ENVIRONMENTAL LAW INSTITUTE

Integrating Remote Sensing Technologies into Wetland Policy and Management: An ELI Webinar Series

JULY 2024

ENVIRONMENTAL LAW • INSTITUTE®

General Overview

The advent of relatively low-cost and highly sophisticated drones with greater ranges and flight durations, global positioning systems (GPS), lightweight cameras and other equipment, drone-mounted LiDAR, as well as the capacity to transmit large amounts of data remotely, have revolutionized environmental monitoring and management possibilities. These technologies are increasingly used in wetland monitoring, restoration, and adaptive management (Brisco, 2015; Merchant, 2019; Guo et al., 2017).

The most substantial need now is some way to integrate these capabilities more fully into the often time-consuming and difficult tasks that relate to the evaluation of compensatory mitigation; tracking and monitoring field conditions and restoration success; facilitating review by wetland programs, interagency review reams (IRTs), state and tribal resource managers; and determining when virtual/digital information can be used in place of boots-in-the-water field sampling. Integration entails a wide range of considerations, and wetland programs will need to tailor and adjust their use of these tools as these technologies evolve and sites change due to climate change and other threats. More research will be needed to understand how to practically maximize cost-effectiveness, accuracy, and data use to incorporate unmanned aerial vehicle (UAV) technology into wetland monitoring techniques.

The Environmental Law Institute (ELI) received a Wetland Program Development Grant (WPDG) from the Environmental Protection Agency (EPA) grant to identify, develop, and disseminate practical approaches to integrate remote sensing techniques and other emerging technologies into state and tribal wetland program policy frameworks. These evolving technologies can contribute to regulatory approvals and compliance (including site selection, credit release, and monitoring for compensatory mitigation); verify the status and performance of voluntary restoration and preservation projects over time; and assist with monitoring and assessing wetlands for other purposes.

To bridge current research and practice, ELI hosted three expert workshops focusing on key issues and opportunities to identify, develop, and disseminate practical approaches to integrate remote sensing techniques and other emerging technologies into state and tribal programs and policy frameworks. The workshops brought together researchers and practitioners who evaluate emerging remote sensing technologies and have experience incorporating and adopting these tools into wetland programs. Each workshop focused on a different area where remote sensing could be leveraged to support state and tribal wetland programs—participatory science, resilience, and compensatory mitigation. This summary will help provide an overview of the presentations, key takeaways from the workshops, and ideas and research for practitioners.

Workshop 1: Participatory Science

Introduction

Participatory science groups are valuable partners in the collection and/or interpretation of wetland data. Remote sensing provides new opportunities for these groups but may require additional time, funds, and skill sets that many programs do not have (Moodley & Wyeth, 2020). "Participatory science" is a commonly used term for the involvement of volunteers in scientific monitoring or research. Other names include citizen science, community science, crowdsourcing science, and civic science (EPA, 2023). Remote sensing expands the scope of data and technologies available to community scientists to support state and tribal programs. State and tribal wetlands programs can leverage these tools to engage the public, reduce costs, and further programmatic goals.

While participatory science programs have the potential to support state, tribal, and local wetland programs, there will likely be challenges. Potential obstacles include:

- Citizen scientists need detailed training (Gruber et al., 2021);
- Programs need continued buy-in from volunteers (Grainger, 2017);
- Technological challenges caused by a large number of data inputs (Grainger, 2017);
- Data quality requires frequent monitoring and accuracy checks, which can be time-intensive (Fritz et al., 2017); and
- Difficulties addressing legal issues related to privacy, ethics, and licensing of volunteered datasets (Fritz et al., 2017).

Workshop Description

To promote creative collaboration between participatory science groups and wetlands programs, the Environmental Law Institute hosted a half-day (4-hour) workshop, Bridging Remote Sensing, Participatory Science, And Wetlands Programs**.** The workshop focused on how strategic integration of remote sensing and participatory science can support state, tribal, and local wetland programs while allowing volunteers the flexibility to help from their backyards or computers.

With over 584 registrations and a peak attendance of 286 participants, the workshop engaged a wide range of stakeholders. According to a group poll, the attendees worked with tribes, the federal government, state governments, local governments, non-governmental organizations (NGOs), academia, and community-based organizations.

Workshop speakers covered practical topics such as:

- Emerging technologies at the intersection of remote sensing, wetlands, and participatory science;
- Benefits and challenges of using participatory science and remote sensing to contribute to wetland programs, such as monitoring, enforcement, and education; and
- Best practices for collecting, assembling, and incorporating remote sensing/participatory science data into programming.

