TECHNOLOGY AND TREES: Increasing Trust and Efficiencies in Forest Restoration

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The Nature Conservancy ("Conservancy") is a 501(c)(3) non-profit conservation organization dedicated to the conservation of biodiversity across the world.[1] Recognizing the multiple values of our forested ecosystems is an organizational priority. In Arizona, the Conservancy collaborates with multiple partners and the U.S. Forest Service ("USFS") to support meaningful efforts to restore forests in a manner that is ecologically appropriate[2] and economically viable.

INTRODUCTION

Extending 250 miles from the Grand Canyon east into New Mexico, northern Arizona is part of a 2.5 million hectare (six million acres) expanse of ponderosa pine (*Pinus ponderosa*) forest.[3] At a range of 6,300–8,000 feet above the surrounding desert valleys at the southwestern edge of the Colorado Plateau, winter snow provides year-round precipitation to four of Arizona's most important rivers—the Salt, Verde, Little Colorado, and San Francisco (Gila).These rivers provide irrigation and municipal water supplies to rural communities and the greater metropolitan Phoenix area.[4] Communities such as Alpine, Heber, Flagstaff, Payson, Pinetop-Lakeside, Show Low, Springerville, and Williams lie within the largest swath of

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1. *See* 26 U.S.C. § 501(c) (2014).
2. *See* RICHARD T. REYNOLDS ET AL., U.S. FOREST SERV., RMRS GTR 310, RESTORING COMPOSITION AND STRUCTURE IN SOUTHWESTERN FREQUENT-FIRE FORESTS 36–37 (2013).
3. RUSSELL T. GRAHAM & THERESA B. JAIN, U.S. FOREST SERV., PONDEROSA PINE ECOSYSTEMS 2 (2005).
4. Marcos D. Robles et al., *Effects of Climate Variability and Accelerated Forest Thinning on Watershed-Scale Runoff in Southwestern USA Ponderosa Pine Forests*, 9 PLOS ONE E111092, 1 (2014), http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0111092.

ponderosa pine forest traversing the Mogollon Rim, and rely on tourism, recreation, home development, and forest products as primary economic drivers.[5]

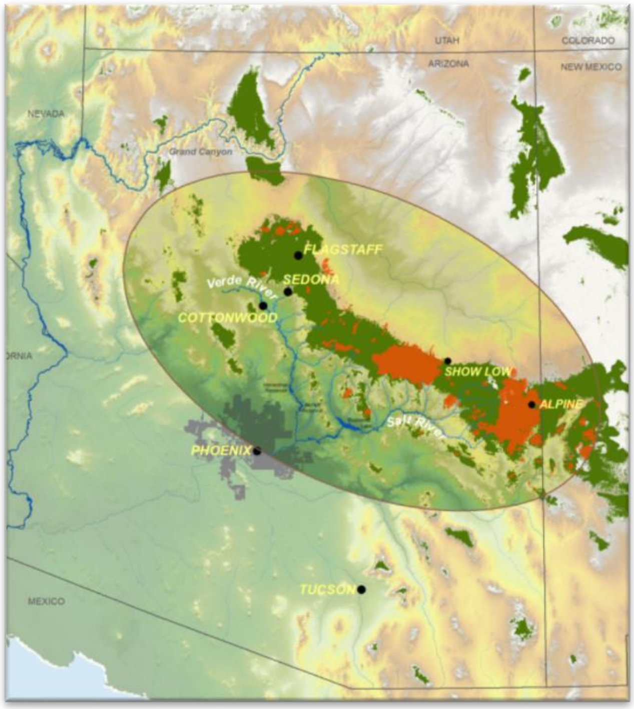

Fig. 1. Arizona conifer forests and fires of the past decade.

Prolonged drought and a warming climate have left the forest stressed for water and highly vulnerable to large fires that are uncharacteristically severe.[6] Between 2002 and 2011, more than one million acres burned in wildfires, affecting infrastructure, local economies, tribal lands, and vast tracts of public lands managed for fiber, wildlife, recreation, tourism, and water supplies.[7]

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5. ARIZ. DEP'T OF LAND, ARIZONA FOREST LEGACY PROGRAM: ASSESSMENT OF NEED 24–27, 172–75 (2005).

6. *See* Phillip J. van Mantgem et al., *Widespread Increase of Tree Mortality Rates in the Western United States*, SCIENCE, Jan. 2009, at 521; A.L Westerling et al., *Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity*, SCIENCE, Aug. 2006, at 940; Robles et al., *supra* note 4, at 1.

