BIOAg Project Report Template

Report Type: **FINAL**

Title: **Technical transfer of cloud-based environmental monitoring (CBEM)**

Principal Investigator: Alexander Fremier

Cooperator(s):
Levi Keesecker (State Conservation Commission), Brad Johnson (Palouse and Garfield CD), Renee Hadley (Walla Walla CD).

Abstract: Sustainable agriculture in Washington State drives to be economically viable while being environmentally responsible through improvements made to both on- and off-farm practices. Effective and efficient monitoring programs are an essential piece of policy implementation and adaptive management for sustainability. In our previous BioAg research, we hypothesized that remotely sensed data are underutilized in these programs due to the lack of specific technical methods for monitoring riparian and natural vegetation in the agricultural setting and the need for a pipeline to integrate these methods into existing monitoring programs. We partnered with the Palouse Conservation District and Washington State Conservation Commission to develop robust methodologies for monitoring riparian structure as a proxy for ecosystem function that utilizes publicly available satellite imagery combined with the capabilities of cloud-based computing (Google Earth Engine) (Stahl, Fremier, Heinse In review BioScience; see Figure 3 attachment for example). We demonstrated the potential of cloud-based environmental monitoring (CBEM) techniques to improve feedback and evaluation of large-scale programs, such as VSP and CREP. Our next step is to complete the technical transfer of the new methodology to diverse Conservation Districts including Palouse, Walla Walla, and Pend Oreille for integration into monitoring programs (this extension proposal). We will meet iteratively with these groups to adapt workflows to their monitoring needs and to prepare online resources for practitioners across the state. Additionally, we will pilot a prototype GEE App to simplify the CBEM workflows for environmental monitoring in agricultural lands. Our goal is to make remote sensing technologies accessible and easily applicable at a low-cost to agricultural communities for more efficient and effective reporting of conservation practices.

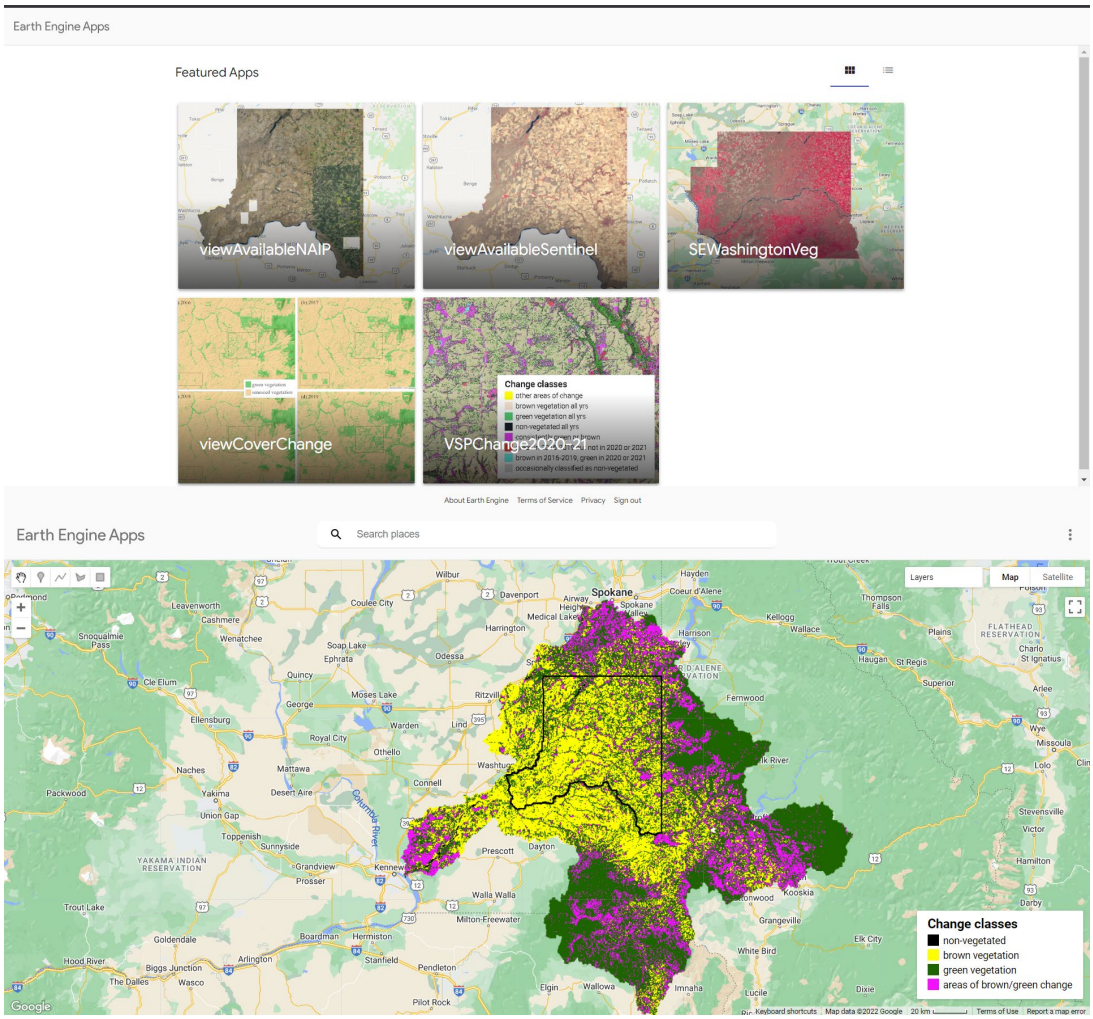
Project Description:
WSU will coordinate with each Conservation District point of contact to provide technical transfer of Cloud-Based Environmental Monitoring (CBEM). Each cooperator will help develop the policy/management question, review WSU analysis, and provide feedback on CBEM use and application in monitoring. WSU will coordinate with the SCC point of contact to inform coordinated implementation of CBEM across VSP counties.

