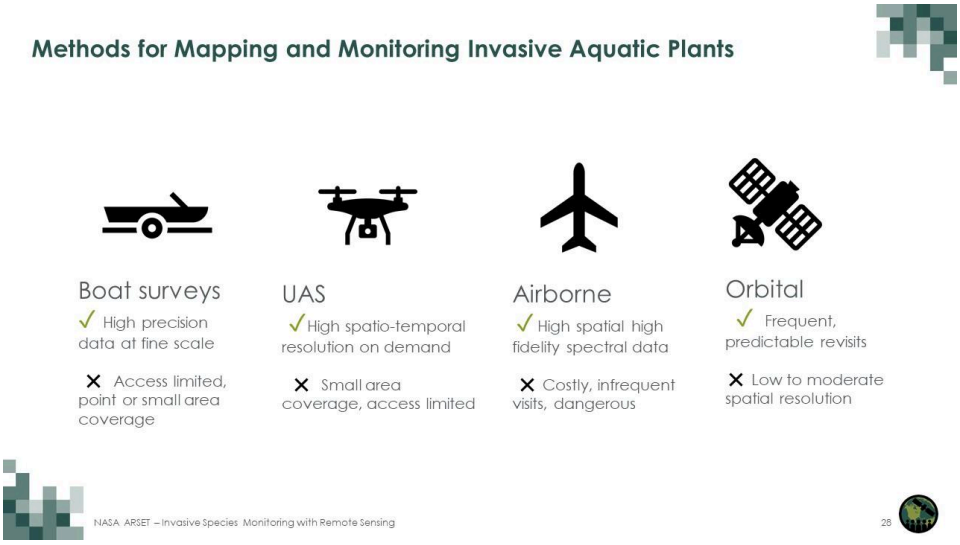
Part 2 Questions & Answers Session

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Sativa Cruz (sativa.cruz@nasa.gov) or Justin Fain (justin.j.fain@nasa.gov).

Question 1: Is there a way to search by species to see which tools might have data associated with that species (rather than searching in each of the platforms for that species)?
Answer 1: The definition of invasive species is highly dependent on the specific ecosystem and context, making it challenging to create a universal remote sensing database for all species. Remote sensing of plant species varies significantly based on the ecosystem and the distinctiveness of the target species compared to other plants in the area. The ability to differentiate a particular species relies on its unique spectral characteristics relative to other plants, and whether the variability between different species is greater than the variability within the target species itself. Additionally, differences in phenology are often utilized to aid in distinguishing these species. For more information, check out this insightful article: Sensing Invasive Species.

Question 2: How does the water hyacinth cause water loss via evapotranspiration?
Answer 2: As part of the plant's biological process, water is taken into the plant and released into the air. This causes more water loss than if the open water channel were simply exposed to air without the influence of the plants. More information about evapotranspiration here:
https://www.nasa.gov/missions/landsat/evapotranspiration-watching-over-water-use/

Question 3: What methodologies or indices would you recommend for effectively assessing the impact of these aquatic invasions? Specifically, how can we accurately measure and monitor the extent of this environmental disaster, given the limitations of traditional in-situ approaches?
Answer 3: This is a perfect example of where remote sensing can provide advantages over in-situ monitoring. I believe that these benefits and limitations were discussed in the presentation (slide 28).



Question 4: How can environmental factors such as temperature and precipitation influence the predictive accuracy of remote sensing tools? Also when integrating machine learning algorithms with remote sensing tools such as Sentinel-2, what are the limitations for monitoring invasive species?
Answer 4: Temperature and precipitation are commonly recorded with remote sensing and can be accounted for in predictive models. The water column can significantly affect the remote sensing of submerged aquatic vegetation (SAV) due to several factors that alter the spectral signals detected by sensors. Here are the key effects: light attenuation, wavelength specific absorption and scattering effects due to variations in water quality, water surface reflectance (glint), water depth, and non-linear spectral mixing. This is a recent open-access review article that covers this topic nicely.

Machine learning is useful in monitoring invasive species (see slide 31 and 32) for more information on classification with a random forest method. Limitations will always be specific to your environment, your species of interest, your data, and the model you choose to use.

Question 5: Will we get the reference spectra for invasive species worldwide? Or on a regional basis? Is there any library that is open access?
Answer 5: One of the most comprehensive spectral libraries of vegetation out there is the open access EcoSIS database. We encourage everyone to contribute to the

database to get more aquatic plants represented in the database. The USGS also has an open access spectral library, but with fewer vegetation species.

Question 6: If you set the classes' numbers to the amount of species known, how does the classifier do?
Answer 6: When using any supervised classification algorithm and setting the number of classes to the amount of known species, the classifier's performance can vary depending on several factors, including the spectral separability of the species, the quality and resolution of the spectral data, and the algorithm's parameters. If the spectral signatures are similar, the classifier may struggle to differentiate between species, leading to misclassification.