7. *See* Figure 1. The orange regions of the map in Figure 1 depict conifer fires.

The structure and density of forest stands have been modified from pre-European settlement conditions due to multiple changes in land use over the past century, including livestock grazing; harvesting of commercial sawtimber; and fire suppression.[8] Across much of the ponderosa pine forest landscape, current conditions are a significant departure from historical forest structure.[9] Areas of larger, mature trees grouped in clumps and interspersed with grassy openings, regulated by regular, low-intensity fires have been replaced by denser stands of small-diameter (less than sixteen inches in diameter at breast height, [dbh]) trees more conducive to high severity fires.[10]

Fig. 2. Example of ponderosa pine stand dominated by young, dense trees.

Recent forest management efforts are focused on ecological restoration and hazardous fuels reduction treatments, focusing on reducing tree densities, maintaining larger, more fire-resilient trees, and increasing openings for herbaceous growth.[11] Such treatments are intended to modify fire behavior from high severity fires to moderated, lower-intensity fires.[12] This modification in fire behavior can result in key resource benefits (nutrient breakdown, vegetation stimulation)[13] as well as mitigation of impacts to

8. *See* Charles F. Cooper, *Changes in Vegetation, Structure, and Growth of Southwestern Pine Forests Since White Settlement*, 30 ECOLOGICAL MONOGRAPHS 129–36 (1960).

9. *See* Joy Nystrom Mast et al., *Restoration of Presettlement Age Structure of an Arizona Ponderosa Pine Forest*, 9 ECOLOGICAL APPLICATIONS 228 (1999), http://library.eri.nau.edu/gsdl/collect/erilibra/index/assoc/HASH57f0.dir/doc.pdf.

10. Cooper, *supra* note 8, at 142; *see also Id*; Figures 2–3.

11. Scott L. Stephens et al., *The Effects of Forest Fuel-Reduction Treatments in the United States*, 62 BIOSCIENCE 549, 549–50 (2012).

12. *Id.* at 550–51.

13. *See* REYNOLDS ET AL., *supra* note 2, at 17, 46.

human safety and communities, wildlife habitat and water resources, and rural economies.

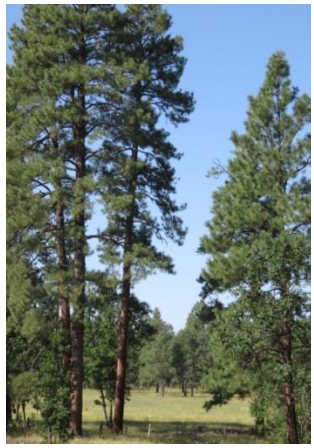

Fig. 3. Example of ponderosa pine stand dominated by groups of larger-diameter trees interspersed with herbaceous openings.

The majority of forested lands are managed by the USFS as National Forests.[14] As federal public lands, the resources therein are guided by federal laws including the National Environmental Policy Act ("NEPA"), which mandates a public input process to determine management actions;[15] the Endangered Species Act ("ESA"), which mandates a consultation process with the U.S. Fish & Wildlife Service to ensure limited or no impact to listed threatened and endangered species;[16] as well as each National Forest's Land Management Plan, developed under the Multiple-Use Sustained-Yield Act of 1960.[17]

Over the past two decades, the USFS modified silviculture practices to emphasize forest restoration-based treatments aimed to reduce the density of smaller-diameter trees through either mechanical treatment or managed fire.[18] Forest management treatments based upon removal of small-diameter trees (generally <16" dbh) do not have the same economic value as historical large-tree harvesting methods, nor the infrastructure to process or add value to this

14. U.S. FOREST SERV., THE U.S. FOREST SERVICE: AN OVERVIEW 11 (2012), http://www.fs.fed.us/documents/USFS_An_Overview_0106MJS.pdf.

15. *See* National Environmental Policy Act, 42 U.S.C. §§ 4321–70 (1982).

16. *See* 16 U.S.C. § 1536 (1973).

17. *See id.* § 1604 (1976); 36 C.F.R. § 219.