Outputs
- Overview of Work Completed and in Progress:
    - Peer-reviewed publication (cited in full below) is now in the journal *BioScience*. https://doi.org/10.1093/biosci/biab100

- Delivered presentations both to the practitioner community and the broader research & development community to raise awareness of our efforts. The slides and/or video from many of these presentations are now publicly available online (see list below under Outreach).
- Publicly available User Library for cloud-based environmental monitoring is online. https://labs.wsu.edu/ecology/research-projects/cbem-user-library/
- Continuing to collaborate with Palouse and Walla Walla Conservation Districts to supporting monitoring needs. We are using these two districts as case studies to provide more general tools for all districts, working with Cooperator Levi Keesecker (SCC).
- Trained incoming GIS-capable staff at Walla Walla Conservation District on Earth Engine methods; collecting input to guide development of web-based products.
- Have met with staff from multiple Conservation Districts across the state to discuss their current and future monitoring capabilities with UAV and Earth Engine image analysis.
- Supplementing this work, have delivered workshops on drone-based riparian monitoring capabilities for practitioners (listed under Outreach below).

Status of deliverables:

1. Digital resources for implementing remote sensing technologies for monitoring by Conservation Districts across WA State
   Delivered — links are provided below under Products
2. Prototype GEE Application – natural areas monitoring in agricultural lands
   Delivered — App is online: "viewCoverChange" https://atstahl.users.earthengine.app/view/viewlateseasoncoverchange, along with complementary Apps in Gallery https://atstahl.users.earthengine.app/



3. Report to BioAg on completed work and strategies for seeking extramural funding including directly from VSP counties, the SCC, NSF-NRT Proposal.
   Delivered -- See section below on Additional funding. We have not sought funding for App development, pending decision at the state level regarding whether to adopt the Google-based platform or another.

