A background image of a dense forest with mist or fog rising between the trees, creating a serene and atmospheric scene.

ARIES for SEEA-EEA for rapid accounts generation

Ken Bagstad, Ferdinando Villa,
Stefano Balbi, Alessio Bulckaen



United Nations
Statistics Division



UNEP



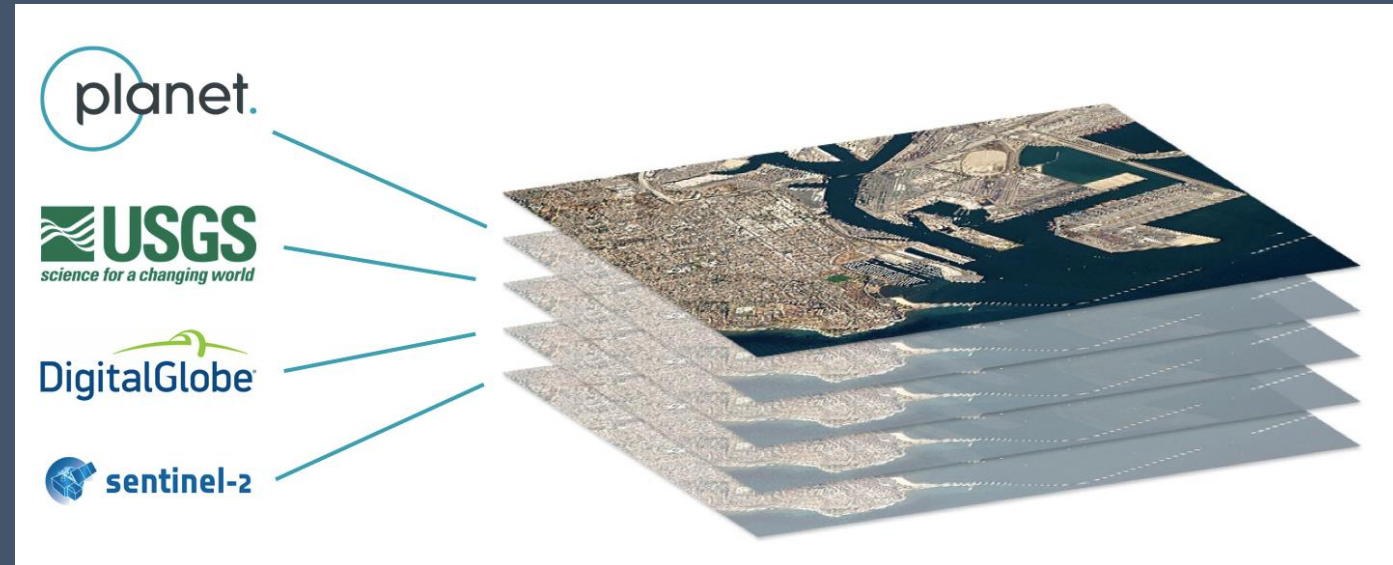
BASQUE CENTRE
FOR CLIMATE CHANGE
Klima Aldaketa Ikergai
Sustainability, that's it!



EXCELENCIA
MARÍA
DE MAEZTU

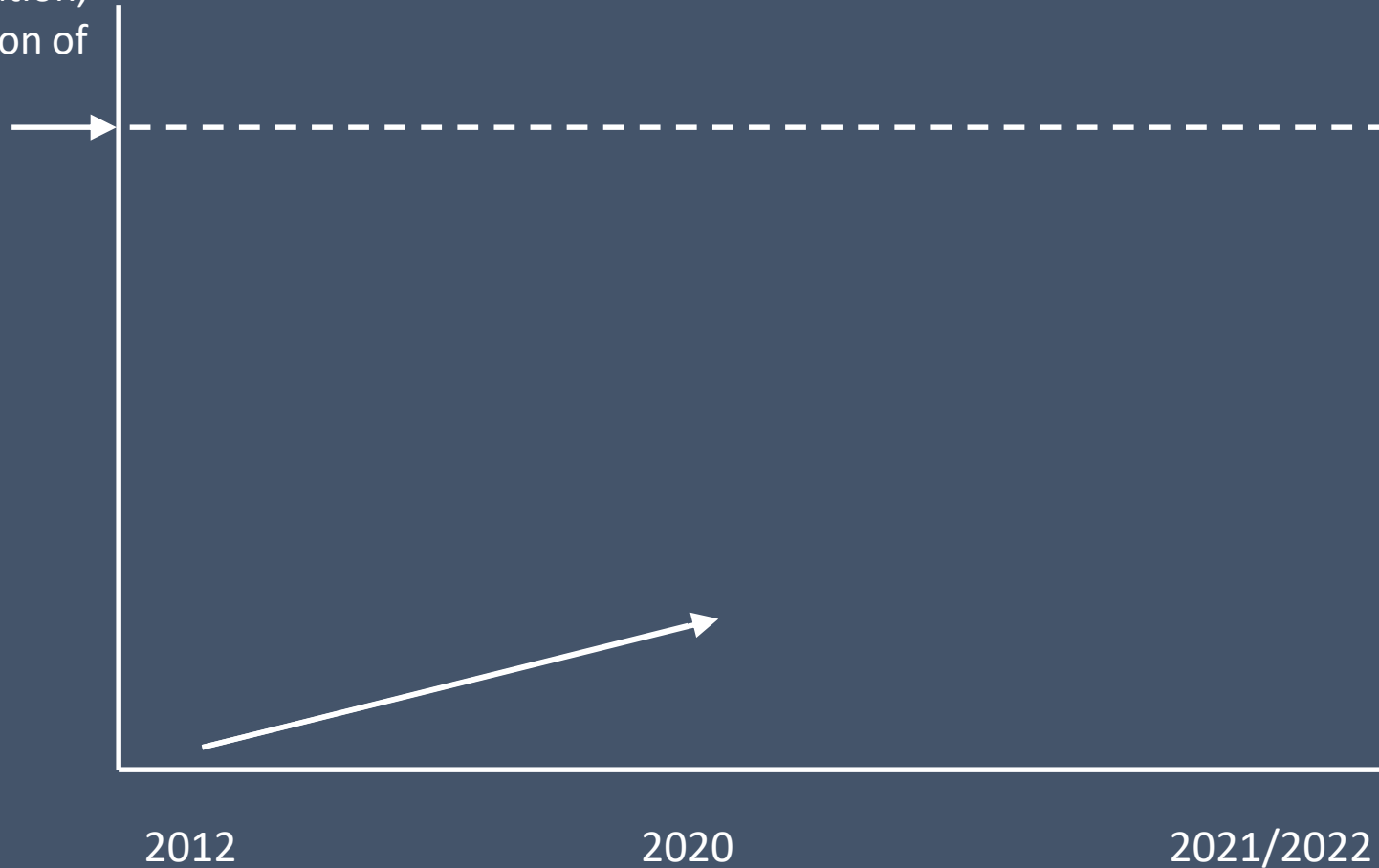
Open data & models state of the art

- “Analysis ready data”
- Model/algorithm libraries
- Not good enough: need *accounts-ready data*



