To succeed at forest restoration, the core strategy of The Nature Conservancy in Arizona helps resolve two challenges: the low value of small-diameter wood and associated biomass; and the tentative social acceptance of large-scale treatments. The use of technology in the form of GPS-enabled tablets can help reduce harvesting costs borne by private industry; increase the amount of acreage prepared by the U.S. Forest Service for treatments; and obtain real-time monitoring data to inform adaptive management. Working with U.S. Forest Service, Arizona State Forestry, and stakeholders, The Nature Conservancy is investing in this innovative project to accelerate the pace and scale of forest restoration.

Challenge and Need

The Nature Conservancy (TNC) and U.S. Forest Service (USFS) wish to accelerate the pace and scale of forest restoration in northern Arizona. To achieve this goal within the 2.4 million acre Four Forest Restoration Initiative (4FRI), USFS costs need to be reduced and processes streamlined. 4FRI restoration treatments require removal of small-diameter trees and the residue or remaining biomass. Both have low value, which creates challenges for private sector contractors to develop and maintain sustainable business models.

Economics

- The USFS is moving away from the traditional “leave tree” paint marking method and implementing a ***Designation by Prescription*** (**DxP**) process. DxP means instructions are provided to private sector wood harvesters in written form. In DxP areas, wood harvesters must decide which trees to remove to create the desired conditions in the contract.

- 75% of mechanical harvest contract acres in the 4FRI may be DxP, reducing project layout costs, but increasing the uncertainty of achieving desired conditions and operator efficiency. The change from marking trees to a “DxP” model could, at least in the near term, slow the pace of forest restoration. With practice, however, we estimate a significant cost savings in both site preparation and harvesting.

Figure 1 - Aerial view of restoration treatments, Apache-Sitgreaves National Forest in Arizona. Credit USFS.

Building Trust

- Minimizing the uncertainty of the DxP process will help foster and maintain the social license obtained through the collaborative process.

- New, low-cost methods are needed to develop monitoring data across large scales. 4FRI Stakeholders and the USFS have developed an adaptive management framework to help resolve concerns over implementation, but traditional field-based data collection is cost-prohibitive. The ability to assess implementation data in near real-time would increase transparency, facilitate adaptive management and enhance trust.

Below we describe a project The Nature Conservancy in Arizona is leading to integrate off-the-shelf hardware, software, and spatial data to facilitate implementation of DxP by the USFS and wood harvesters, as well as to provide a low-cost approach to collecting landscape scale data that can be used to facilitate adaptive management.

Digital Restoration Guide (DRG)

Enhancing Project Layout and Implementation

Using ESRI ArcGIS online and the Collector App on handheld tablets (Android or IOS), restoration units can now be marked digitally in place of traditional painting methods. Marking crews use tablets (Figure 2) to designate where tree clumps and groups should be placed (Figure 3), and generally how the structure in those areas should look.

Figure 2 – Tree Marker using tablet to digitally mark groups to be thinned.

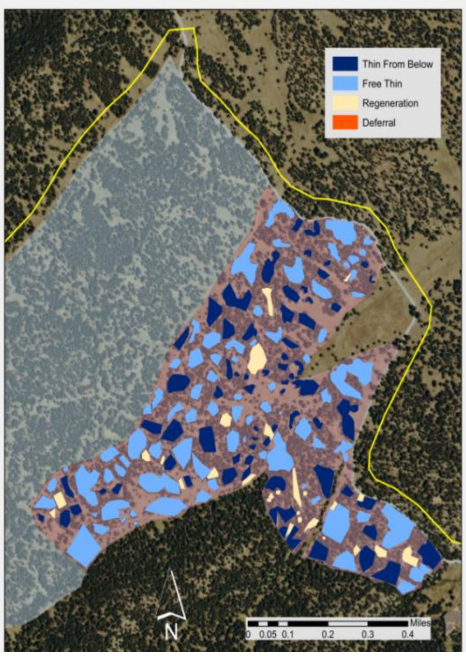


Figure 3 – Group prescriptions marked in the field using the tablet-based Digital Restoration Guide.

Figure 3 illustrates how polygons designating groups of trees in a ponderosa pine stand were recorded as either a deferral (no entry; e.g., archeological sites), thinned based on a diameter limit, or thinned to a designated number of trees remaining in certain size classes. Using a stylus, a tree marker "draws" the polygon for which he/she is designating and determines the best group/size and category based on what structure and density currently exists.

