Part 1 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 geodatabase we can query for invasives lists globally?
Answer 1: The mentioned report from the IPBES 2023 is a good starting point. It can be accessed here: Thematic Assessment Report on Invasive Alien Species and their Control | IPBES secretariat. Also, another source is the IUCN Global Invasive Species Database: GISD (iucngisd.org). Citizen science approaches are available as well. Another participant also mentioned GBIF (Global Biodiversity Information Facility) as a resource.

Question 2: I want to monitor a lake which is covered with an invasive species "Ceratophyllum demersum." I have a lot of problems accessing the affected lake, can you help me please?
Answer 2: If the issue is physical access then remote sensing is a good approach. Using something like NDVI can differentiate the invasive species from the background water signature. Depending on the size of the lake, many sensors may be available with sufficient spatial resolution. In part 2 we will cover approaches to monitoring aquatic environments. Part 3 will cover grassland species. This is an old (2003) but useful paper on the spectral responses of Ceratophyllum demersum obtained with an ASD hand-held spectroradiometer which is a commonly used tool for satellite data validation: The spectral responses of Ceratophyllum demersum at varying depths in an experimental tank: International Journal of Remote Sensing: Vol 24, No 4 (tandfonline.com).

Question 3: Where can I find the values or spectral signatures of each of the species? Is there a library? I ask this because sometimes the plants are mixed and it is difficult to differentiate which is which during classification.
Answer 3: Spectral signatures of living organisms can change slightly based on their environmental conditions. The gold standard for determining spectral signatures is to use an in-situ signature collection approach with a handheld device. This is also important for classification as it helps tie RS observations to their "ground truth"

spectral signatures. Using a double approach, but a combination RS and in-situ phenology is a consideration to keep in mind to help differentiate species.

Question 4: Can you comment on examining relatively short sized herb/shrub invasive species such as artemisia, ones that could be sometimes covered by nearby tree canopy?
Answer 4: GEDI uses LiDAR to record vertical composition and can peer through (between) the leaves of taller species. However, it is unlikely that LiDAR alone will be enough to determine that a plant is an invasive species unless they have a structure that is distinct from all other background species. LiDAR can be part of the solution, but would likely need to be combined with some spectral data. LiDAR does *not* enable classification based on spectral signatures, however. Phenology may help!

Question 5: Why is SeaWifs no longer operational?
Answer 5: All satellite missions have a life cycle until eventually they become no longer operational. The SeaWiFS mission lasted from August 1997 to December 2010. Data and additional information can be accessed via the NASA Ocean Color website, particularly NASA Ocean Color.

Question 6: With hyperspectral bands, what is the method for determining which spectral band combinations/ratios will be the most useful for specific plants?
Answer 6: Assuming that the spectral signatures of the plants are known, the goal is to maximize the difference between the target species and background. There are many algorithms that aim to optimize hyperspectral band selection and reduce redundancy so that the clearest signal can be obtained with minimal inputs. Some examples of these algorithms are partition optimal band selection and machine learning based optimization methods.

Question 7: How can I differentiate invasive species from other vegetation? Can you please explain the method and methodology, and required spatial and temporal resolution?
Answer 7: There is no “one size fits all” method for determining which plants are invasive versus the background vegetation. It is important to consider phenological differences such as an early leaf-out and time data collection to maximize the differences between your target species and background vegetation. We will cover examples of these approaches in Parts 2 and 3 of this series.

Question 8: How can machine learning and AI be applied to improve the detection and mapping of invasive species in remote sensing data?
Answer 8: There are many papers and ongoing research projects on this topic. In short, machine learning performs well at classification and is well-suited for sifting through large datasets to find the small differences in spectral and temporal signatures that can differentiate between an invasive species and non-invasives. Though not strictly ML in the sense we usually think of, techniques like multitarget multiple-instance spectral match filters and other approaches derived from signal processing and statistical disciplines have long found use in remote sensing.

Question 9: Could you recommend a hyperspectral dataset with a resolution of less than 5 meters?
Answer 9: I am not currently aware of any freely available data that meets those specifications. Some commercial data may meet those criteria, but cost will become a consideration.

Question 10: How can I monitor invasive species such as hyacinth in a lake and the reason it is growing so much and fast? Can we use a remote sensing based approach for this objective?
Answer 10: Please stay tuned to Session 2 of this webinar series which is entirely dedicated to invasive aquatic plant species.

