DJ GLISSON, II/FIREFLY IMAGEWORKS

Remote Monitoring Technologies for Colorado Land Trusts

An analysis produced by Land Trust Alliance for Keep It Colorado

May 2021

Land Trust Alliance
Together, conserving the places you love

KEEP IT COLORADO

Contents

DJ GLISSON, II/FIREFLY IMAGEWORKS

Introduction

Land trusts have long employed a diverse set of tools to monitor the conservation easements and fee-owned lands they steward each year. Whether by walking a property with a landowner to document changes in land use or flying over a property to get a view from above, a thorough and efficient approach to monitoring is invaluable to any stewardship team seeking to understand potential threats to the conservation values of a property and how to address them.

Increasingly, remote monitoring technologies — which can include satellite imagery, unmanned aerial vehicles (UAVs), aviation-based resources and other tools — have become more widespread and accessible to land trusts in recent years. These alternatives to traditional in-person monitoring provide land trusts with a suite of new approaches for conducting effective stewardship and offer new options to supplement existing efforts and bring new perspectives to their work. Additionally, the Land Trust Accreditation Commission, which requires that accredited land trusts monitor conservation properties on at least an annual basis, permits remote monitoring in four out of every five monitoring years.

In August 2020, the nonprofit coalition Keep It Colorado received $205,000 in grant funding from Great Outdoors Colorado and the Gates Family Foundation to launch a program that would help Colorado land trusts monitor conservation properties across the state. Motivated by the challenges brought on by the COVID-19 pandemic, which prevented many stewardship teams from safely visiting landowners and traveling to properties around the state, Keep It Colorado saw remote monitoring as an opportunity to ensure that land trusts' stewardship obligations could be met despite these obstacles. At the same time, this support would provide land trusts with a chance to evaluate these tools' broader value for stewardship as a long-term solution.

With an RFP process open to Keep It Colorado member organizations, the program allowed grantees to identify remote monitoring solutions that would work best to achieve their own stewardship objectives. According to a press release issued by the organization, land trusts would be able to use regrant funds "at their discretion to purchase satellite and aerial imagery of properties where they hold conservation easements, purchase imagery analysis software, hire a geographic information systems consultant for technical support, and pay for staff time to design and implement their remote monitoring approach." The application process yielded $185,000 in requested funding, of which $155,000 was awarded to 12 land trusts across the state.

This report details the results of a series of interviews, focus groups and surveys that tracked the experiences of the 12 land trusts in this grantee cohort as they acquired and implemented new remote monitoring technologies during the 2020 monitoring season.

Executive Summary

With grant funding from Great Outdoors Colorado and the Gates Family Foundation, **Keep It Colorado enabled 12 land trusts in Colorado to monitor over 1,608,000 acres** across the state in 2020 using remote monitoring tools. Land trusts were motivated to explore remote monitoring tools for a number of reasons, including safety concerns related to the COVID-19 pandemic as well as increasing pressure on stewardship teams' capacity to monitor growing portfolios. Some were particularly intrigued by the opportunity for a low-risk trial year to test out new methods, as well as the reduced cost which had seemed prohibitive for some without the grant opportunity.

Land trusts in the cohort used four different remote monitoring technology vendors in 2020. Seven organizations contracted with Planet Labs, five organizations used Upstream Tech's Lens product, and two organizations purchased imagery from Airbus or Nearmap. Overall, both the Airbus and Nearmap users were pleased with their experiences and would recommend these products to other land trusts considering them for remote monitoring applications. Lens users were also generally very satisfied, with four out of five land trusts recommending them. Of the seven Planet Labs users, five reported that they were very dissatisfied with their experiences, and only one would recommend working with them again.

The learning curve associated with trying a new technology was more significant than anticipated for some organizations, particularly for those that worked directly with a larger vendor, whose products required extra technical expertise to use effectively. Spatial resolution of the imagery that land trusts received ranged from 3-inch to 6-meter, with an aerial-based platform providing the highest-quality imagery due to the fact that commercial satellite imagery sales are restricted to a minimum resolution of 0.3 meters. Generally, resolutions coarser than 1.5-meter were not suitable for detecting the kinds of small-scale changes that might constitute a violation. Price, customer service, spatial resolution, geographic coverage and data accessibility were identified as the most important considerations when selecting a remote monitoring technology and vendor.

Most land trusts used visual review methods to make monitoring observations using imagery, sometimes with reference photos from previous years for comparison. Slider bar features were a popular tool to help spot potential changes on the landscape. The timing of when imagery was received, particularly for tasked imagery that was custom ordered, was slow or unpredictable for many land trusts, which made scheduling monitoring and other stewardship activities more difficult and stressful.

When follow-up was required to confirm an observed change, contact with the landowner by phone or in-person was always the first step to address a potential issue, and no observations were marked as violations based solely on the imagery. All land trusts in the cohort characterized landowner responses to their remote monitoring approaches overall as neutral (5), positive (5), or very positive (2). Some land trusts reported benefits in using remote monitoring to engage with absentee landowners, seasonal residents and landowners with mobility limitations who may not otherwise participate in on-site monitoring visits in a typical year.

Of the 10 land trusts that provided cost data, three estimated seeing higher costs by using remote monitoring methods than they had when monitoring in-person, while seven reported spending less. At each end of the spectrum, one Planet Labs user estimated spending 162% more while one Lens user reported a 55% decrease in spending in 2020 compared to 2019. For 164 properties monitored using Lens, on average, properties smaller than approximately 6,000 acres were more cost-effective to monitor remotely than in-person, while larger properties were less cost-effective.

Of the six land trusts that provided monitoring effort data, four Lens users reported declines in personnel hours needed to complete monitoring, ranging from a 46% reduction to an 80% reduction. Of two Planet Labs users, one reported an 83% reduction and one reported a 15% increase in personnel hours.

Seven organizations avoided a total of more than 56,800 miles of travel by monitoring remotely. In terms of avoided emissions, this represents a gross reduction of 46,676 pounds of carbon dioxide emissions, using figures for average car fuel economy.

Violation detection accuracy is a multi-year process and validating the effectiveness of remote monitoring tools in identifying violations will require follow-up over the coming years.

After their first-year experience, most of the 12 land trusts in the grantee cohort believe that remote monitoring will either play a major role (33%) in stewardship efforts or that they'll likely use it to monitor a handful of properties each year (42%) moving forward. Funding and capacity are perennial concerns for land trusts, and any mechanism offering the potential to stretch conservation dollars further may be powerful in increasing an organization's ability to fulfill its mission.

Continued support for land trusts through educational and capacity-building opportunities would enable Colorado land trusts to expand their use of remote monitoring tools and ability to learn more about effective implementation.

DJ GLISSON II/FIREFLY IMAGEWORKS

Methods

This analysis of Keep It Colorado's 2020 remote monitoring grant program includes results from both qualitative and quantitative methodologies that were employed beginning in September 2020, when grantees had received funds and, in most cases, began work on their projects. In a typical monitoring season, many organizations would prefer to have monitoring underway earlier in the year. However, due to unforeseen delays and accommodations related to the pandemic, many organizations did not begin use of remote monitoring tools until early fall.

From late September to late October 2020, the Land Trust Alliance's NRCS Pilot Project Manager, Jake Faber, conducted 12 semi-structured interviews with grant recipients lasting for one hour each to assess initial expectations regarding anticipated use of new remote monitoring tools. He also collected baseline information from participants regarding monitoring systems and stewardship challenges. These one-on-one interviews were replicated after the end of the monitoring season (February/March 2021) to gather qualitative data on project successes and capture reflections on the process from start to finish. Interview guides that were used can be found as an appendix to this report. Individual participant responses have been anonymized throughout this report to maintain privacy where possible.

Additionally, three focus group conversations were organized in March 2021 to gather: (1) the entire cohort representing the 12 land trust grantees, (2) Planet Labs users and (3) Upstream Tech's Lens users. Through these conversations, group reflections illuminated some of the shared and comparative experiences of grantees who employed similar approaches.

Grantees completed pre- and post-program surveys as well, which were deployed after the completion of each round of interviews. Surveys incorporated feedback from participants about specific metrics to include in the comparative analysis portion of the project, and captured general quantitative data regarding conservation portfolios, staffing and other details as well as qualitative data regarding technology selection and platform satisfaction. Along with the post-project survey, participants had access to a return-on-investment calculator that captured data on labor and costs associated with monitoring — adapted from a tool developed by The Nature Conservancy — which grantees used to report on year-over-year stewardship program efforts to compare results across remote and in-person monitoring methods.

Participation

A dozen organizations operating across Colorado were awarded grants by Keep It Colorado to conduct remote monitoring in 2020. Participants ranged from large statewide organizations to smaller local and regional organizations serving a diverse swath of the state's conserved lands:

- **Aspen Valley Land Trust:** Serves the Roaring Fork and middle Colorado River valleys
- **Colorado Cattlemen's Agricultural Land Trust:** Serves regions across the state
- **Colorado Open Lands:** Serves regions across the state
- **Eagle Valley Land Trust:** Serves the Eagle Valley
- **Palmer Land Trust:** Serves southern Colorado
- **Rio Grande Headwaters Land Trust:** Serves the San Luis Valley
- **San Isabel Land Protection Trust:** Serves southern Colorado
- **The Nature Conservancy:** Serves regions across the state
- **West Slope Conservation Partners**: Includes **Crested Butte Land Trust** serving the Gunnison Valley, **La Plata Open Space Conservancy** serving southwest Colorado, **Montezuma Land Conservancy** serving southwest Colorado, and **Colorado West Land Trust** serving western Colorado

This cohort of grantees represents not only a diversity of geographies within Colorado, but also differences in the sizes of their conservation portfolios, experience levels and organizational capacity.

Collectively, these 12 organizations monitored over 1,608,000 acres across Colorado in 2020 using remote monitoring tools, including conservation portfolios that ranged from 874 acres to 664,000 acres, with a median portfolio size of 44,218 acres.

Most land trusts in the cohort had adequate in-house geospatial data expertise to understand how to use and analyze remotely sensed imagery before the beginning of the 2020 monitoring season, with wide variation within the cohort in familiarity with geospatial tools. Some staff members reported extensive background in spatial analysis and at least one large statewide organization had dedicated GIS staff. One smaller organization in the cohort reported no on-staff GIS experience, and it outsources most of its spatial analysis.

Only four grantees reported previous experience with any remote monitoring approaches, with a range among these few organizations from beginner to advanced experience levels. Two organizations previously used freely available high-resolution aerial imagery from USDA's National Agricultural Imagery Program (NAIP), and one paid for aerial imagery. Additionally, several organizations previously used passenger flights — three on a volunteer basis and two on a contracted basis — to monitor properties via aerial flyover. One land trust previously used unmanned aerial vehicles (UAVs) to supplement monitoring efforts as well.

Stewardship team capacity at these land trusts varied as well. However, most organizations had fewer than two full-time stewardship staff members, with a median stewardship team size in the cohort of 1.25 and a maximum of seven.