In the restoration unit depicted in Figure 3, interspace between groups has simple rules defining what to leave. Oak trees will be released by removing small pine trees around existing clumps. All yellow pines and trees >24" in diameter are left. All remaining trees in interspace areas are to be removed.

A final category was developed to account for advanced regeneration. If advanced regeneration occurs, a category is designated to remove mid-age overstory trees to allow for an uneven age/size class distribution into the future.

The digitally marked polygons from handheld tablets can be further labeled (Figure 4) before being uploaded to GPS-enabled in-cab tablets (Figure 5). The operator uses this digitally-marked map to navigate within a stand and to assist with decisions regarding placement and structure of clumps/groups and interspace.

The in-cab GPS-enabled tablet technology designed for forestry applications (Figure 5) provide harvesters with a digital map of the harvest unit and other data such as aerial imagery, roads, stand/unit boundaries, and enhanced DRG polygons. The tablets record productivity data, such as the number of trees harvested per unit of time enabling operators to evaluate efficiency.

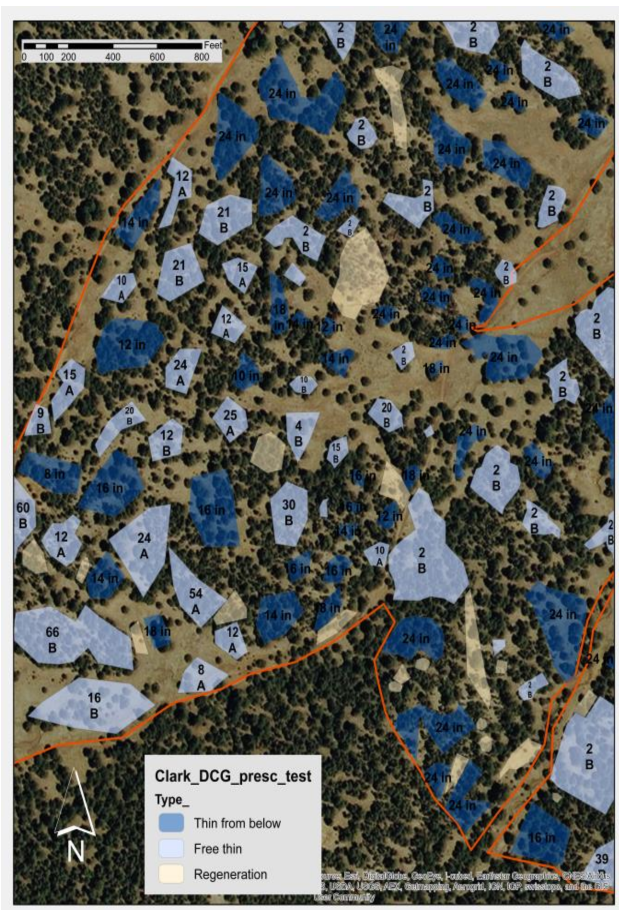


Figure 4 – DRG input to in-cab tablets for use by operators. A number + a letter indicate the number of trees to leave in a group and whether the diameter distribution should be focused on larger (A) or smaller (B) trees.

Figure 5 – In-cab tablet technology used by operators near Mormon Lake, AZ to assist with restoration treatments and collect tree harvest data.

Integration of DRG Harvest Data with Monitoring and Adaptive Management

Monitoring and adaptive management plans within the Four Forest Restoration include a focus on the structural and spatial patterns created. These attributes occur at multiple scales, from groups of trees and openings up to landscape scale patterns. However, acquiring ground-based data at landscape scales using current methods can be time and cost prohibitive.