18. *See* REYNOLDS ET AL., *supra* note 2.

material (mills, processing plants, biomass utilization facilities).[19] Harvesting contractors struggle to complete these projects for a variety of reasons: limited markets for wood products; minimal profits from products that may or may not offset the cost of harvesting and transportation of raw material to processing plants; and limited infrastructure to process material into goods.[20] Investment in all aspects of the harvesting-to-product supply chain is an economic risk when raw material is not guaranteed over the life of a return-on-investment ("ROI") investment cycle (ten or more years).[21] Until 2004, when the U.S. Congress approved federal agency ability to initiate long-term "stewardship contracts" up to ten years, the USFS could not legally assure a long-term supply to meet industry investment requirements.[22] The need for a new economic paradigm became evident. This was recognized not only by private industry and the USFS, but also by stakeholders with a vested interest in restoring forest health, including state, county, and local governments; economic and rural development entities; and numerous conservation organizations.[23]

Added to economic challenges, a recent history of legal conflicts and litigation from various interest groups over management of these forests affected levels of social trust and support.[24] While significant collaborative effort has been made in establishing mutual social agreements for a forest management framework through significant efforts in collaboration among interest groups and the USFS, limited large-scale forest restoration projects have been initiated.

To succeed in restoring forests to a point that reduces the rate and impacts of increasingly larger uncharacteristic wildfires, all aspects of forest management must be addressed. This includes planning and preparing for treatments by the USFS to treatment implementation by private industry to

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19. MARCUS SELIG ET AL., U.S. FOREST SERV., FOUR FOREST RESTORATION INITIATIVE LANDSCAPE STRATEGY: ECONOMICS AND UTILIZATION ANALYSIS 4 (2010), http://4fri.org/pdfs/documents/CFLRP/econ_and_utilization_final_draft.pdf.

20. *Id.* at 9.

21. DEBRA LARSON, THE SUITABILITY OF VARIOUS MARKETS FOR USING SMALL DIAMETER PONDEROSA PINE TO SUSTAIN FOREST HEALTH AND FIRE-RISK REDUCTION PROGRAMS IN NORTHERN ARIZONA 5, 31 (2001), http://library.eri.nau.edu/gsdl/collect/erilibra/archives/HASHf94e.dir/doc.pdf.

22. U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-09-23, FEDERAL LAND MANAGEMENT: USE OF STEWARDSHIP CONTRACTING IS INCREASING, BUT AGENCIES COULD BENEFIT FROM BETTER DATA AND CONTRACTING STRATEGIES 2 (2008).

23. David N. Bengston, *Changing Forest Values and Ecosystem Management*, 7 SOC'Y & NAT. RESOURCES 515, 515–19 (1994).

24. Amanda Miner et al., *Twenty Years of Forest Service National Environmental Policy Act Litigation*, 12 ENVTL. PRAC. 116, 123–26 (2010), http://scholarworks.wmich.edu/cgi/viewcontent.cgi?article=1003&context=politics_pub.

the development of assurances for, and subsequent trust from, the public. The urgent need is to restore forests at a pace and scale to match the size of the ecological problem.

CHALLENGES IN FOREST RESTORATION: A DEEPER LOOK

To facilitate and design innovative and meaningful solutions to restore forest health, understanding the complexity of challenges facing the management of national forests is warranted.

A. Agency Challenges

The need to increase the scale of forest restoration has grown beyond the ability to use traditional approaches to forest management. The USFS is proposing to accelerate forest thinning three- to four-fold above the current pace while faced with declining agency budgets.[25] With the goal of "doing more with less," current agency practices are not sustainable.

1. Planning Forest Treatments

Most forest management activities through the late 1980s and early 1990s involved small (i.e. less than 10,000 acre [ac]) timber sales focused on harvesting larger-diameter commercially-valuable sawtimber.[26] Timber sales were sold to the highest bidder and considered short-term contracts, often held by long-standing wood industries having the singular ability to process only large trees.[27] Mandated changes to all southwestern national forest plans in 1994 halted all timber harvesting for nearly two years as forests modified plan guidelines under court direction to maintain suitable habitat for the Mexican spotted owl (*Strix occidentalis*).

While the USFS finalized new management guidelines to comply with the 1994 mandates, few industries remained viable. Concurrently, a growing awareness of the need to reduce tree density by removing small-diameter trees impacted the sawtimber-based wood product industry. With small-diameter trees comprising the bulk of volume needing to be removed from the forest, wood processing infrastructure had to diversify to create products from smallwood (5"–12" dbh), biomass (less than five inches dbh residue

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25. *See* Robles et al., *supra* note 4, at 5–6.
26. *See* Miner et al., *supra* note 24.
27. *Id.*

[stems, slash]), and a more limited sawtimber supply (>12” dbh).[28] Marginal profits and limited markets for some of these products mandated that businesses have a consistent supply rather than face the risk of short-term delays in bringing wood to processing sites. Larger projects (i.e. >10,000 ac) were needed to supply emerging industries and assure investors that a long-term wood supply could be met.[29]