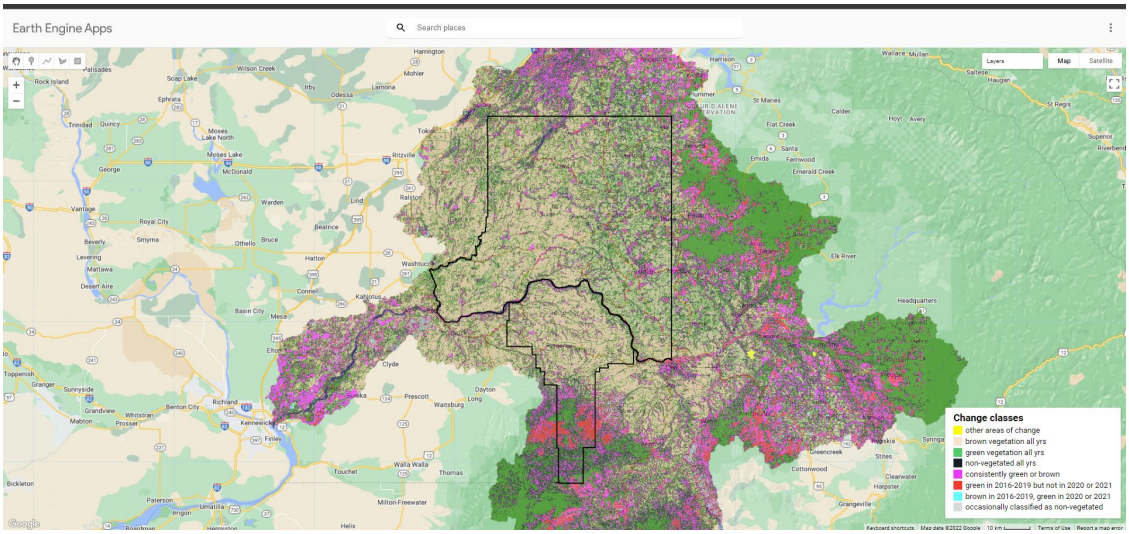
- **Methods, Results, and Discussion:**
  We investigated the potential to streamline the process of accessing and analyzing satellite remote sensing data for monitoring through the Google Earth Engine platform. We have developed scripts for querying available data sets, clipping to areas of interest, coarsely classifying vegetation within potential riparian areas as “evergreen” or early-senescing (agricultural land use), and computing differences in vegetation indices to document seasonal patterns of senescence within each class. With these scripts, the user can easily repeat processes on new imagery as it becomes available and potentially compare images across years by season to detect change. This workflow is designed to make natural inter-annual variability in vegetation vigor (e.g. due to moisture availability) transparent so that we can reduce uncertainty in detecting change due to restoration or agricultural practices.
  - In the initial study (Stahl et al., 2021), we repeated a subsample of the spatial analysis in ArcGIS to confirm the accuracy of area-based statistics in GEE. The results were nearly

identical (with errors < 0.02 NDVI, much less than the standard deviation in NDVI values by vegetation class).

- All satellite image classification in this study is scripted in Google Earth Engine (GEE). The first step is a coarse cover classification to distinguish natural from agricultural or dryland vegetation. The next step applies a set of nested conditional statements to categorize pixels by patterns of change in cover class over the years of interest. The resulting "stability classification" can be used to (1) assess whether detected change is natural vs. anthropogenic and (2) provide more accurate context for evaluating changes in NDVI or other metrics through time.
- We worked with PCD staff to determine the capability of this GEE-based approach to accurately detect change in a way that can be reasonably integrated into VSP, CREP, RCPP monitoring and reporting processes.