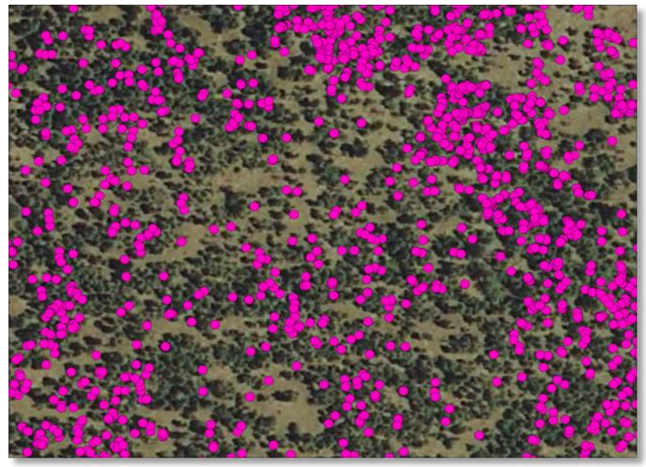
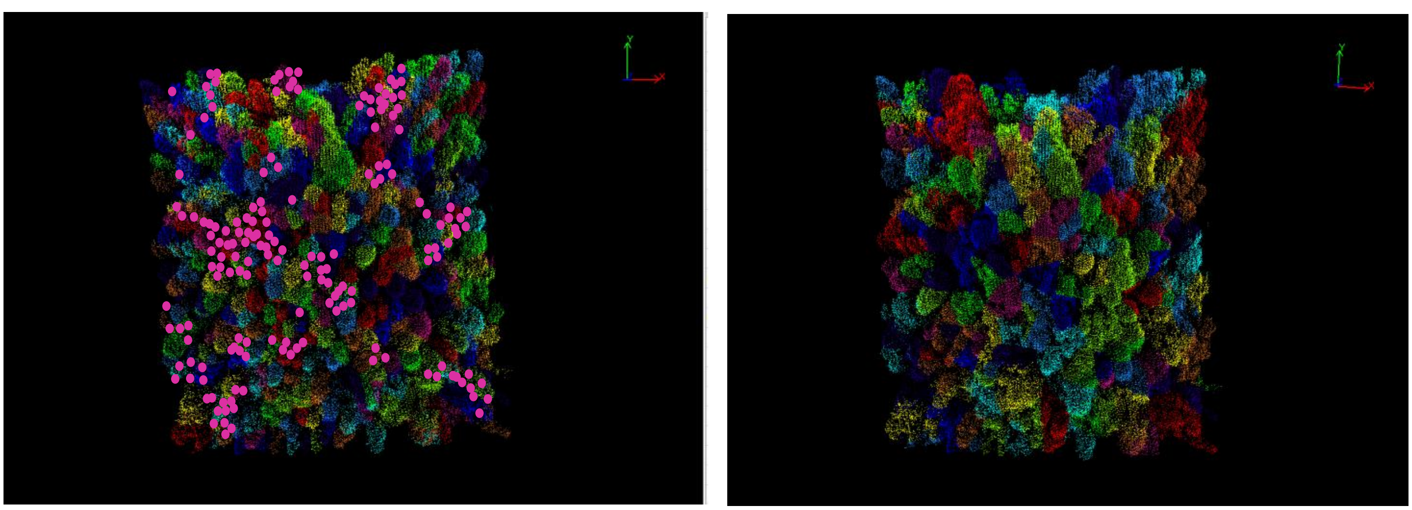


Figure 6 – Tree harvest location data from in-cab tablet near Mormon Lake, AZ.

The GPS-enabled in-cab tablets being tested currently record the spatial location, and potentially diameter, of trees harvested in real time (Figure 6). Evaluating implementation, however, involves analyzing data on what is left following treatments. To address this need, TNC is testing the integration of harvest tree location data with remotely-sensed stand data, particularly LiDAR, a detection system that works on the principle of radar but uses light from a laser (Figures 7A & B).

Updating pre-harvest LiDAR data with post-harvest forest structural changes could provide a low-cost, rapid method for monitoring implementation. In addition the three-dimensional nature of these data can provide a powerful platform for modeling important metrics of forest health, such as fire risk and wildlife habitat attributes. Post-treatment basal area, canopy cover, and sizes or randomness of openings created can be determined without the need to obtain additional post-harvest remotely-sensed imagery.



Figures 7A & B – A (left figure) 3D top view of a 1 ha plot Point cloud of LiDAR data showing individual tree crowns in a mixed conifer plot on the Mogollon Rim with tablet harvest points (pink) overlaid; B (right figure) Top view with harvested trees removed illustrating post-harvest structure. ***Credit: Wasserman NAU***

DRG Outcomes to Date

The Flagstaff Ranger District on the Coconino National Forest has currently allocated an additional 5,000 acres for digital tree marking.

