National Aeronautics and Space Administration

Remote Sensing for Freshwater Habitats

Amber McCullum, Juan Torres-Pérez, Guest Speaker Kashif Shaad (Conservation International)

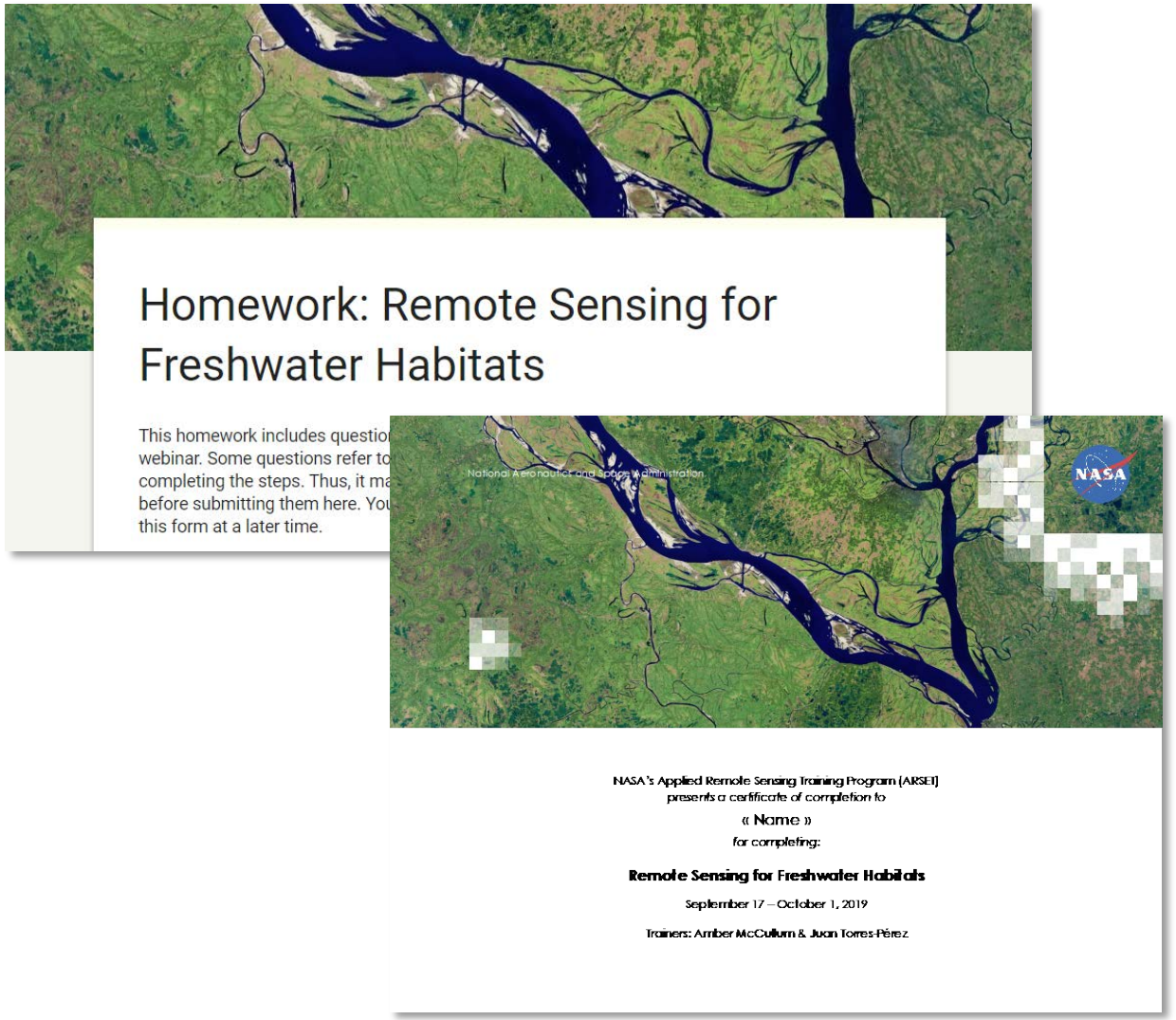
17 September – 1 October, 2019

Course Structure

- Three, 1-hour sessions on September 17, 24, and October 1
- The same content will be presented at two different times each day:
  - Session A: 10:00-11:00 EST (UTC-4)
  - Session B: 18:00-19:00 EST (UTC-4)
  - **Please only sign up for and attend one session per day**
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - **https://arset.gsfc.nasa.gov/land/webinars/2019-freshwater**
- Q&A: Following each lecture and/or by email
  - amberjean.mccullum@nasa.gov
  - Or juan.l.torresperez@nasa.gov

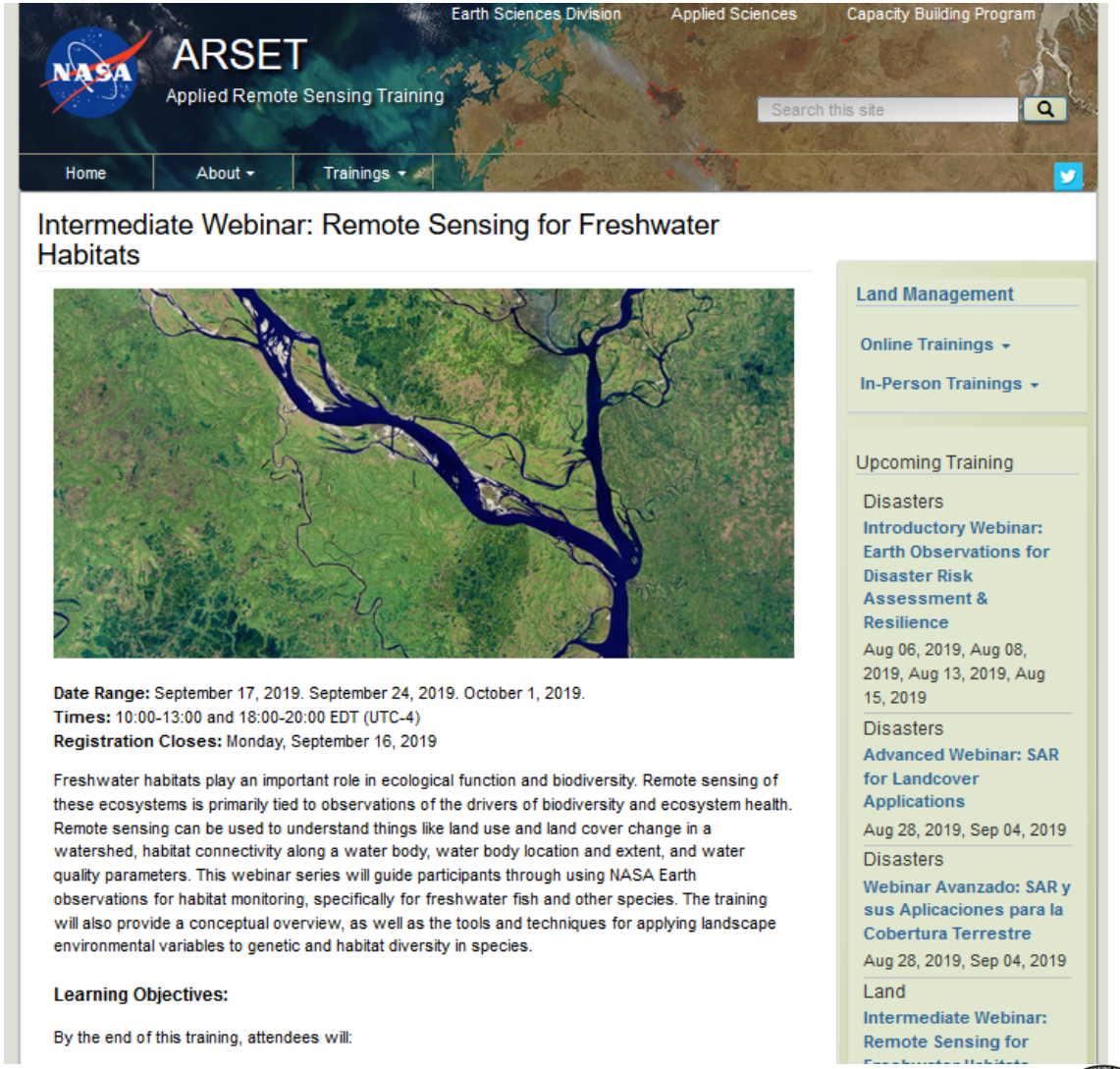
Homework and Certificates

- Homework
  - One homework assignment
  - Answers must be submitted via Google Forms
- Certificate of Completion:
  - Attend both live webinars
  - Complete the homework assignment by the deadline (access from ARSET website)
    - **HW Deadline: Tuesday Oct 15**
  - You will receive certificates approximately two months after the completion of the course from: marines.martins@ssaihq.com



Prerequisites and Course Materials

- Prerequisite
  - Please complete **Sessions 1 & 2A of Fundamentals of Remote Sensing**, or have equivalent experience
    - Attendees who do not have this knowledge may not follow the pace of the training
- Course Materials
  - Found here: **https://arset.gsfc.nasa.gov/land/webinars/2019-freshwater**



Course Outline

Session 1: Aquatic Remote Sensing

- Satellites and sensors
- Data limitations
- Combining multiple data types for freshwater habitat mapping
- Some case study examples

Session 2: Riverscape Analysis Project (RAP)

- Case studies
- RAP overview
- Data and analysis with RAP
- RAP demo

Session 3: Freshwater Health Index

- Freshwater health metrics overview
- FHI overview
- FHI demo

Session 3 Agenda

- Overview of Freshwater Health Index – Links to social-ecological system
- Conducting an FHI assessment
- FHI tool Demonstration – links to remote sensing data
- Question and Answer session

