Williams and Tusayan Ranger Districts.

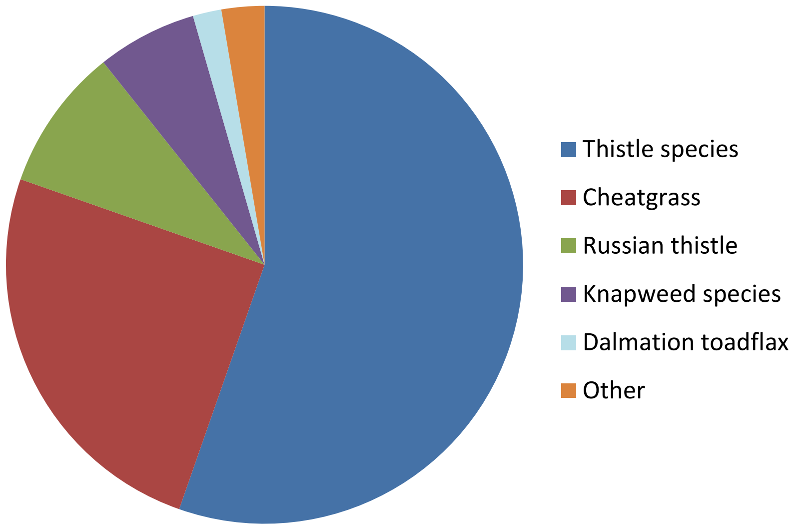

Figure 3. Relative proportions of the different invasive species detected in rapid plots across the North Kaibab, Tusayan, and Williams Ranger Districts during the 2014 pilot field season.