By setting the number of classes to the exact number of known species, you are assuming that each species has a unique spectral signature. If this assumption holds true, most classification algorithms can effectively classify the species. However, in cases where species have overlapping or very similar spectral signatures, the classifier might not be able to distinguish them accurately. If the reference spectra are well-represented and capture the variability within each species, the classifier's performance will improve. On the other hand, poor or unrepresentative reference spectra can lead to incorrect classification.

The spatial and spectral resolution of the data also plays a role. High-resolution data that captures fine spectral differences can enhance SAM's ability to distinguish species. Conversely, low-resolution data might obscure these differences, leading to decreased accuracy.

Question 7: In the case study, high-resolution data was utilized to achieve certain results. If we were to use Sentinel and Landsat data for the same study, what level of accuracy could we expect? How would the resolution and data quality of Sentinel and Landsat compare in terms of achieving similar outcomes?
Answer 7: In the case study shown, Sentinel-2 was successfully used with slightly reduced accuracy and fewer, more coarser classes. However, because of the 10 m pixel sizes, we missed several small patches of invasive plants. We determined that Landsat with 30 m pixels was not capable of resolving patches in our system, and resulted in both low accuracy and very poor maps.

Question 8: Is there any concern of a different species not initially determined that may skew results of detecting endmembers or any other spectroscopy decisions?
Answer 8: This is certainly a concern, and because plant invasions in degraded landscapes are highly dynamic and you may continue to have variations in community composition and turnover in space and time, in the Delta we have found it is critical to continue to conduct field surveys to support validation of the work. Remote sensing is a complement to field surveys, and allows us to fill gaps that boat surveys cannot fill, but remote sensing is not a complete replacement for field observations in dynamic environments.

Question 9: It seems the presentations and the webinar deal with water invasive species, what about the inland invasive species? Are there any studies? Would appreciate it if you could share some details on the same.
Answer 9: Please see parts one and three of this training. The first part gives a general overview of invasive species monitoring with remote sensing. Part 3 (upcoming) will deal specifically with grassland invasives.

Question 10: With which GIS, images and scales have you carried out these investigations?
Answer 10: These studies were conducted using imaging spectroscopy images (HyMap, AISA, AVIRIS, and Nano-HyperSpec) and multispectral satellite imagery (Sentinel-2). The scale of the Delta is approximately 75,000 ha. The software used varies from study to study, but key software used include ENVI + IDL, Python and R.

Question 11: Is it possible to calibrate remote sensing-based water quality monitoring data using in-situ water quality data with the help of a relative index from empirical mathematical equations? If so, how can the relative index be validated for each water quality parameter?
Answer 11: Yes it is! ARSET provides a number of useful training courses for water quality. See here for a full list. In particular, check out:

1. https://appliedsciences.nasa.gov/get-involved/training/english/arset-integrating-remote-sensing-water-quality-monitoring-program
2. https://appliedsciences.nasa.gov/get-involved/training/english/arset-monitoring-water-quality-inland-lakes-using-remote-sensing

3. https://appliedsciences.nasa.gov/get-involved/training/english/arset-monitoring-coastal-and-estuarine-water-quality-transitioning

Question 12: Do you guys have a table for what platform is most suitable for specific species mapping/monitoring and for which scale?
Answer 12: Unfortunately I am not aware of any database that fits this description. You have to imagine that it would need to consider an incredible number of species, hundreds of platforms and sensors with their own technical specifications, and geographic/environmental differences which may make one sensor more appropriate. Furthermore, that wouldn't be able to consider customizable sensor/platform combinations such as the UAVs used in the water hyacinth study discussed today.

Question 13: When you are calculating costs, are you including any time for ground truthing efforts? How much of your tests using the different imaging require on the ground surveys for QA/QC purposes?
Answer 13: The costs shown in the case study are just for image acquisition, and do not include surveys for validation. In our studies and working with managers in this system, field surveys are a critical component to quantifying the uncertainty of the maps, and helps us re-calibrate machine learning models under highly variable conditions (see Answer # 8 as well).

Question 14: What are the transferable aspects/concepts/approaches from this case study that would apply in other contexts? That is, what can we generalize for use elsewhere?
Answer 14: The tradeoffs between platforms and resolution considerations are something that every case study will need to evaluate for their own context. We have articulated the tradeoffs, and now you can evaluate these tradeoffs for your own study purposes. The general frameworks of analyses, and the multiple tools we have presented are all widely available in open source software such as Python and R, and may be useful for your studies. Additionally, we hope the management studies conducted with the maps give users an idea of the types of analyses they could conduct once they have their own maps developed.

Question 15: How can I validate the real-time monitoring data generated from a mobile camera integrated with a remote sensing-based ML model to ensure it accurately reflects invasive species presence?

Answer 15: There are models that use computer vision to ID species. A smartphone with a computer vision libraries, it can assist to ID species.

Question 16: Is TIMESAT freely available?
Answer 16: Yes. https://web.nateko.lu.se/timesat/timesat.asp.