The recording and workshop materials are publicly available on the workshop's event page on ELI's website.

Summary of the Event

Session 1: Overview of Remote Sensing Technologies

Overview of Remote Sensing Technologies by Pete Kauhanen, Senior GIS Manager, San Francisco Estuary Institute

Pete presented an overview of the remote sensing platforms commonly used for wetlands, such as satellites, planes, and unoccupied aerial systems (e.g., drones). He also covered the benefits and challenges of mapping wetlands using aerial imagery, elevation data (e.g., LiDAR), and Synthetic Aperture RADAR (SAR) data.

Session 2: Best Practices for Incorporating Participatory Science Data in Wetlands Programs (panel)

Incorporating Participatory Science into State/Tribal Programs by Barb Horn, Founder, Colorado River Watch

Barb shared best practices for participatory science programs considering a new direction, method, technology, or strategy. She articulated the following steps to creating study design: (1) designing the purpose and "why" of the project; (2) technical design of the project; (3) data analysis and interpretation; and (4) evaluation design.

Creating Standards of Procedures for Drone Data by Brent Walls, Upper Potomac Riverkeeper, Upper Potomac Riverkeepers

Brent shared how the Upper Potomac Riverkeepers set standard operating procedures (SOPs) for using drones, including taking aerial imagery and water samples to help with Clean Water Act (CWA) enforcement issues. Key components of the Potomac River Network's Surveillance SOPs include determining regulatory limitations and conducting a flight path assessment. He also shared a copy of a Potomac Riverkeeper's SOP with the group.

Session 3: Wetlands, Remote Sensing & Participatory Science Case Studies (panel)

Arizona Water Watch – Leveraging Technology and Engaging Community Scientists by Meghan Smart, Senior Scientist, Arizona Department of Environmental Quality

Meghan described the Arizona Department of Environmental Quality's (AZDEQ) Arizona Water Watch (AWW) program. AWW conscripts volunteers to help with trash cleanup, storm sampling, and pollution identification, and they use phone apps to help them upload the data. Using the apps allows AZDEQ to remotely receive and analyze the data so they can act in a timely manner if needed. Meghan also emphasized the importance of code sharing amongst water programs and offered to share the code AWW uses with interested parties.

Fast and Economic Mapping of Potential Wetlands Using Openly Available Remote Sensing Data and Artificial Intelligence by Adnan Rajib, Assistant Professor for Civil Engineering, Texas A&M University, Kingsville

Adnan's presentation centered on the idea that remote sensing is not enough to track the loss of America's wet landscape and that AI learning is necessary for a better picture. His presentation highlighted the challenges of using open-source remote sensing data (e.g., Google Earth) to gather wetland information. For example, one dataset can mark an area as water while another marks it as wetland. He then presented his research on how to overlay multiple datasets best to create a more accurate assessment.

Land Loss Lookout by Scott Eustis, Community Science Director, Healthy Gulf, and Sophie Spatharioti, Postdoctoral Researcher, Cartoscope

Sophie and Scott presented their work developing Land Loss Lookout, an online platform where participants sort through an aerial image database to help identify patterns associated with different types of land impact in the Gulf of Mexico (e.g., oil and gas, sea level rise, and restoration). The project has been successful as an educational tool and has provided an opportunity to collect data on land loss in the Gulf.

Use of EcoAtlas in Program Implementation by Pete Kauhanen, Senior GIS Manager, San Francisco Estuary Institute

Pete discussed EcoAtlas, a tool to support California's Wetland and Riparian Area Monitoring Plan (WRAMP). The comprehensive assessment framework from WRAMP allows users (non-profits and state agencies) to engage with the EcoAtlas tool at three levels: Landscape Assessment (Level 1), Rapid Assessment (Level 2), and Intensive Assessment (Level 3). This framework provides insight into the landscape, in-situ, and site-specific sampling levels. Pete also explained how the public can use EcoAtlas to edit the California Aquatic Resource Inventory, which will be validated by a regional expert. This data helps track and summarize cumulative impacts on wetlands.