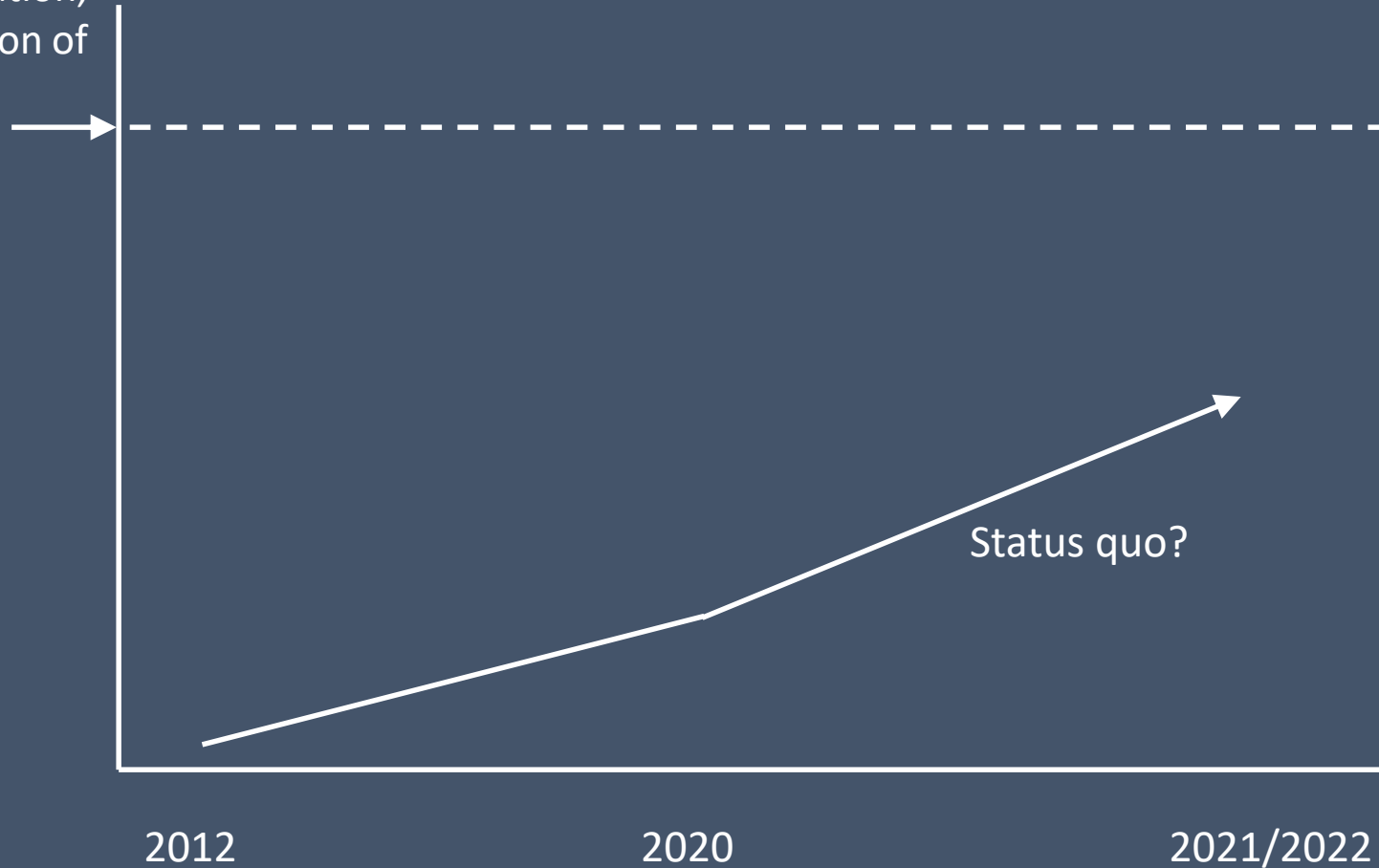
Bending the curve for global ecosystem accounting

Independent compilation,
use, institutionalization of
accounts possible
everywhere



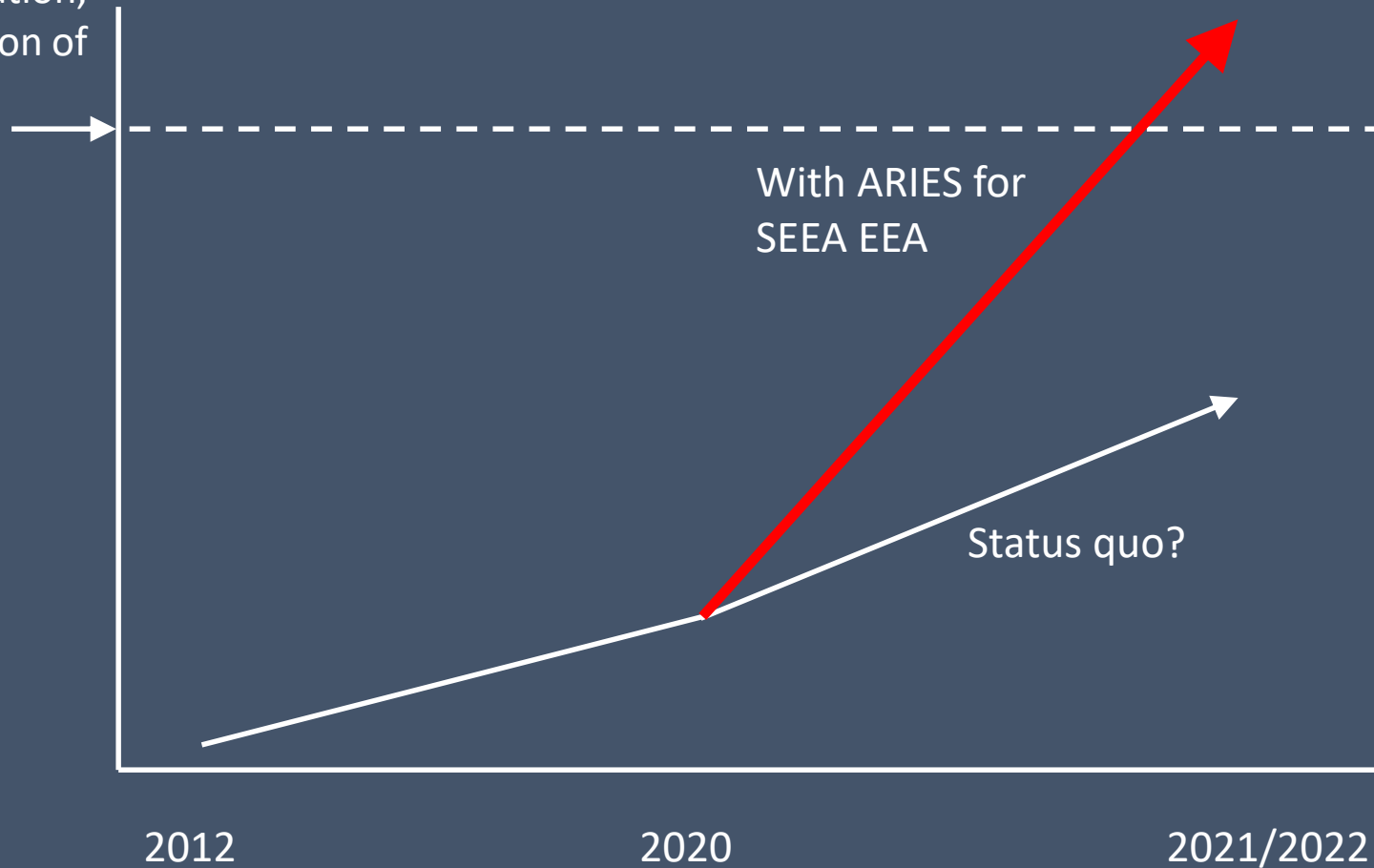
Bending the curve for global ecosystem accounting

Independent compilation,
use, institutionalization of
accounts possible
everywhere



Bending the curve for global ecosystem accounting

Independent compilation,
use, institutionalization of
accounts possible
everywhere



How do we bend the curve?