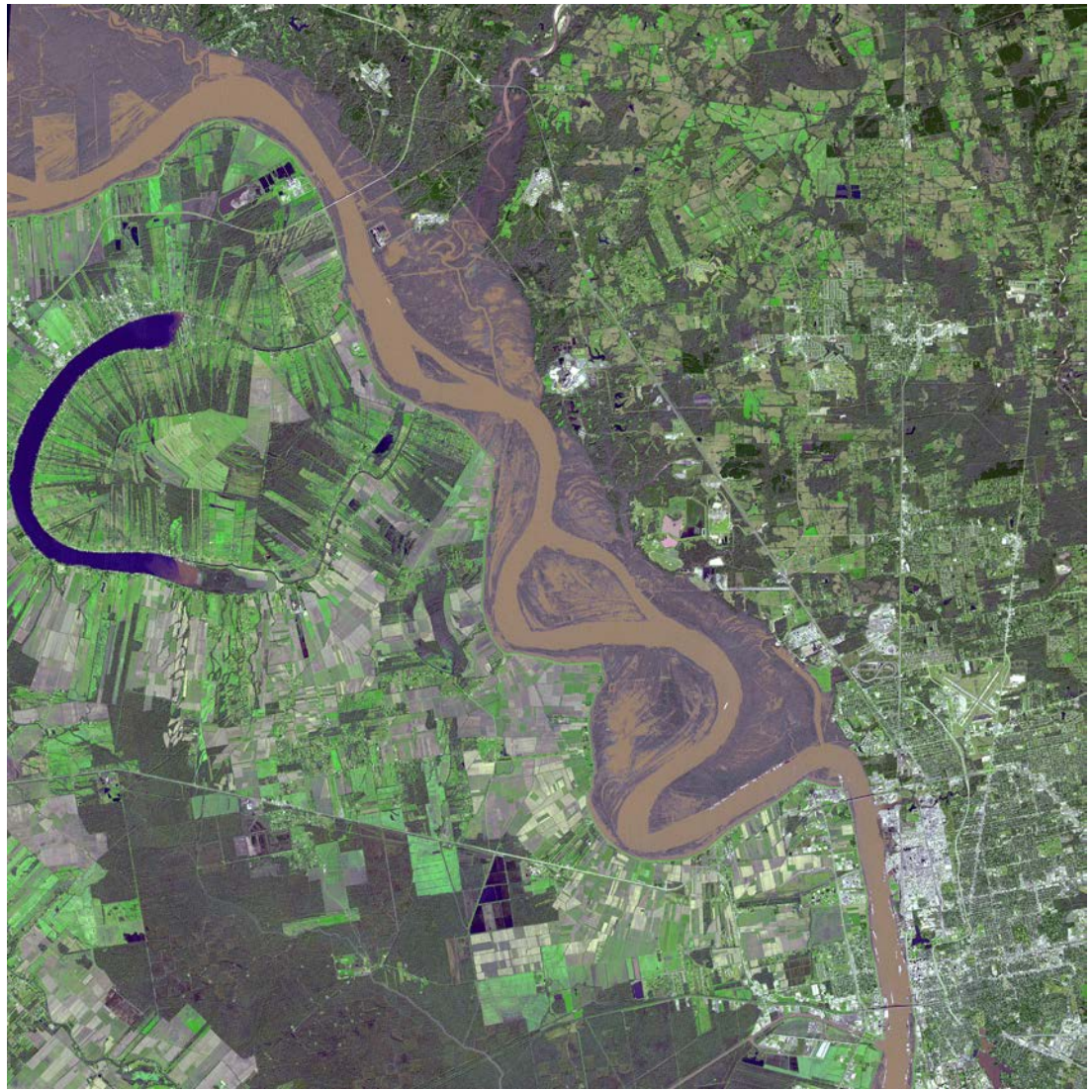


Image Credit: Jet Propulsion Laboratory

Review of Session 2

- Landscape genetics can be a powerful tool to study freshwater species and their vulnerability to changing conditions
  - eDNA can be used for elusive and/or sensitive species to estimate abundance and understand genetic diversity
- Remote sensing, GIS, and modeling technology is key in multi-step vulnerability assessments
- The Riverscape Analysis project provides information, opportunities for citizen science, and multiple online tools for acquiring and analyzing freshwater habitats in the Pacific Northwestern region of the U.S.

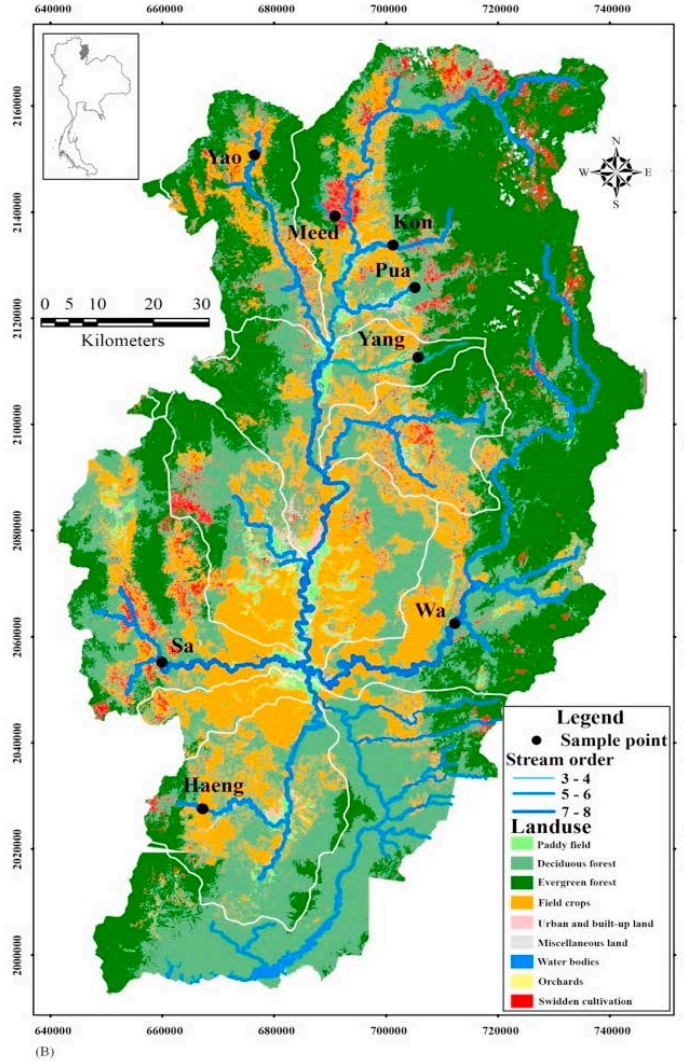


Image Credits: (Top left) Diszhal.info; (Right) Jaisuk and Senanan, 2018

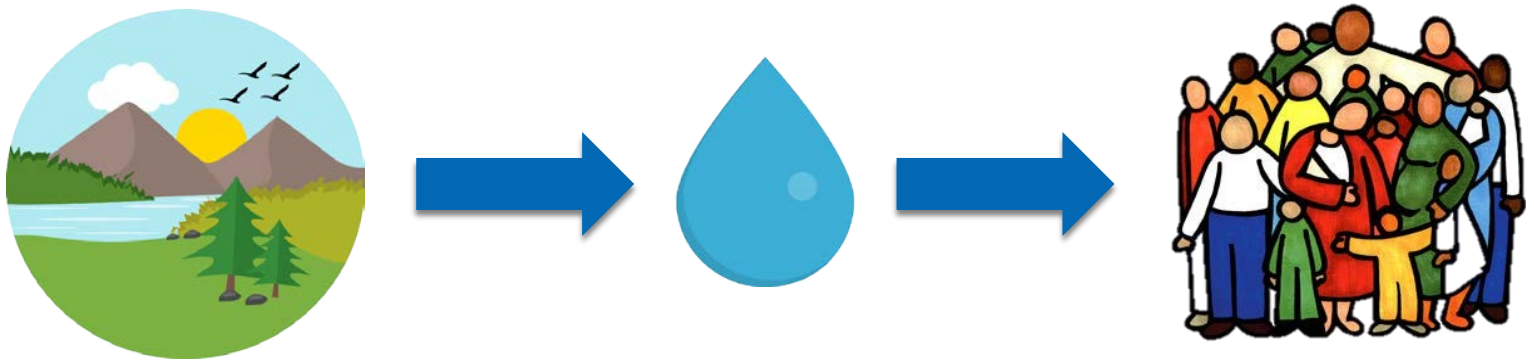
Freshwater Health Index Overview

Guest Speaker: Kashif Shaad

Freshwater Health

- ‘Health’ is a common shorthand for ‘good condition’ - grounded in science but accessible to citizens
- Links ecological integrity to ecosystem service delivery, and combines social with ecological dimensions

We define “freshwater health” as the ability to deliver water-related benefits **sustainably and equitably**