Session 4: Discussion with Attendees using MentiMeter, an interactive polling platform

MentiMeter allows participants to view everyone's responses in real time. The table below presents the questions asked and summarizes participants' responses:

Questions	Summary of Participant's Responses
What types of organizations do you work with?	• Tribes (12) • Federal government (21) • State government (30) • Local government (17) • NGOs (20) • Academia (18) • Community-based organizations (11) • Other (5)
What region(s) do you work with?	• West (14) • Midwest (17) • Southwest (6) • Southeast (14) • Northeast (19) • US Territories (1) • International (5)
What opportunities do you see to incorporate participatory science and remote sensing into your program after this workshop?	• Restoration monitoring • More accurate wetlands mapping • Data collection and validation • Community education/involvement • Identification of restoration potential
What are the challenges of incorporating participatory science and/or remote sensing into your program?	• Lack of funds • Staffing limitations • Lack of technical know-how • Lack of time • Data quality and/or ability to utilize volunteer-collected data
What resources are you missing?	• Technical assistance • Time • Money • Staff • Funding • Standards of Procedures
What do you want to learn more about?	• How to acquire a drone license • Wetland mapping • Transferring programs from one state to another • Data monitoring and management • How to develop training for volunteer groups
What is the best way for this group to stay connected?	• Webinars • Listserv • Conferences

	• Code and/or data sharing

Key Takeaways

- Remote sensing offers new and creative ways to include the public in wetland programs, but these initiatives need more training, technical assistance, and funds to be fully successful.
- Data can easily sit on a shelf—it is important that wetland programs seriously consider study design, quality assurance and quality control, and how remote sensing data will be used before implementing a participatory science initiative.
- NGOs and state, tribal, and local programs using data for Clean Water Act implementation or enforcement must have clear standards of procedures.
- Open-source remote sensing (e.g., EcoAtlas, GoogleEarth) can provide remote sensing data to programs lacking the capacity, funds, or expertise to collect it.
- Many programs are willing to share their code, standard operating procedures, or techniques to promote participatory science.

Workshop 2: Resilience

Introduction

Resilient wetlands can withstand, adapt, or recover from disturbances like drought, human activity, and climate change (Tooth, 2018). To ensure the long-term sustainability of wetland habitats, climate change and other threats must be considered in preserving and restoring wetlands, streams, and other aquatic resources. At the same time, critical wetlands habitats sequester significant amounts of carbon and provide essential functions that can lessen the impacts of climate change and make communities more resilient (Rodriguez, 2022).

Remote sensing data can be particularly useful in determining a wetland's vulnerability or resiliency. As part of a nationwide mapping initiative, for example, the U.S. Geological Survey (USGS) released a map created from remote-sensing data to identify the most vulnerable coastal marshes in the US in 2021. The resulting map uses Unvegetated-Vegetated marsh ratio data from 2014-2018 to complement detailed mapping from the National Wetland Inventory (NWI) and the Coastal Elevation Database to help compare vulnerability to other important metrics like sea-level rise or wetland type.

Remote sensing data may also be helpful in understanding the temporal trends of wetland health and resilience to changing environments. For example, using long-range temporal datasets obtained by remote sensing allows researchers to determine changes in wetland characteristics, such as cover, structure, condition, and spatial patterns of vegetation (Moffett, 2015). Remote monitoring is an effective tool for resilience work because it can allow for wetland characteristics to be more easily tracked and analyzed over longer periods of time than traditional monitoring techniques.

Integrating the vast amount of available data into programmatic development and implementation is challenging and requires technical knowledge and capacity building. To address this challenge, NASA offers training to teach practitioners to use "Earth-observing data," including one specifically targeted at tribal programs. Rajib et al. published supplemental materials, like instructional videos on reproducing the dataset and a tutorial to facilitate classroom applications of the code, to make their study "the template for developing similar datasets for other river basins across the globe" (Rajib et al., 2021).

While remote sensing data offers many opportunities for state, tribal, and local program development, there will likely be challenges:

- Remote sensing data can help wetland programs better understand wetland vulnerability and how these resources can benefit communities' resilience. However, communities, government agencies, and other organizations may need more training and capacity building to best co-produce and manage data.
- Remote sensing can efficiently assess and compare various wetland characteristics and temporal trends to better understand a wetland's resilience (Moffett, 2015).

- Most research into wetland resilience or vulnerability assesses it retrospectively. Finding opportunities for data to model specific future scenarios will likely be key to states' and tribal programs' effective use of remote sensing in climate/disaster planning (Smith et al., 2014).
- Better data coordination is needed to use remote sensing beyond the case-study level (Rajib et al., 2021).

Workshop Description

Remote sensing techniques can help us better understand how wetlands react to changing environments, from predicting sea-level rise to monitoring watershed-level changes. Yet, with more technologies and data available than ever before, it can be difficult for wetland programs to determine *what* data to use and *how* to use it in resilient management and decision-making.