- Strategic *investment in web-based data & model reuse & interoperability* for SEEA EEA
 - An interoperable, country-supported *global NCA database* that meets modern scientific standards (FAIR)
- ES *models easy enough to use* that developing countries can *truly* master them; real South-South learning becomes possible
- *Training workshops* aim for rapid customization of global models in regional communities of practice (less 1-on-1)

ARIES for SEEA EEA

for rapid, standardized account creation

- *Global, customizable models approach* enables SEEA EEA compilation anywhere & improvement with local data where available
 - Faster & easier to learn than other biophysical modeling approaches
- Automate production of maps & accounting tables for all accounts
- Support adoption of SEEA EEA as statistical standard by providing a *consistent, easy-to-use application enabling ecosystem accounting anywhere on Earth*
- First phase April-October 2020



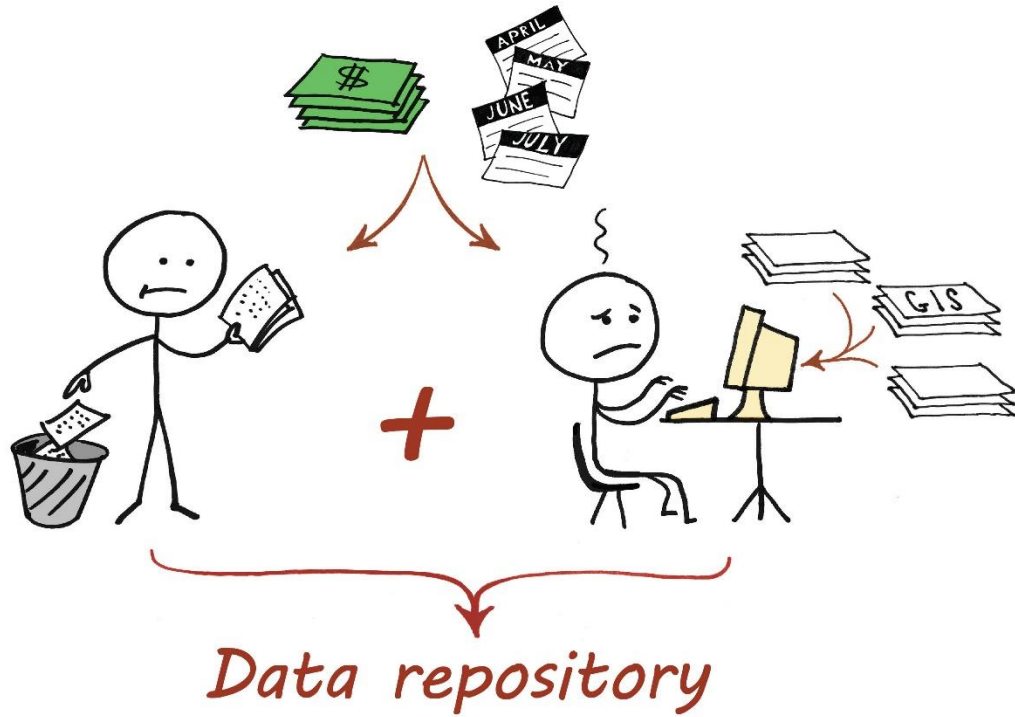
United Nations
Statistics Division



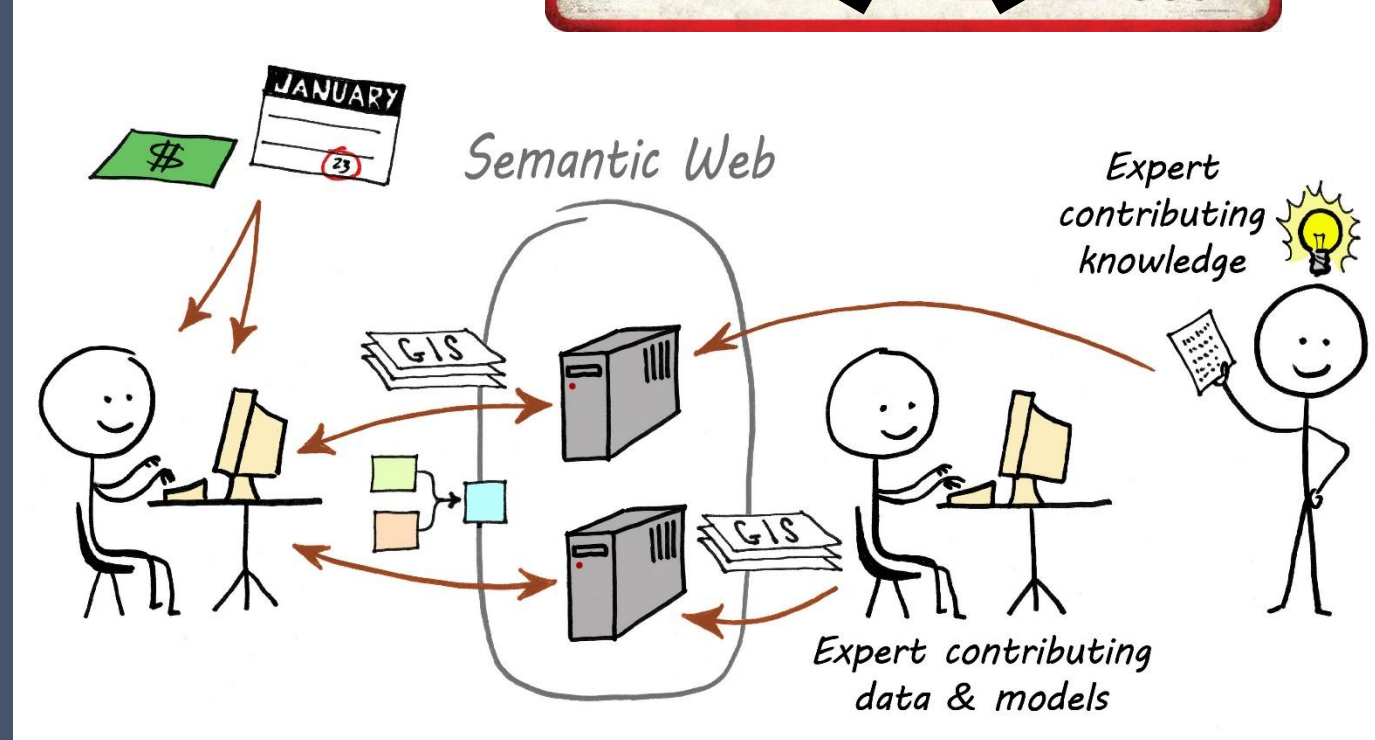
UNEP



Does ecosystem services modeling always need to be painstakingly slow?



