Questions & Answers Part 2

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 Amber McCullum (amberjean.mccullum@nasa.gov) or Juan Torres-Pérez (juan.l.torresperez@nasa.gov).

Question 1: Is it possible to estimate the ecosystem services provided by microorganisms with remote sensing?
Answer 1: Remote sensing can be used to monitor some microorganisms, for example cyanobacteria that causes Harmful Algal Blooms or HABs can be detected because they give off a unique spectral signature on top of the water. However, monitoring things like microorganisms in soil that may be beneficial to things like water quality mitigation is unlikely to be studied by remote sensing. I am not aware of specific studies that have used remote sensing for evaluating ecosystem services of microorganisms. Lately, some studies combine eDNA (environmental DNA) with remotely-sensed environmental parameters (water quality, availability of water, nutrients, etc.). This allows researchers to study how species including microorganisms are affected by these factors and how they move through the landscape. Here are a couple of recent examples:
https://www.sciencedirect.com/science/article/pii/S0301479721024774
https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15045

Question 2: Generally, the land use and land cover classification process is study orientated. It makes it difficult to compare studies. Is there a classification standard for ecosystem services? How do we treat different ecosystem services needs related to land use and land cover in an integrated study (considering various ecosystem services)?
Answer 2: That is a good point, and last session we highlighted the benefits of creating your own land cover classification for a particular ecosystem, because you are more likely to have ground-based data and knowledge of the region you are studying. However, we did mention some global and regional land cover classifications that are available, such as MODIS land cover or the products provided by ESA.

At the same time, from an interoperability perspective this is a major, and important challenge - to be able to reuse existing land use/land cover data and studies in future

ones. The UN FAO, who works on the Land Cover Classification System (LCCS) and Land Cover Metalanguage (LCML), is at the forefront of these efforts.

Question 3: What are the parameters used in developing the costing nature index?
Answer 3: Based on the costing nature website: "The tool estimates the current provision of 18 ecosystem services including Timber (softwood, hardwood), Fuelwood (softwood, hardwood), Grazing/fodder, non-wood forest products, water provisioning (quantity, quality), fish catch, carbon, natural hazard mitigation (flood, drought, landslide, coastal inundation), culture-based tourism, nature-based tourism services, environmental and aesthetic quality services, wildlife services (pollination, pest control), wildlife dis-services (crop raiding, pests) and identifies the beneficiaries, then analyzes current human pressures on the land, future threats and levels of biodiversity. It derives conservation priority from these factors. Users can then apply scenarios for land-use or land management change, and examine the impacts on ecosystem services and the implications for beneficiaries."

Question 4: What mathematical equation is used to transform NDVI into woody biomass? It would be great to get some of those equations that convert NDVI to ecosystem services!
Answer 4: The most commonly used method is through empirical models that use predictor variables, such as ground-based estimates of Above Ground Biomass (AGB) to NDVI values. This requires local forest inventory data in a region. These types of studies have used data from Landsat for making these comparisons. Airborne optical and LiDAR data have also been used, but the data are less widely available. Here is a paper that explains an empirical approach using Landsat:
https://www.sciencedirect.com/science/article/pii/S0924271614002202

Question 5: In the question session of the first webinar, you mentioned the article by Townsend which suggests the challenge of marine ecosystem evaluations. But given processes such as seagrass assessment, NPP, etc., as well as available information on fish stocks, what might be an appropriate tool/combination of resources to provide an economic assessment for a coastal region?
Answer 5: There is much more data scarcity for the oceans and marine ecosystems than land-based ones. The same applies to valuation of marine ecosystems and most times this is either region-specific or for a particular country or zone within that country. In session 3 we will go into the Townsend example in more depth.

The Global Ocean Accounts Partnership (https://www.oceanaccounts.org/) is working on a standard approach to measuring and valuing ecosystem services in the ocean, compatible with SEEA EA.
Another good source of information is the MarineGEO portal: https://marinegeo.si.edu/

Question 6: Is LUCI only available for the UK and New Zealand? If we have required datasets for an area of interest, can we use the service?
Answer 6: Yes LUCI has mainly been used in the UK and New Zealand. According to their website: "the team is exploring applications in Australia, the Philippines, Vietnam, Samoa and other Pacific Islands. Due to limited resources we are unlikely to be able to meet requests from outside these areas in the short term."

This is the information on LUCI's availability from their website:
https://www.lucitools.org/faqs/

Question 7: In these lectures all areas have a good amount of forests which have a good number of trees so the ecosystem services can be quantified in terms of forest products. How can we quantify ecosystem services in arid or Semiarid regions where plants are few with no canopy cover?
Answer 7: While many examples are provided for forest ecosystems, valuations can still be made in semi-arid and arid ecosystems using similar methods.
Arid/semiarid systems still supply important services like carbon storage (often in lower amounts than in wetter systems), dust regulation, habitat for important species, and a wide range of cultural ecosystem services.