Text References: Karr, 1999; Vollmer et al., 2018

Freshwater Social-Ecological System

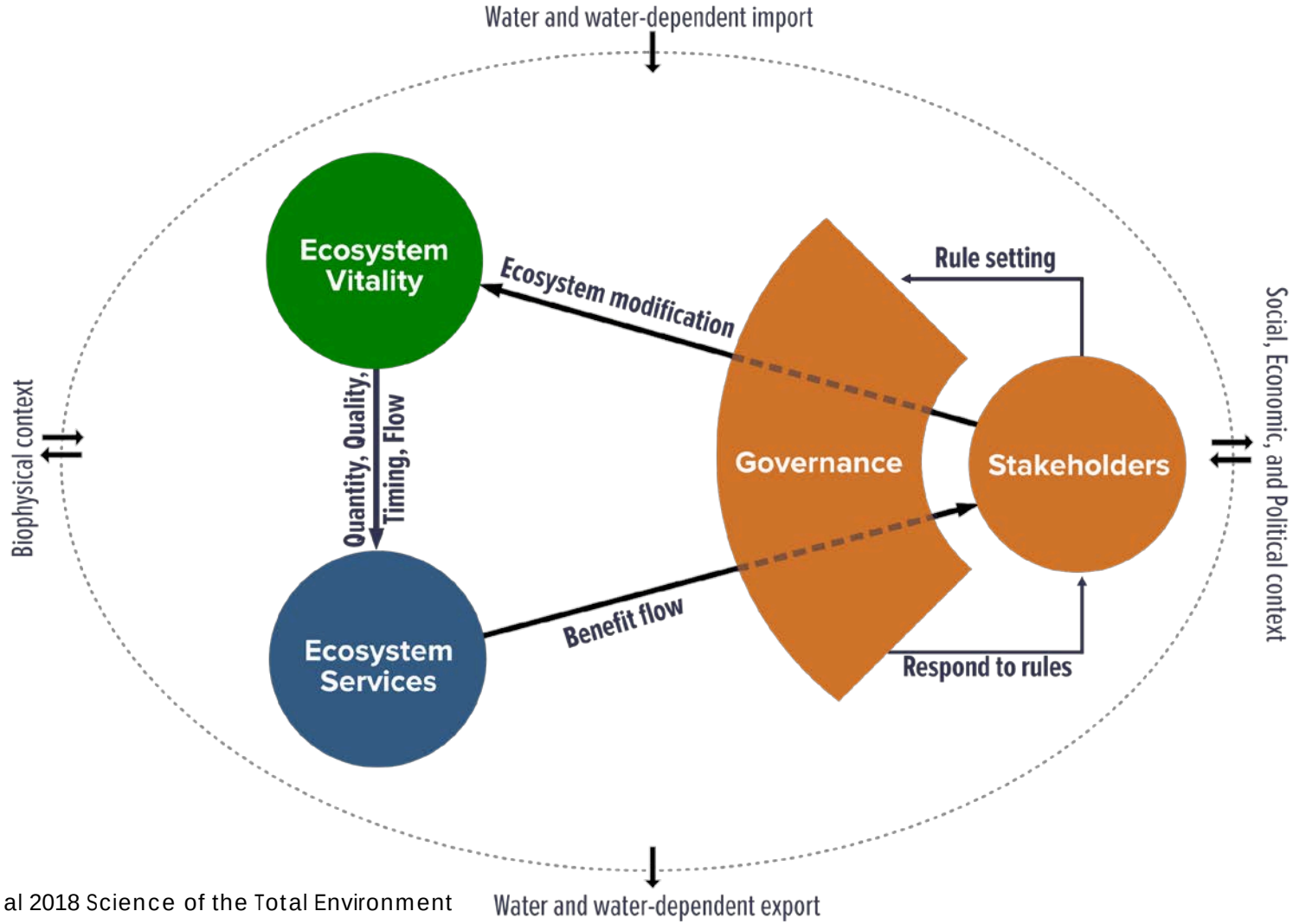


Image Source: Source: Vollmer et al 2018 Science of the Total Environment

Focus Areas

Maintenance of ecosystems central to freshwater health

- Basin Condition
- Water Quantity
- Water Quality
- Biodiversity

Monitor ability to deliver water-related services

- Provisioning
- Regulating
- Cultural

Gauge responsiveness of governance

- Enabling Environment
- Stakeholder Engagement
- Adaptive Governance
- Effectiveness

Locally Adaptive Sub-Indicators

Ecosystem Vitality

Water Quantity
- Deviation from natural flow
- Groundwater Storage Depletion

Water Quality
- Suspended Solids
- Total Nitrogen
- Total Phosphorus
- Other indicators of concern

Drainage Basin Condition
- Extent of channel Modification
- Flow connectivity
- Land Cover Naturalness

Biodiversity
- Species of concern
- Invasive Species

Ecosystem Services

Provisioning
- Water supply reliability relative to demand
- Biomass for consumption

Regulation and Support
- Sediment regulation
- Deviation of water quality from benchmarks
- Flood regulation
- Exposure to water-associated diseases

Cultural
- Conservation/Cultural heritage sites
- Recreation

Governance & Stakeholders

Enabling Environment
- Water resource management
- Rights to resource use
- Incentives & regulations Financial & technical capacity

Stakeholder Engagement
- Information access & knowledge
- Engagement in decision-making

Vision & Adaptive Governance
- Strategic planning & adaptive management
- Monitoring & learning mechanisms

Effectiveness
- Effectiveness & compliance
- Distribution of benefits from ecosystem services
- Water-related conflict

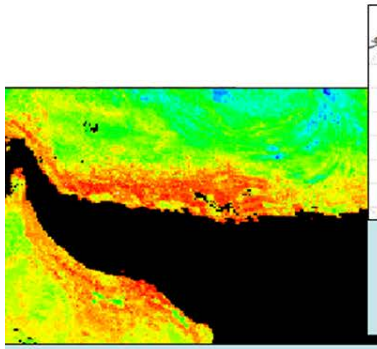
Conducting a FHI Assessment

[1] Define Scope and Engage Stakeholders

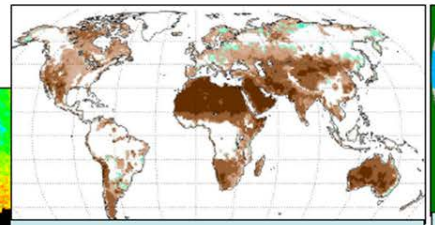
A Freshwater Health Index assessment is a standardized way to involve multiple agencies and stakeholders in setting priorities for better water resource management.

Image Credit: Nine dragons/Gisling

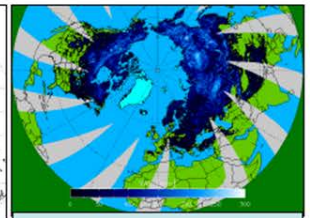
[2] Data Gathering



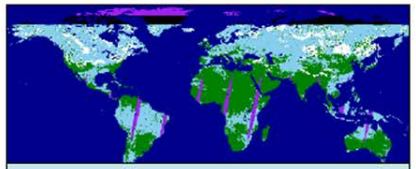
Land surface temperature
(MODIS, AVHRR,GOES,...)



Surface soil moisture
(SMMR, TRMM, AMSR-E,
SMOS, Aquarius, SMAP)

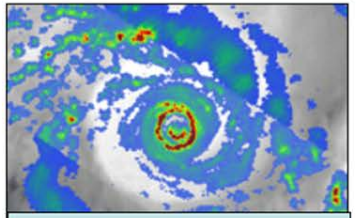


Snow water equivalent
(AMSR-E, SSM/I,
SCLP)

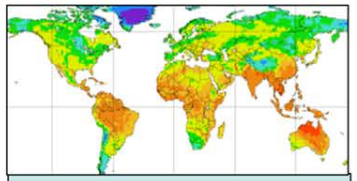


Snow cover fraction
(MODIS, *VIIRS, MIS*)

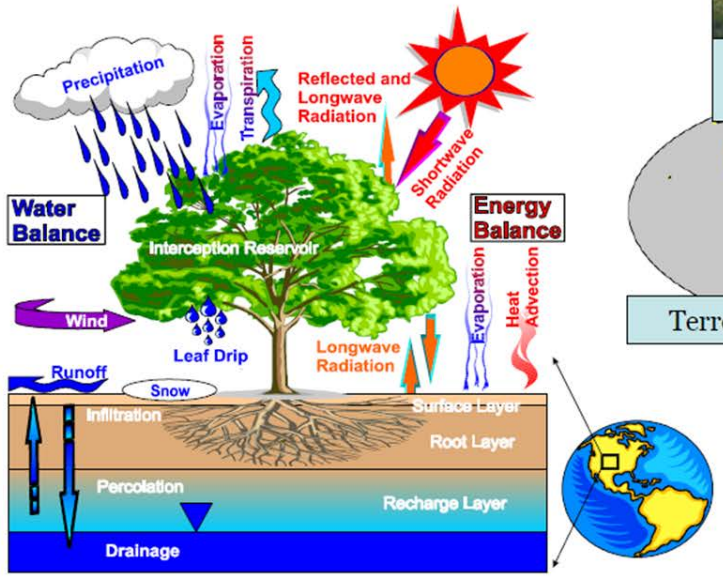
Water surface elevation
(*SWOT*)

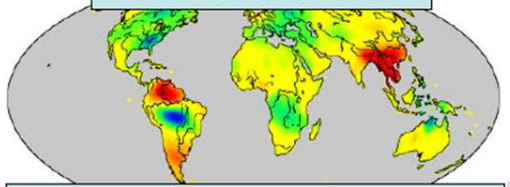


Precipitation
(TRMM, *GPM*)



Radiation
(CERES, *CLARREO*)





Terrestrial water storage (GRACE)

Vegetation/Carbon
(AVHRR, MODIS, *DESDynI, ICESat-II, HyspIRI, LIST, ASCENDS*)

In-Situ Measurements

"Real" data **but** labor intensive/quality control issues

Remote Sensing

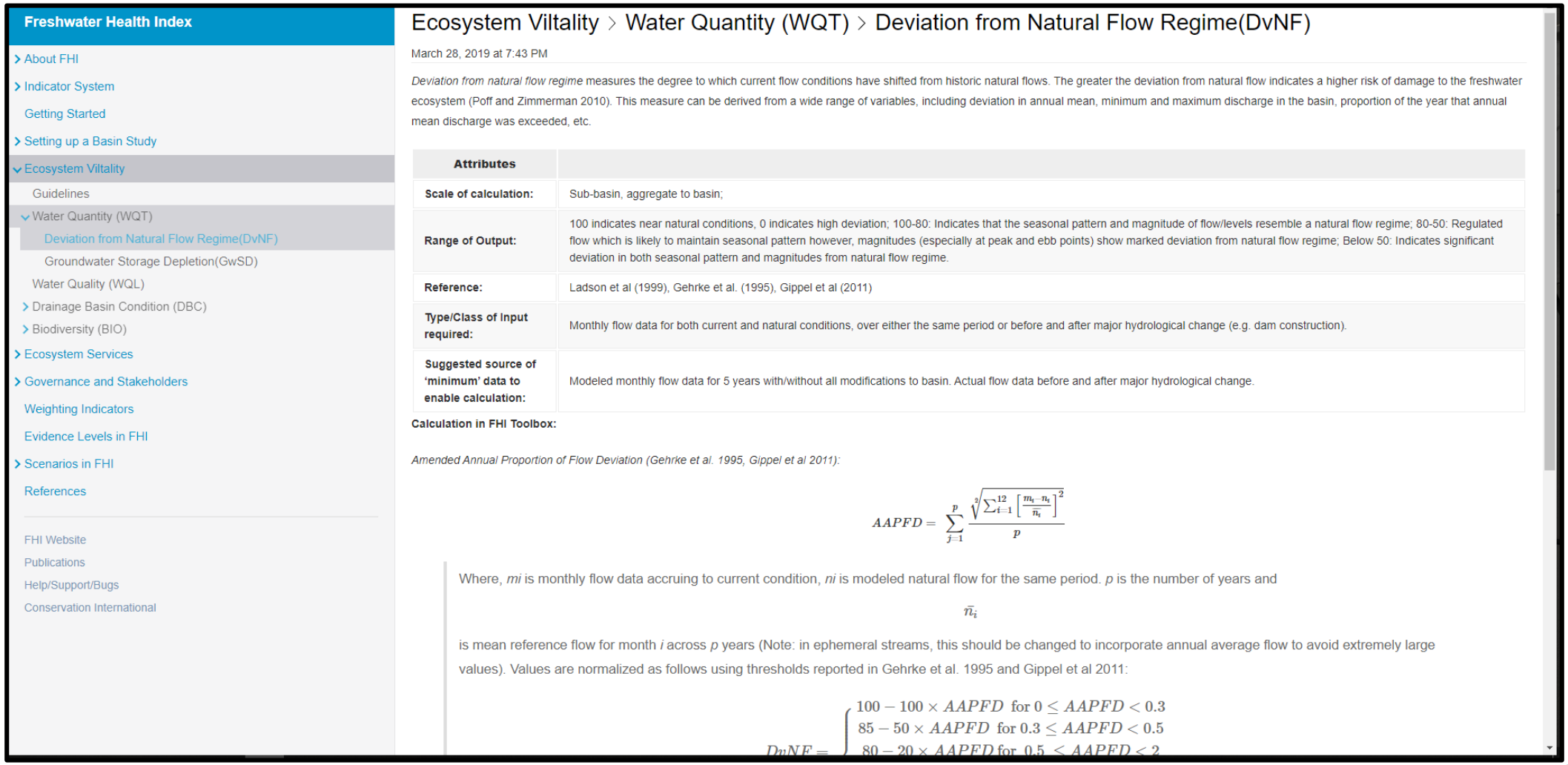
Good spatial coverage **but** resolution and sensing limitations