Status quo



Linked, web-based collaborative modeling

Achieving *interoperability*

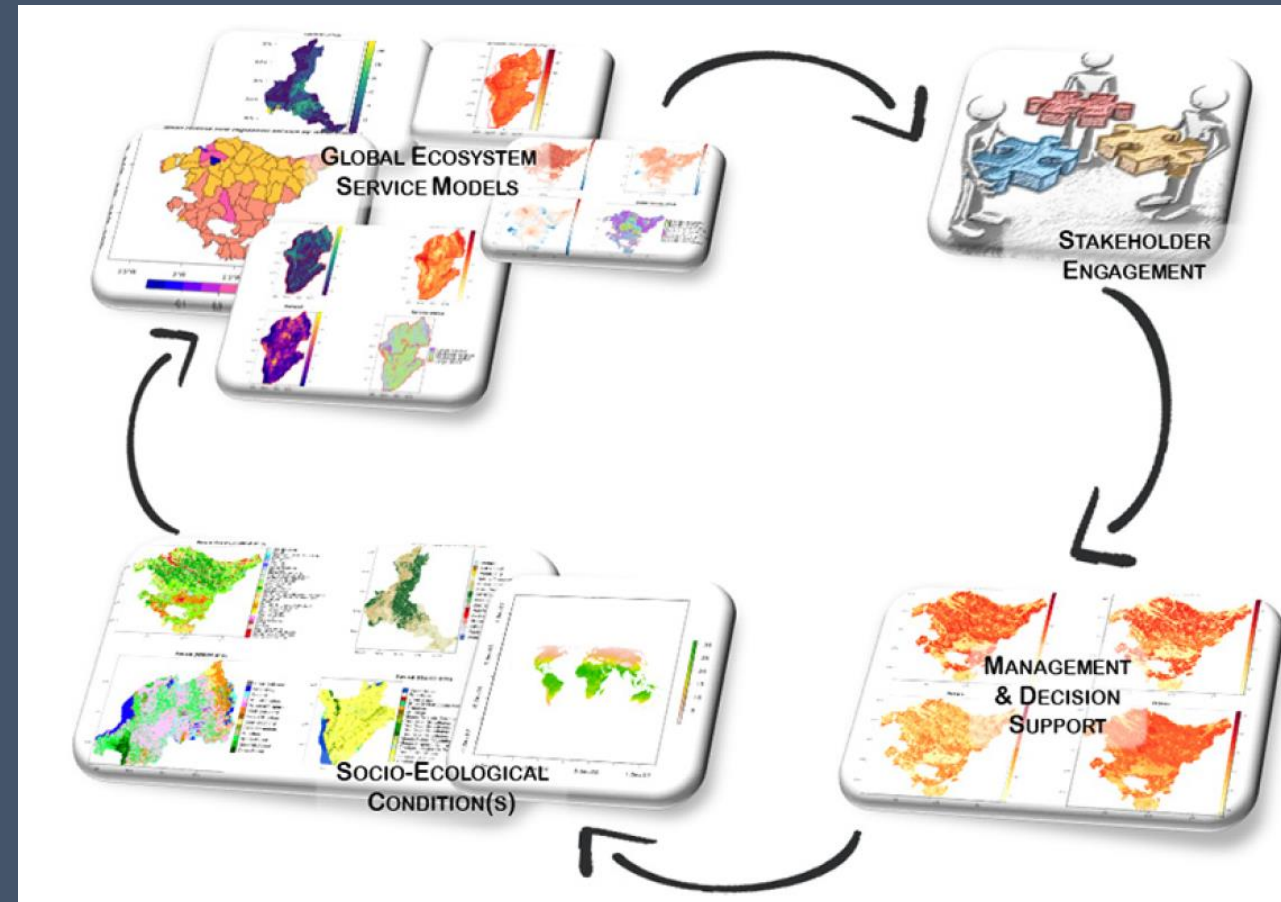
1. *Share data on the web*
 1. Consistent labeling makes it interchangeable
 2. Automate data use by models
2. *Share models on the web, specify when & where to use each model*
 - Models are *global* (run anywhere) yet *highly customizable*
3. Open-source software for stakeholders (modeling & visualization) & modelers (contribute data & models)
4. Fast & transparent (show all data sources & calculations)
 - Can *co-generate/analyze* accounts with stakeholders



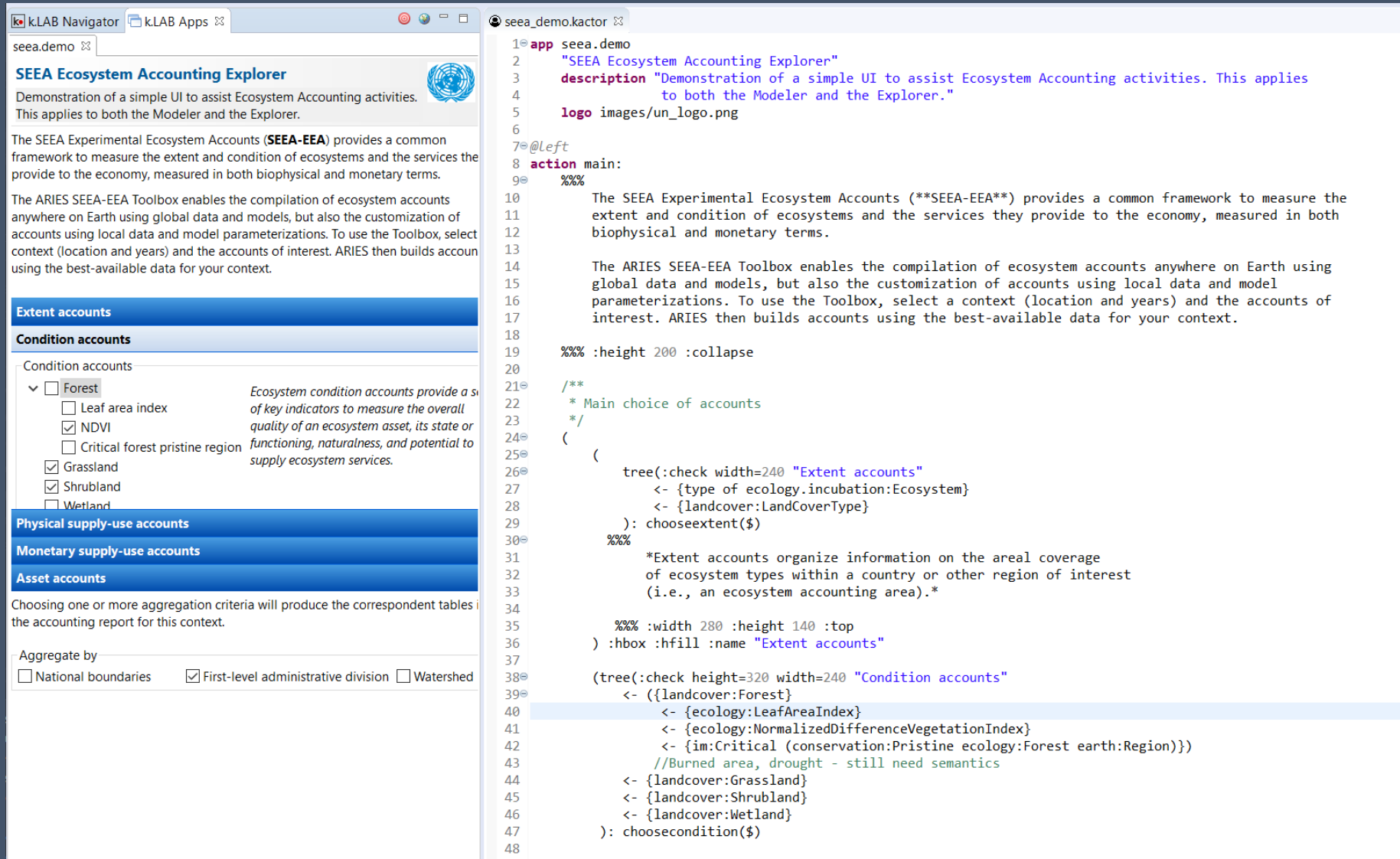
<https://www.go-fair.org/>

A global knowledge network for ecosystem service data & models

- “Global yet customizable” models
- For SEEA EEA, requires:
 - Global data
 - Time series of adequate length (many back to 2000; single-year snapshots less useful)



ARIES for SEEA EEA: Custom web interface



The image displays a custom web interface for the ARIES for SEEA EEA project, alongside the KActor code that generates it.