Question 11: How can I map invasive species which are actually understory species using spaceborne data?
Answer 11: Please refer to our response for question 4.

Question 12: Is it possible to identify individual tree species using multispectral imagery, or is hyperspectral best?
Answer 12: This is context and species specific and highly dependent on surrounding vegetation and land use and cover. For example, multispectral imagery can assist in differentiating between conifers and deciduous trees but less so to differentiate between two very similar species. Due to limitations for spatial resolution, it may be more appropriate to approach forest stand scale investigations with the remote sensing data and refine produced maps with field data. Hyperspectral data provides more information that may reveal differences between species, but it may still be possible to use multispectral in some cases.

Question 13: Which satellite data would be best used for smaller islands? For invasive species, land mass is a lot smaller, therefore trying to minimize the effects of invasives would be very important.
Answer 13: Consider using satellite products with a sufficiently high spatial resolution. 30 meter (Landsat, NASA) and 10 meter (Sentinel, ESA) data is widely available for free and even finer spatial resolutions can be purchased or collected with airborne sensors though these approaches may be cost prohibitive.

Question 14: Does NASA use PRISMA data and/or EnMAP data for this application?
Answer 14: These aren't NASA datasets but that does not necessarily mean NASA researchers aren't using them. At this time we are unaware of invasive species applications at NASA.

Question 15: Is there a guide of how to do one's own ground survey (however localized) and link to a remote sensing option?
Answer 15: In general, the approach is as simple as measuring your quantity of interest (reflectance, vegetation health, etc.) for a representative sample of in-situ observations as well as recording the geographic and temporal information related to those observations. This gives you two data sets that you can use to draw correlations between what is observed on the ground and what is observed by the sensor for the same time and place.

Question 16: Can you provide a citation for your work with the hemlock wooly adelgid?
Answer 16: Here is the link to the DEVELOP page.

Question 17: How useful is the optic sensor based-analysis for invasives that are covered by tree canopy?
Answer 17: See the information provided about GEDI for an overview of LiDAR-based analysis of vertical structure. With purely optical instruments it is important to time collections to maximize your view through obstructions. If possible, consider collections in the spring and fall when understory plants are unobstructed. Also note that approaches such as Maximum Entropy SDM can help to predict the presence of invasives based on their preferred growing characteristics when direct observation is not possible.

Question 18: Could you suggest protocols / methodology for ground truthing remote sensing based detection? My project involves working with local communities and indigenous communities using digital mobile phones.
Answer 18: This would fall under the category of “citizen science” and approaches can vary based on the training of the citizen scientists, the tools available (mobile phones can often capture GPS coordinates with photos, for example), and the expected outcome. There is a great deal of research available on using citizen science to lessen

the burden of collecting ground observation data. The protocols and methodology you decide on will be influenced by those factors as well as the environment you’re studying and the communities you are engaging with.

Question 19: What spectral bands are most useful for identifying and distinguishing Prosopis from other vegetation?
Answer 19: Though not an expert on Prosopis, a cursory search shows that this species may be most easily identified using its impact on the surrounding environment. Effects of aridification and loss of grasslands may help to identify areas affected by Prosopis invasion. Without more information about the background vegetation I am unfortunately not able to give a more direct answer. Session 3 of this webinar is dedicated to grassland invasive species. We encourage the participant to attend that session for additional information.

Question 20: Can we predict invasive animal disease vectors by the same mechanisms discussed here for invasive plant species?
Answer 20: Invasive plants are more easy to identify with remote sensing because of their propensity to move slowly across a landscape. Invasive and infectious diseases in plants have been studied using remote sensing techniques. The major hurdle when applying this methodology to animal pathogens is that the interactions which spread disease are not easily detected with remote sensing. Range and habitat maps can be coupled with reports of disease outbreaks to treat and isolate populations or to predict at-risk populations with a distribution that overlaps a known infected population.

Question 21: I primarily work on phenology and species classification, focusing on plants and trees. However, I'm facing challenges with spectral mixing, leading to misclassification, especially over larger areas. Compounding this issue are my limitations: reliance on open-source imagery, minimal in-situ measurements, and

frequent cloud cover in my region. Do you have any recommendations on addressing these challenges?
Answer 21: Many cloud detection and gap filling methods are available to assist with obtaining cloud-free imagery, though this will limit the temporal resolution of your available data. Spectral mixing can be addressed with spectral unmixing which is a method for decomposing composite spectral signatures into their constituent parts.