We have utilized this method to generate data that filled gaps in VSP reporting by 3 counties: Whitman, Garfield, and Walla Walla. Combined with existing data sources such as WSDA crop type maps, we have been able to produce watershed-scale measurements of change. *The VSP Technical Panel gave these methods positive reviews, and reportedly noted that these counties produced some of the strongest reports in the state in terms of area-based change detection with appropriate reporting of error and uncertainty.*

To follow up on the initial analysis and help prepare the Conservation Districts for the next reporting cycle (Cooperator: Brad Johnson), we compared patterns of change from satellite imagery in 2016-2019 to 2020-2021 (the VSPChange2020-21 App: https://atstahl.users.earthengine.app/view/vspchange2020-21). As we accumulate more years of imagery that we can classify, we improve the ability to track interannual variability and detect trends through time. This includes distinguishing directional trends from fluctuations in moisture availability causing greenness, brownness, or loss of vegetative cover. There are many applications for this type of workflow, including potential future ability to provide similar Apps to share data related to regional trends related to agricultural practices.



- **Publications, Handouts, Other Text & Web Products:**
  - Published article: Stahl, A.T., Fremier, A.K., Heinse, L., 2021. Cloud-Based Environmental Monitoring to Streamline Remote Sensing Analysis for Biologists. *BioScience* 71, 1249–1260. https://doi.org/10.1093/biosci/biab100
  - User Library: https://labs.wsu.edu/ecology/projects/satellite-data/cbem-user-library/
  - GitHub repository: https://github.com/ATStahl/CBEM
  - Earth Engine Apps: https://atstahl.users.earthengine.app/

- **Outreach & Education Activities:**
  - News/Blog coverage:
    - https://www.agclimate.net/2021/04/12/how-can-new-remote-sensing-technologies-help-evaluate-the-effectiveness-of-resource-conservation-measures/
    - https://dailyevergreen.com/101885/research-research-2/wsu-researchers-produce-technology-to-monitor-ecology/
    - https://news.wsu.edu/press-release/2021/02/15/eyes-sky-help-make-streamside-ecosystems-sustainable/
  - Invited talks/workshops
    - Stahl, A.T. 2022. Riparian Conservation: Why and Where It Matters to People and Nature. *Conservation Talk Series* hosted by Palouse Conservation District, WA. https://www.youtube.com/watch?v=UPfq5yusuGo&list=PL50CYDWKi42azth2slN-Qc2HVDku_KP50&index=12 WADE
    - Stahl, A.T. 2022. Broadening and streamlining access to remote sensing data for natural scientists and natural resource professionals. *DSOS22: Virtual Summit in Data Science and Open Science for Aquatic Research*. https://aquaticdatasciopensci.github.io/program_2/
    - Stahl, A.T. 2022. Update on effective and efficient riparian monitoring with drone and satellite data. *Eastern Washington Riparian Planting Symposium.* https://ybfwrb.org/outreach/populus/2022-eastern-washington-riparian-planting-symposium/
    - Stahl, A.T. 2022. Timely cover classification to track vegetation change in Google Earth Engine. *Michigan State University*.
    - Stahl, A.T. 2022. Mapping land cover change at watershed scales in Google Earth Engine. *Voluntary Stewardship Program Monitoring Symposium*.
    - Expert panelist for virtual workshop on use of drones for riparian monitoring, *Populus*, 2022
    - Led field workshop on drone use for conservation practitioners from across eastern Washington, 2022
    - Stahl, A.T. 2021. Developing practical remote sensing workflows for ecosystem monitoring. *Washington Association of District Employees Annual Meeting.* https://sites.google.com/site/wadistrictemployees/wade-conference/presentations#h.o4pe7o9mrb5z
    - Stahl, A.T. 2021. Potential options for effective and efficient riparian monitoring with drone and satellite data. *Eastern Washington Riparian Planting Symposium.* https://ybfwrb.org/outreach/populus/annual-symposium/ , https://www.youtube.com/watch?v=V4QEUwq3LjA

- Conference presentations
  - Stahl, A.T. 2022. Filling gaps in ecosystem monitoring with GIS and Google Earth Engine. *Society for Conservation GIS Annual Conference*.
  - Stahl, A.T. 2021. Adding Earth Engine to the conservation toolbox. *Google's Geo for good Summit 2021*. https://earthoutreachonair.withgoogle.com/events/geoforgood21 , link to poster: https://docs.google.com/presentation/d/1RmpdL6Yu8Gd6h7XJcvMbbkyXJrDG6VUQGdpdikBInog/edit#slide=id.g1036138f303_4_263
  - Stahl, A.T. 2021. Adding satellite data to the toolbox of conservation professionals with Earth Engine. *Geo for Good Lightning Talks Series #5: Nature Conservation.* https://earthoutreachonair.withgoogle.com/events/lightningtalk5