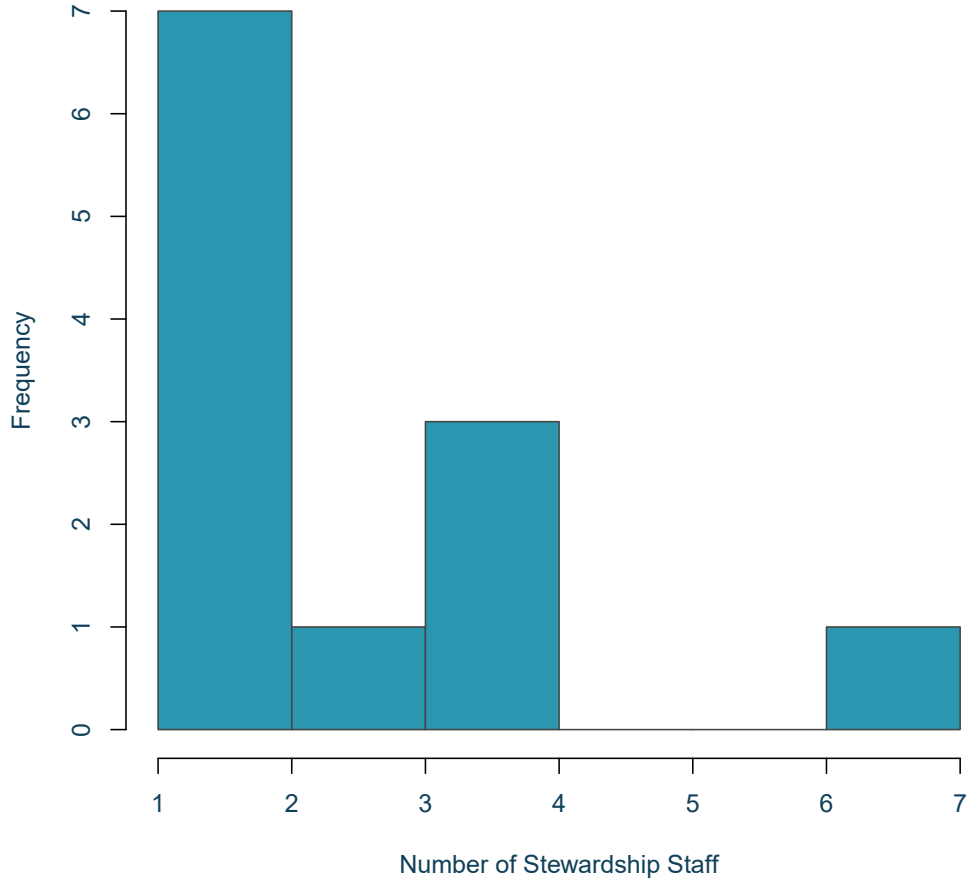


Figure 1. Stewardship staff capacity among grant recipients. Of 12 participants in the remote monitoring grantee cohort, a majority have fewer than two full-time stewardship staff members. The largest-staffed organization represented has a full-time stewardship team of seven.

Baseline stewardship practices and priorities

Composition of the grantee cohort varied not just in terms of organizational diversity, but also in terms of baseline stewardship practices and monitoring priorities at each land trust. Monitoring methodologies are best considered from the perspective of how to ensure that the conservation values of a property are being adequately maintained. Therefore, monitoring goals are driven by the questions that a monitor must answer through careful observations of a property. Certain approaches are superior to address certain goals and questions, and **any evaluation of a remote monitoring approach must consider the diverse objectives of its users.** Within this cohort, many similarities were shared in baseline stewardship practices, with some variations in monitoring priorities and concerns.

Prior to 2020, all participating organizations used in-person monitoring as a primary method, and stewardship practices varied based mainly on organizations' staff capacity, type and frequency of violations encountered, and organization-specific protocols. In general, in-person monitoring in Colorado is limited by seasonality and is typically completed during the snow-free season, which can range from May to September in parts of the state. Many Colorado land trusts expressed that current workload for monitoring properties is at capacity for the number of staff members on hand.

Land trusts noted that in-person monitoring requires an extensive amount of time investment, including driving to properties, scheduling with landowners, and working around varying weather. Additionally, stewardship of some properties can be challenging due to difficult terrain and remote locations of conserved properties. **Many land trusts are also experiencing increased need for staff members to handle other aspects of land stewardship such as restoration, fire mitigation and addressing reserved rights and violations, and they see increasing the efficiency of monitoring as a valuable way to build capacity for this work.**

Some organizations noted that they try to emphasize enforceability in drafting easement terms to make effective stewardship more feasible. Others manage lands that may have been put under easement decades ago with terms that may vary significantly from more recent language and make monitoring more challenging, particularly for some hard-to-spot agricultural practices. Along similar lines, variations in the use of reserved rights among landowners were shared across different organizations, with leniency toward these cases.

Concerns about transitioning to use new forms of monitoring also helped to illuminate the diverse stewardship priorities within the cohort. Loss of valuable landowner interactions were a common concern when considering the use of remote monitoring to meet stewardship needs, for example. One land trust noted a fear of losing anecdotal observations of landscape change and wildlife movements on the landscape by shifting away from in-person interactions in 2020. Additionally, land trusts expressed concerns about natural factors that might interfere with remotely captured imagery such as dense canopy cover, seasonal rainfall (especially increased difficulty to assess imagery in drier years), smoke from wildfires and snow cover.

Uncertainty about the resolution and quality of imagery was also of concern, with some organizations particularly wondering what types of features would be visible on imagery and whether inadequate resolution would reduce the overall quality of monitoring and increase the likelihood of missing potential violations or changes on the landscape. **Specific features that land trusts were worried about identifying successfully included boundary encroachment, noxious weeds, alteration of water flow, use of wildlife-friendly fencing and unauthorized expansions of a preexisting structure.** Several organizations working in areas with a heavier footprint of extractive industries, particularly oil and gas, also prioritized being able to observe new industrial operations and access roads.

Participant Motivations and Program Expectations

Motivations for exploring remote monitoring

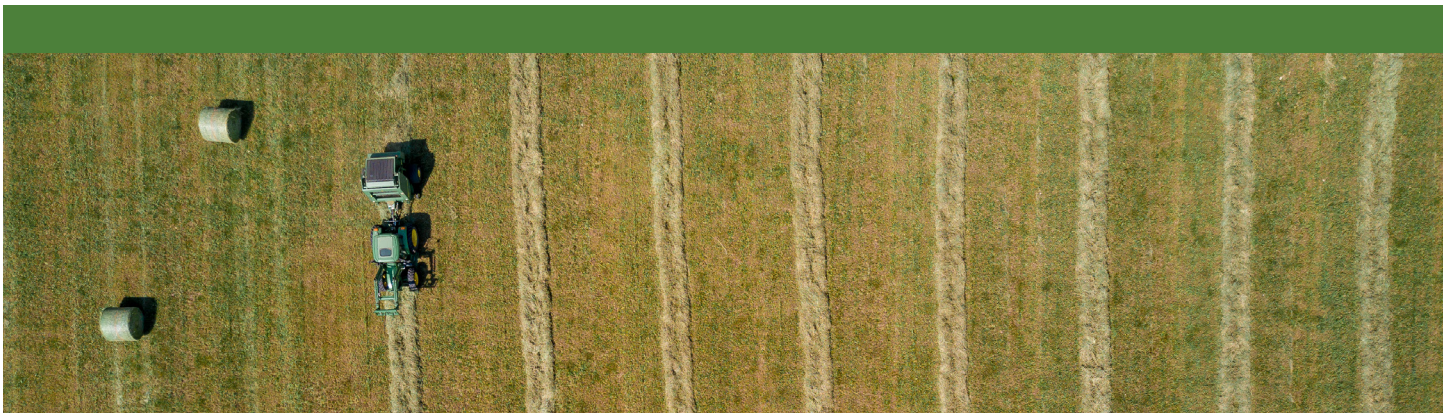
Land trusts in Keep It Colorado's grant program cited many factors in choosing to explore remote monitoring tools in 2020 and to participate in the regrant program. **For many organizations, this opportunity provided the first foray into remote monitoring, while others had used tools such as UAVs and aerial flyovers in past years and were more familiar with off-site methods.** Even for some of the organizations with remote monitoring experience, however, the use of satellite imagery was a new experiment.

Almost all participants, including those who had never considered using remote monitoring previously as well as those that had been interested in or used these tools for years, mentioned the COVID-19 pandemic as a significant motivator to pursue new approaches to monitoring in 2020. In particular, participants noted safety concerns for monitors going into the field as well as the potential for staff travel to pose a burden on rural communities' health care systems and at-risk landowners and neighbors. Some specifically noted that the typical demographics of easement holders, including older landowners and multi-generational homes, could be at particularly high risk of infection through in-person contact. Additionally, participants were motivated by the potential for remote monitoring to help stewards more safely and effectively observe changes on more remote landscapes that pose accessibility challenges.

While the pandemic necessitated creative solutions for many land trusts to overcome immediate obstacles to monitoring, it was not the sole reason for most land trusts to turn to remote monitoring. Land trusts in the regrant cohort also noted that remote monitoring could help to improve efficiency of stewardship operations, which can be especially important when there may be pressure across an organization to justify stewardship expenses due to budget cuts, unexpected loss of volunteer or staff resources, or other organizational priorities. Particularly in stewardship, one participant noted, the increasing pressure to justify costs for monitoring growing portfolios can be a challenge that warrants exploring any possible options to address these ongoing concerns. Another participant, whose organization was undergoing the intensive Land Trust Accreditation renewal process in 2020, anticipated remote monitoring being a great way to reduce the overall workload her team was taking on this year.

For those involved in the Western Slope Conservation Partnership's joint regrant proposal, the benefits of leveraging collaboration to reduce costs and staff time spent on starting up a new program were also an important motivator in pursuing remote monitoring. The ease of jumping into a group effort coordinated by an individual project lead at one organization helped reduce some perceived barriers, particularly for smaller organizations in the partnership.

When the grant opportunity was presented to the Keep It Colorado membership, introducing these tools as an option and providing support for land trusts to explore them incentivized some participants to consider remote monitoring for the first time. Some were particularly enticed by the opportunity for a low-risk trial year to test out new methods, as well as a reduction in costs, which had seemed prohibitive for some without the grant opportunity.



DJ GUSSON, II/FIREFLY IMAGEWORKS

Expectations for program success

Expectations for implementing remote monitoring approaches varied somewhat among the cohort, largely with respect to what depth different organizations had previously considered remote monitoring options. Organizations that had previously explored remote monitoring tended to view the project as an opportunity for a lower-risk trial year to see how new remote monitoring approaches could work, with the expectation even initially that it would inform a longer-term implementation, perhaps on a rotational basis. Some organizations that had not put as much consideration into these technologies previously saw them primarily as a way to fulfill immediate obligations with the possibility for future use to be explored later. Recognizing the unique challenges of this particular monitoring season and the resulting extra workload many organizations have encountered, some land trusts, even those that had high hopes for longer-term use of remote monitoring, made clear that there was no appetite to take on much more than implementing basic features this year with resources and energy stretched thin across the board.

Regardless of how much energy land trusts were able to put into monitoring this year or what initial expectations for the technology were, most organizations were particularly interested in the unique opportunity of this project to establish a cohort of organizations trying new approaches together, which could facilitate knowledge sharing and peer learning. As this was a goal for the grant funding, participants' responses validated that this aspect of the project seemed worthwhile.

Some land trusts also considered this a **good opportunity to think more broadly about big-picture goals and directions for stewardship in the coming years.** Land trusts also viewed this as an opportunity to inventory current approaches and consider new ways of approaching this critical aspect of their work. Land trusts also frequently cited a curiosity about how the land trust community more broadly, whether at the local, state or national level, could coordinate more effectively using partnership models as seen with the Western Slope Partnership's remote monitoring project this year. For instance, several interview participants mentioned an interest in the possibility of purchasing imagery through a state-based partnership in future years, noting that such a program would require consensus on a choice of technology.

The use of remote monitoring raises several issues on an organizational level that land trusts were curious to learn more about through the project. In particular, many mentioned a curiosity to explore the efficiency of remote monitoring in practice, including specifically an analysis of organizations' return on investment. Additionally, some wondered about how remote monitoring could impact the legal defense of easements, as well as the potential applications of remote monitoring for improving long-term record keeping and institutional memory.

While this year many land trusts did not explore potential applications of remote monitoring to supplement non-stewardship goals such as development and conservation planning, the potential for those applications (as well as value-added benefits for landowners by sharing high-quality images) was raised by some participants. Additionally, one land trust mentioned the potential in the future to use remote monitoring to help quantify landscape-scale impacts and gather more statistics to improve communications with members, donors and the public. Gathering better data insights, some land trusts shared, would also improve management of fee-owned properties as well as easements. Documenting long-term effects of climate change, for instance, as well as documenting landowner use of water rights could help to improve management decisions over time, and data insights could similarly aid in planning restoration projects or tracking recreation impacts on fee-owned lands.

A few land trusts also raised the question of whether reliance on large technology companies to conduct monitoring would reduce the organization's participation in the local economy by, for instance, hiring local contractors to conduct in-person monitoring.

Stewardship staff also shared a number of technical questions and curiosities during interviews. For instance, identifying tradeoffs associated with spatial resolution of different imagery sources, oblique vs. vertical angles, and database integration capabilities of different technologies were all mentioned by participants. Additionally, land trusts wanted to find out more over the course of the project about what

criteria should be used to assess ideal candidate properties for remote monitoring, how to handle unexpected snags in accessing imagery on time, and compliance with *Land Trust Standards and Practices* and Land Trust Accreditation Commission guidance. Land trusts also hoped to learn from peers in the cohort what protocols should be used to review imagery, how GIS-savvy monitors need to be to accurately review imagery, and whether the potential for incorporating advanced change detection capabilities would be a helpful supplement to manually reviewing imagery. Some participants were also concerned about the ability to visualize long linear features, such as trails.