Web Interface (Left Panel):

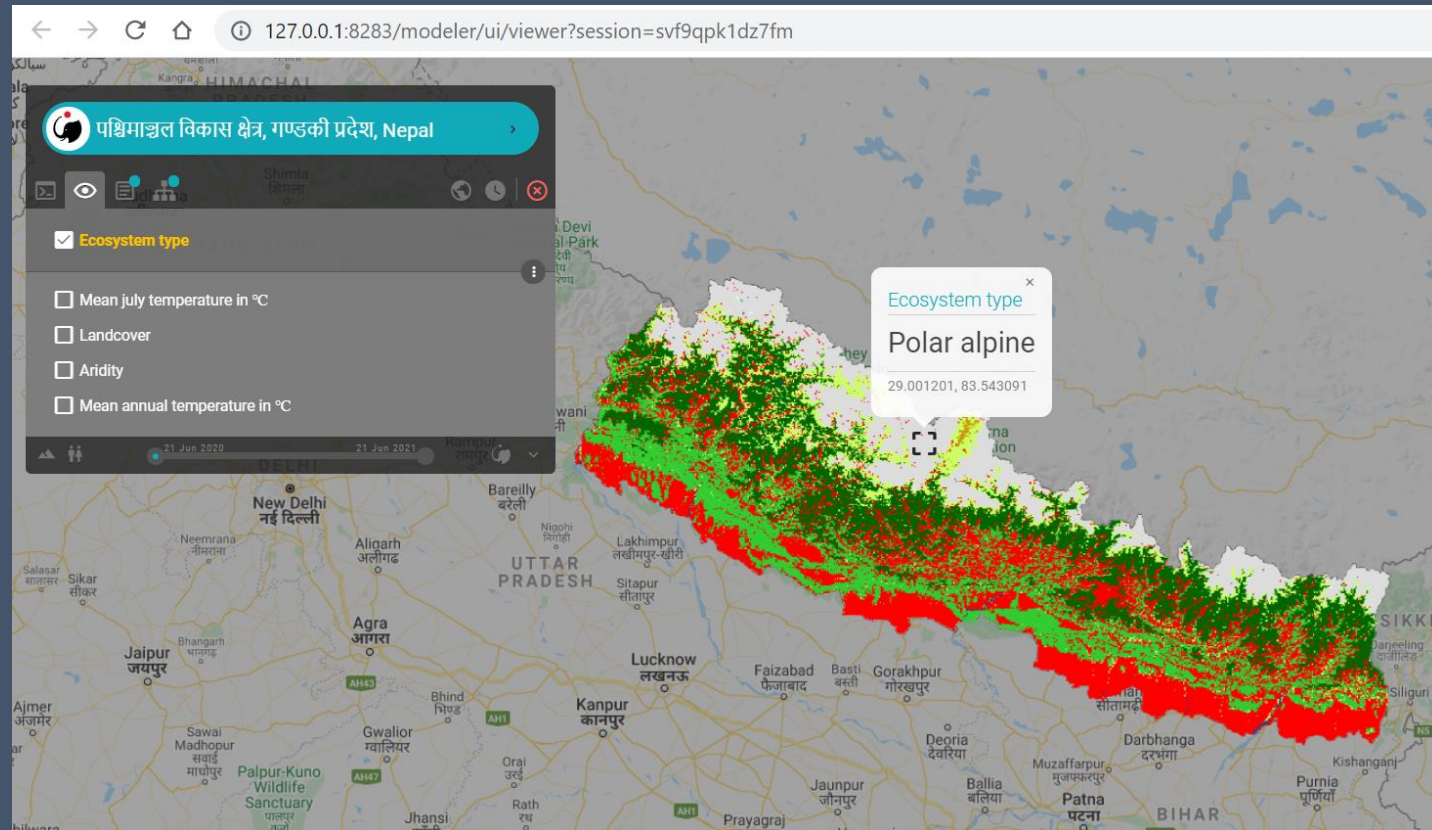
- SEEA Ecosystem Accounting Explorer**: Demonstration of a simple UI to assist Ecosystem Accounting activities. This applies to both the Modeler and the Explorer.
- The SEEA Experimental Ecosystem Accounts (SEEA-EEA)** provides a common framework to measure the extent and condition of ecosystems and the services they provide to the economy, measured in both biophysical and monetary terms.
- The ARIES SEEA-EEA Toolbox** enables the compilation of ecosystem accounts anywhere on Earth using global data and models, but also the customization of accounts using local data and model parameterizations. To use the Toolbox, select a context (location and years) and the accounts of interest. ARIES then builds accounts using the best-available data for your context.
- Extent accounts**: A section for selecting ecosystem extent accounts.
- Condition accounts**: A section for selecting ecosystem condition accounts. The interface shows a list of condition accounts with checkboxes for selection:
 - ☐ Forest: Ecosystem condition accounts provide a set of key indicators to measure the overall quality of an ecosystem asset, its state or functioning, naturalness, and potential to supply ecosystem services.
 - ☐ Leaf area index
 - ☒ NDVI
 - ☐ Critical forest pristine region
 - ☒ Grassland
 - ☒ Shrubland
 - ☐ Wetland
- Physical supply-use accounts**
- Monetary supply-use accounts**
- Asset accounts**
- Choosing one or more aggregation criteria will produce the correspondent tables and the accounting report for this context.**
- Aggregate by**:
 - ☐ National boundaries
 - ☒ First-level administrative division
 - ☐ Watershed

KActor Code (Right Panel):

```
1 app seea.demo
2 "SEEA Ecosystem Accounting Explorer"
3 description "Demonstration of a simple UI to assist Ecosystem Accounting activities. This applies
4 to both the Modeler and the Explorer."
5 logo images/un_logo.png
6
7 @Left
8 action main:
9   %%
10   The SEEA Experimental Ecosystem Accounts (**SEEA-EEA**) provides a common framework to measure the
11   extent and condition of ecosystems and the services they provide to the economy, measured in both
12   biophysical and monetary terms.
13
14   The ARIES SEEA-EEA Toolbox enables the compilation of ecosystem accounts anywhere on Earth using
15   global data and models, but also the customization of accounts using local data and model
16   parameterizations. To use the Toolbox, select a context (location and years) and the accounts of
17   interest. ARIES then builds accounts using the best-available data for your context.
18
19   %% :height 200 :collapse
20
21   /**
22    * Main choice of accounts
23    */
24   (
25     (
26       tree(:check width=240 "Extent accounts"
27         <- {type of ecology.incubation:Ecosystem}
28         <- {landcover:LandCoverType}
29       ): chooseextent($)
30       %%
31       *Extent accounts organize information on the areal coverage
32       of ecosystem types within a country or other region of interest
33       (i.e., an ecosystem accounting area).*
34
35       %% :width 280 :height 140 :top
36     ) :hbox :hfill :name "Extent accounts"
37
38     (tree(:check height=320 width=240 "Condition accounts"
39       <- ({landcover:Forest}
40         <- {ecology:LeafAreaIndex}
41         <- {ecology:NormalizedDifferenceVegetationIndex}
42         <- {im:Critical (conservation:Pristine ecology:Forest earth:Region)})
43       //Burned area, drought - still need semantics
44       <- {landcover:Grassland}
45       <- {landcover:Shrubland}
46       <- {landcover:Wetland}
47     ): choosecondition($))
48
```

Ecosystem extent: Modeling IUCN Level 2 Global Ecosystem types

- IUCN GETs are brand new (Keith et al., Feb. 2020)
- No global maps exist yet
- We've coded Level 2 terrestrial GETs, wetlands, open water (n = 9) using global data, lookup table, climate cutoffs from Sayre et al. (2020)
- Calculates annual change based with land cover as an input
- Can code Level 3 GETs if we have decision rules & data to allow their coding (from IUCN late 2020?)