To provide a longer, more consistent wood supply that met private industry needs, the preferred footprint for project plans became larger. In 2004, the White Mountain Stewardship Project was initiated on the Apache-Sitgreaves National Forests.[30] It was the first ten-year stewardship contract in USFS history and by 2014 had accomplished approximately 75,000 acres in forest restoration treatments.[31] During the implementation of White Mountain Stewardship, consensus built among stakeholders, local business, and the USFS to attempt a larger project, which became the Four Forest Restoration Initiative.[32] Spanning portions of four northern Arizona forests (Apache-Sitgreaves, Coconino, Kaibab, and Tonto), this 2.4 million acre landscape was parsed out into three distinct large planning areas.[33] While planning time may be lengthier in these larger planning footprints, the result was envisioned to offer a longer, more consistent supply that meets the needs of investors in wood product industries. Planning large-scale projects, particularly with emphasis on developing public support through front-end collaboration with the public, was a change in operational practices for the USFS, but the process was intended to result in lower cost/acre plans; a longer-term supply to meet private business needs; and a reduction in the risk of litigation.[34]

2. Implementation and Oversight

Treatments through either long-term or short-term contracts involve multiple implementation and oversight tasks to be undertaken by agency personnel, ranging from ensuring road improvements for wood hauling to

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28. *See* OLGA EPSHTEIN & KAREN KAO, ARIZ. STATE UNIV. GLOB. INST. OF SUSTAINABILITY, MODELING THE ECONOMIC VIABILITY OF RESTORATIVE THINNING (2013), https://sustainabilitysolutions.asu.edu/files/2014/09/TNC_ExecSummaryReport_Final.pdf.

29. *Id.*

30. *White Mountain Stewardship Monitoring Board Background*, U.S. FOREST SERV., http://www.fs.usda.gov/detail/asnf/workingtogether/partnerships/?cid=stelprdb5207073 (last visited Mar. 10, 2016).

31. *Id.*

32. SELIG ET AL., *supra* note 19.

33. *Id.* at 7.

34. SUZANNE SITKO ET AL., U.S. FOREST SERV., THE FIRST FIVE YEARS OF THE WHITE MOUNTAIN STEWARDSHIP PROJECT 17–18 (2010), http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev7_020040.pdf.

monitoring soil and water conditions under which heavy equipment operate.[35] One initial and costly site preparation activity involves marking trees for harvest. Traditional methods include the painting of trees (either mark trees to be left, or mark trees to be cut) with specialized non-toxic tracer paint. Markers, on average, can paint approximately eight acres per day, with an associated cost of $22 per acre for paint.[36] At the desired accelerated pace of treating over 30,000 acres per year, this could result in an exponential increase in both paint supplies (greater than $600,000 per year) and labor costs that may not be within agency budgets.[37]

Fig. 4. Example of marked trees.

With the desire to accelerate the pace and scale of forest restoration treatments coupled with the above challenges and overall budget constraints, planning, contract implementation, and monitoring need to be more efficient in both costs and time.

B. Private Industry Challenges

Traditional selling of commercially-valuable sawtimber to private industries does not conform to current needs. Products and processes using less economically-valuable wood material must be integrated into an economic model that promotes the creation of value for all tree components: dimensional lumber, poles, and residual biomass.

35. *Id.* at 17, 21–22.
36. Telephone Interview with Dick Fleishman, Assistant Team Leader, Four Forest Restoration Initiative, U.S. Forest Serv. (Sept. 9, 2015).
37. *Id.*

Fig. 5. Harvesting equipment, forest restoration treatment, Apache-Sitgreaves National Forests, AZ.

Challenges faced by private industry to invest in harvesting, transporting, and manufacturing products from wood supplied by the USFS include: (1) a lack of a guaranteed and adequate supply over a period of time necessary to receive a return on investment, an incentive to invest; (2) the risk of litigation holding up planning efforts, delaying implementation of treatments; (3) economic outlets for small-diameter material are slow to materialize due costs of business start-ups, permitting processes, and construction times; (4) weather variations and restrictions to reduce wildlife disturbances can often halt active harvesting for weeks at a time, creating challenges to maintain employees and sustainable wood supplies to industry purchasing material; (5) inter-business competition for the same wood may cause imbalances in localized supplies; and, likely the most challenging, (6) biomass, the residual limbs/branches, needles, and bark leftover from treatments, has the least amount of value but must be hauled off site.[38] The biomass component can comprise up to 40% of the total volume of woody material cut from restoration treatments.[39]

38. *See* SITKO ET AL., *supra* note 34, at 16–18 (noting the challenges faced by the private industry and the White Mountain Stewardship Project's potential solutions).