Numerical Models

Continuity **but** quality limited by input/assumptions

[3] Indicator Calculation

https://www.freshwaterhealthindex.org/tool/



Freshwater Health Index

- About FHI
- Indicator System
- Getting Started
- Setting up a Basin Study
- Ecosystem Viltality
  - Guidelines
  - Water Quantity (WQT)
    - Deviation from Natural Flow Regime(DvNF)
    - Groundwater Storage Depletion(GwSD)
  - Water Quality (WQL)
  - Drainage Basin Condition (DBC)
  - Biodiversity (BIO)
- Ecosystem Services
- Governance and Stakeholders
- Weighting Indicators
- Evidence Levels in FHI
- Scenarios in FHI
- References

FHI Website
Publications
Help/Support/Bugs
Conservation International

Ecosystem Viltality > Water Quantity (WQT) > Deviation from Natural Flow Regime(DvNF)

March 28, 2019 at 7:43 PM

Deviation from natural flow regime measures the degree to which current flow conditions have shifted from historic natural flows. The greater the deviation from natural flow indicates a higher risk of damage to the freshwater ecosystem (Poff and Zimmerman 2010). This measure can be derived from a wide range of variables, including deviation in annual mean, minimum and maximum discharge in the basin, proportion of the year that annual mean discharge was exceeded, etc.

Attributes	
Scale of calculation:	Sub-basin, aggregate to basin;
Range of Output:	100 indicates near natural conditions, 0 indicates high deviation; 100-80: Indicates that the seasonal pattern and magnitude of flow/levels resemble a natural flow regime; 80-50: Regulated flow which is likely to maintain seasonal pattern however, magnitudes (especially at peak and ebb points) show marked deviation from natural flow regime; Below 50: Indicates significant deviation in both seasonal pattern and magnitudes from natural flow regime.
Reference:	Ladson et al (1999), Gehrke et al. (1995), Gippel et al (2011)
Type/Class of input required:	Monthly flow data for both current and natural conditions, over either the same period or before and after major hydrological change (e.g. dam construction).
Suggested source of 'minimum' data to enable calculation:	Modeled monthly flow data for 5 years with/without all modifications to basin. Actual flow data before and after major hydrological change.

Calculation in FHI Toolbox:

Amended Annual Proportion of Flow Deviation (Gehrke et al. 1995, Gippel et al 2011):

$$AAPFD = \sum_{j=1}^{p} \frac{\sqrt[3]{\sum_{i=1}^{12}\left[\frac{m_i - n_i}{\bar{n}_i}\right]^2}}{p}$$

Where, *mi* is monthly flow data accruing to current condition, *ni* is modeled natural flow for the same period. *p* is the number of years and

$$\bar{n}_i$$

is mean reference flow for month *i* across *p* years (Note: in ephemeral streams, this should be changed to incorporate annual average flow to avoid extremely large values). Values are normalized as follows using thresholds reported in Gehrke et al. 1995 and Gippel et al 2011:

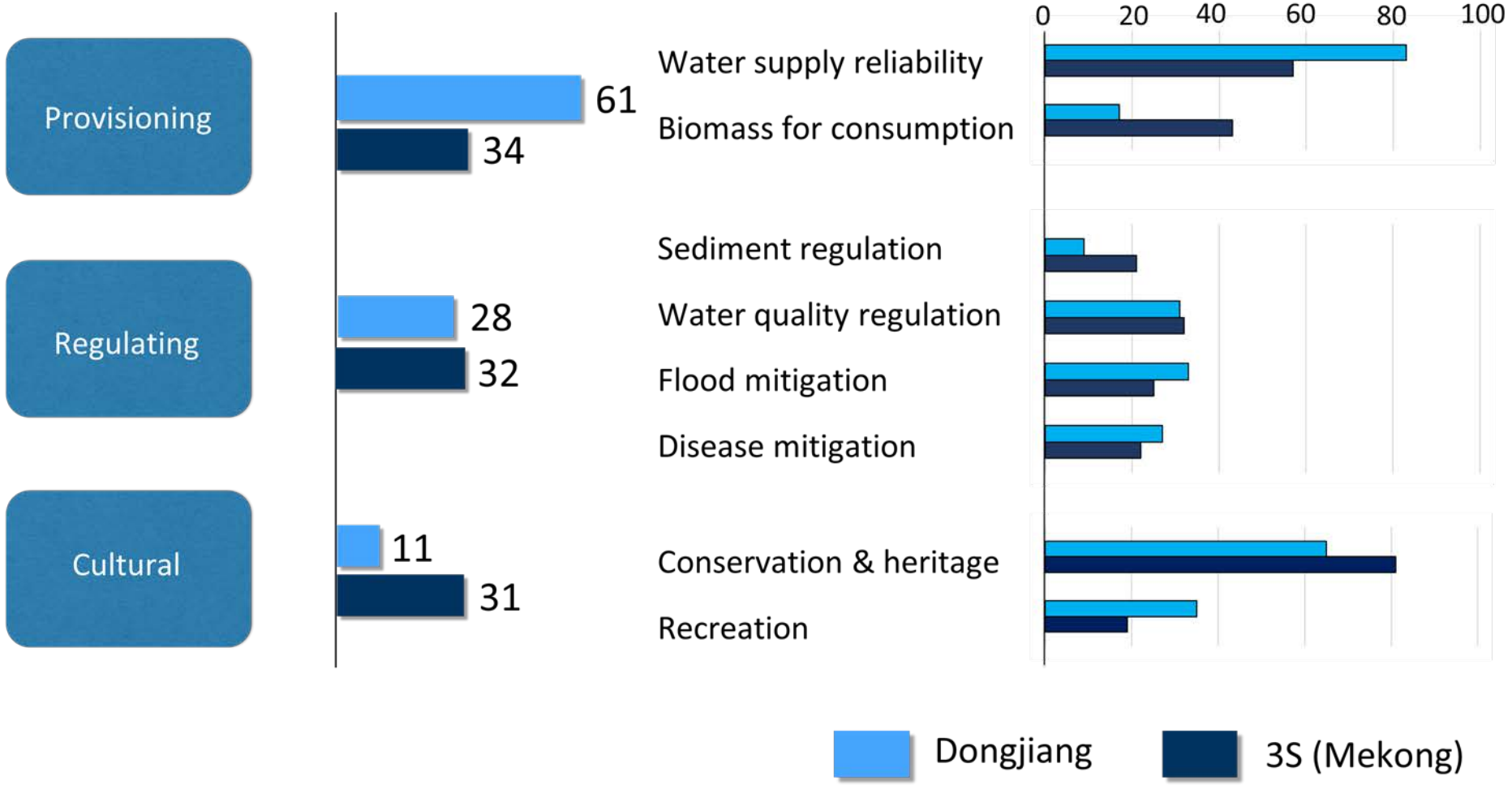
$$DvNF = \begin{cases} 100 - 100 \times AAPFD \text{ for } 0 \le AAPFD < 0.3 \\ 85 - 50 \times AAPFD \text{ for } 0.3 \le AAPFD < 0.5 \\ 80 - 20 \times AAPFD \text{ for } 0.5 \le AAPFD < 2 \end{cases}$$

Collaborating for an Enhanced Exchange: Dongjiang Basin

	Indicator Domain	Champion Organization
	Water discharge and quality	South China University of Technology
	Basin Biodiversity information	IUCN Guangzhou, China
	Flooding, Water supply & other services	Pearl River Hydraulic Research Institute
	Fisheries	Pearl River Fisheries Research Institute
	Water Governance	Sun Yat-sen University