Example completed in about a minute

Can also be used to compile SEEA CF land accounts

Ecosystem condition: Initial accounts for forests

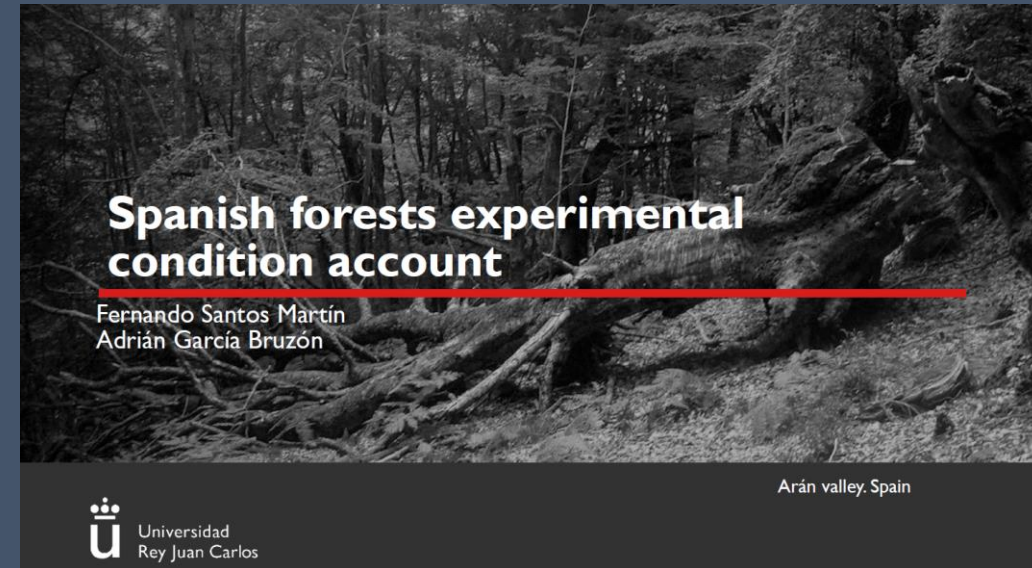
SEEA ECT group	SEEA ECT class	Indicators	Notes
Abiotic characteristics	Physical state	Drought index	https://crudata.uea.ac.uk/cru/data/drought/#global ; monthly resolution at 0.5 degrees for 2001-2018
	Chemical state	No known forest-relevant indicators available globally and in time series	
Biotic characteristics	Compositional state	No known multiyear indicators available	
	Structural state	NDVI Burned area Tree canopy cover LAI	NDVI: MODIS monthly 1 km data, 2000-2018 Burned area: MODIS monthly 500 m data, 2000-2018 Tree canopy: Hansen, annual data, 2000-2018 LAI: MODIS 8-day 500 m, 2000-2018
	Functional state	GPP/NPP	MODIS monthly 1 km data
Land/ seascape characteristics	Landscape level characteristics (e.g., connectivity, fragmentation)	Intact Forest Landscape	https://data.globalforestwatch.org/search?groupIds=577b964b7d8b41b9822d39a7be261bff ; available annually for the years 2000, 2013, 2016

Global time series ca. 2000-present

Challenges: time series data of adequate length, aggregating 8-day to monthly data into yearly totals/averages, etc.

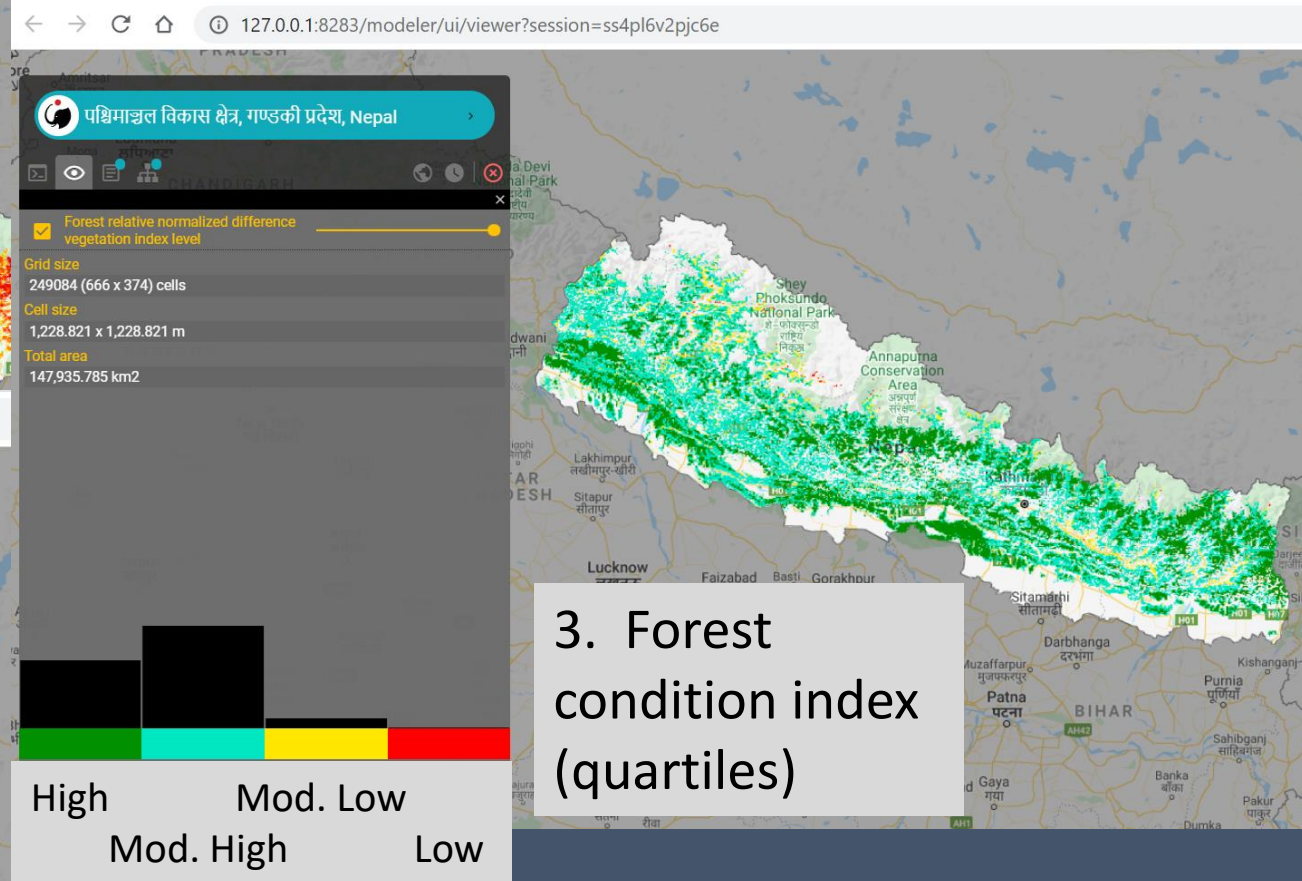
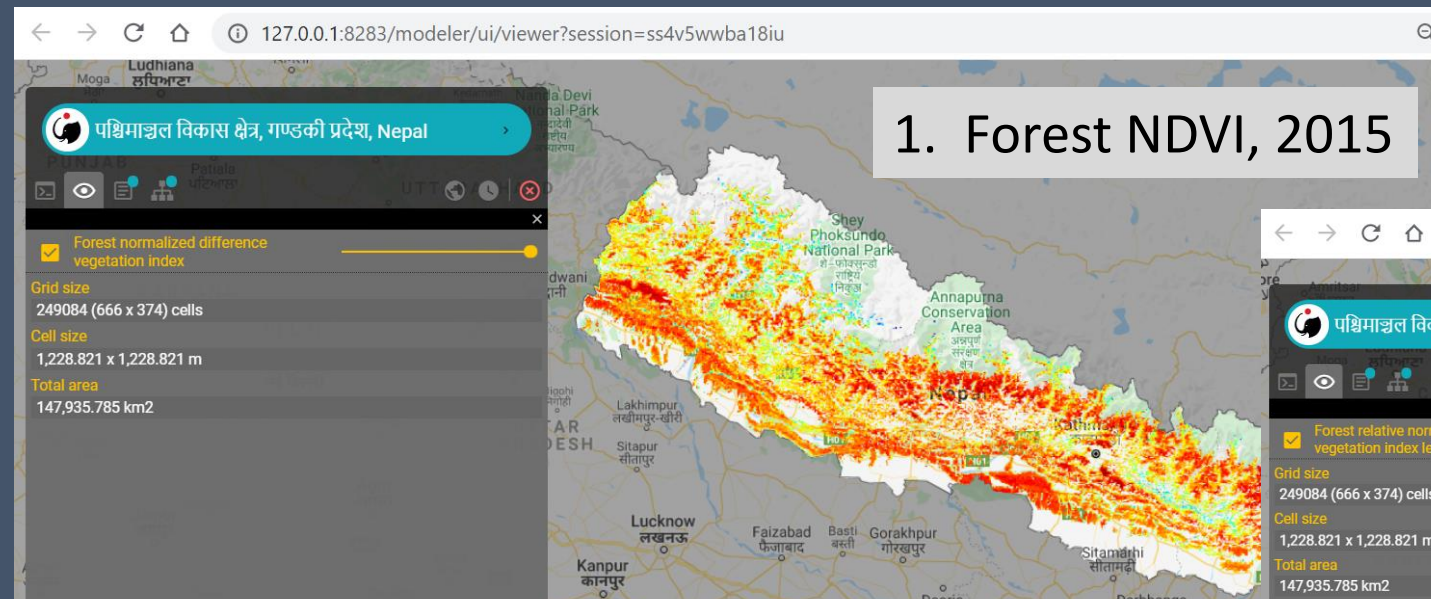
Condition accounts: Aggregating metrics & reference condition