Project Implementation

Initial decision-making

In assessing how to approach a first year of a remote monitoring program, grantees initially had to decide on several important aspects of how to design and execute the projects — for instance, whether to remotely monitor all or a subset of conserved properties, which vendors to work with and what type of technology would adequately meet a stewardship team's needs.

Criteria used to make these decisions varied across organizations. Some, for instance, extensively researched remote monitoring technologies — in at least a few cases for years prior to 2020 — while others jumped on opportunities spearheaded by partner organizations. For some, options were limited by geographic constraints and for all organizations, price was an important consideration.

Access to GIS software and technical familiarity also affected technology and vendor choices. The accessibility of data and analytical tools to those with a non-technical background is something that one larger organization considered when evaluating technologies, as web-based platforms can make the need for GIS skills unnecessary for monitoring and improve accessibility. Another larger organization with more GIS capacity, by comparison, considered more advanced monitoring systems using automated change detection algorithms. However, the land trust determined, based on the high error rate at such a small scale, that it was not worth pursuing more technically advanced options at this time.

In several cases, an organization's choice of approach was guided by the work of others with whom it intended to collaborate. For instance, a pilot program to expand the use of Lens was a natural fit for one organization working statewide and provided additional funding that made remote monitoring work possible in 2020. The Western Slope Partnership's coordinated efforts to establish a joint contract with an imagery vendor made the participation of smaller organizations in the partnership possible as well.

Planned approaches

At the beginning of the monitoring season, most grantees intended to exclusively use remote methods to complete 2020 monitoring requirements. A few organizations planned to still conduct some in-person monitoring to varying extents, with one organization only monitoring five of its larger properties using satellite imagery. One organization intended to overlap remote and in-person visits for some properties to compare effectiveness of different approaches.

All grantees expressed an initial interest in continued use of remote monitoring tools pending the results of this pilot year, and in some cases noted that continued interest would depend on further financial support from grant opportunities or strategic partnerships like the Western Slope Conservation Partnership. In some cases, organizations believed even before beginning to use these tools that they would likely be implemented on a rotational basis moving forward. Additionally, some organizations expressed interest in using satellite and aerial imagery for other projects such as tracking changes in vegetation, analyzing changes in critical habitat, incorporating rangeland monitoring tools and identifying areas of overgrazing.

Incorporating new tools

Depending on whether an organization chose to task custom satellite imagery or use archived data, timing of data delivery varied dramatically. In some cases, organizations that primarily tasked imagery waited up to four months for data delivery. This diverged significantly from expectations of turnaround times closer to two weeks. Without access to data, it was not possible for monitoring to occur. One organization which had signed a contract with a satellite imagery vendor earlier in the year did not see these same delays, indicating that getting a head start early in the year was advantageous.

With most remote monitoring tools, flexibility appears to be a key expectation to manage inconsistencies around when data, particularly satellite data, can be acquired and delivered to customers, so an additional time buffer to account for possible delays was helpful for the land trust that was able to build that into monitoring in 2020. Additionally, technical challenges in ordering tasked imagery delayed the process further for some. One land trust struggled with a lack of clarity from a vendor about the size and shape of tasking area requests, resulting in incorrect data initially being delivered and further delaying data acquisition.

For some organizations, since the timing of data delivery affected the timing to conduct monitoring, certain times of year that typically would have been busy with monitoring were slow-paced, while the already busy end of the monitoring season became overburdened with extra work once imagery became available. In many cases organizations saw a decline in the total number of hours needed to complete stewardship by using remote methods; the distribution of how staff effort became reallocated during the year, however, was identified by some as an important consideration. If time was being saved at inconvenient times of year, that was not helpful for some despite seeing an overall savings in personnel time spent on monitoring.

Spatial resolution of the imagery that land trusts received ranged from 3-inch to 6-meter, with an aerial-based platform providing the highest-quality imagery due to restrictions on satellite imagery being sold at a minimum of 0.3-meter resolution. Generally, grantees were in consensus that resolutions coarser than 1.5-meter were not suitable for detecting the kinds of small-scale changes that might constitute a violation. Some organizations working with one vendor received imagery that was much worse quality than had been promised in contracts, which in at least one case prevented remote monitoring from being used as a sole approach altogether. On the other hand, some were pleasantly surprised by how much they could see at 1.5-meter resolutions or better. One organization noted that with sub-meter imagery, it was possible to look at individual trees on a property undergoing permitted forest thinning to ensure that each tree harvested had been appropriately authorized, confirming that no violations had taken place.

All of the land trusts reviewed imagery manually, relying on a visual scan of each property to identify changes or unknown features. Some monitors, particularly those with more experience on the ground who know the properties they work with well, only reviewed single images, while others compared imagery to imagery from prior years from publicly available sources such as NAIP or Sentinel or to proprietary base e organization using this slider bar feature reported that imagery review was quite fast even for some larger properties, taking anywhere from under 30 minutes to about an hour.

Land trusts sometimes included additional modifications to existing reporting templates to document remote monitoring observations. Some included imagery screenshots and metadata, and some used entirely new monitoring report formats, such as attaching PDF reports that were created within monitoring platforms.

Figure 2. Monitoring report generated within Upstream Tech's Lens platform. This sample report provided by one land trust includes side-by-side imagery from 2019 NAIP imagery and 2020 Airbus SPOT imagery with a user-generated focus area marking a solar array on a property.

IMAGE, TOP

CAPTURE DATE

6/15/19

SOURCE

PlanetScope (3m)

IMAGE, BOTTOM

CAPTURE DATE

6/15/20

SOURCE

PlanetScope (3m)

INTERPRETATION

CENTER

NOTE

No man-made changes were observed, other than hemp field previously planted on NE side of south parcel was not planted in 2020. Drought effects in 2020 can be seen, even in June - less irrigated area and lower density grass response; non-irrigated areas particularly dry appearance.

AREA ACRES

590

INTERPRETER

INTERPRETATION DATE

12/7/20

Figure 3. Monitoring report with Planet Labs imagery. This sample report provided by one land trust uses a custom format that includes side-by-side screenshots of 2019 and 2020 PlanetScope imagery.

When follow-up was required to confirm an observed change, contact with the landowner by phone or in-person was always the first step to address a potential issue, and no observations were marked as violations based solely on the imagery. However, in one specific case a land trust that had been previously notified about a possible issue was able to confirm a violation that had been previously missed in-person, and was able to work with the landowner to fully resolve the issue. This stewardship team believes that if it had been using imagery the year before that the violation would have been noticed sooner.

Technology Use

Technology selection

Land trusts have countless options when considering where to acquire geospatial data that can be used to support stewardship work. Many technologies are available, with numerous companies and agencies offering data and analytical tools to help users access and understand landscape-scale dynamics. The process of selecting which specific technology a land trust will use to monitor properties remotely can be a difficult one, with many considerations to take into account.

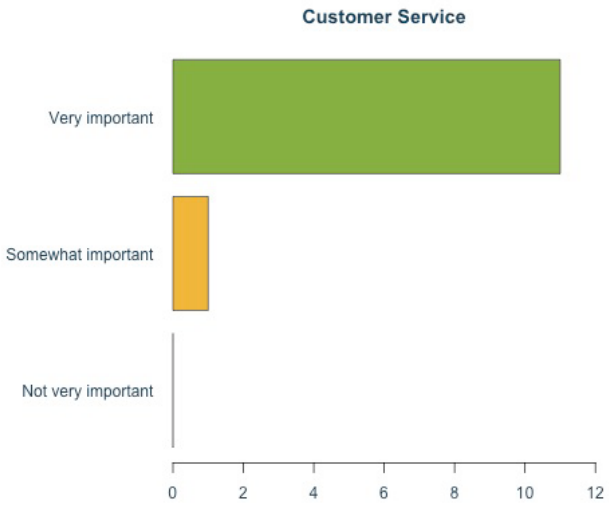
First, a land trust must consider which kinds of technology it will need to implement based on its specific objectives. For instance, land trusts may opt to capture the kind of high-resolution imagery and small-scale, detailed coverage offered by UAVs, oblique-angle photographs captured from the window of a small passenger aircraft, or multispectral imagery captured by a satellite in orbit. Each technology has its advantages and drawbacks, and can be applied for different stewardship needs depending on a monitor's objectives.

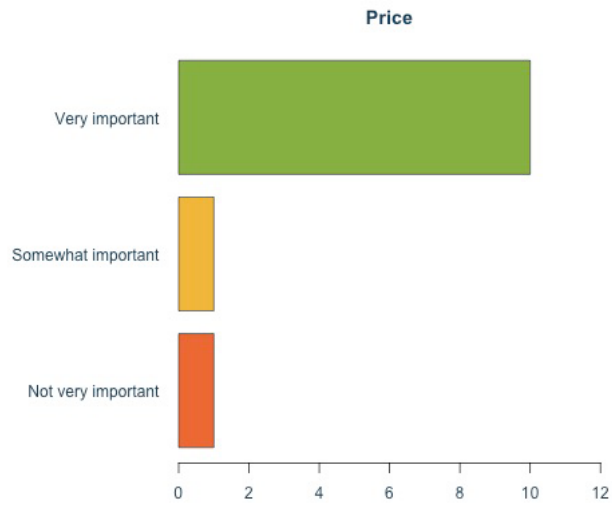
In addition to the type of technology, a land trust must decide on a source for that technology. For instance, different Earth-observing satellites have different technical specifications, and perhaps one with a high temporal frequency like that offered by the European Space Agency's Sentinel program would be preferred in certain situations over a satellite with slower revisit rates but higher image resolution.

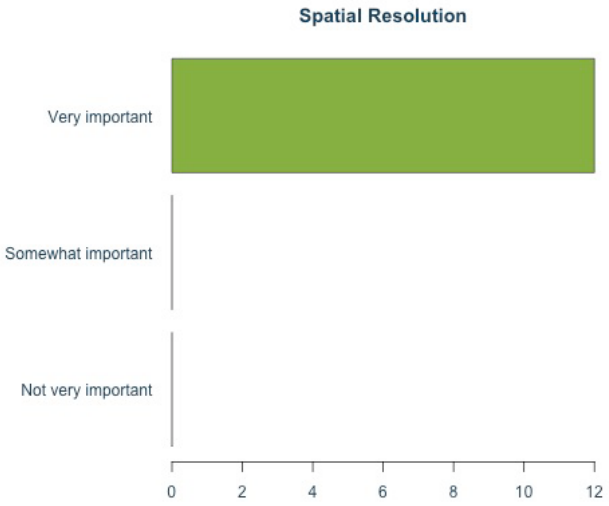
The choice of technology vendor is perhaps one of the most important considerations after a land trust has identified remote monitoring as a feasible method for conducting stewardship. Vendors are the companies or agencies that provide data (and sometimes a viewing platform or user interface) to land trusts to use to conduct monitoring. Land trusts that work with private companies to access data typically enter into a contract for services and work closely with that entity's support team to deliver products and troubleshoot issues.

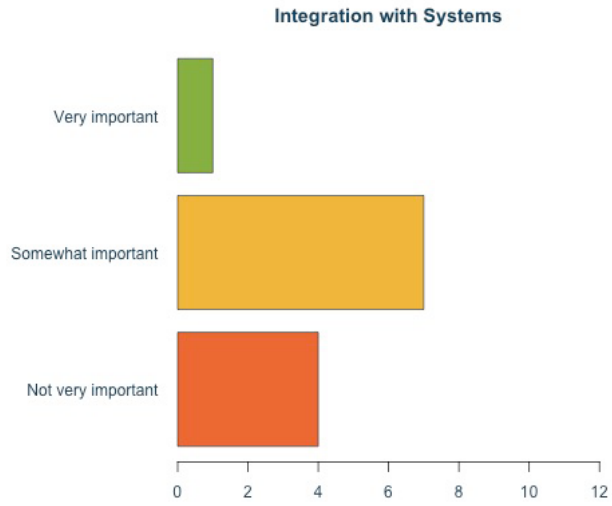
Vendors are sometimes, but not always, the same entities that are capturing source imagery. For example, the aerospace company Airbus operates a constellation of Earth-observing satellites that produce imagery for land trusts, and Airbus sells a data-viewing platform called OneAtlas. OneAtlas was purchased through the third-party reseller L3Harris by one land trust in the grantee cohort. In this instance, the land trust used data sourced from Airbus on an Airbus-hosted platform, but worked with L3Harris as a vendor of that product. Considering all aspects of a technology's sourcing and access is therefore important for land trusts to understand the tools available so that they can be used most effectively.