The initial 327 acre test site for the Digital Restoration Guide is the Clark Task Order (Figure 9), part of a 300,000-acre stewardship contract issued within the Four Forest Restoration Initiative. This site provides a comparison of three different methods of planning and implementation for forest restoration in ponderosa pine that will be harvested in 2016.

1) 680 acres: Traditional leave-tree paint marking
2) 1,004 acres: Designation by Prescription
3) 327 acres: Digital Restoration Guide

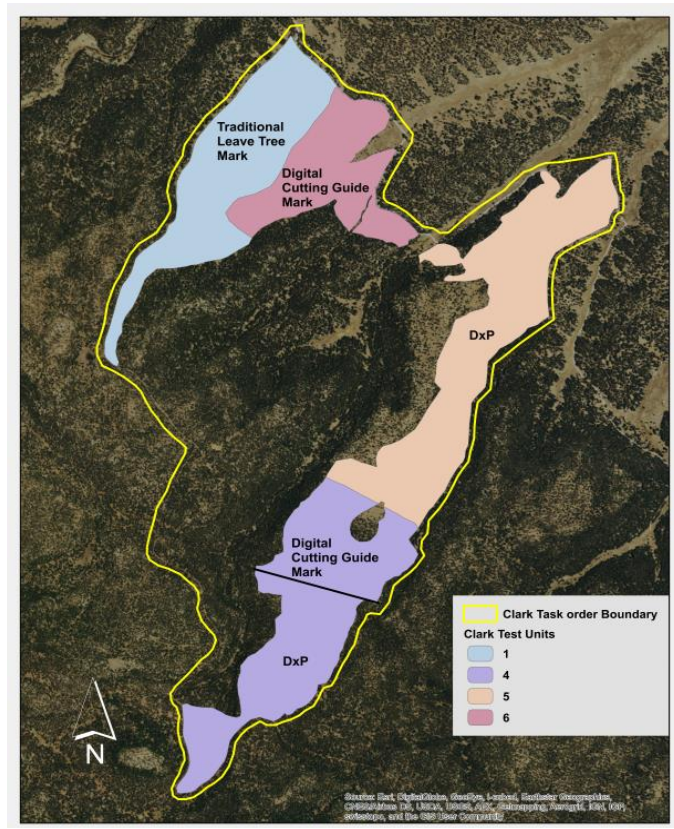


Figure 9 – Clark Task Order - Pilot project Study area.

During our pilot work on the Clark Task Order DRG marking productivity was 40-60 acres/day compared 8 acres/day with traditional paint marking. Layout costs decreased from about $40 per acre to under $16 (table 1).

Through this process we were able to gain necessary feedback from our test marking crew that enabled us to identify ways to simplify both the marking and symbology used to guide operators.

The second location for DRG testing is on Arizona State Land managed by Arizona State Forestry (AZSF.) This restoration unit will implement a similar approach and harvest operations will begin when conditions allow in Spring 2016. Comparing the DRG results for USFS and AZSF prescriptions will help us better refine the process.

The third location for DRG testing is the Fort Valley timber sale. TNC, 4FRI and Coconino National Forest staff are currently developing the geodatabases and protocols and the USFS Enterprise Teams will begin digitally marking the site in late April 2016.

Table 1 – Comparison of productivity, administrative steps, and costs associated with three methods for planning and implementing restoration treatment prescriptions

	Traditional Paint Marking	Current DxP	Digital Restoration Guide
Production	8 ac/day/person	17 acres/day/person	40-60 acres/day/person
Paint	Trees/boundary	Boundary Only	Boundary only
Extra Admin. steps	None	Yes	None
Desired Condition	Exact as marked	Unknown^	As marked by DRG^
Costs of Layout and Admin	$40/acre+	$13/acre+	$16/acre+
Implementation Production	*	*	*

^Potential to test once harvesting operations occur
* Currently awaiting harvesting operations for testing
+ Currently being assessed by USFS

Future Potential DRG Uses and Testing

- Inventory: USFS Silviculturalists can complete site "walk throughs" and cruising activities using a modified version of the existing DRG. This would allow for time savings and better data transfer to the Timber staff that prep the site for operations.

- Oversight: Having the ability to compare digital marking to what occurred on the ground in a rapid fashion will help obtain desired conditions. The harvest data will either reinforce success or support well informed adaptive changes if desired conditions are not being met.

- Productivity: The in-cab system collects productivity data that can be used to improve economic models and potentially estimate wood volume removed.

For More Information

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