Question 8: Can you point me in the right direction to find the current work relating to the ethics around valuing the priceless?
Answer 8: Here are two papers that highlights the need to include Indigenous peoples and their value systems in ecosystem valuation:
https://www.nature.com/articles/s41599-022-01149-w,
https://link.springer.com/article/10.1007/s13280-022-01746-8
BCK: You can also access the Summary for Policymakers of the recent IPBES Values Assessment: https://ipbes.net/the-values-assessment Full report will be released by the fall.

Question 9: For water-related Ecosystem Services, which metrics that are easily taken in the field do you recommend? For example, for the valuation of the importance of different types of vegetation in the water supply.

Answer 9:
This question is more tailored to modelers, but we need more field-based water quality data that can be combined with streamgage data to calibrate water-quality models. This is a frequent limitation that I run into when using water-quality models, which could be solved with more field data.

ARSET Aquatic Vegetation training URL:
https://appliedsciences.nasa.gov/join-mission/training/english/arset-monitoring-aquatic-vegetation-remote-sensing

Question 10: What are some of the tools we can use to assess ecosystem services using QGIS or Google Earth Engine rather than downloading new programs or tools that require ArcGIS?
Answer 10: Both of the tools you're hearing about today - ARIES and InVEST - can be run without needing ArcGIS (using QGIS to prepare inputs in advance of an analysis and analyze model outputs afterwards).

Google Earth Engine can also be used for conducting land cover mapping, and we will go into more depth on an example from Libera that highlights the use of GEE and R. We also have a previous training on the uses of GEE for land cover classification:
https://appliedsciences.nasa.gov/join-mission/training/english/arset-using-google-earth-engine-land-monitoring-applications

Question 11: What is the best data format for rasters to use in InVEST?
Answer 11: InVEST takes .tif or geotiffs as rasters.

Question 12: How do you integrate expected changes brought by climate change into your model? Example: Planting trees that will be unfit for climatic conditions in three decades will not bring the services or values we expect of them now.
Answer 12:
KB: There are a few ways to approach this problem. First, rather than using land cover data that just indicates "forest", that model inputs distinguish between different types of forests, including planted species that may have different impacts on ecosystem services (e.g., eucalyptus and pine plantings for instance are known to have different effects on water ecosystem services, and that ought to be reflected in models). Second, climate scenarios will drive future ecosystem services - both in terms of future temperature and precipitation that directly drive services and how that reflects in land cover inputs to models (i.e., ecosystems that don't function well under climate change).

There's a lot of uncertainty here but by addressing these factors you could better account for climate change.

BCK: Agreed, this is a challenging frontier for ecosystem services modeling, and actually enters more into the scenarios generation process than the ecosystem service models themselves. There are a lot of dynamic global vegetation models or ecosystem models that can generate future ecosystem responses to climate change -- some of these are included in Integrated Assessment Models used by IPBES, for example. Linking ecosystem service models to ecosystem models will require us to move ecosystem service modeling beyond discrete categories like we find in a LULC map (distinguishing between forest and cropland, for example), toward more continuous measures of ecosystem function (such as how the productivity or biomass in a forest affects its retention capacity, hazards mitigation, resources for pollinators, etc.). This is an exciting area of research that I'm actively pursuing so if you're working on similar themes please get in touch! becky@springinnovate.org

Question 13: What is the state of the science in terms of quantifying the number of beneficiaries? Which tools can measure this metric and are there ways to disaggregate and/or take equity and vulnerability of different populations into account?
Answer 13: The team working on InVEST is starting to build these types of tools, but they can be difficult to standardize into tools because methods to delineate beneficiaires are as diverse as not only the delivery mechanisms of the ecosystem service models but also the ways in which people use and interact with ecosystems (which may vary based on demographic group). One way InVEST does this is through the DelineateIT tool, which can delineate the upstream watershed for any point designated downstream. The user can set that point based on water access points for different populations.

The team at SPRING (https://www.springinnovate.org/) is taking this one step further to map beneficiaries onto the pixels of habitat that benefit them. We currently have code to do this for downstream beneficiaries as well as coastal protection beneficiaries and people who benefit from access to nature based on travel time across landscapes (these are all still in active development, please contact Becky to learn more: becky@springinnovate.org).

KB: On the ARIES Project, we're also working to make data underlying beneficiaries (populations and their characteristics) more reusable within ecosystem service models

(as Becky pointed out, the ways that people access nature and use ecosystem services varies widely by service).

Question 14: Can these models be applied to hypothetical scenarios or projections of land use change?
Answer 14: Yes - nearly all of them can, by substituting one or more projected land use-land cover change maps for present-day values to show changes and differences between different scenarios.