Besides these broad differences in ways that land trusts can source and access geospatial data for monitoring, a number of more specific criteria can guide an organization's process of selecting a particular technology approach. Not all organizations weigh these criteria in the same way, however. Land trusts in the grantee cohort were asked about the importance of a number of these criteria in effectively implementing remote monitoring; their responses are shown in the figure below:

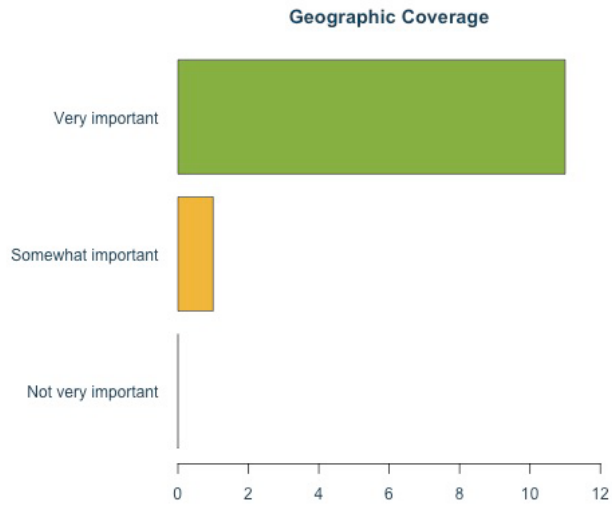

Customer Service
Very important
Somewhat important
Not very important
0
2
4
6
8
10
12


Price
Very important
Somewhat important
Not very important
0
2
4
6
8
10
12


Spatial Resolution
Very important
Somewhat important
Not very important
0
2
4
6
8
10
12


Integration with Systems
Very important
Somewhat important
Not very important
0
2
4
6
8
10
12


Data Availability
Very important
Somewhat important
Not very important
0
2
4
6
8
10
12


Geographic Coverage
Very important
Somewhat important
Not very important
0
2
4
6
8
10
12

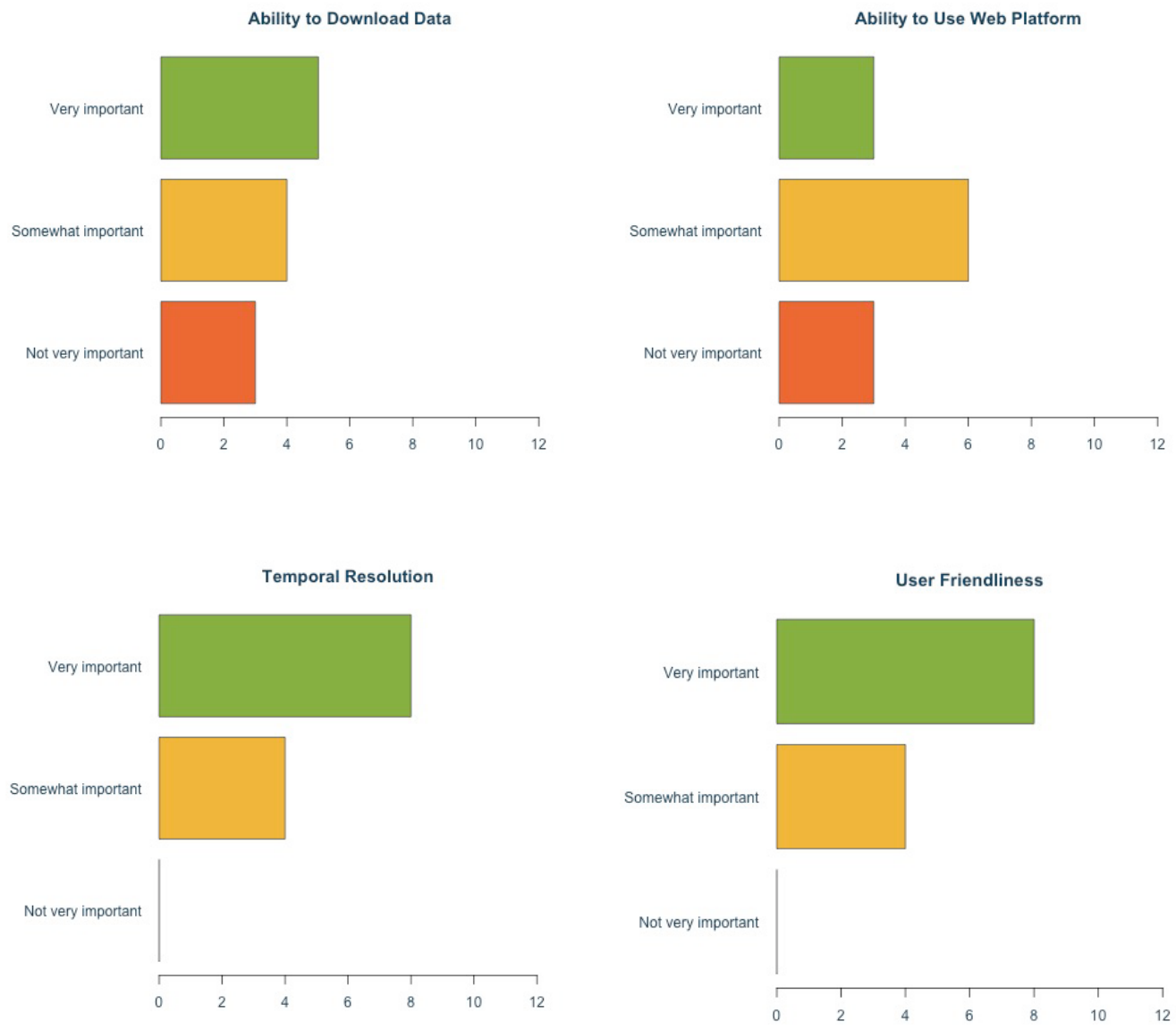


Figure 4. Importance of various criteria for selecting remote monitoring technology options. Twelve land trusts reported qualitative perspectives on relative importance of 10 technology selection criteria. Data were captured after the completion of one year of remote monitoring, reflecting lessons learned over the course of a full season implementing these approaches.

These data demonstrate consensus among the cohort that price, customer service, spatial resolution, geographic coverage and data accessibility are particularly important considerations when selecting a vendor and technology approach. Remote monitoring is often thought of as advantageous to save time and cost, so price remains a key consideration for most organizations. Customer service was initially underestimated by many land trusts in the cohort as a key factor in remote monitoring success, but all but one organization cited it as a very important consideration after the first-year experience. Spatial resolution also is a key factor in selecting a technology that will work for meeting stewardship goals; without an adequate level of detail in imagery, it can be difficult for monitors to properly assess conditions on the landscape and meet monitoring obligations, and all respondents cited it as a very important factor. Geographic coverage, similarly, is critical for stewardship teams: Without sufficient coverage of properties that require monitoring, even the best of technologies is rendered useless. Finally, data accessibility was noted as one of the most important considerations: Monitors need to be able to access imagery at the right time of year to meet obligations and adequately observe key features on the landscape, and if imagery is available inconsistently or with poor timing, it can be of little use to monitors.

The ability to download images, use a web-based platform and integrate with other reporting and database systems were cited as less-important factors on average. However, a majority of respondents still identified these criteria as somewhat or very important in selecting a technology approach. Some organizations initially anticipated that the ability to download images for long-term storage and more customizable analysis would be important to meet their stewardship needs. They often found, though, that the challenges of working with large file sizes and confusing data delivery platforms for download and viewing in a GIS platform were excessively difficult, with some land trusts surprised to find a preference for easier-to-use web-based platforms which could be accessed on any computer without needing to download any data or software.

Vendor use

Land trusts in the cohort used four different vendors to acquire remote monitoring technologies in 2020. Most of the land trusts used either Upstream Tech's Lens product or worked directly with the private Earth imaging company Planet Labs to access remote monitoring technology in 2020. One Lens user also contracted separately with the aerial imagery company Nearmap (which has since been added to Upstream's list of imagery sources accessible through Lens), and one organization opted to use Airbus' web-based OneAtlas platform.

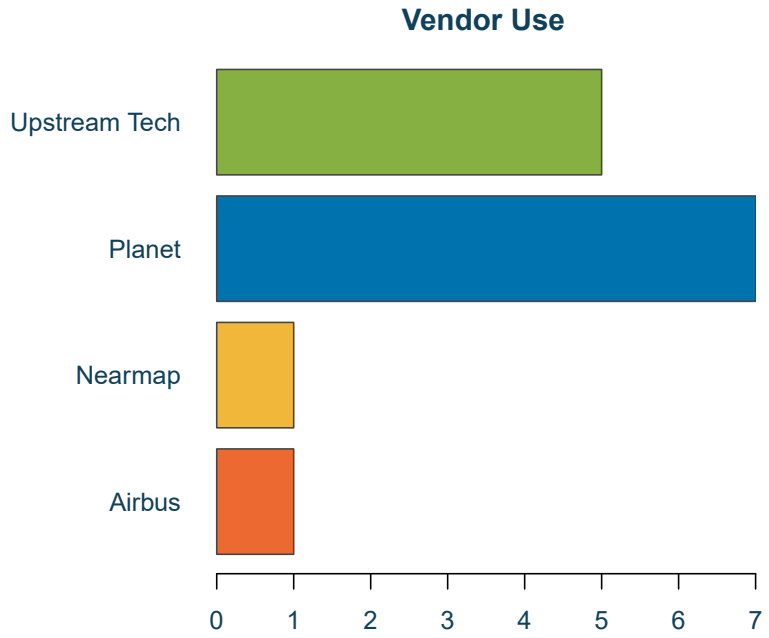


Figure 5. Technology vendor use among grant program participants. Of the 12 land trusts in the grantee cohort, five used Upstream Tech's Lens platform, seven worked directly with Planet Labs (including the four organizations in the Western Slope Partnership), one organization contracted with the urban aerial imagery service Nearmap and one used Airbus's OneAtlas platform. (Note: one organization used multiple vendors in 2020, while all others only used one.)

Upstream Tech's Lens platform was designed as an end-to-end imagery viewing and analysis tool in partnership with The Nature Conservancy in California to facilitate easement and fee property monitoring. Users receive an annual subscription including free public satellite imagery, and can order high-resolution satellite and aerial imagery from multiple sources (including both Planet Labs and Airbus) on an as-needed basis. Reporting and analysis features are embedded in the web-based platform. Subscription costs depend on the size of a land trust's stewardship operation and include an allocation of high-resolution imagery beyond which there may be a per-acre fee.

Planet Labs is a large private satellite operator offering a robust constellation of Earth-observing satellites that provide both an archive of high-resolution data (up to 50 cm resolution) as well as the option to "task" a satellite to retrieve imagery on demand for a higher cost. Planet Labs also offers frequent global coverage, up to every 24 hours for some of their products. Because of the scale at which it operates, land trusts working with the company mentioned minimum purchase requirements of $5,000 in 2020, as well as large minimum capture areas for tasked imagery of at least 25 square km.

Nearmap is an aerial imagery service that provides high-resolution vertical and oblique imagery covering primarily urban and suburban areas. Its imagery, which is derived from aviation-based sources, is housed on a web-based platform and tends to be one of the more cost-effective options available, though its geographic coverage is currently limited.

Airbus, a French aerospace company that operates many Earth-observing satellites, provides its proprietary OneAtlas product on a web-based platform that one land trust accessed via L3Harris, a preferred reseller of Airbus products. Airbus data are often less expensive than other high-resolution imagery and are available at 1.5-meter resolution. This can be a better tradeoff in terms of quality vs. cost for monitoring across large landscapes that do not require sub-meter resolution imagery. The OneAtlas platform also offers a number of data analytics tools.

One land trust also hired contractors to acquire UAV data, however due to the unique nature of UAV-based approaches (including a need to be on-site to operate a UAV per FAA regulations) as well as the organization's prior use of this technology, this report does not explore UAV use in-depth as part of this analysis.