To help wetland programs learn to interpret and utilize remote sensing data, the Environmental Law Institute presents **From Data to Decisions: Remote Sensing & Wetland Resilience.** This workshop will focus on how the strategic integration of remote sensing has the potential to support the resilience efforts of state, tribal, and local wetland programs. Speakers will cover practical topics such as:

- Emerging technologies at the intersection of remote sensing, wetlands, and resilience
- Benefits and challenges of using remote sensing to contribute to wetland programs' resilience efforts, such as adaptive management practices and mapping of sea-level rise.
- Best practices for collecting, assembling, and incorporating remote sensing data into resilience programming.

The recording and workshop materials are publicly available on the workshop's event page on ELI's website.

Summary of Event

Welcome & Introductory Questions with Attendees using MentiMeter, an interactive polling platform

Question	Summary of Participants' Responses
What type of program/organization are you involved with?	• Academia (8) • Federal Government (28) • Local Government (4) • NGOs (12) • Other (15) • State Government (65) • Tribal Program (5)
What region(s) do you work in?	• Pacific Northwest (12) • Gulf Coast (7)

	• Midwest (24) • Northeast (31) • Southeast (29) • West (21) • International (7) • U.S Territories (2) • Southwest (11)
How would you describe your position?	• Manager (21) • Scientist (71) • Policymaker (15) • Contractor (5) • Academic (4) • Educator (2) • Other (19)
What do you hope to learn about today?	• Best practices for using remote sensing data (69) • Emerging technology (58) • What metrics can help measure resilience (60) • How remote sensing data can help account for rapid changes (50) • Other (3)

Session 1: Overview of Wetland Remote Sensing Technologies

Dr. Meghan Halabisky, Senior Science Advisor, Digital Earth Africa

Dr. Halabisky's session provided an overview of remote sensing tools and how they can help better understand wetland dynamics across landscapes, both historically and into the future under changing climates. Her research leverages multi-sensor data (LiDAR, aerial imagery, satellite) and machine learning to map cryptic wetlands and model soil carbon stocks. Another project of Meghan's used Landsat's long-term archive to characterize wetland hydrologic regimes across the semi-arid Columbia Plateau and model potential drying under climate scenarios.

While mapping and modeling wetlands comes with unique challenges due to their diversity, dynamic hydrology, and disturbed conditions, recent advances in wetland technologies and research have made remote sensing more accessible for tasks in wetland conservation and management. While technical hurdles remain, Dr. Halabisky sees an exciting shift towards building remote sensing solutions directly into decision support tools for real-time monitoring and adaptive management.

Session 2: Facilitated Discussion with Attendees using MentiMeter

Question	Summary of Participants Responses
How familiar are you with remote sensing techniques or technologies?	• Focus of my everyday work (4) • Use RA data in much of my work (17) • Understand the science and informs my work (29) • New to the field (27)
If you are, what types of remote sensing technology are you using (e.g., drones, satellites, AI, apps, other)?	• Satellites • LiDAR • Drones • Apps • Google Earth engine • Wetland mappings • AI • GIS
What types of remote sensors are most useful in your work?	Participants ranked each sensor from not useful (1) to very useful (5) • Aerial imagery (4.3) • LiDAR (4) • Satellite Imagery (3.9) • Hyper-spectral imagery (2.7) • Radar (1.6) • Other (1.3)
Where do you get your remote sensing data?	• Open source (44) • Partnerships with other organizations (10) • Collect yourself (9) • Contract out (4) • Other (4)
What are the challenges/barriers to using remote sensing?	• Knowledge/training • Funding • Image resolution • Age of data • Capacity • Ground verification of data • Availability of data • Clouds/weather
What resources are you missing to address these challenges/barriers?	• Training • Funding • Capacity • Time • Statewide data • Buy in from other users

	• In-house knowledge

Session 3: Emerging Remote Sensing Techniques & Wetland Resilience (panel)

Measuring Coastal Wetland Shoreline Change with Remote Sensing by Dr. Kathryn Smith, Research Ecologist, St. Petersburg Coastal and Marine Science Center, USGS

Dr. Smith's presentation outlined how the USGS is developing novel techniques to extend shoreline change analysis traditionally used for beaches to wetland shorelines. By compiling modern and historical data from sources like aerial photos and satellite imagery, USGS can utilize methods to quantify rates of shoreline movement. However, more advanced methods are still needed to analyze shoreline change in these environments.