Question 15: Have the Natural Capital Project thought about ways to bring in Human and Social Capital into the InVEST tool? As far as I'm aware, we can't include socio-economic maps directly into InVEST models, only cross information afterwards. Is that right?
Answer 15: This is true, many of the valuation models in InVEST have been deprecated because they oversimplified the specificity of different valuation techniques that can be applied. They can still be found in earlier versions of InVEST, if you're interested I can point you to which ones. But the best practices in the field right now are to consider the specific values and preferences of the stakeholders involved rather than plugging into a one-size-fits-all valuation method. The Natural Capital Project team at University of Minnesota is also working on integrating InVEST with the Global Trade Analysis Project (GTAP) to connect ecosystem services to metric like GDP globally - you can find out more here:
https://nicholasinstitute.duke.edu/events/global-earth-economy-modeling-linking-gtap-and-invest-address-sustainability-challenges
Report available here:
https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=6309

Question 16: Please, as a country example, is there any Policy Framework that enforces the use of this approach of Ecosystem Valuation?
Answer 16: We will provide country examples from Liberia, Indonesia, Uganda, and more in session 3.

Question 17: Which method of valuing ecosystem service is more accurate and easy to apply? Benefit transfer or InVEST?
Answer 17: Benefits transfer treats all habitats of a particular type as having equivalent value, regardless of the spatial context in which ecosystem services are produced. It therefore ignores how close habitat is to a stream or a farm or any other point of interest where the service may be needed, on how steep of a slope or in what type of

climate or type of soil, its proximity to people or to access points by people, etc. I won't say that InVEST is better than any other spatially-explicit ecosystem service modeling framework out there (many of those reviewed today may be more appropriate to your specific contexts) but I will say that any spatially-explicit ecosystem service model will be superior to benefits transfer at representing the spatial heterogeneity in ecosystem service provision across landscapes.

Question 18: Can InVEST be used to model the services of a seabird to an island whether in economic or ecological values? For example if I provided it with bird location data, data on the amount of nutrients from the bird feces, LULC, etc.
Answer 18: Hmm, this depends on which services in particular you are thinking about. It sounds like maybe the contribution of guano to soil fertility? We don't have a model for that in particular, but if you're interested in knowing how those nutrients might be transported across a landscape, and you can relate your data on bird feces to a map, you could use that as an input to the InVEST Nutrient Delivery Ratio (NDR) model instead of/combined with a LULC map. I would recommend posting this question to the NatCap User Forums to get more information
https://community.naturalcapitalproject.org/

Question 19: How is time variable considered in these tools and how much is time evolution important? For example, thinking about forest restoration, ecosystem services providing change over time, sometimes in a non-linear way.
Answer 19: First we need to have science that tells us how ecosystem services change over time and in non-linear ways (which is often missing). If we have that information - which we don't always - we can usually incorporate it into models in various ways, ranging from dynamic process models to simpler types of models (ideally with some form of uncertainty analysis incorporated, given the uncertainties involved).

Question 20: What is the latest year of available data in ARIES?
Answer 20: A number of the datasets are available for 2020, which is about as recent as data are available. As newer data become available, if they're made interoperable, they can be prepared and hosted for integration within ARIES.

Question 21: Can we derive data of ARIES for regional and local level?
Answer 21: ARIES can be used anywhere on Earth, but benefits greatly from national/local data, models, and model parameters. The more scientists contribute data and models in an interoperable way, the better the quality of ARIES results will be for parts of the world where better data and models are available.

Question 22: How can the accuracy of ARIES for SEEA Explorer in specific areas be assessed?
Answer 22: You can always compare the results of ARIES to other datasets and models, but we'd really encourage the research and practitioner communities to instead make other forms of data interoperable with ARIES, which improves the quality of results for future users. By moving away from a paradigm of "model A is best in a certain location, so model B's results are inaccurate" (when we know that all models are wrong and some are useful), a better approach would be to make models A and B interoperable, run model A where it operates best and B where it operates best. The AI technology underlying ARIES, called machine reasoning, can do this, if the scientific community understands the importance of this approach and helps to make data and models interoperable!

Question 23: How do you track changes in the dynamic ARIES models so that it does not confuse users?
Answer 23: Changes are represented in a few different ways - in tables that show changes in ecosystem service values over time, in raster data outputs that show initial, final, and (if requested) intermediate year values, and in animations that can be played and to show how dynamic inputs and outputs are changing over time. All of these are intended to be as intuitive as possible.

Question 24: To have a baseline of the erosion and sedimentation processes, a hydrological model such as SWAT (Water and Soil assessment tools) can be used?
Answer 24: SWAT is a well-respected model that has been used around the world. It represents more sophisticated hydrologic processes than most InVEST models but it also has heavier data requirements. It can definitely be used to represent the biophysical supply of hydrological ecosystem services, and then combined with other (socioeconomic) data to bring in the beneficiaries and values perspectives.