- Santos et al. (in prep) reference forests as those in protected areas that have remained forested since 1970 (earliest available data)
- Compare forest condition within & outside reference forests, normalize all values. Aggregate using equal weights.
- Earliest current global time series land cover starts in 1992 (CCI)
- Propose Santos et al.'s method for global forest condition accounting

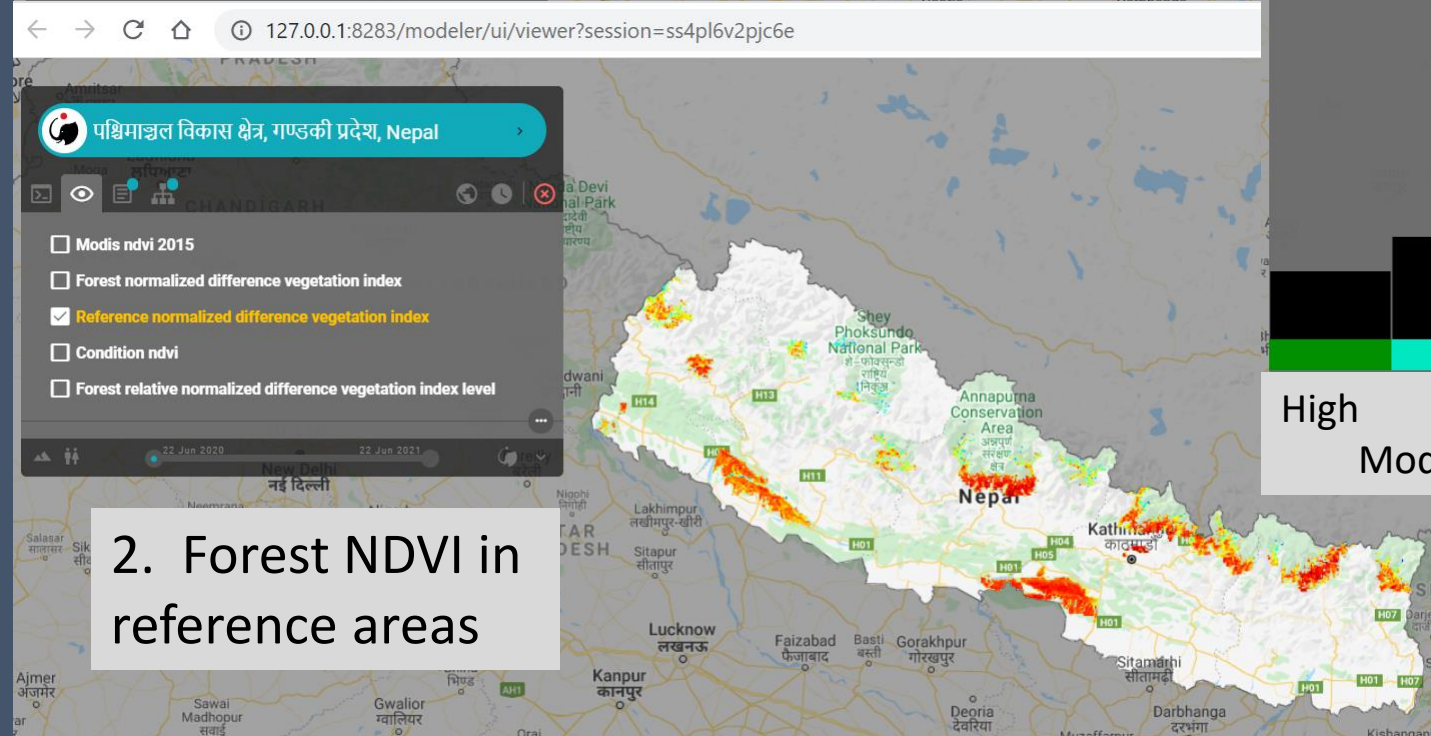


$$Var\downarrow nor = X - min\downarrow ref / max\downarrow ref - min\downarrow ref$$

1. Forest NDVI, 2015




2. Forest NDVI in reference areas



Done in minutes through a web browser, using cloud-based data, anywhere on Earth

Transparent data assembly & reporting



im-data-global-landcover.c3s_lc_300m_2018

This processing step retrieves the contents of a data or model resource from the semantic web. Resources can be data files, data services (using protocols such as OGC or OpenDAP), or may interface to more complex computations or running simulations.

Resources are identified by a unique Uniform Resource Name (URN) used together with the scale of observation to retrieve data or trigger computation. Metadata and provenance records associated with this resource are shown below.

Title

European Space Agency Climate Change Initiative (ESA-CCI) land cover, v.2.1.1

Originator

European Space Agency

Description

The ESA-CCI project has generated annual global land cover maps at 300 m spatial resolution, initially covering the years 1992 to present year and with extension of the time series underway to cover years following 2018.

URL

<https://www.esa-landcover-cci.org/>

Keywords

Land cover

Ecosystem type

Precipitation volume to potent

WCS resource

Evalu

Atmospher

WCS res

Atmospher

WCS res

Land cover type

WCS resource



k.LAB Contextualization report

Computed at Mon Jun 22 18:29:14 CEST 2020

1 Introduction

1.1 Ecosystem Extent

The Ecosystem Extent Account is the first SEEA-EEA account. It defines the spatial extent of each ecosystem type, showing how ecosystems change over time. Ecosystem types are used in all other accounts, so are fundamental to SEEA-EEA.

Ecosystems are defined as units whose functioning is governed by resources, ambient environmental conditions, disturbance regimes, biotic interactions, and human activity. Ecosystems in this context should not be confused with habitats (provided by ecosystems for particular species).

A complete list of all the diverse ecosystem types remains a work in progress; IUCN's Global Ecosystem Typology is the current standard proposed for ecosystem accounting [Reference 1](#). IUCN's ecosystem typology improves on past ecosystem extent data, which for many past SEEA-EEA applications relied exclusively on land cover data [Reference 2](#).

A full ecosystem extent account includes changes (additions and reductions), as well as net change between opening and closing values among subcomponents of the same ecosystem type and for each accounting period. Each change can be classified into managed expansion/regression, natural expansion/regression, and reappraisals upward or downward. Each ecosystem is influenced by different abiotic and biotic conditions, which interact to produce a supply of ecosystem services in the formulation of the SEEA-EEA.