The session also discussed how the increasing frequency of satellite data collection allows for resolving seasonal and storm-driven changes, an exciting prospect compared to previous reliance on infrequent airborne data. As USGS builds out these remote sensing products and tools, they seek partners among wetland managers to apply the data and validate it through field observations.

Automated Habitat Mapping and the Shoreline Resilience Framework by Alex Braud, GIS Specialist, San Francisco Estuary Institute

Alex discussed how the San Francisco Estuary Institute (SFEI) is taking an automated approach to habitat mapping and change detection to support the Wetland Regional Monitoring Program's (WRMP) adaptive management framework. They have established rule-based models driven by relative tidal elevation data from LiDAR, which can help map coastal habitats across the entire San Francisco Bay estuary more efficiently. These remote sensing products track changes in habitat extent and condition to assess resilience over time based on factors like connectivity and diversity within their Strong Resilience Framework.

Alex also discussed how object-based image analysis and machine-learning classification of aerial imagery can provide complementary high-resolution habitat maps. SFEI is working to account for uncertainties contributing to these techniques, like vegetation bias, and is trying to integrate additional data.

Session 4: Using Remote Sensing for Resilient Wetland Management (panel)

Using an Adaptive Management Framework to Examine a Few Examples of Mapping Wetlands with Remote Sensing in the Chesapeake Bay, Alex Gunnerson, GIS Analyst, Chesapeake Research Consortium

Alex presented his work at the Chesapeake Research Consortium, which aims to increase wetland extent and function through the 2014 Watershed Agreement's

Wetlands Outcome. However, inconsistent monitoring data has made tracking progress difficult, especially for non-tidal wetlands. To improve wetland mapping, projects are leveraging remote sensing techniques like the AI Wetlands Mapping Project and USGS' Wetland Cover Mapping for tidal areas.

As new remote sensing data becomes available, Alex's team can incorporate it into adaptive management processes to improve the evaluation of restoration strategies and make decisions about resource allocation. This allows their overall goals for wetland enhancement to be pursued through an iterative process of assessment and adjustment.

Making Management Relevant Sense of Recent Advances in Remote Sensing, Dr. Owen McKenna, Research Ecologist, Northern Prairie Wildlife Research Center, USGS

Dr. McKenna discussed USGS's research in the prairie pothole region spanning parts of the northern U.S. and Canada. The research aims to understand how climate change and land use affect these critical wetland ecosystems for wildlife and water quality. The team uses long-term monitoring data and process-based models to simulate wetland hydrology responses to climate variability. Remote sensing aids in parameterizing these models where ground data is lacking.

Collaborations with partners like the U.S. Fish and Wildlife Service have enabled Dr. McKenna's team to integrate remote sensing analyses into field observations to inform on-the-ground management decisions directly. On a larger scale, he posits that spatial tools combining remote sensing and climate data can guide land use policies across public and private lands.

Wetlands Regional Monitoring Project by Christina Toms, Ecological Engineer, San Francisco Bay Regional Water Quality Control Board

Christina's presentation outlined how The Wetland Regional Monitoring Program (WRMP) coordinates mapping and data collection to assess landscape impacts on San Francisco Bay's tidal wetlands and support science-based management decisions. The Balanced Change-Based Map is a key product that uses relative tidal elevation to classify habitat types and distribution. When coupled with supplementary remote sensing products like hydrogeomorphology and vegetation maps, the program can evaluate wetland conditions, resilience to sea level rise, and needs for restoration or sediment augmentation.

The WRMP integrates this remote sensing data with field measurements across the estuary's sub-regions through a tiered monitoring framework designating benchmark, reference, and restoration project sites. While developing standardized protocols remains challenging, Christina discussed how their long-term goal is to provide regional stakeholders with the scientific basis for promoting healthy, diverse, and resilient natural and human communities.