DJ GLISSON II/FIREFLY IMAGEWORKS

Vendor satisfaction

Experiences varied with regard to each organization's satisfaction with its chosen approach, and limited sample sizes of some user groups make it somewhat challenging to draw broad conclusions about which vendors offer the best opportunities for Colorado land trusts across the board. Additionally, it is important to note that **each organization's needs may be different in some significant ways, and what works for one organization may not work for another.** However, important insights were shared by participants that do offer critical lessons for future work in this space for many organizations.

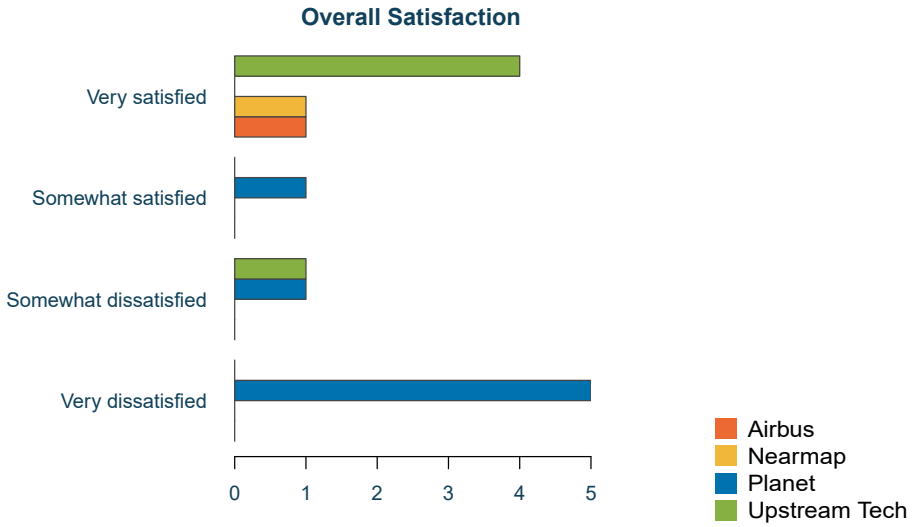


Figure 6. Land trusts' overall satisfaction with vendor choice. Responses represent one Airbus user, one Nearmap user, seven Planet Labs users and five Upstream Tech users.

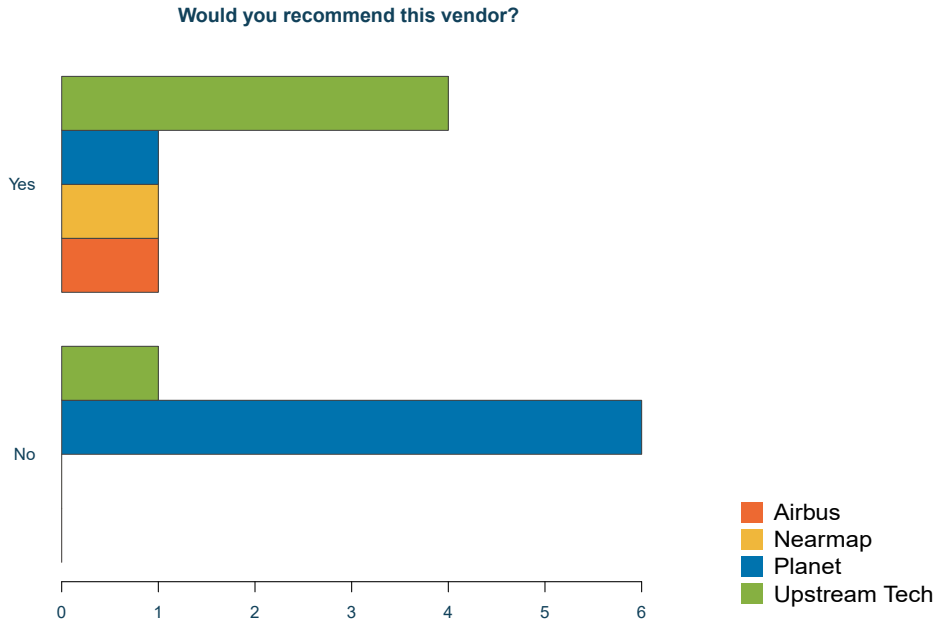
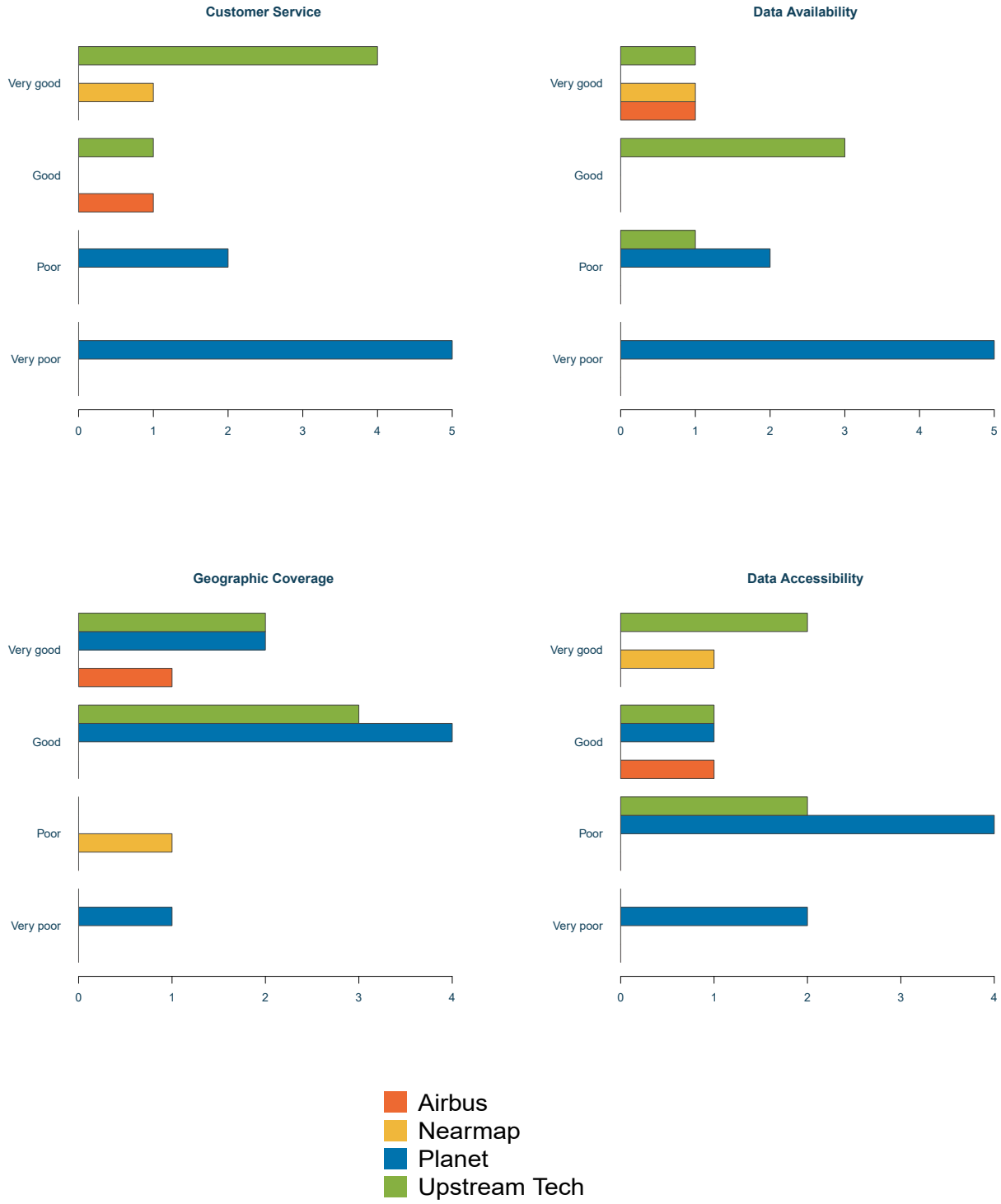


Figure 7. Recommendation of selected vendors. Responses represent one Airbus user, one Nearmap user, seven Planet Labs users and five Upstream Tech users.

Overall, both the Airbus and Nearmap users were pleased with their experiences and would recommend them to other land trusts considering technologies for remote monitoring applications. Lens users were also generally very satisfied, with four out of five land trusts making the recommendation. In a focus group setting, the outlier organization in the survey response noted that it would recommend Lens "with some reservations." Of the seven Planet Labs users, five reported that they were very dissatisfied, and only one would recommend working with them again. In a Planet Labs user focus group attended by six grantees, half of the participants cautioned that they saw "major red flags" with the vendor and would not recommend Planet Labs to other land trusts.



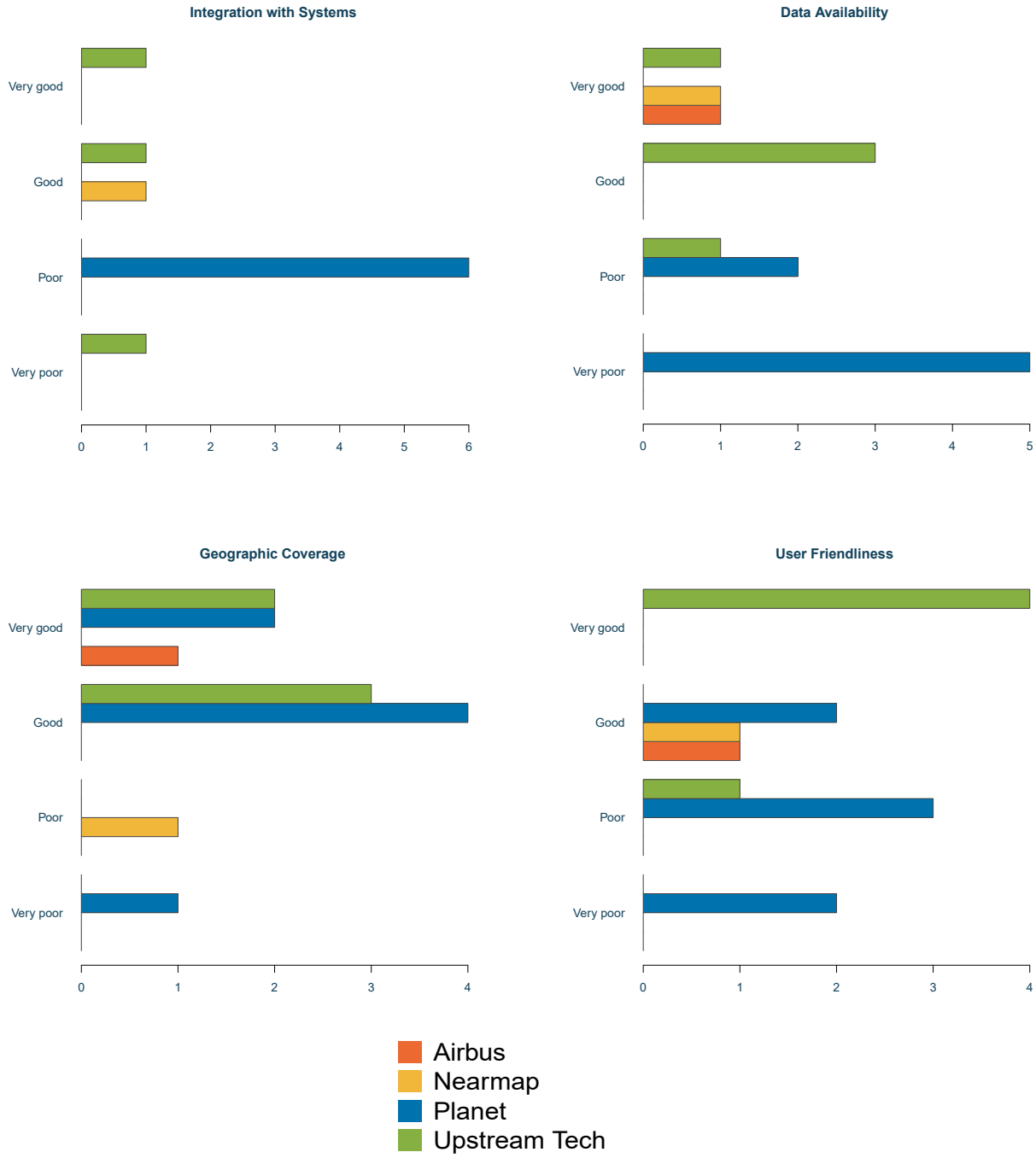


Figure 8. User experiences of specific technology features. Responses represent one Airbus user, one Nearmap user, seven Planet Labs users and five Upstream Tech users after completing a full monitoring season implementing remote monitoring approaches.