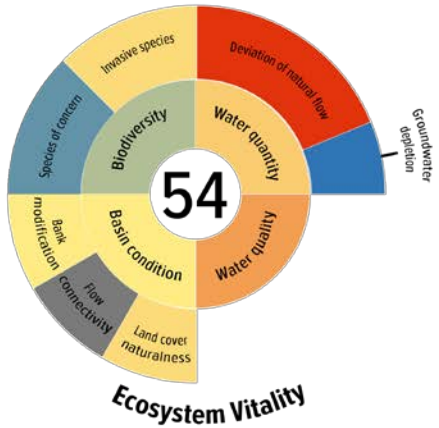
Photo Credits: CI

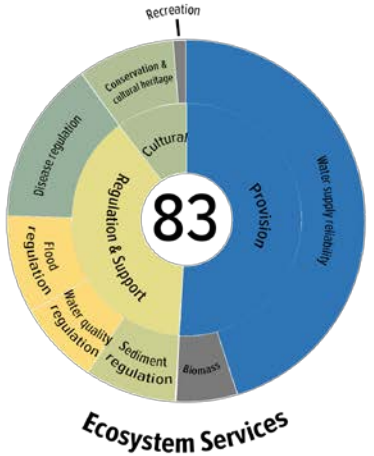
[4] Perception Surveys



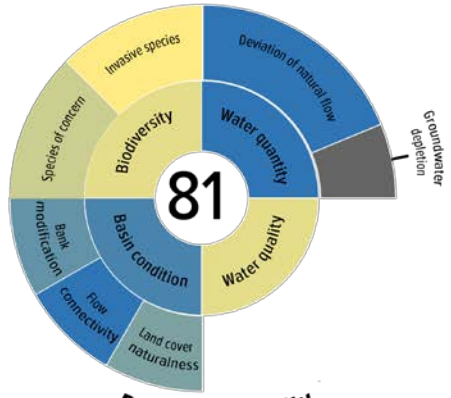
[5] Put It All Together

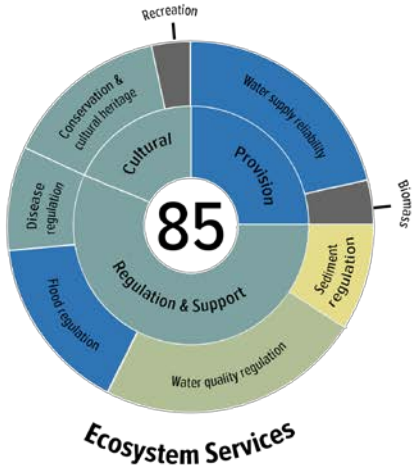
Guandu Basin, Brazil





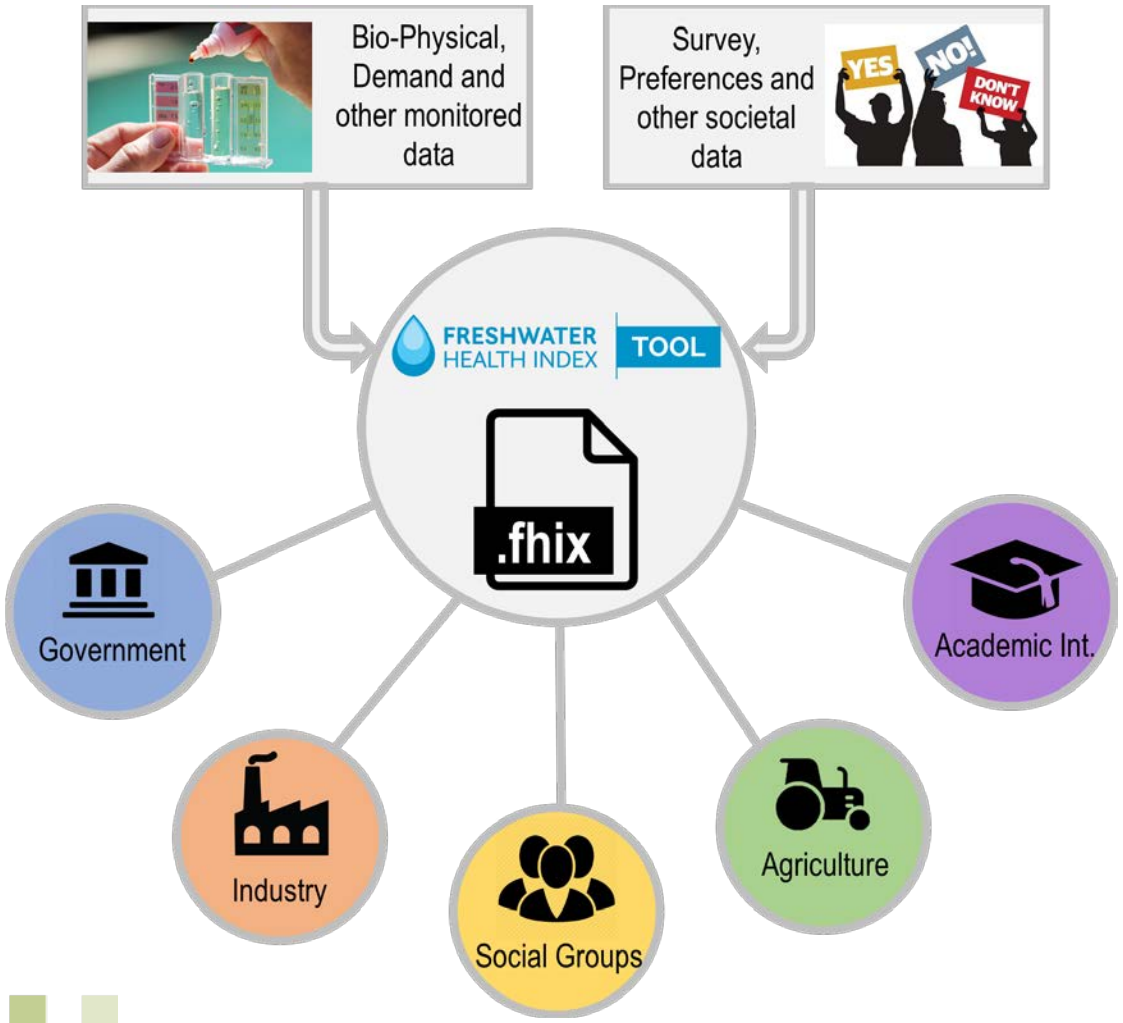
Alto Mayo, Peru





FHI Desktop Tool

http://freshwaterhealthindex.org/fhi-tool-download

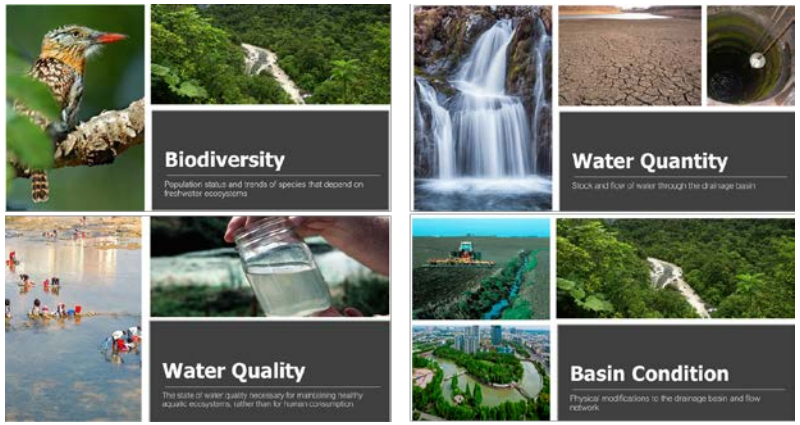


Key ideas behind the tool

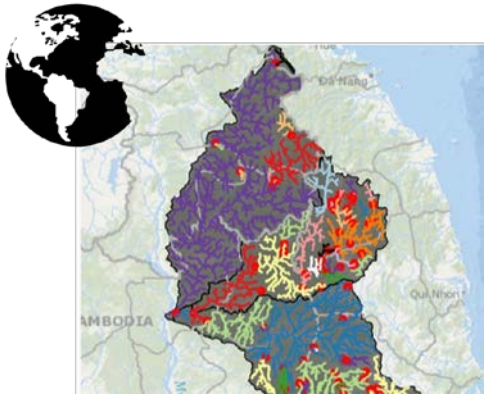
1. Ease of adoption
2. Common platform
3. Cumulative impact
4. Reusability of results