2 Methods

2.1 Ecosystem Extent

Keith et al. [Reference 1](#) recognize 25 Level 2 ecosystems (termed biomes): four marine, three freshwater, seven terrestrial, four subterranean, and seven in transitional realms. These are further subdivided into 100 Level 3 Ecosystem Functional Groups. However, information is currently lacking on how to map these Level 3 ecosystems using global data. At the biome level, we similarly lack reliable data to distinguish between biome types for all but terrestrial biomes. ARIES thus currently models seven terrestrial biomes as well as open water and wetlands. With additional global data and rules describing how to use spatial data to map the remaining biomes, we will be able to better distinguish additional biomes, as well as ecosystem functional groups.

The methods for mapping Level 2 ecosystems follow's Sayre et al.'s [Reference 3](#) temperature and moisture domains, combined with land cover data in a lookup table. This enables the mapping of ecosystem change over time using the best available data.

landcover	aridity	mean_annual_temperature	mean_july_temperature	ecosystem_type
landcover:Forest	> 0.05	>18	*	ecology.incubation:Tropical
landcover:Forest	> 0.05	0 to 18	*	ecology.incubation:Temperate
landcover:Shrubland	> 0.05	>0	*	ecology.incubation:Shrubland
landcover:BareArea	> 0.05	>0	*	ecology.incubation:Shrubland
landcover:LichenMoss	> 0.05	>0	*	ecology.incubation:Shrubland
landcover:SparseVegetation	> 0.05	>0	*	ecology.incubation:Shrubland
landcover:Grassland	> 0.05	>0	*	ecology.incubation:Savanna

Replacing global data with national/local

- Happens automatically when datasets are annotated the same:
 - E.g., a national-scale 10 m DEM replaces global 90 m data when both are stored on the cloud & annotated as “elevation in m”
 - Categorical data like land cover are more complex, need to be given consistent names (e.g., “open water” = “water bodies”)
- Substituting custom data not yet possible from the web interface; requires use of a more advanced Modeler interface that comes with the software
 - We’ll provide written & video documentation for this by fall

Stay tuned for additional features (Summer/Fall 2020)

- Automatic compilation of accounting tables
- NCAVES country examples
- Guidance on model customization with national data

Multiple modeling platforms can assist with SEEA EEA



Tools for measuring, modelling, and valuing ecosystem services

Guidance for Key Biodiversity Areas, natural World Heritage sites, and protected areas

Rachel A. Neugarten, Penny F. Langhammer, Elena Osipova, Kenneth J. Bagstad, Nirmal Bhagabati, Stuart H. M. Butchart, Nigel Dudley, Vittoria Elliott, Leah R. Gerber, Claudia Gutierrez Arrellano, Kasandra-Zoica Ivanić, Marianne Kettunen, Lisa Mandle, Jennifer C. Merriman, Mark Mulligan, Kelvin S.-H. Peh, Ciara Raudsepp-Hearne, Darius J. Semmens, Sue Stolton and Simon Willcock

Craig Groves, Series Editor



Table 3. Purpose of measuring, modelling or valuing ES of KBAs, natural World Heritage sites, and protected areas, and tools that might be applied. ✓ = can potentially be used; ✓✓ = can potentially be used and there are case studies available. For case studies, see Annexes II and IV.

Reasons for measuring ES provided by sites	ARIES	C\$N	EST	InVEST	MIMES	PA-BAT	SoIVES	TESSA	WW
Public/policy support									
Provide additional evidence and justification for the importance of conserving a particular site	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓
Foster local awareness of the ES provided by a particular site	✓	✓✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓
Build support for the conservation of multiple sites through increased understanding of their wide range of benefits	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Link ES contributed by all sites in a country to international or national sustainability goals and national policies (e.g. SDGs)	✓	✓✓		✓✓	✓	✓✓			✓✓
Site management									
Establish the baseline of ES provided by a site to enable monitoring of changes and support management planning	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓

Good data & model interoperability
practices can benefit all modeling platforms

Discussion/Feedback on:

- General approach
- Approach to ecosystem extent
 - IUCN Level 2 GET with potential to map Level 3 given appropriate global data & rules for how to map
- Approach to ecosystem condition
 - Selected forest ecosystem condition indicators
 - Measuring reference state

Learn more and get started (functionality will evolve quickly this summer/fall):

https://www.integratedmodelling.org/get_started

- Code for ecosystem extent (IUCN Level 2 GETs)

```
define IUCN_GLOBAL_ECOSYSTEMS as {{
  landcover | aridity | mean_annual_temperature | mean_july_temperature | ecosystem_type
  -----
  Landcover:Forest | > 0.05 | >18 | * | ecology.incubation:TropicalSubtropicalForest
  Landcover:Forest | > 0.05 | 0 to 18 | * | ecology.incubation:TemperateBorealForestWoodland
  landcover:Shrubland | > 0.05 | >0 | * | ecology.incubation:ShrublandShrubbyWoodland
  landcover:BareArea | > 0.05 | >0 | * | ecology.incubation:ShrublandShrubbyWoodland
  landcover:LichenMoss | > 0.05 | >0 | * | ecology.incubation:ShrublandShrubbyWoodland
  landcover:SparseVegetation | > 0.05 | >0 | * | ecology.incubation:ShrublandShrubbyWoodland
  landcover:Grassland | > 0.05 | >0 | * | ecology.incubation:SavannaGrassland
  landcover:TransitionalWoodlandScrub | > 0.05 | >0 | * | ecology.incubation:SavannaGrassland
  Landcover:ScrubHerbaceousVegetation | < 0.05 | >0 | * | ecology.incubation:DesertSemidesert
  Landcover:SeminaturalOpenSpace | < 0.05 | >0 | * | ecology.incubation:DesertSemidesert
  Landcover:ScrubHerbaceousVegetation | * | < 0 | <10 | ecology.incubation:PolarAlpine
  Landcover:SeminaturalOpenSpace | * | < 0 | <10 | ecology.incubation:PolarAlpine
  landcover:GlacierAndPerpetualSnow | * | * | * | ecology.incubation:PolarAlpine
  landcover:ArtificialSurface | * | * | * | ecology.incubation:IntensiveLandUseSystem
  landcover:AgriculturalVegetation | * | * | * | ecology.incubation:IntensiveLandUseSystem
  landcover:Wetland | * | * | * | ecology.incubation:Wetland
  landcover:WaterBody | * | * | * | ecology.incubation:Aquatic
}};
```

Infrastructure for FAIR, AI-supported scientific modeling

Box 2 | The FAIR Guiding Principles

To be Findable:

- F1. (meta)data are assigned a globally unique and persistent identifier
- F2. data are described with rich metadata (defined by R1 below)
- F3. metadata clearly and explicitly include the identifier of the data it describes
- F4. (meta)data are registered or indexed in a searchable resource

To be Accessible:

- A1. (meta)data are retrievable by their identifier using a standardized communications protocol
 - A1.1 the protocol is open, free, and universally implementable
 - A1.2 the protocol allows for an authentication and authorization procedure, where necessary
- A2. metadata are accessible, even when the data are no longer available

To be Interoperable:

- I1. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.
- I2. (meta)data use vocabularies that follow FAIR principles
- I3. (meta)data include qualified references to other (meta)data

To be Reusable:

- R1. meta(data) are richly described with a plurality of accurate and relevant attributes
 - R1.1. (meta)data are released with a clear and accessible data usage license
 - R1.2. (meta)data are associated with detailed provenance
 - R1.3. (meta)data meet domain-relevant community standards



1. Semantics



3. Open, linkable models



2. Open, linkable data



4. Software infrastructure