Looking more closely at the experiences of users, each vendor offered grantees different pros and cons in using their products and services. The Airbus user reported very high satisfaction with several features of the OneAtlas platform, including a reasonable price, thorough geographic coverage for imagery, and very good data availability loaded into the platform. This user also reported positive experiences with customer service — including technical support and an approachable sales process — as well as adequate 1.5-meter spatial resolution, good data accessibility and a user-friendly platform that easily allowed data to be downloaded as well as viewed on a web-based platform. In a focus group, this user noted that despite the positive experience, they prefer in-person approaches and would likely not continue using imagery as a primary monitoring tool in the future.

The Nearmap user noted highly positive experiences with customer service, a reasonable price, high quality spatial resolution, and very good data accessibility and data availability. This user also reported positive experiences with user friendliness of the platform as well as easy integration with existing stewardship workflows, but noted that geographic coverage, which was limited to urban areas, was poor.

Planet Labs users reported some of the most difficult experiences of the cohort. Notably, two organizations that originally had signed on to use Planet Labs services backed out of their contracts within the first several weeks due to red flags that raised concerns about continuing to work with the company. While the brief experiences of these two former Planet Labs users are not captured by these post-project figures, grantees who did complete the monitoring season using the service tended to report poor to very poor customer service, data accessibility and availability, as well as challenges in efficiently integrating monitoring data into stewardship workflows, especially when files were delivered in very large and unwieldy downloads. In a focus group conversation, Planet Labs users noted that sales and support contacts were sometimes rude and communicated poorly once contracts were signed, and they often found themselves inexplicably at the bottom of priority lists for tasking imagery in a timely manner.

Responses from Planet Labs users were mixed in terms of price, which varied for those who worked through their own contracts with Planet Labs or purchased imagery collectively as part of the Western Slope Conservation Partnership. Feedback about user friendliness and geographic coverage were also mixed, and according to several users, coverage was spotty across certain parts of Colorado in 2020. Additionally, spatial resolution of products delivered to Planet Labs customers varied, with some land trusts in the Western Slope Conservation Partnership in particular noting that image quality was very poor, sometimes at resolutions as coarse as 6-meter, which were insufficient to conduct adequate monitoring. Several organizations that requested tasked imagery from Planet Labs on an as-requested basis also noted challenges in timing of image delivery, waiting in some cases several months before imagery was captured. Sometimes imagery was captured when there already had been snow on the ground, rendering any remotely captured imagery largely useless for stewardship purposes.

Overall, Upstream Tech customers in the cohort reported positive experiences with customer service as well as geographic coverage. Customer service was a particularly high point for most Lens users, and several members of the cohort were appreciative of their personal interactions with Upstream staff who helped them resolve specific issues, provided consistent support and feedback sessions throughout the monitoring season, and were responsive to requests to add new functions to the platform to streamline user experiences.

On several features, Lens users' feedback was slightly mixed, with generally positive responses noted for pricing, spatial resolution, data availability and user friendliness, but there was one outlier in each of these categories. The Lens platform provides imagery from a number of sources with varying quality, and users had mixed responses to what constituted adequate resolution. Some were surprised to be able to see objects as small as fence posts, and others worried about missing violations using 1-meter or 1.5-meter resolutions. It is important to note, however, that this feedback is not unique to the Lens platform, as these represent the typical high-resolution image quality found in any satellite-based product.

DJ GUISSON II/FIREFLY IMAGEWORKS

Data accessibility was considered very good by two Lens users and poor by another two, likely due to struggles resulting from the company's process of renegotiating a reseller contract with Airbus in 2020. During these negotiations, some Airbus data were unavailable on the Lens platform, which was an important imagery source in some parts of Colorado. By mid-fall these issues were resolved, but some land trusts found it challenging to schedule monitoring visits around the uncertainty of data access during that time.

Lens only permits imagery review via a web-based platform, and some organizations expressed concerns about longer-term data access should subscriptions lapse, as imagery is currently only downloadable in PDF formats. The web-based platform was cited by some, however, as a significant perk for teams that needed to enable monitors without access to GIS software or advanced technical knowledge to participate in imagery review and reporting. Similarly, organizations experienced mixed results integrating Lens reporting processes into existing stewardship workflows, as cross-platform communication — for instance with stewardship databases that some organizations use — is not yet well-integrated into Lens.

It is important to highlight that these experiences represent only a handful of land trusts in Colorado, and they may not be shared among organizations working with different stewardship needs, landscapes or capacity. Additionally, an element of self-selection exists in the use of these tools: At the beginning of the season, land trusts expressing an interest in remote monitoring often conducted extensive research to identify the technologies that might best suit their needs, and experiences in many cases validated this initial research and decision-making process. However, the experiences of this cohort also demonstrate that unexpected challenges and pleasant surprises are common when exploring new approaches to stewardship, and the results reported may guide more careful consideration of these tools more broadly in the future.

User Experiences

Overall impressions

While remote monitoring experiences varied across different stewardship needs and selected approaches, land trusts in the cohort were generally very appreciative of the opportunity to try something new and to be able to meet monitoring obligations despite the many challenges of working in the middle of a pandemic year. While satisfaction with the process of acquiring and using imagery was largely influenced by the technologies that different organizations used, **most grantees shared that they found remote monitoring to be a worthwhile addition to their stewardship toolkits.**

One statewide organization that used satellite imagery through Lens noted that the monitoring season had gone better than expected, and it found remote monitoring to provide **increased flexibility to monitor properties regardless of weather, long distances, scheduling with landowners and other factors.** For that organization, satellite imagery had always felt out of reach due to the upfront cost required to access it, but taking the initial risk to try something new paid off for the organization in significant time and cost savings to complete monitoring as well as more capacity to prioritize other stewardship needs.

Another smaller organization that used Lens was impressed with the versatility of the tools used. The land trust also noted surprise at the high level of detail with which it was able to observe the landscape across a larger area than is typically visible in-person. **The land trust described remote monitoring as simply a "game changer" for stewardship.**

However, as several organizations with more challenging experiences noted, trying a new approach can also backfire in unpredictable ways, and they cautioned that always having a backup plan to fulfill obligations is critical, particularly in the early stages of learning how to implement new technologies.

The learning curve associated with trying a new technology was more significant than anticipated for some organizations, particularly for those that worked directly with a larger vendor and required extra technical expertise. For one Planet Labs user, having a strong GIS background felt essential to be able to understand how to request, download and view imagery in ArcGIS. For one Lens user, the time needed to set up a new monitoring workflow took longer than anticipated and required some commitment and patience to get up and running smoothly.

Using aerial and satellite imagery

Land trusts used imagery to monitor a range of properties that varied by size, landscape type and land use, but some common threads can be drawn from the cohort's experiences in 2020. Several organizations highlighted, for instance, that reviewing imagery can be challenging without the context of past in-person monitoring. One staff member at a large statewide land trust described satellite imagery as "flat" without the cues of topography easily visible, and recognizing features from that perspective can be challenging without a discerning eye. It was also helpful for some organizations to have past years' imagery as a comparison point, as even experienced monitors sometimes struggled to interpret imagery without a clear reference point. This point was validated by one newer staff member at a smaller land trust who had not yet had the chance to visit all of their properties in-person.

Additionally, using imagery that may not become available on a predictable schedule can be stressful, and for organizations that waited until quite late in the year for imagery to arrive, there was sometimes concern about having time to conduct field visits on short notice if adequate imagery did not come through. Sometimes if imagery did not appear on a platform until several months after it had been captured, it was also challenging for monitors to follow up on observations that may have been affected by seasonal changes. For example, in the image below from one organization's monitoring report developed in Lens, an unidentified object (likely a late-persisting snow field upon further investigation) that was seen on imagery from July 2020 had disappeared by the time it was viewed in late fall.

Figure 9. Unidentified observation. The light-colored object in the highlighted area in the bottom image, sourced from Airbus SPOT imagery via Lens, was later determined to likely be a late-persisting snow field at high altitude.

However, when high-quality imagery is available, it can provide an extremely insightful new way to understand landscape dynamics. One organization was surprised, for instance, by the ecosystem changes that could be seen from satellite imagery accessed via Lens, including trees burned in wildfires and the progression of mountain pine beetle infestations. Another land trust that holds easements on a number of agricultural properties noted that open ranchlands are particularly well-suited to remote monitoring as well due to the lack of obstructions from forest cover and other features.

Partnerships and collaboration

The unique approach of the Western Slope Conservation Partners to access satellite imagery on a group contract provided a valuable example of what a model for regional collaboration can look like to help organizations in similar geographies access remote monitoring tools. With one organization centralizing interactions with the vendor, partner organizations were able to save time on some of the more difficult aspects of preparing for tasking requests and negotiating with a large company.

The partnership contracted with a large satellite imagery company that was often challenging to work with, however, and there were frequent miscommunications and struggles in accessing critical data to complete monitoring. Several partners noted that it was helpful to have one point of contact with the company to work through these miscommunications, but occasionally also found it difficult not to have a direct line of communication with the vendor to resolve pressing issues.

One land trust in the partnership did not access any usable imagery in 2020 and had to monitor all properties in-person as a result. Others also had significant challenges in accessing the high-quality imagery that

the vendor had promised, and did not receive adequate imagery to meet all of their anticipated needs by the end of the year. One participant noted that it would have been helpful for all the partners to have been more involved in the process of negotiating contract terms to ensure clear recourse if needs were not met.

Despite these stumbling blocks, the partners found their collective efforts worthwhile, and some of the smaller organizations involved would not have been able to access these tools at all if not for the ability to pool resources to meet minimum purchase requirements.

Efficiency of stewardship efforts

The potential for remote monitoring to improve the efficiency of stewardship teams' efforts was cited as a motivating factor for many land trusts to explore new technologies in 2020. While quantitative analysis of monitoring data provided by the cohort helped to better understand and measure these dynamics, stewardship teams also often shared firsthand perspectives on how they spent their time and effort to fulfill their obligations.

For two land trusts in the grantee cohort that worked with different technology vendors, time savings from more efficient monitoring workflows allowed them to reallocate their effort to other projects, enabling them to decide wheretime would be best spent rather than simply meeting requirements. For instance, these organizations were able to give deeper consideration to restoration projects and broader land management concerns that otherwise they may have had less capacity to address.

One organization that struggled with unwieldy tasking orders from Planet Labs, however, felt that it spent much more time simply acquiring imagery than it would have taken to visit properties in-person. Download times alone for imagery files would sometimes take hours, and additional processing time made the process frustrating and difficult to manage.

One land trust expressed caution about drawing broad conclusions about efficiency based on such an unusual year, and that while it felt that staf spent just as much time conducting monitoring in 2020 as in years past, the land trust suspected that might have been different but for such extenuating circumstances and reshuffling of plans. Additionally, the upfront investment of staff time to learn to use new technologies and get a new program up and running can detract from potential time savings that could be seen with remote monitoring in the future.

The implications of efficiencies the cohort did see, however, were at times unexpected. One smaller organization, for instance, noted that the unpredictability of when imagery would become available during the year meant that, while staff saved time overall, the workload was shifted to times of year when it did not have capacity due to other priorities. Another statewide organization noted that because staff saved so much time completing monitoring by using satellite imagery, budgeting to cover stewardship staff time became a challenge. In a typical year, stewardship staffwould spend more time on monitoring and be compensated with restricted stewardship funding, however when they no longer were spending those hours on monitoring, funding to cover their time had to be allocated from other sources.

Landowner engagement

For all stewardship teams, maintaining positive and close relationships with landowners is a crucial aspect of effective long-term stewardship. Particularly during a pandemic year, many stewards noted that landowners appreciated the safety precautions that factored into land trusts' decisions around avoiding in-person interactions. One land trust specifically noted that working with at-risk older landowners, multi-generational homes, and rural communities required extra caution when planning to transition to remote monitoring in 2020.