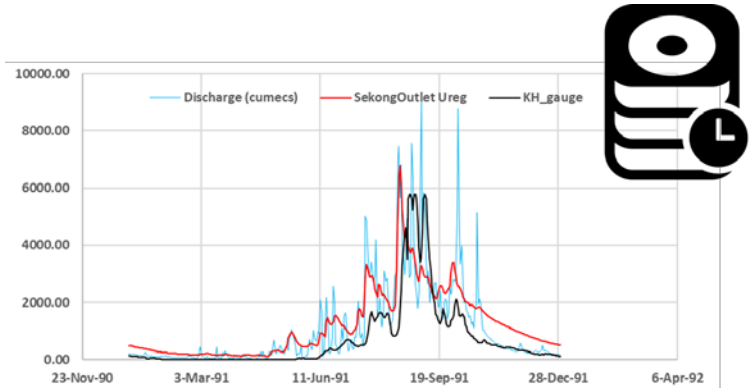
Tool Features

1. Classification of Data

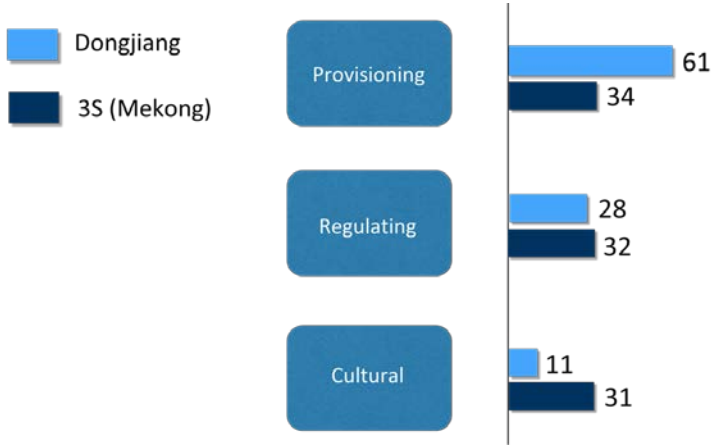


2. Archiving Data





3. Integration of Information



4. Report Generation

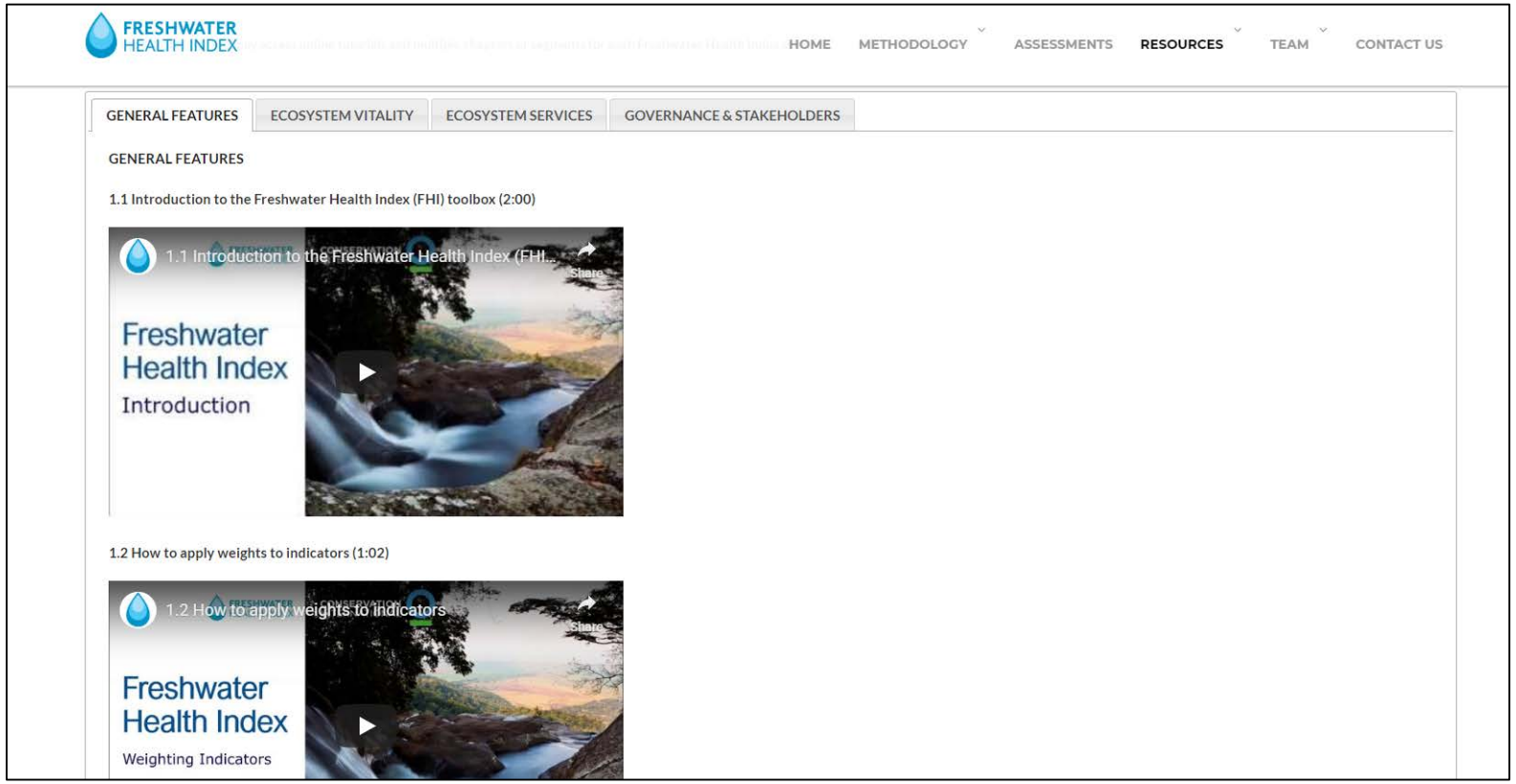
FHI Tool Demonstration

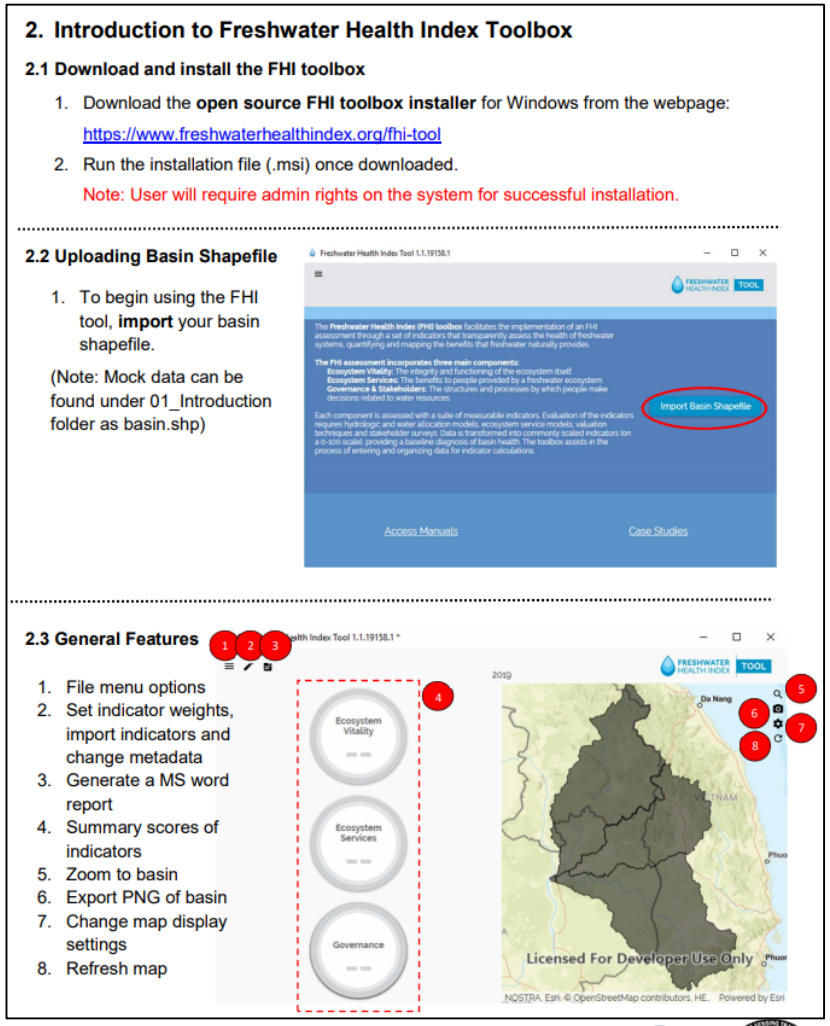
FRESHWATER HEALTH INDEX