Question 22: How can I differentiate invasive species from other vegetation? Can you please explain the method and methodology, required spatial temporal resolution. Since all the plants or vegetation is reflected by NIR and absorbed by red in multi or hyperspectral. Are there any indices or algorithms particular to invasive species?
Answer 22: Invasive species don't have an obvious signature across the board. It is important to understand your target invasive species as well as the background vegetation to make use of phenological differences, spectral differences, and effects on the environment to optimize your ability to differentiate between invasives and non-invasives.

Question 23: Is the Earthdata viewer failing? Because before downloading data from Modis Aqua it allowed viewing them, now it doesn't.
Answer 23: We are unaware of any issues with the Earthdata viewer. You may want to consider contacting support@earthdata.nasa.gov.

Question 24: What database do you suggest to look for phenotyping of trees through the year? I need to type tree species within a large area. Different trees would have different colors or structures at different times through the year...
Answer 24: We suggest referring to the Understanding Phenology with Remote Sensing (ARSET - Understanding Phenology with Remote Sensing | NASA Applied Sciences) webinar for additional information.

Question 25: Can you explain the in situ spectral signature collection procedure you mentioned? Is there some kind of handheld device for this? How does this work?

Answer 25: There are handheld spectrometers and colorimeters which measure the spectral signatures of objects on the ground. You can take a series of readings for a particular plant in order to establish the spectral signature that is associated with that species. Doing this for multiple species may allow you to pick out small differences that you can then use to differentiate between species. Note that the spectral signatures of plants can change over the phenological cycle so don't assume that a spectrometer reading taken in one part of the year will match perfectly with imagery obtained in a different season.

Question 26: Given the current excitement surrounding hyperspectral data for biodiversity monitoring, could you please elaborate on its specific value, particularly in light of the cost implications when compared to the remote sensing datasets we currently have, especially those that are open-source? What kind of costs are associated with high resolution hyperspectral imagery, particularly UAS services vs others possible?

Answer 26: With invasive species in particular it is important to catch them early and begin remediation efforts before there is significant damage to the ecosystem. This means that we want to have the highest spatial resolution available to make it easier to identify the geographically limited beginning phase of invasive species spread when the plants are small and easier to remove. Hyperspectral data is useful for similar reasons. Having more bands gives us more opportunities to identify the small markers that can identify a plant as an invasive species versus the background vegetation. In the earliest phases of invasive species establishment they are likely to be interspersed with non-invasives, so any increase in spatial or spectral resolution gives a small advantage that we can leverage to create more accurate assessments of invasive species and respond quickly.

Question 27: What are the key characteristics of invasive species that make them detectable through remote sensing?

Answer 27: This is highly dependent on the invasive species in question, the environment, and the other plants which are not of interest. Invasives are by definition not native to the environment where they are considered invasive so in general you would expect invasive species to have characteristics and effects which are unlike non-invasives. As an example, invasive honeysuckle in North America is often

identifiable by its early leaf-out and late leaf-off compared to non-invasive deciduous trees and shrubs in the area. This is one of the ways that honeysuckle manages to outcompete other understory plants and avoid competition for resources, but we can use it to our advantage in remote sensing detection.

Question 28: Are there any open sources that provide resolution below 1m to allow individual plant classification?
Answer 28: We are unaware of any open sources below 1m. The USGS/NASA Landsat archive provides 30m resolution and the European Space Agency Sentinel satellites provide 10m resolution data. Most data available lower than 10m is likely a commercial dataset and would incur some cost.

Question 29: Is it possible to establish a trend in the occurrence of invasive species in a landscape using remote sensing data over 2 or 3 decades? What satellite products can I use to establish this trend? Is past data directly comparable to present data given the improvements in resolution and sensor tech?
Answer 29: Yes. Long archives can be tricky to work with because the bands between sensors are not always directly comparable, though there is often overlap and follow-on missions often consider backwards compatibility in their sensor design specification. Harmonized products can provide longer archives by combining observations from multiple sensors to produce a dataset which stretches back further than the lifecycle of any of the individual sensors.

Question 30: What are the best practices for processing and analyzing remote sensing data for invasive species monitoring?
Answer 30: On this Introductory webinar we only cover basic information on remote sensing of invasive species with two case studies added (grasslands and aquatic plant species). ARSET is planning a more intermediate or advanced training course where we will go more in-depth on processing and analyzing remote sensing datasets for invasive species. Stay tuned!