For most stewardship teams, responses from landowners were positive, with many grateful for the consideration of safety precautions in deciding to avoid in-person visits in 2020. Some landowners, however, were disappointed to miss the annual visits with familiar monitors. Only a few mentioned skepticism about

remote monitoring technologies or privacy concerns, and those occasional concerns were quickly allayed by monitors' reassurance and further explanation of the technology. In at least one instance, a landowner mistakenly believed at first that a land trust would be monitoring via a UAV, which did raise privacy concerns, but once it was explained that the technology was satellite-based, the landowner was receptive to the concept.

Additionally, some land trusts working with "absentee landowners" or seasonal residents who are often out of town or unavailable for in-person monitoring visits with stewardship staff noted that remote monitoring provided a great opportunity to review digital imagery together over video chat, leading to improved communication opportunities to discuss landowners' plans for their properties. Similarly, one land trust noted the potential value of these tools for elderly or mobility-limited landowners who are often unable to join for more physically strenuous walks around larger properties.

Even for landowners that receive an in-person visit, sometimes the option to share high-quality images of their land can be particularly interesting, and some landowners have requested to have copies of imagery for their own personal use. Additionally, one land trust that uses UAVs to monitor some properties noted that its landowners love to see the UAVs in action, and that it has had some very positive interactions while using them.

DJ GLISSON II/FIREFLY IMAGEWORKS

Efficiency and Effectiveness

Many land trusts in the cohort expressed interest in better understanding how to assess the efficiency and effectiveness of remote monitoring tools. **Indeed many, if not most, organizations cited expectations around these issues as motivating factors for exploring these tools in 2020.**

In order to evaluate the efficiency of using these tools compared to traditional monitoring alternatives, land trusts in the cohort used a return on investment (ROI) calculator tool to track monitoring costs, staff time and other aspects of their experiences. The calculator was adapted from a similar tool developed by The Nature Conservancy for use in an internal pilot led by the TNC California chapter with a number of other state and international chapters in 2020. It asked participants to collect data describing year-over-year monitoring efforts in 2020 as well as 2019, or the most recent year in which a traditional approach was used, to provide a representative baseline as a comparison point.

In deploying this tool, it became clear that the methodology used by some organizations did not neatly comply with the expectations of the tool, and data collected were sometimes incomplete or inconsistent. Data reported here should be considered estimates, and only reflect reported figures which were not measured uniformly, with users occasionally incorporating different assumptions and interpretations as they reported these figures. Additionally, because land trusts in the grantee cohort did not have access to this data tracking tool in previous years or early in the monitoring season, data collection in many cases required staff to recall estimates that had not been documented in real-time. Due to these challenges, results from this ROI analysis included small sample sizes and are reported here primarily as raw data.

For future iterations of similar ROI analyses, it is recommended that such efforts:

- Are introduced as early as possible to set clear expectations regarding data tracking needs.
- Incorporate participatory approaches that reflect the needs and capacities of users.
- Provide thorough documentation to ensure full clarity on model assumptions and parameters.
- Do not rely on reporting past years' data if they had been tracked using different methods.
- Prioritize consistency and replicability.

Despite these challenges and lessons learned, grantees' responses to the ROI analysis did provide sufficient information to draw preliminary conclusions and generalizations about their experiences that will be helpful in identifying some of the specific inefficiencies that users of remote monitoring tools in Colorado have seen. **Additionally, initial and final survey results from participants helped to supplement provided cost and labor data with qualitative perspectives that, in many cases, contextualize reported figures with critical firsthand insights.**

Effectiveness, a subjective measure in many cases that depends on individual organizations' monitoring goals and objectives, was evaluated primarily through qualitative interview responses. Stewardship staff frequently described their perspectives on the quality of monitoring completed as well as satisfaction with thorough documentation, landowner engagement and other important features of effective monitoring programs.

Survey results also indicated preliminary results regarding documented violations and other challenges to conserved land. Violation detection accuracy is a multi-year process, however, and validation of the effectiveness of remote monitoring tools in identifying violations will require follow-up over the coming years to thoroughly assess this critical objective.

Costs

Cohort participants reported a wide variation in total costs to complete remote monitoring in 2020; however it is difficult to draw clear conclusions about cost trends due to the small sample size of users of different technology platforms, as well as difficulties in reporting accurate data.

Requested cost data included not just imagery expenses, licensing fees and subscription costs, but also personnel and contractor expenses and other expenses. Data for 2020 were reported based solely on remote monitoring experiences, and exclude costs associated with monitoring properties via other methods including any in-person monitoring visits. Data for 2019 were reported based on, in some cases, strictly in-person monitoring data for 2019, but in other cases more typical recent years or averages of past years were used to estimate costs. It is important to note that these data represent estimates, and assumptions and parameters that guided these calculations may vary between organizations.

Of the 10 organizations that were able to provide complete cost data, three estimated having spent more than they had when monitoring in-person, while seven reported spending less. At each extreme, one Planet Labs user estimated spending 162% more on remote monitoring compared to in-person, while one Lens user reported a 55% decrease in 2020 compared to 2019.

Table 1. Estimated year-over-year change in total costs to complete annual monitoring. Values were adjusted to reflect a typical year, which in some cases drew from years prior to 2019 to capture representative figures. Reported data were adjusted to account for changes in portfolio size over time as well as to control for monitoring method, as some land trusts had previously used a blend of in-person and remote approaches. Administrative costs and other additional expenses may have been included or excluded at individual organizations' discretion.

	Platform	2019 Estimated Total Costs	2020 Estimated Total Costs	Estimated Total Costs Percent Change
Land Trust 1	Lens	$13,793	$14,610	6%
Land Trust 2	Lens	$2,348	$3,982	70%
Land Trust 3	Lens	$37,115	$28,438	-23%
Land Trust 4	Lens	$81,587	$36,701	-55%
Land Trust 5	Lens	$30,783	$19,985	-35%
Land Trust 6	Planet	$1,540	$1,250	-19%
Land Trust 7	Planet	$20,953	$9,825	-53%
Land Trust 8	Planet	$29,352	$77,017	162%
Land Trust 9	Planet	$83,082	$51,733	-38%
Land Trust 10	Airbus	$75,818	$36,558	-52%

Among Planet Labs users, several who reported cost data acquired technology as part of the Western Slope Partnership, and costs incurred, including base fees, were not evenly distributed among partners. One land trust that served in a coordinating role for the partnership took in a disproportionate share of the upfront costs, which are reflected in these cost data and may account for some of this variation.

Additionally, several land trusts only used remote monitoring for several properties, and reported cost data indicate that efficiencies may best be observed when these tools are used at greater scale. One organization in particular only monitored five of its largest properties using Lens, and may have seen shifting efficiencies if a greater share of its portfolio had been included in the project.

Costs may also be reduced if users did not fully implement their chosen technology. For example, several

Planet Labs users who were dissatisfied with their platform's quality had intended to conduct additional expensive tasking of imagery, and due to challenges in placing orders and other issues, declined to fully implement the platform as originally intended, saving on cost while perhaps sacrificing effectiveness or limiting sunk costs.

In addition to platform experience and implementation factors, aspects of different land trusts' conservation portfolios affected the cost efficiencies seen in 2020 compared to previous in-person approaches. Three organizations, all Lens users, submitted data as part of their ROI calculations that broke down monitoring data on a property-by-property basis. With this more detailed information, it was possible to analyze the correlation of property size to cost efficiency. **Trends demonstrated in the visualization below, which shows the results for 164 properties monitored using Lens, reveal that, on average, properties smaller than approximately 6,000 acres were more cost-effective to monitor remotely than in-person.** For larger properties, however (likely due to the per-acre imagery fees associated with the Lens platform), costs increased rapidly for the largest properties in these organizations' portfolios. These trends only represent one platform used by three organizations, however, and more robust property-by-property monitoring data over time would enable a stronger analysis of these dynamics.

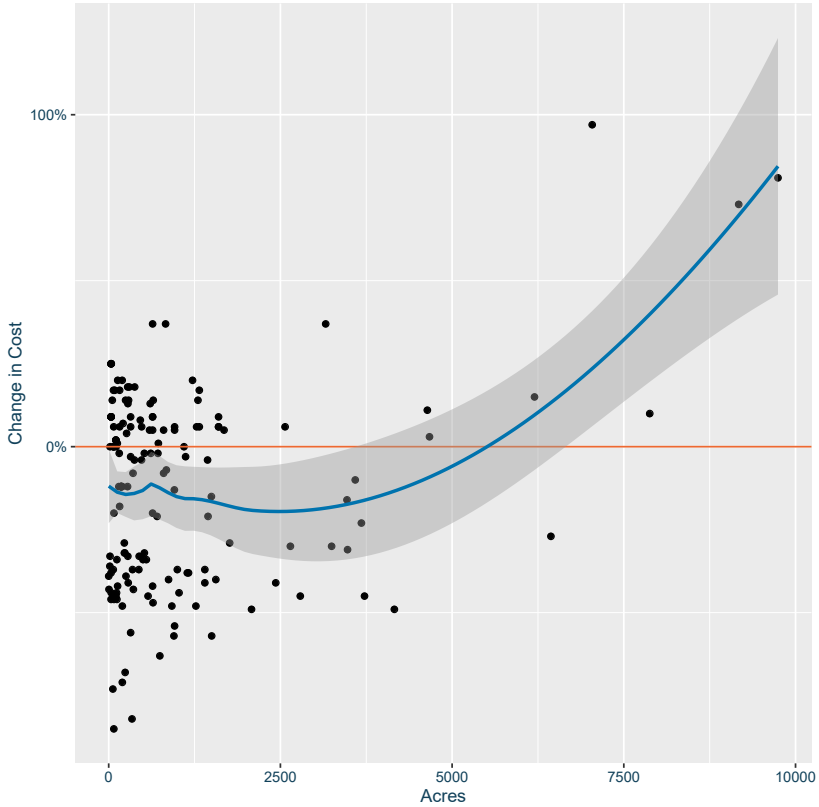


Figure 10. Estimated change in monitoring cost by property size. Three land trusts using Lens reported year-over-year monitoring cost data on a per-property basis (n = 164). Percent changes in estimated monitoring costs from 2019 to 2020 were plotted against property size in acres. A LOESS (locally estimated scatterplot smoothing) curve, a type of local regression analysis, was applied and models a trend of decreased monitoring costs, on average, with individual properties smaller than approximately 6,000 acres in size when using Lens. Costs increased relative to traditional in-person approaches for properties larger than approximately 6,000 acres.

Cost, it should be noted, is not always the sole or primary motivator for land trusts to make decisions about technology use. One land trust that opted to use Airbus's OneAtlas product saw significant efficiencies compared to in-person monitoring, **reducing costs by an estimated 55%,** but does not intend to continue to conduct monitoring remotely in future years due to the organization's high value on in-person landowner engagement each year. This decision exemplifies the case-by-case process of weighing tradeoffs of effectiveness and efficiency to evaluate remote monitoring approaches.

Staffing and personnel effort

While cost efficiencies can be easily seen on a year-to-year basis, changes in staffing and personnel needs due to changes in stewardship practices are less immediately responsive to new approaches in a given year, particularly when learning and setting up new platforms can involve an initial time investment. Nonetheless, Colorado land trusts were able to quantify some of the efforts of their staff, contractors, volunteers and other stewards who participated in monitoring in 2020. These data help us to better understand how land trusts might be able to save time on monitoring which, after several years of reliable data collection, could potentially inform stewardship staffing needs, reallocation of personnel efforts to other priorities or need to engage external resources.

As with other aspects of these organizations' ROI calculations, data for 2020 were reported based solely on remote monitoring experiences, and exclude costs associated with monitoring properties via other methods including any in-person monitoring visits. Data for 2019 were reported based on, in some cases, strictly in-person monitoring data for 2019, but in other cases more typical recent years or averages of past years were used to estimate costs. It is important to note that these data represent estimates, and assumptions and parameters that guided these calculations may vary between organizations.

Of the six organizations that provided data, four Lens users all reported declines in personnel hours needed to complete monitoring, ranging from a 46% reduction to an 80% reduction. Of two Planet Labs users, one reported an 83% reduction in personnel hours and one reported a 15% increase in personnel hours.

Table 2. Estimated year-over-year change in total personnel hours to complete annual monitoring. Values were adjusted to reflect a typical year, which in some cases drew from years prior to 2019 to capture representative figures. Reported data were adjusted to account for changes in portfolio size over time as well as to control for monitoring method, as some land trusts had previously used a blend of in-person and remote approaches. Administrative costs and other additional expenses may have been included or excluded at individual organizations' discretion.