CONSERVATION INTERNATIONAL

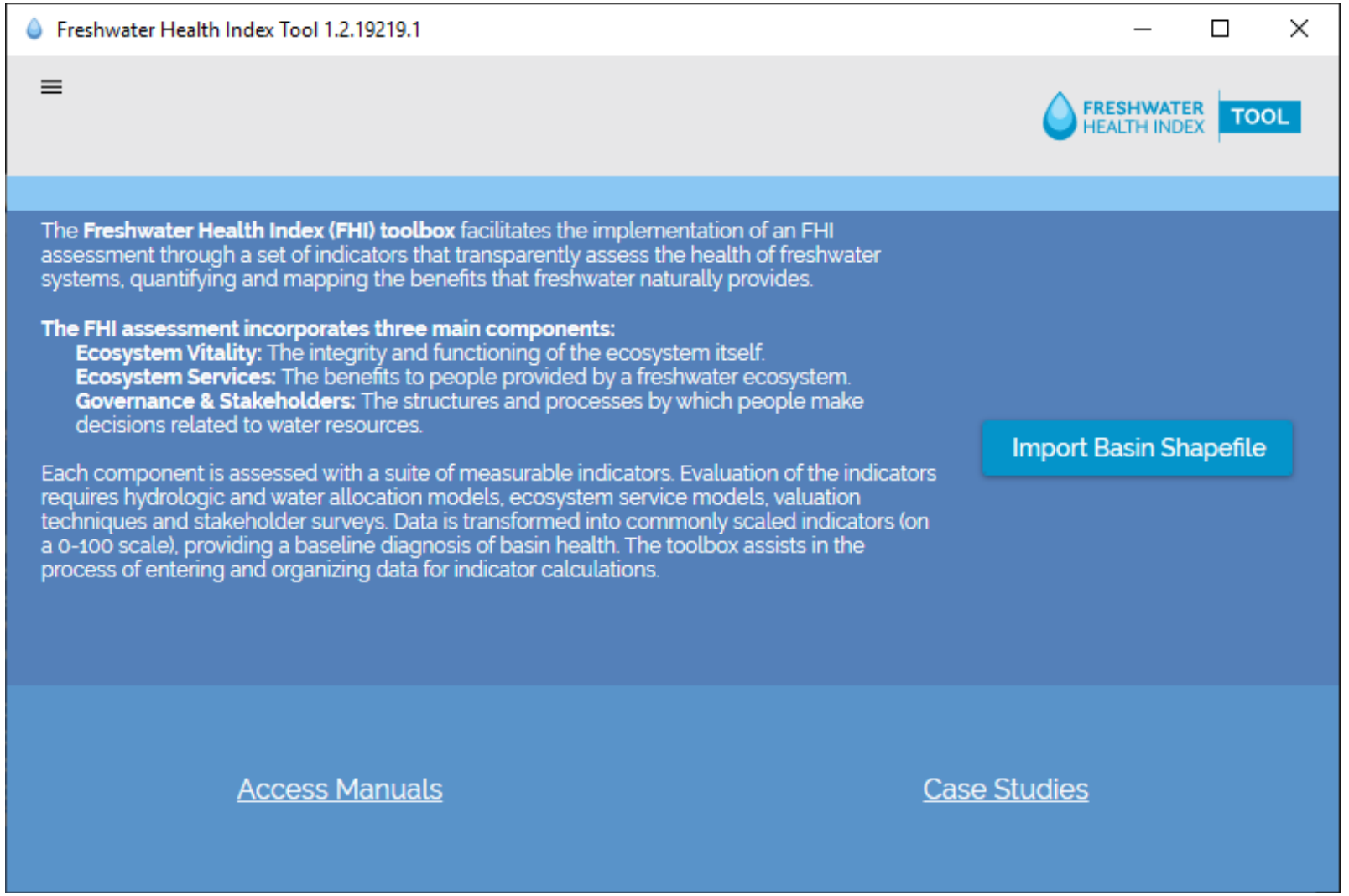
Tool Tutorial

https://www.freshwaterhealthindex.org/fhi-tool-tutorial





[1] Start an Assessment



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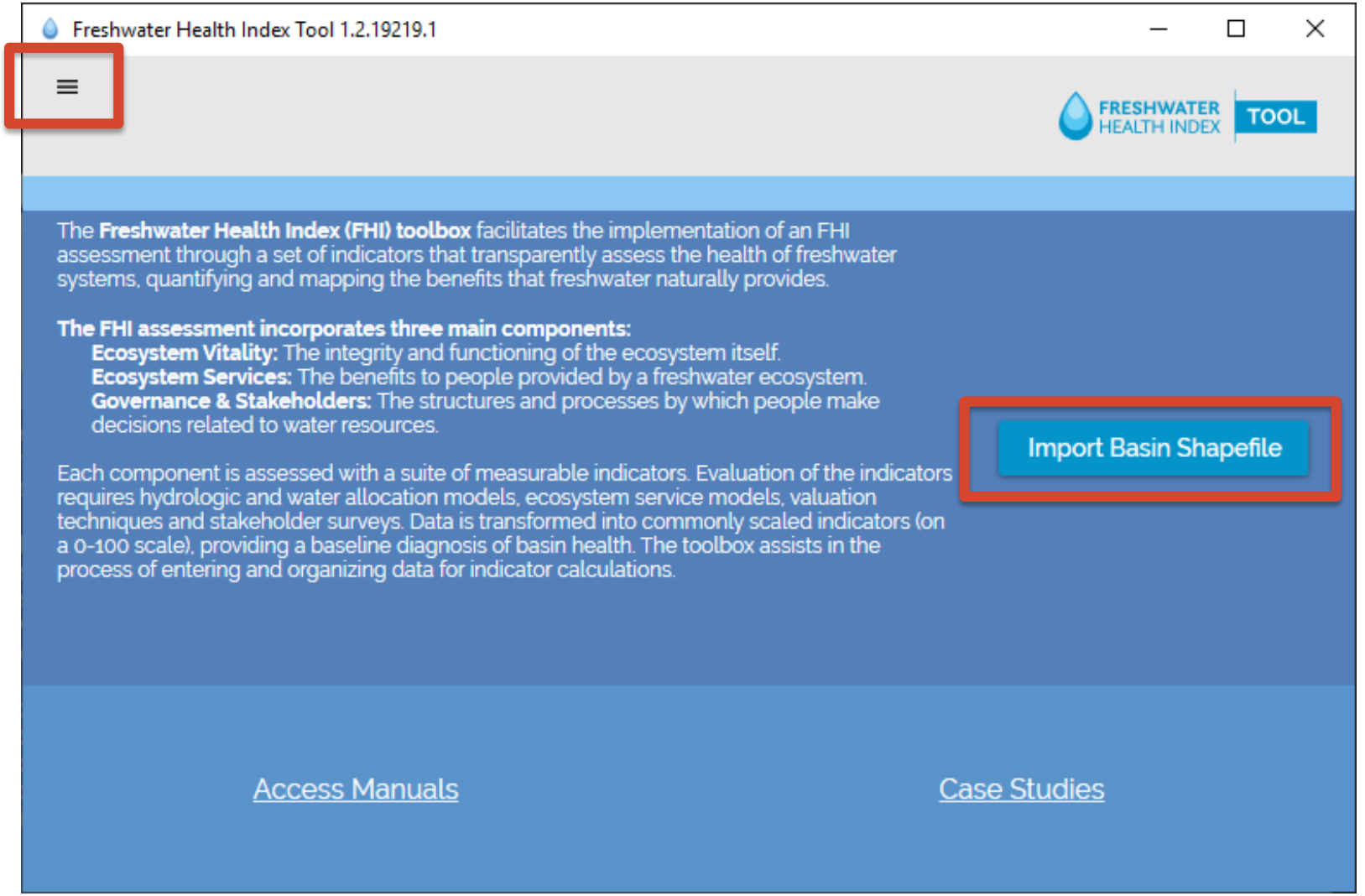
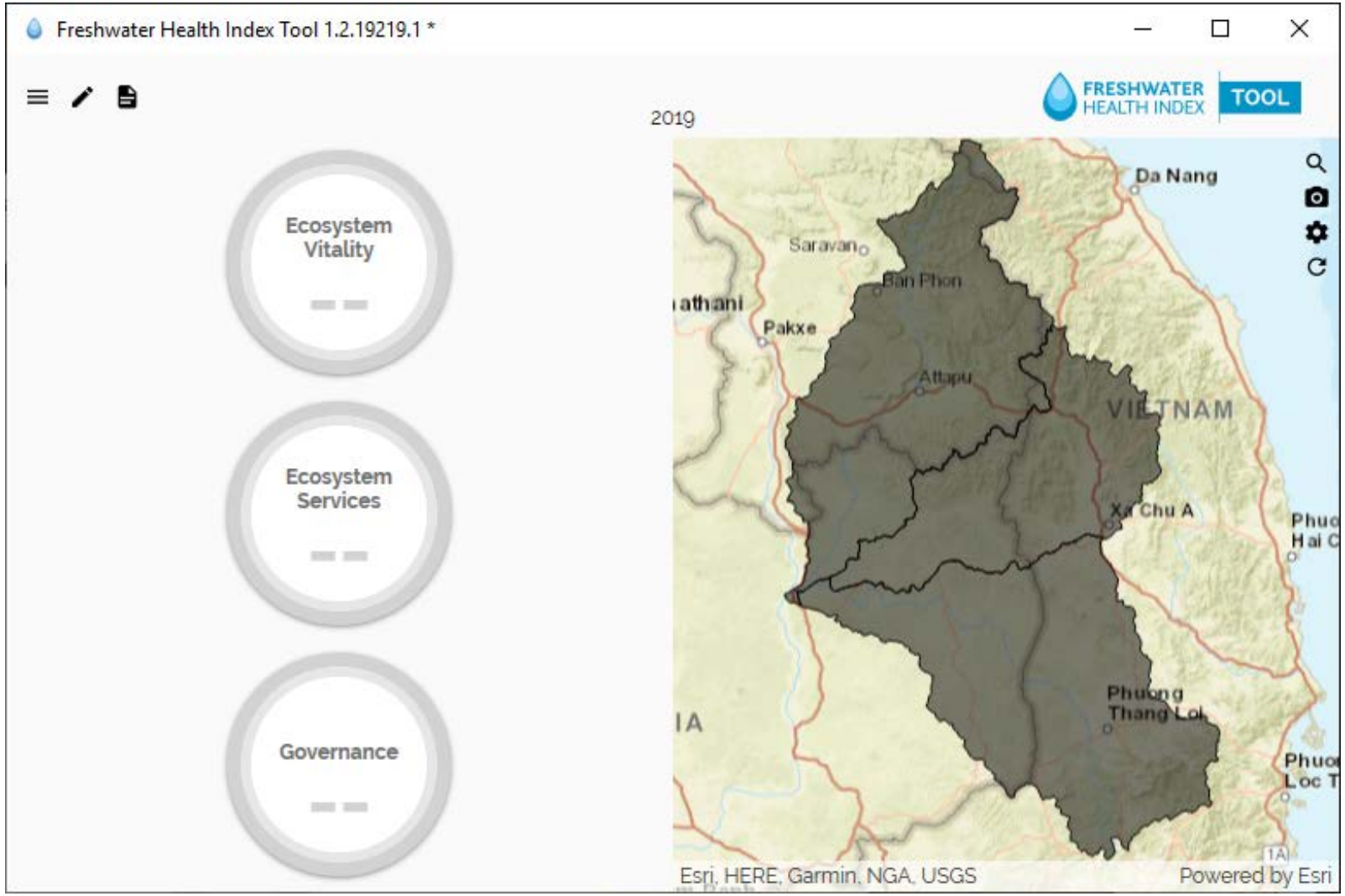
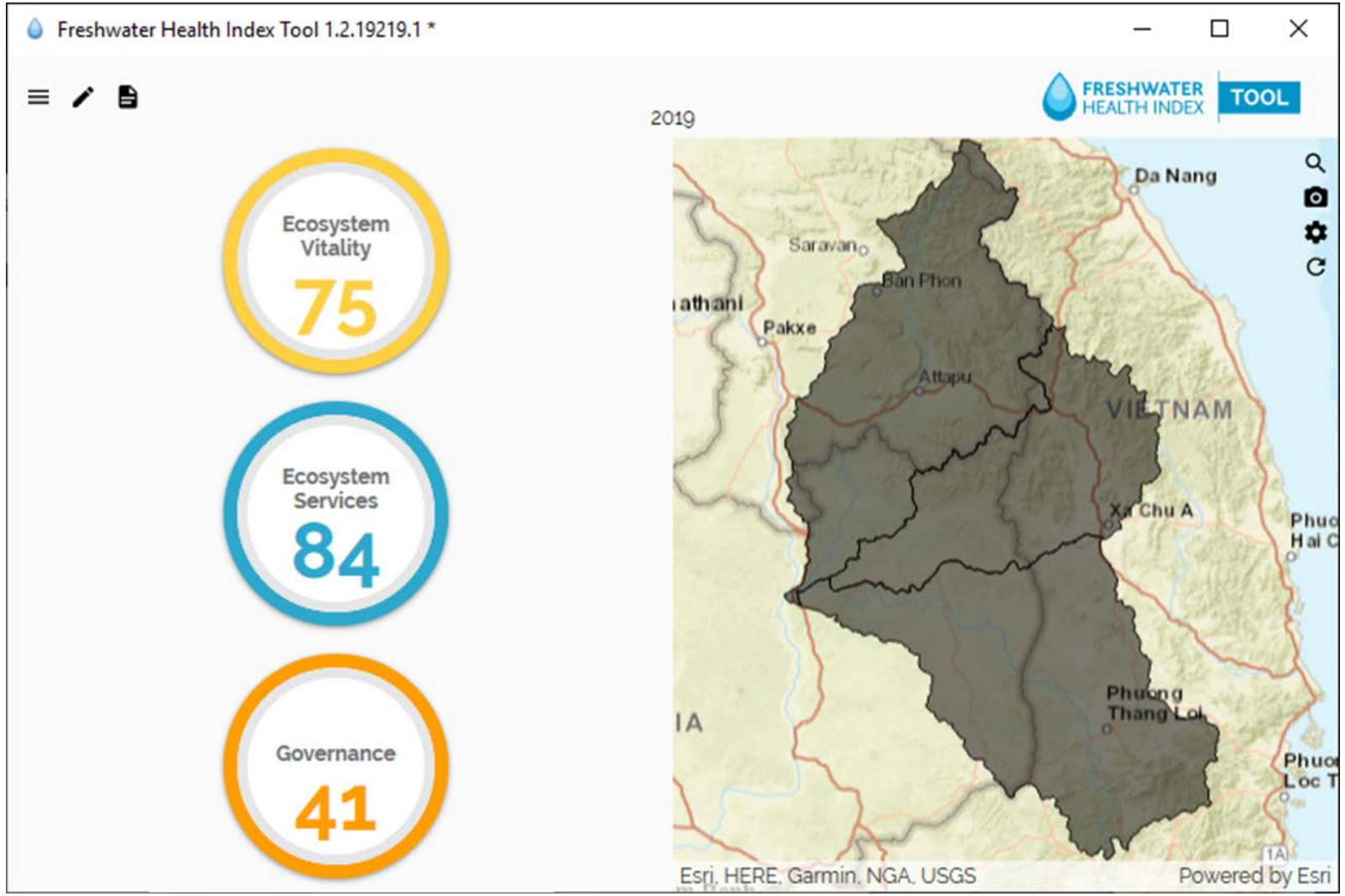