Question 25: Is ARIES a platform for developing standards for interoperability for data and models?
Answer 25: Yes, precisely. See https://seea.un.org/sites/seea.un.org/files/seea_interoperability_strategy.pdf for more details.

Question 26: What is the difference between ecosystem services and nature's contribution to people?

Answer 26: SUCH a good question. The intent of nature's contributions to people (NCP), introduced by IPBES a few years ago, was to take a broader, more holistic approach to valuing nature, incorporating more world views, including, importantly, those of Indigenous people. Within the IPBES framework, ecosystem services sit within NCP, which also includes relational values and other ways people conceptualize themselves as part of nature. Many within the ecosystem services community argued that the ecosystem services approach was already intended to do that as well, and cultural ecosystem services were the way of capturing those relational values. But the fact is many communities, especially Indigenous communities, felt disenfranchised by the term "ecosystem services" and NCP were introduced to be more inclusive to those communities. The authors who introduced the concept described the distinction here, as "Ecosystem services are a subset of NCP, but there is more to NCP than ES. Beyond apparent similarities in definitions (e.g. services = contributions in some cases), the ES and NCP framings are different, with NCP being epistemologically, ontologically and methodologically more pluralistic. ES are part of NCP, that is, the ES approach represents an important subset of ways to understand nature's diverse contributions to people." Some good papers describing NCP are here:
https://www.sciencedirect.com/science/article/pii/S2590332221003511
https://www.science.org/doi/abs/10.1126/science.aap8826
https://www.sciencedirect.com/science/article/pii/S1877343517300040

Question 27:How can we evaluate the ecosystem services provided by wild animals?

Answer 27: This is a great question. The best example I have in mind is the InVEST pollination model, which tries to capture the contribution of wild pollinators to pollination-dependent crop production. InVEST also has a fisheries model, although it doesn't include mobility of the organisms. Other frameworks (like Co$tingNature) include hunting and foraging as benefits, although I think that one in particular is an index-based model and includes other non-timber forest product (NTFP) benefits lumped in with it. There's certainly a lot of place-based hunting and fishing models out there in the literature. GLOBIO has a pest control model, although I would caution that this vastly oversimplifies the complexities that make it difficult to generalize whether nature will improve pest control by being a source of natural enemies of agricultural pests, or exacerbate pest problems by being more of a source of the pests themselves. In my experience, ecosystem service modeling dealing with mobile organisms generally

tends to look at the habitat those organisms use than modeling the organisms themselves (see e.g., https://www.sciencedirect.com/science/article/pii/S2212041617304023 and similar work for a few other species in North America). But there is also a food-web based framework called the Madingley model that captures the organism-level contributions with more sophistication (see http://dx.doi.org/10.1371/journal.pbio.1001841 for more detail).

Question 28: Can seasonal variations in ecosystem services possibly be mapped using ARIES?

Answer 28: With the right inputs, they could. For instance, ARIES contains a variant of the InVEST seasonal water yield model that can be run on any desired time-step.
BCK: Just a caution that while some ecosystem services are seasonal by nature and there are models specifically intended to capture that (e.g., the seasonal water yield model), some ecosystem service models are based on long-term averages (e.g., the sediment retention model, nutrient retention model, etc). It's important to look at the model structure and assumptions if you're trying to capture intra-annual variability. (KB: +1!)

Question 29: Have either of these tools been used to evaluate impacts of mining activities on ecosystem services (f.e. on tribal land)?

Answer 29: Yes, InVEST has quite a few applications evaluation development impacts of mines in particular. One of the earliest was this working paper: https://keeyask.com/wp-content/uploads/2013/08/Working-Paper-%E2%80%9CServicesheds%E2%80%9D-Enable-Mitigation-of-Development-Impacts-on-Ecosystem-Services.pdf
I believe that eventually made its way into this more conceptual framework, which is about assessing and mitigating development impacts in general (related but not exclusively to mines): https://www.sciencedirect.com/science/article/pii/S0195925515000566
The tool OPAL within the InVEST suite of tools was developed exactly to deal with impacts and mitigation, for mines as well as other development projects: https://www.sciencedirect.com/science/article/pii/S1364815216302110
The impacts assessment for Indigenous communities that I mentioned in my talk was for a road not mines, but similar techniques could and have been applied to mining. That paper is here: https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/140337

The Natural Capital Project work on mining development has mostly been outside the US but others have applied InVEST to mining projects within the US (not sure whether these include considerations of tribal lands):
https://www.mdpi.com/353584
https://www.tandfonline.com/doi/abs/10.1080/26395916.2022.2043445