	Platform	2019 Estimated Personnel Hours	2020 Estimated Personnel Hours	Estimated Personnel Hours Percent Change
Land Trust 1	Lens	388	208	-46%
Land Trust 2	Lens	43	9	-80%
Land Trust 3	Lens	602	274	-55%
Land Trust 4	Lens	3324	675	-80%
Land Trust 5	Planet	30	5	-83%
Land Trust 6	Planet	1568	1806	15%

Survey data also revealed several qualitative perspectives that help to contextualize these figures. Land trusts were asked before and after completing remote monitoring whether they anticipated requiring more, fewer or about the same staff resources to complete monitoring objectives. At the end of the program, seven organizations reported using fewer personnel resources to complete monitoring, two used more, and three used about the same amount. Incorporating this feedback, it is unclear that land trusts across the cohort found a consensus on staff and personnel time efficiencies in 2020.

While the ROI data show a pattern of reduction in personnel hours needed to complete monitoring, in some cases these qualitative results reflect that staff time inputs were affected by image quality issues. If the technology was insufficient to adequately meet monitoring goals, staff sometimes did not spend as much time trying to use it, recognizing early on that it would not yield results they needed. For at least one Planet Labs user who struggled with image quality and data management of tasked imagery files, however, time inputs were reported to be significantly higher due to issues accessing data in order to set up a workflow and complete monitoring.

Overall, qualitative responses regarding staff and personnel time on average tracked with initial expectations: Of the 10 responses received, four organizations correctly predicted the amount of time they would spend implementing remote monitoring in 2020, while three underestimated and three overestimated time inputs.

Travel and carbon emissions

Perhaps one of the more evident advantages of remote monitoring approaches is the reduction in carbon emissions seen due to avoided in-person travel. When a steward's presence on-site is limited to only a handful of properties each year, much of their work can be accomplished without expending the resources required to travel to sometimes far-flung properties. According to survey responses, the median distance from a steward's home base to a land trust's furthest conserved property is 110 miles, with some organizations reporting up to a 350-mile trip one-way.

Monitoring remotely, by definition, means there is typically no need to travel to acquire imagery. One organization in the cohort did work with a contractor to acquire imagery from a UAV, which did require the contractor to travel on-site in order to deliver this data to the land trust, however. In all other cases, satellite and aerial imagery acquisition did not require stewards to travel.

In 2020, seven members of the cohort reported that they were able to avoid traveling a total of more than 56,800 miles than they would have if conducting in-person annual monitoring as they had in prior years. In terms of avoided emissions, **this represents a gross reduction of 46,676 pounds of carbon dioxide emissions, using figures for average car fuel economy provided by the U.S. Department of Energy, or 64,547 pounds of carbon dioxide using figures for trucks.**

Calculating net impacts on emissions due to monitoring activities would need to consider fuel expended to launch and operate imagery-collecting aircraft and satellites, however, and a more complete picture of emissions would depend on other factors relevant to individual organizations and technology providers. It is worth noting that, as organizations with an explicit mission to protect landscapes across the state that are vulnerable to the impacts of a changing climate, land trusts may feel that their stewardship obligations require them to consider how they can reduce their carbon footprints through innovative solutions like remote monitoring. Some organizations may find value in investing in further research to conduct a thorough accounting of carbon emissions at their organizations to better understand the environmental impacts of their stewardship programs.

It is also worth noting that in addition to avoided mileage and carbon emissions, time avoided in-transit may also free up staff or contractor capacity to prioritize other tasks, such as landowner communications, more detailed imagery review or other stewardship projects. Avoided travel can thus be seen not only as a carbon reduction benefit, but also as a time savings and organizational efficiency benefit.

Table 3. Estimated carbon dioxide emissions reductions from avoided in-person monitoring travel. Eight land trusts provided data for the miles their stewards traveled to conduct annual monitoring in 2019 and 2020. Land trusts that conducted both in-person and remote monitoring in 2020 were excluded from this analysis, however one organization acquired remote imagery from a contractor operating a UAV which required travel on-site. Estimates for vehicle miles per gallon used in this analysis use average fuel economy statistics for cars (24.2 MPG) and trucks (17.5 MPG) cited by the U.S. Department of Energy's Alternative Fuels Data Center in February 2020. CO2 emissions estimates were calculated using the EPA's Carbon Footprint Calculator.

	2019 Mileage	2020 Mileage	Emissions Avoided at 24.2 MPG (lbs CO2)	Emissions Avoided at 17.5 MPG (lbs CO2)
Land Trust 1	29,388	0	24128	33365
Land Trust 2	343	0	282	389
Land Trust 3	3696	90	2960	4093
Land Trust 4	12556	0	10308	14255
Land Trust 5	300	0	246	341
Land Trust 6	2,690	0	2208	3054
Land Trust 7	7,971	0	6544	9050
Total	**56,944**	**90**	**46,676**	**64,547**

Violations and follow-up

A key aspect of monitoring effectiveness is how well a land trust's chosen approach enables stewards to detect threats to the conservation values of a property. **According to survey data, six respondents did not note a change in the number of violations or other threats to conserved land during annual monitoring in 2020 compared to 2019. Two noted that fewer violations and other issues were detected compared to the previous year, and four reported more, including one organization that noted 34 issues requiring follow-up compared to four the previous year.**

Changes on the landscape only sometimes count as violations depending on the specific circumstances of the issue and the terms of a particular easement. **It is unclear how many of the reported issues discovered via remote monitoring in 2020 will indeed be classified as violations requiring more diligent follow-up with a landowner, as these determinations often take time.** For this reason, the number of violations may be inflated due to the timing of this survey before stewards were able to conduct this follow-up. On the other hand, it cannot be known whether land trusts did, in fact, discover all possible changes on conserved properties in 2020 while using remote technologies. Accuracy rates can only be validated and understood after a period of years using in-person and remote approaches, and in this way the reported figures may underreport the number of violations and other issues that occurred in 2020.

Several land trusts noted specific instances of how remote monitoring tools helped to uncover issues that may have been previously overlooked. For example, using 1.5-meter satellite imagery, one organization spotted a dumping site on a property of several thousand acres that had gone unnoticed previously. After observing the issue on the imagery and following up with the landowner, the organization now has a remediation and restoration plan in place to resolve the issue. Particularly on such a large property, it can be difficult to thoroughly observe every part of a large landscape on an in-person visit, and this success demonstrates the value of implementing multiple approaches to see and understand the landscape. By using a diverse suite of tools with which to observe change, it is more likely that a monitor can see something new and approach it with fresh eyes.

One persistent challenge in evaluating remote monitoring's success in detecting change, however, is the selection bias of determining which properties to include or exclude from remote monitoring protocols. For instance, many land trusts choose to consistently maintain an on-site presence on properties that are considered higher risk for a violation for reasons that may include a history of violations, a change in ownership or an intention to exercise reserved rights.

In addition to detecting changes on properties effectively and consistently, maintaining positive and strong relationships with landowners is often cited by land trusts as a measure of monitoring effectiveness. **According to survey responses, all land trusts in the cohort characterized landowner responses to their remote monitoring approaches overall as neutral (5), positive (5), or very positive (2).**

Future Applications and Recommendations

After their first-year experience, **most of the 12 land trusts in the grantee cohort believe that remote monitoring will either play a major role (33%) in stewardship efforts or that they'll likely use it to monitor a handful of properties each year (42%) moving forward.** While remote monitoring may not be the perfect solution to meet every organization's needs for every property it stewards, this pilot year has demonstrated that remote monitoring can be a valuable addition to a stewardship team's toolkit, and will likely continue to be an important tool for most of the organizations that participated in this program.

Among the benefits that land trusts saw in implementing remote monitoring, the value of these new perspectives was an important one, and seeing the landscape through a new lens can reveal insights that may otherwise be looked over. Additionally, the potential to track longer-term trends as well as vegetation indices, drought patterns and other ecological changes can enhance monitoring insights. With the right tools, remote monitoring can improve the efficiency of stewardship programs to save valuable resources. **Funding and capacity are perennial concerns for conservation organizations, and any tools that offer the potential to stretch conservation dollars further can be a powerful tool to increase land trusts' ability to fulfill their missions.** While saving time and cost on monitoring, stewardship teams are also enabled to reallocate their resources and prioritize other important work such as restoration efforts.

Plans for future use of remote monitoring tools

Most land trusts that intend to continue using remote monitoring on an annual basis see these tools as part of a **rotational plan that will complement existing in-person methods.** For some properties, particularly larger ones that are less cost-effective to monitor remotely as well as those requiring a more careful eye towards potential issues, in-person monitoring will likely remain an important priority. But many properties that are at lower risk for violations and are of more modest size will likely be great candidates for incorporating into a rotational approach. At least one organization sees an additional opportunity to capture imagery for all properties each year whether or not it will be the primary monitoring method, as they see immense **value in having these records for longer-term comparisons.**

Some organizations would love to also see a continuation or expansion of coordinated efforts to work with remote monitoring technology vendors, especially if those collaborations have the potential to reduce costs for smaller organizations. However, for future partnerships some organizations noted that they would want to restructure some of the approaches to these arrangements, particularly by having direct lines of communication between all partner organizations and the vendor.

One organization, despite having a very positive experience using remote monitoring, will not be continuing to use remote monitoring barring other extenuating circumstances, as it places a particularly high value on in-person landowner interactions. This example is a good reminder that **different organizations will place different values on various factors that guide stewardship decisions,** and the trade-offs among different tools are unique to each organization.

Regardless of what tools land trusts will use next year, many shared enthusiasm for returning to an in-person presence on the land in the coming year after being forced to keep a distance from landowners and their communities in 2020 due to the pandemic.

Recommendations for further support

Colorado land trusts have demonstrated that with support and guidance from organizations like Keep It Colorado, they can make great strides in equipping their stewardship teams with innovative new tools. There are several key opportunities to continue to support these efforts:

- Facilitating partnership-building efforts among land trusts as well as other entities such as state and local government agencies and academic institutions to make remote monitoring tools and knowledge more accessible.
- Researching remote monitoring technology providers and sharing information to help land trusts understand their options.
- Building relationships with technology vendors to ensure that they are well-prepared to provide land trusts with the products and services they need to meet their stewardship obligations.
- Providing remote monitoring technologies and GIS support as a membership benefit, potentially via a fee-for-service model.
- Developing robust tools such as an enhanced ROI calculator that land trusts can use to analyze their own efficiencies.
- Offering trainings, workshops and discussion spaces to build technical capacity and facilitate peer knowledge sharing.
- Exploring and providing additional guidance on the legal aspects of remote monitoring tools for conservation defense.

With these kinds of support from the broader community, land trusts can continue to explore these exciting new options to enhance their work in the coming years and will be well-equipped to learn more about how remote monitoring can help to protect conserved lands for the long-term.

Keep it Colorado (www.keepitco.org) is a nonprofit coalition of conservation organizations working to protect the lands and waters that define the state of Colorado. The organization is intent on creating a future in which conservation, protection and stewardship are priorities for Colorado's communities. Land trusts form the core of Keep It Colorado's membership, but the coalition also serves as a voice for public agencies, nonprofits and other conservation champions that are conserving and stewarding Colorado's private and public lands and water. With a vision to create a Colorado where people, lands, waters and wildlife thrive, Keep It Colorado works on behalf of its statewide members through five core focus areas: Policy Advocacy; Member Connection & Coalition Building; Emerging Issues & Opportunities Forum; Health & Sustainability Solutions; and Advancing a Culture of Conservation. Collectively, the coalition's work continues the legacy and heritage of Colorado's working family farms and ranches; protects Colorado's large, connected natural areas including open spaces and scenic vistas, rivers and lakes, and fish and animals; and enables Coloradans and visitors to enjoy the state's iconic beauty, from the prairies and deserts to the mountains.

DJ GLISSON, II/FIREFLY IMAGEWORKS

Jake Faber, Land Trust Alliance

Additional contributors: Amanda Hill, Elizabeth Ward, Lori Faeth, Lindsy Crutchfield, Morgan Zenter and Sierra Moen

Special thanks to Keep It Colorado's Melissa Daruna, executive director, and Linda Lidov, director of membership and communications

Land Trust Alliance
Together, conserving the places you love

KEEP IT COLORADO