Impacts

- **Short-Term**: Knowledge gained from this research has been shared through presentations, workshops, and technical documentation. The prototype App provides a basis for a tool for agriculture-related agencies across Washington State to directly and effectively access remotely sensed data.
- **Intermediate-Term**: This project will continue to develop a hub for remote sensing at WSU. The outputs of this study will provide an improved methodology for aerial and satellite data for monitoring of riparian vegetation or other areas with natural vegetation structure in agricultural areas. With subsequent work to address variability among counties, this methodology can be applied to enhance existing monitoring approaches for the VSP and CREP, evaluating the effectiveness of conservation actions over time at multiple scales with minimal cost. Additionally, this set of current and future projects will make these technical capabilities accessible to practitioners worldwide, particularly those in economically disadvantaged areas. The ability to demonstrate the effectiveness of voluntary stewardship will likely assist counties in meeting VSP requirements and thus avoiding direct regulatory oversight.
- **Long-Term**: This and subsequent projects will establish a program at WSU that effectively integrates these technologies, serving as a resource for state and federal agencies as well as farming communities and producer-oriented groups to track technical advances and seek assistance in remote sensing applications. Information gathered from effectiveness monitoring over broader spatial extents and through time may inform CREP buffer requirements and identify reliable indicators that can serve as measurable benchmarks for reporting and evaluation of VSP and other conservation programs. Demonstrating the effectiveness of actions to conserve natural vegetation structure in agricultural areas may help to refine practices or validate incentive programs that make conservation economically feasible for the agricultural community.

Additional funding applied for/secured:

- NRT: Rivers, Watersheds, Communities: Training an Innovative, Cross-Sector Workforce for Equitable, Multi-Scale Decision-Making Towards Human and Ecosystem Health. US National Science Foundation Research Traineeship (NRT) ($ 3,000,000, Fremier Co-PI). 2021-2026
- Integrating drones into weed management on the Palouse. BioAg 2023. Fremier, Burke, Auerbach. ($40,000). *In review*.
- Applied for subsequent funding via Smith Fellowship in 2021 (declined)

- Partnered with and received additional funding support from Palouse Conservation District (Cooperator: Brad Johnson) to provide data for VSP reporting in Whitman County
- Knowledge and skills acquired during this project have contributed to a subsequent project funded by the BIOAg Program (mapping tillage practices in eastern Washington) and subsequent USDA-DSFAS proposal contributed to by Amanda Stahl (researcher supported by this grant).
- Mentored a Conservation District staff person who is now able to adapt CBEM as needed (Walla Walla CD, Cooperator: Renee Hadley)
- Have ongoing conversations with SCC staff (Cooperator: Levi Keesecker) regarding statewide adoption of CBEM technology for VSP and other programs (Science HUB in Spokane)
- Plan to write additional proposals for USDA and/or NSF in 2023 to take next steps;

Graduate students funded: N/A

Recommendations for future research:

We envision two main avenues for future research stemming from this work:

(1) Using cloud-based environmental monitoring and image analysis to model relative naturalness in agricultural areas. (This was the topic of the Smith Proposal submitted in 2021, attached.)
(2) Further exploring and transferring capability to utilize drone-based data collection to inform, monitor, and ideally expand the adoption of conservation practices in agricultural areas. (This was the topic of the BIOAg 2023 proposal recently submitted.)
(3) We have begun scoping each of these ideas and will continue to seek funding support from USDA-CIG, SCC, and Conservation Districts to pursue them. Once we have proof of concept, we will apply for larger grants from USDA-NIFA or NSF-DISES programs.