39. *See id.*; SELIG ET AL., *supra* note 19.

Fig. 6. Example of biomass accumulation from forest restoration treatment, Apache-Sitgreaves National Forests, AZ.

C. Social Challenges

Finally, to treat our forests in a timeframe that brings substantive change to forest conditions and overcomes years of controversy and litigation, transparency must increase to enhance trust between interest groups, private industries, and the USFS. Understanding the treatments occurring in the forest—plans, prescriptions, and results—mandates a robust and scientifically-sound monitoring program that allows data to be collected and analyzed in a rapid timeframe. In addition to monitoring results being provided to the public, assurances must be made to rapidly modify practices if warranted by monitoring data (otherwise termed "adaptive management"). Monitoring, however, can be a costly component of overall restoration

Fig. 7. Four Forest Restoration Initiative Stakeholder Group field trip, Coconino National Forest, AZ

efforts, and at times limited by budgets and the urgency to continue investing limited funds in additional planning or treatments.

PROMOTING EFFICIENCIES AND BUILDING TRUST: AN INITIATIVE BY THE NATURE CONSERVANCY

As a supporter, the Conservancy initiated a program that creates multiple efficiencies in both agency operational and private industry harvesting practices, while simultaneously providing the information needed to assure stakeholders that restoration efforts are meeting ecological principles and objectives. The Conservancy is focusing our investment in forest restoration across Arizona on our theory that two primary issues have stood in the way of accelerating the pace and scale of forest thinning in Arizona and across many national forests the United States: economics and trust. To facilitate the resolution of these issues, we are promoting the use of new technology that will cut costs for both the agency and private sector, streamline agency processes, and provide timely and rapid monitoring information that assures stakeholders that treatments are meeting collaboratively-driven ecological objectives.

The Nature Conservancy is developing the use of tablets that integrate associated digital data and Global Positioning System (GPS) technology that can reduce costs for both the USFS and private harvesting operations/businesses. These technologies also provide real-time monitoring data that can be analyzed quickly and used to make changes in treatment practices if warranted.

Fig. 8. Tablet installed in harvesting equipment.

For example, traditional forest management practices such as marking trees to be harvested will be infeasible at the needed scale of 30,000 to 50,000 treatment acres per year, due to the expenses associated with labor and supplies (paint).[40] To address this, the USFS hopes to gradually implement a "cutter select" operational model whereby wood harvesters select the trees to be harvested rather than agency staff, thereby minimizing the use of paint and associated labor costs.

To work efficiently under this model, harvesters will need better information to guide harvesting decisions. Among the capabilities of the tablet-based technology we are developing is the ability to upload spatial information such as boundaries, sensitive areas to avoid, and areas to employ different treatment types.[41] Integrating this type of information into the cab of harvesting machines to guide harvesting is a prototype for the agency.

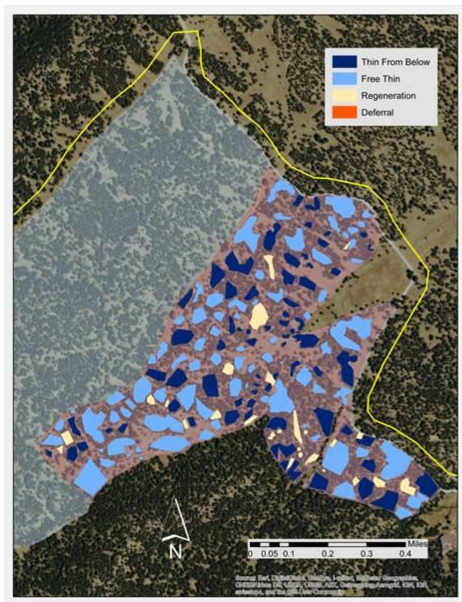

Fig. 9. Example of spatial information and prescription differentiation on tablets placed in harvesting equipment.

Preliminary experiments with harvesters indicate that this technology increases their level of efficiency as well. As harvesters treat areas, the harvested trees are marked via GPS on in-cab tablets, and can be transferable via Wi-Fi connectivity to skidders equipped with tablets to improve collection and transference of wood on skid roads and to landings.