Question 17: Do the vegetation indices change in different environments? Does it need to be calibrated for each region? For example, the information from the Bay Delta showing the primrose and hyacinth, will that same imaging taken in North Carolina show the same plant species from the satellite images? Or will it be different?
Answer 17: There is an ARSET webinar entirely dedicated to spectral indices which might be useful: ARSET - Spectral Indices for Land and Aquatic Applications | NASA Applied Sciences

Question 18: Could I access airborne magnetic, gravity, and spectrometry data for GIS mapping and interpretation purposes?
Answer 18: Not certain on magnetic, but a NASA mission (GRACE) has data on gravity.

Question 19: Would this method be able to detect duckweed separately?
Answer 19: Using imaging spectroscopy, we have been able to detect duckweed in the California Delta case study. The ability to detect duckweed will depend on the size of the patch of duckweed, the density, and the ecosystem context. See answer number 2 and 6 for more details.

Question 20: Is there a rule of thumb for the maximum reasonable area of coverage for UAS high priority sites, above which it is better to use manned flights?
Answer 20: When deciding between Unmanned Aerial Systems (UAS) and manned flights for covering high-priority sites, the choice depends on several factors, including the area to be covered, the mission's objectives, the terrain, and the specific capabilities of the UAS. There isn’t a strict "rule of thumb" universally applied, but there are general guidelines that can help inform the decision:

- Over small areas drones are ideal for high-resolution data collection and detailed surveys. UAS are flexible and effective for these areas. UAS could be preferred for high-resolution, low-altitude data.
- Manned aircraft are more efficient for covering large areas quickly, with greater flight endurance and range. Manned flights are suitable for broad-area surveys where slightly lower resolution is acceptable.

You also need to consider flight endurance and range. Drones are limited by battery life and range, generally covering smaller areas in a single flight. Manned aircraft are capable of covering larger areas in one mission due to longer flight times and higher altitudes.

Question 21: Have there been any biocontrols explored to tackle the issue of invasive aquatic plants?
Answer 21: Yes. In the Delta they tried to introduce weevils to help control water hyacinth, with mixed success. Here is an interesting blog post that tells the story of the experiment.

Question 22: Why EVI for phenology?
Answer 22: There are many indexes that can be used for phenology studies. In this case study, we evaluated several indexes and performed a sensitivity analysis to determine how variable our results would be to our selection of indexes. It is recommended that you select an index most appropriate to your study and conditions. Please see answer 17 for a link to a dedicated training on indexes.

Question 23: Is there any association or club I can join to stay connected with people having similar interests related to such sessions?
Answer 23: There are many user groups. Look geographically first. Online communities. Feel free to collect the introductions of participants in this training and start a Community.

Question 24: Shouldn't the uncertainty of machine learning-based classification be higher? The range in the presentation still seemed to hover around 90.
Answer 24: The uncertainty in machine learning-based classification for remote sensing can indeed be a concern, especially when high precision is required. However, a classification accuracy in the range of around 90% is often considered acceptable

when applied to such a large study area with such a large number of validation points. One of the things to note when you read ML studies is that they are often conducted over limited datasets, and often do not include very large independent validation datasets. It is common to see high accuracy in ML models because they have been overfitted, and when you apply those models to large areas, the maps won't actually make a lot of coherent sense.

Remote sensing involves analyzing complex and often heterogeneous environments, where achieving perfect accuracy is difficult. Natural variability, mixed pixels, and spectral similarity between classes can all contribute to classification challenges. The goal is to achieve a reliable, interpretable outcome that meets the specific needs of the application, even if some uncertainty remains. Our large independent validation datasets have ensured we are not overfitting, and are getting maps that align with field surveys and manager expectations.

Question 25: Are the HyMap, AISA, etc. free for download?
Answer 25: AVIRIS is open access and free for download. HyMap and AISA are commercial sensors and have to be contracted to be flown over a given region.

Question 26: How can I identify invasive species in a kelp forest and seagrass meadow? Which sensor is recommended to use for optimal results?
Answer 26: This is dependent on your region.

There is an ARSET training that can give you more details.
https://appliedsciences.nasa.gov/get-involved/training/english/arset-monitoring-aquatic-vegetation-remote-sensing

Question 27: Sediment-laden waters are usually quite apparent in imagery. How does this affect the ability to monitor aquatic species?
Answer 27: Absolutely. See answer #4.

Question 28: Can we use the same models in the case of Wadis? Especially if there is chemical pollution?
Answer 28: Sure. See question 14, as there will be local context for your sites. One big consideration will be spatial resolution. You will need to identify a platform and sensor that can resolve the Wadis of interest.

Question 29: With which images have the investigations obtained 0.05 m of spatial resolution?
Answer 29: Images acquired with low altitude UAS.

Question 30: Are there any practical exercises that can be shared for reproduction using, for example, Jupyter Notebooks?
Answer 30: We are considering a follow up training on invasive species where we can introduce coding with exercises on this subject. Be sure to fill out the survey at the end of this training for us to use to help determine the scope of an advanced course.