Session 5: Concluding Discussion with Attendees using MentiMeter

What are the specific resilience challenges you're trying to address with remote sensing information?	• Drought • Wetland/habitat loss • Sea level rise • Saltwater intrusion • Environmental justice/equitable investment • Water quality • NAIP • Extreme weather events • Infrastructure/development setting
What is something you learned today that sparked a new idea?	• Networking • New technologies and data sources • Habitat migration • Use of NAIP for remote sensing • Using LiDAR

<u>Key Takeaways</u>

- Remote sensing offers powerful capabilities for mapping and monitoring wetlands across large spatial and temporal scales, which is critical for assessing resilience to climate change impacts like sea level rise and extreme events. However, wetlands' diversity and dynamic hydrology pose unique challenges.
- New and emerging technologies like high-resolution imagery, LiDAR, and cloud computing enable more automated, efficient habitat mapping and change detection. Applications include modeling coastal marsh vulnerability, tracking shoreline movement, and classifying wetland types based on relative tidal elevation.
- Long-term remotely sensed data archives (e.g., Landsat) are invaluable for characterizing baseline wetland conditions and hydrologic regimes and modeling potential future climate scenarios.
- Several regional programs (e.g., Chesapeake Bay, San Francisco Bay) leverage remote sensing products within adaptive management frameworks to guide strategic decisions around wetland restoration, sediment augmentation needs, and allocating conservation resources.
- While many one-off mapping projects exist, coordinating the widespread implementation of remote sensing into state/tribal wetland program operations remains a barrier due to technical capacity gaps. Continued training and development of decision-support tools is needed.

- Combining remote sensing analysis with complementary ground-based data is crucial for reducing uncertainties, validating models, and making restoration outcomes more directly applicable to on-the-ground management needs.

Workshop 3: Compensatory Mitigation

Introduction

Each year, thousands of acres of wetlands and linear feet of streams are restored, enhanced, established, or preserved to compensate for permitted impacts under section 404 of the Clean Water Act. Compensatory mitigation is required to offset unavoidable adverse impacts to aquatic resources that remain after all practicable and appropriate impacts that are permitted under the Clean Water Act (CWA) section 404, section 10 of the Rivers and Harbors Act of 1899 (RHA), and some state wetland permitting programs have been avoided and minimized. In March 2024, there were more than 2,500 approved compensatory mitigation sites and approximately 600 pending sites (RIBITS Banks and Sites Data).

Emerging technologies such as drones, LiDAR, and satellite imagery (Dronova et al. (2021)) present key opportunities to enhance compensatory mitigation project development and review. For example, using unmanned aerial vehicles (UAVs) in various wetland applications may improve the cost-effectiveness, accuracy, and application of data in mitigation monitoring and management. New technologies may also improve precision in mapping and monitoring wetland topography, hydrology, and vegetation and increase workload efficiency by reducing the number of site visits needed by mitigation banks and in-lieu fee (ILF) programs.

However, integrating these advanced remote sensing technologies into compensatory mitigation programs may require significant investments in technology, the development of workforce expertise, and guidelines for effective implementation and utilization. Additionally, policies and regulations must evolve alongside these technological advancements to ensure that mitigation practices are effective and compliant with environmental standards. Enhancing collaboration among regulatory bodies, mitigation providers, and environmental managers will be essential to scaling successful practices across different regions and sectors.

Workshop Description

The Environmental Law Institute hosted a virtual workshop on how remote sensing and other new technologies can be applied to compensatory mitigation projects and programs. The 3-hour workshop, New Approaches for Integrating Remote Sensing Tools and Other New Technologies Into Compensatory Mitigation Programs, brought together researchers and practitioners in the remote sensing and compensatory mitigation fields to discuss opportunities for the integration of new technologies in the program.

Workshop participants discussed:

- The role of developing technologies, such as drones, cameras, LiDAR, and satellite imagery, to improve and support project review and approval, monitoring, and adaptive management in a changing ecological and permitting landscape.

- Benefits and challenges of using remote sensing to contribute to compensatory mitigation programs.
- Best practices for collecting, assembling, and incorporating remote sensing data into mitigation projects.

The recording and workshop materials are publicly available on the workshop's event page on ELI's website.

Summary of the Event

Welcome & Introductory Questions

- The workshop had 303 registrations and a peak of 180 attendees.

Session 1: Welcome & Introductory Questions with Attendees using a Zoom poll

Question	Summary of Participants' Responses
What program/organization are you involved with?	• IRT Member (42) • Other government agency (not IRT) (49) • NGOs (5) • Mitigation Bank (35) • ILF Program (7) • Academia (3) • Other (14)
How would you describe your position? (Scientist, manager, policymaker, academic)	• Scientist (61) • Academic (3) • Manager (29) • Policymaker (2) • Other (29)
What region are you from?	• Southeast (23) • Pacific Northwest (28) • East (30) • Midwest (9) • Gulf Coast (17) • International (2) • Other (16)