A unique attribute of our technology development is the incorporation of simultaneous monitoring. Monitoring forest restoration effects to wildlife

40. Fleishman, *supra* note 36.

41. *See* Brandon Loomis, *Arizona Forest Fires: High-Tech Equipment Aids Fight*, AZ CENT. (June 9, 2013, 11:59 PM), http://www.azcentral.com/news/articles/20130606arizona-forest-fires-technology-aid.html?nclick_check=1.

habitat and other resources is time and labor intensive, often traditionally requiring skilled professionals to collect, analyze, and interpret data.[42] As a result, monitoring programs are expensive and difficult for agencies to prioritize, particularly when funding is limited. Additionally, with the need to provide statistically-significant data, some monitoring activities take years to collect enough random data points to ensure a desired level of confidence in results.

In our model, harvesters are empowered to collect monitoring data as trees are harvested. A high-accuracy GPS antenna is placed on each piece of harvesting equipment, and wired directly to both the equipment's installed tablet and the harvester's directional control unit (joystick). Every tree cut by the harvester delivers a precise GPS location to the tablet's software program.

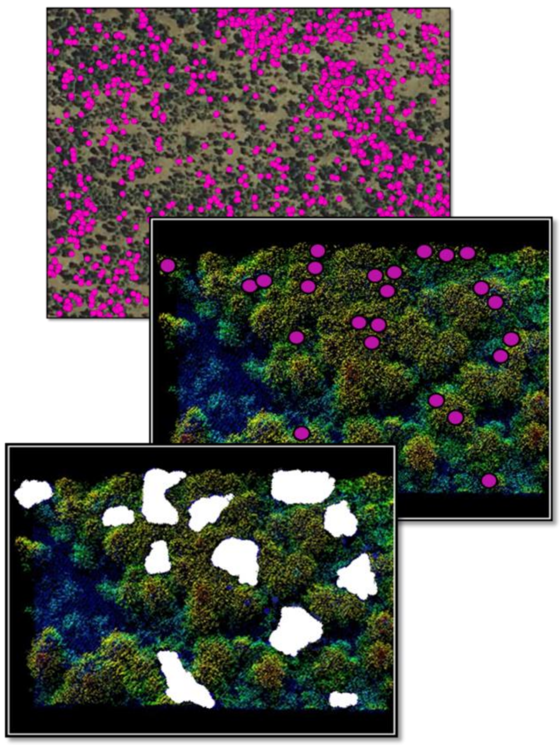

Fig. 10. Data from tablet in harvesting equipment analyzed for treatment results.

With this technology in place, the USFS could have a spatial record of trees harvested without having to fund some of the data collection phase for its monitoring. The USFS is primarily interested in the structure and components of the forest after restoration treatments. Using remotely sensed data in combination with tree harvest points, it may be possible to quickly

42. *See* SITKO ET AL., *supra* note 34, at 1–3.

determine if objectives are being met, such as canopy cover, opening size, density, and basal area. In addition, the use of tablets as digital restoration guides to replace, or at least minimize, the cost and use of paint and tree markers is showing promise to increase the rate of prepared acres by fivefold. Preliminary calculations by The Nature Conservancy indicate a change in marking rate from eight acres per day painting trees to over 40 acres per day digitizing prescriptions on a tablet in our first experiment.

As a result of increasing the use of technology and marrying it to GPS, Light Detection and Ranging ("LiDAR") data, and the harvesting equipment, three challenges can be resolved. First, harvesters benefit from information provided on the tablets such as productivity, routes, and inventories, thereby becoming more efficient in their daily operations. Second, USFS costs for site preparation (tree marking, special area designations, landings/skid road locations, etc.) are reduced as these processes become increasingly more digitized. Lastly, stakeholders benefit from real-time data collection to rapidly evaluate treatment prescriptions and determine the degree to which restoration goals are being met. Currently, The Nature Conservancy and several partners are testing and refining all stages of this technology strategy to determine its full capacity in creating a more efficient harvesting model.

The Nature Conservancy's support for, and investment in, tablet-based technology will provide a level of transparency that is greatly needed to sustain forest restoration treatments over time. Combined with facilitating agency development of science-informed, stakeholder-driven adaptive management programs, our efforts are designed to address the need for transparency as well as provide an affordable, reliable data stream that evaluates progress and resolves issues that arise as implementation progresses. In addition, this technology has the potential to reduce agency costs in treatment implementation as well as improving the efficiencies of wood harvesters. By addressing these significant challenges facing forest restoration efforts today, the ultimate goal of assuring healthy forests for our wildlife, water, and human communities can be realized.