Session 2: Remote Sensing Questions with Attendees using a Zoom poll

Question	Summary of Participants' Responses
How familiar are you with RS techniques/methodologies?	• Focus of my everyday work (3) • Use RS data in much of my work (25) • Understand the science and it informs my work (57) • New to the field (32)
If you are familiar, what types of remote sensing	• Drones (57) • Satellites (63)

technology are you using? (e.g., drones, satellites, AI, apps, other)	• AI (4) • Apps (7) • LiDAR (22) • Machine Learning (1) • ArcGIS (2) • Other (12) • None (3)
What kinds of remote sensing data are most useful to you? (e.g., LIDAR, satellite, etc.)	• LiDAR (59) • Satellite (30) • Multispectral imagery (6) • Drones (5) • Other (11)
Where do you get your remote sensing data (Open source, collect yourself, contract out, etc.)?	• Open source (35) • Contract (23) • Agency (6) • Collect myself/ourselves (16) • Other (3)

Session 1: Introduction to Remote Sensing Technologies

Dr. Mac McKee, Former Director, Utah Water Research Laboratory, Utah State University

Dr. Mac Mckee introduced remote sensing technologies, focusing on their application in monitoring wetlands and other environmental areas. He discussed the challenges and advantages of using drones compared to satellite methods, emphasizing the importance of selecting the right tools and methodologies for specific projects. He also shared examples from his work, illustrating how remote sensing assists in environmental monitoring and adaptive management. His insights into the precision and challenges of drone use in environmental studies highlighted the evolving nature of ecological research and monitoring.

Session 2: Examples of Remote Sensing Technologies (Panel)

Andrew Mindermann, Geospatial Operations Manager, Skytec LLC

Andrew Mindermann discussed advancements in remote sensing technologies at Skytec, highlighting their impact on environmental monitoring. He explained how Skytec uses multiscale sources to acquire geospatial data using new platforms, like Planet and PCTA, that enhance the ability to monitor habitat changes, like vegetation, over time. Andrew emphasized the lowered barriers to entry in remote sensing technology, which is now more accessible and provides robust tools for ecological management. He also touched on the importance of integrating these technologies with existing geographic information systems (GIS) to maximize their utility in real-world applications.

Clay Word, Growth & Partnerships, Upstream Tech

Clay Word introduced Lens, a remote monitoring platform developed by Upstream Tech. He described how Lens helps aggregate and analyze environmental data, facilitating more efficient project management and oversight. Clay showcased Lens's tools for change detection and data analysis, which can be useful for assessing the effectiveness of mitigation and restoration projects. He highlighted how such platforms transform the field by enabling practitioners to track and manage environmental changes more effectively and responsively.

Session 3: Applying Tools to Compensatory Mitigation (Panel)

Applying Tools to Compensatory Mitigation U.S. Army Corps of Engineers

o Justin Elkins, Mitigation Subject Matter Expert

o Ryan Hendren, Mitigation Programs Team Project Manager

o David Shaeffer, Technology Program Manager

Justin Elkin, Ryan Hendren, and David Shaeffer discussed using the National Regulatory Viewer and its role in compensatory mitigation projects. They highlighted how regulatory tools support using the best available science in project reviews and assessments, focusing on practical applications within regulatory frameworks. Their presentation underscored the importance of collaboration and innovation in regulatory practices to adapt to the rapidly changing environmental and technological landscapes.

Jeannette Blank, Montana ILF Program Director, Montana Freshwater Partners

Janette Blank shared insights from her experience with the ILF Wetland and Stream Mitigation Program in Montana. She discussed how remote sensing technologies are pragmatically applied to manage and monitor remote mitigation sites efficiently despite the challenges posed by geographical and climatic variability. Janette emphasized the value of these tools in providing detailed and timely data that supports better decision-making and resource allocation in environmental conservation.

Bob Siegfried, Senior Project Manager, Resource Environmental Solutions (RES)

Bob Siegfried discussed the need for more holistic and transparent monitoring methods in mitigation projects. He emphasized the advantages of integrating modern technologies like drones and real-time data systems to improve the accuracy and effectiveness of environmental monitoring and adaptive management. His reflection addressed the need for evolving traditional methodologies to include comprehensive data analysis, enhancing the ability to swiftly identify and respond to environmental changes.

Tee Clarkson, Executive Director, Broadwater Innovations

Tee Clarkson discussed Broadwater Innovations' role in managing the long-term stewardship of mitigation banks. He highlighted integrating remote sensing tools with traditional monitoring techniques to enhance the long-term management and sustainability of conservation efforts. Tee elaborated on the challenges and opportunities presented by funding and technological advancements, advocating for a forward-thinking approach to the stewardship of environmental resources.

Key Takeaways

- The workshop emphasized the significant role of emerging technologies like drones, LiDAR, and satellite imagery in enhancing the development and review of compensatory mitigation projects. These tools offer improved accuracy and efficiency in monitoring environmental changes, aiding project approval and ongoing management.
- Advances in remote sensing technologies have lowered barriers to entry, making these tools more accessible and cost-effective. This democratization of technology allows for more widespread application in environmental monitoring and management, enabling real-time data collection and analysis.
- The workshop highlighted the opportunities for regulatory frameworks to incorporate emerging remote sensing technologies. Tools like the National Regulatory Viewer by the U.S. Army Corps of Engineers provide insight into how regulatory bodies integrate new data sources to inform and streamline decision-making processes.
- Panelists shared practical applications of remote sensing in various management site examples, discussing the benefits and the challenges of integrating technologies, including funding constraints and technological limitations. These examples underscored the need for tailored solutions that address technical and logistical issues specific to different sites.
- The workshop showcased examples of how collaboration among tech companies, regulators, and program managers can lead to more effective wetland mitigation and restoration projects.
- The discussions pointed towards future innovations in remote sensing and environmental monitoring, focusing on sustainability and long-term management by mitigation banks. This will be essential for ensuring that conservation efforts remain effective in the face of changing ecological and climate conditions.

Moving Forward

Based on the extensive discussions and insights from the three workshops on remote sensing and wetland management, significant opportunities and challenges lie ahead in fully integrating these technologies into wetland conservation and management practices. There is a compelling opportunity to further embed remote sensing technologies, such as drones, LiDAR, and satellite imagery, into the regular operations of wetland management. This integration should focus on creating standardized protocols that enhance the accuracy, reliability, and cost-effectiveness of these technologies for monitoring wetland conditions, assessing vulnerability, and tracking restoration outcomes.

To overcome the barriers to adopting these technologies and scaling up the technical expertise of advanced remote sensing tools, dedicated training programs, and capacity-building initiatives should be developed. These programs could support state, tribal, and local wetland managers, equipping them with the necessary skills to implement existing and emerging technologies and interpret remote sensing data effectively.

Collaboration between academia, government agencies, non-profits, and community volunteers has also proven invaluable. Expanding these partnerships will allow for a more extensive sharing of knowledge, resources, and best practices, particularly in participatory science initiatives where community involvement is critical. To support this collaborative framework, practitioners can encourage the use of open-source remote sensing tools and sharing data among different entities and stakeholders.

This openness fosters innovation and allows for more comprehensive and collective approaches to managing wetland ecosystems. Remote sensing technologies can offer dynamic insights into wetland ecosystems, significantly enhancing adaptive management strategies. Developing frameworks incorporating real-time data acquisition will allow managers to respond more effectively to changes and disturbances in wetland ecosystems. This dynamic relationship with management strategies will be particularly crucial as climate change results in fast-paced and dramatic changes to wetland ecosystems.

While a variety of stakeholders are critical to adopting remote sensing technologies, adjusting and drafting policies and regulations that govern their use will be a critical step to improving the current management framework. It will be important to develop flexible, forward-thinking policies that can adapt to new technologies and the data they provide while ensuring that wetland management practices can continue to be effective and uphold environmental standards. The policy can also help establish the consistent funding streams that will be essential to support the ongoing application and development of remote sensing technologies. Increased governmental and private funding will be crucial to sustain these innovative approaches to wetland management.

Finally, government agencies, researchers, communities, mitigation banks, and in-lieu fee programs should prioritize the development of long-term monitoring strategies in the face of climate change. Remote sensing can be leveraged to track the effectiveness of wetland mitigation and restoration over extended periods and provide insight into variability due to increasing periods of drought and unpredictable rain patterns. This long-term focus will aid in understanding the impacts of climate change and human activities on wetland resilience and help formulate strategies to mitigate these effects. However, funding is a critical barrier to effective long-term stewardship, and efforts should be made to improve the sustainability of these programs.

These strategic directions aim to harness the full potential of remote sensing technologies in enhancing the resilience, mitigation, and research of wetlands across various regions. By addressing these recommendations, stakeholders can ensure that wetlands continue to provide their essential ecological, economic, and social benefits amidst the challenges posed by climate change and other threats to vulnerable ecosystems.