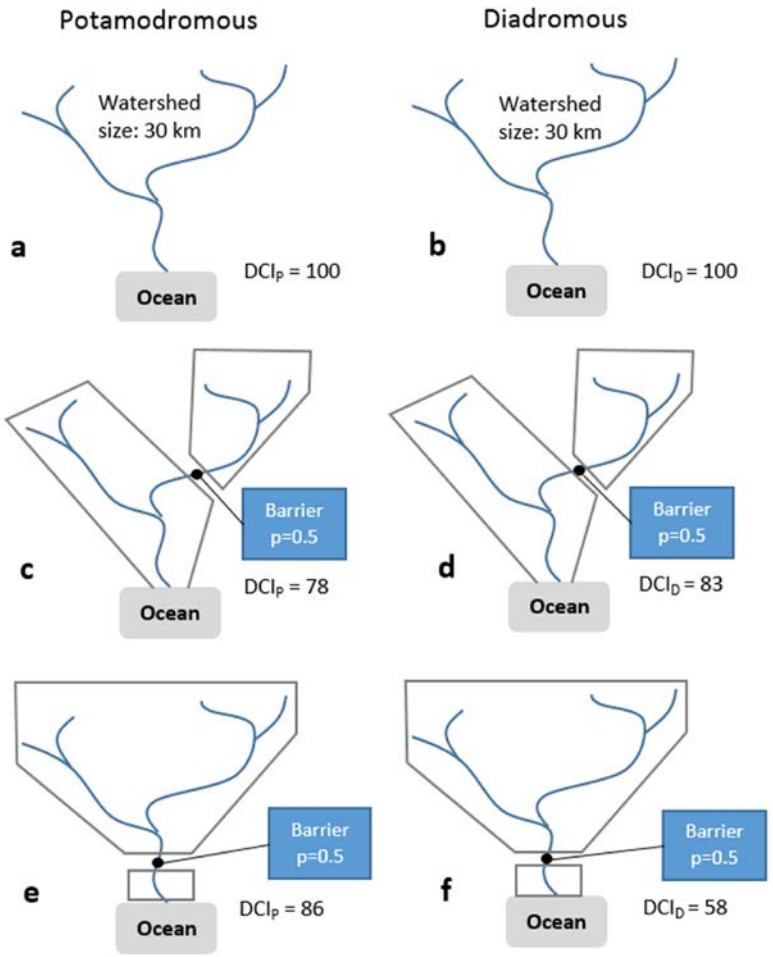
[2] Start an Assessment



[3] Populated Assessment

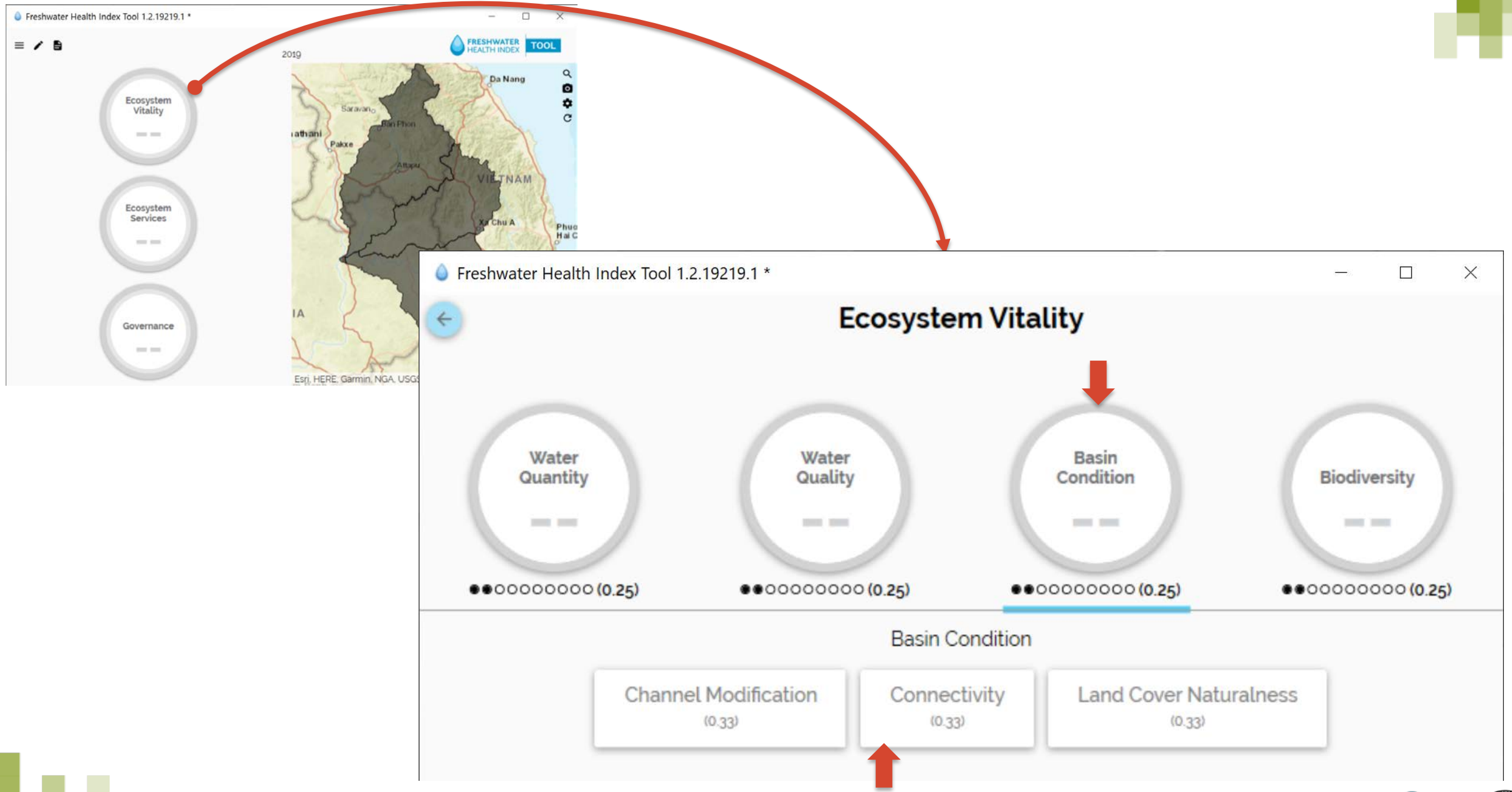


Drainage Basin Condition: Connectivity



"Habitat connectivity is a central factor in shaping aquatic biological communities."

Reference: Cote, David, Dan G. Kehler, Christina Bourne, and Yolanda F. Wiersma. 2009. "A New Measure of Longitudinal Connectivity for Stream Networks." Landscape Ecology 24 (1): 101–13. Image Credit: © Copyright Walter Baxter - geograph.org.uk/p/3191870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FRESHWATER HEALTH INDEX TOOL
2019
Ecosystem Vitality
Ecosystem Services
Governance
Da Nang
Saravan
Pakxe
Attapu
VIETNAM
Xe Chu A
Esri, HERE, Garmin, NGA, USGS
Freshwater Health Index Tool 1.2.19219.1 *
Ecosystem Vitality
Water Quantity
Water Quality
Basin Condition
Biodiversity
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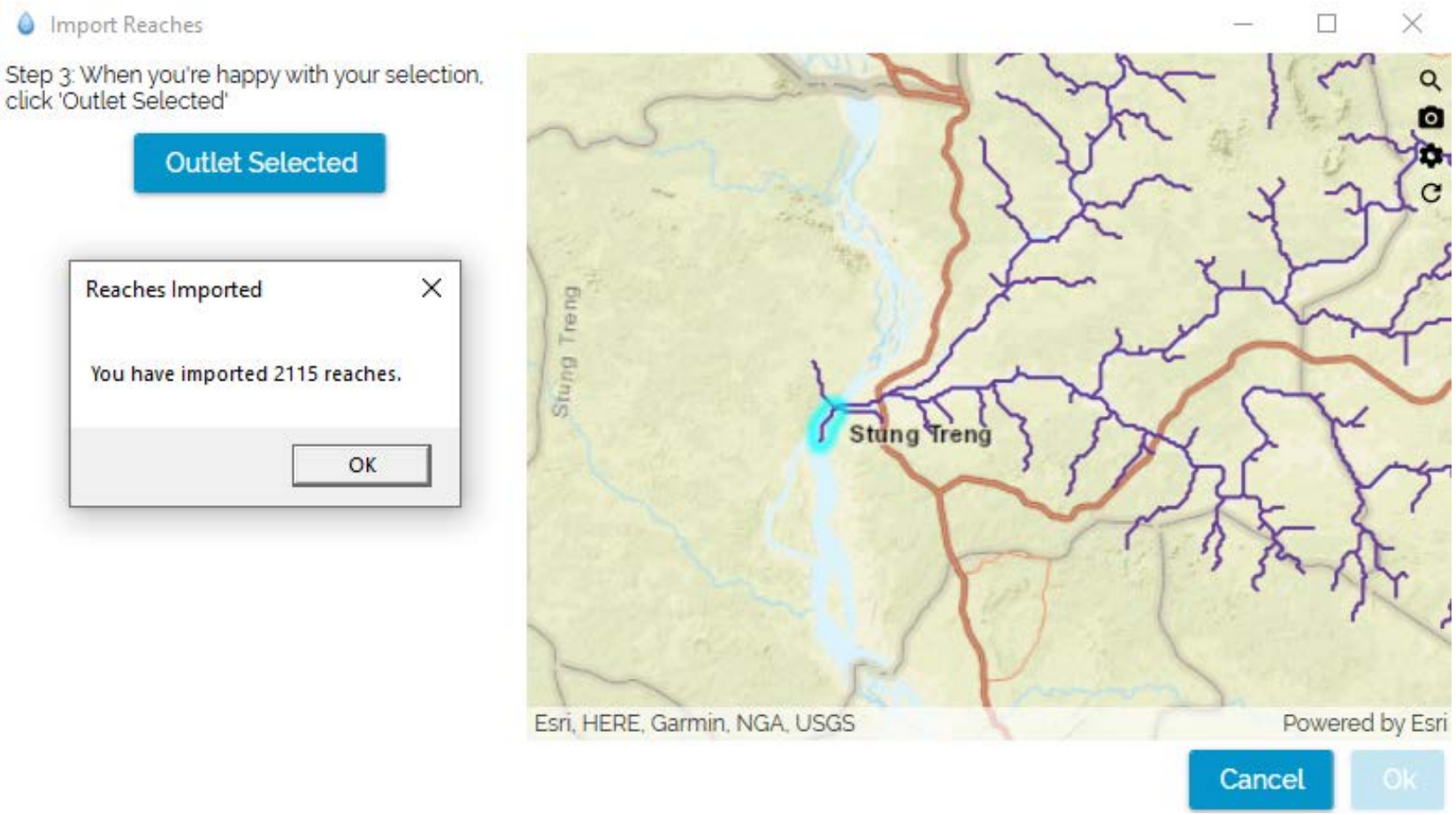
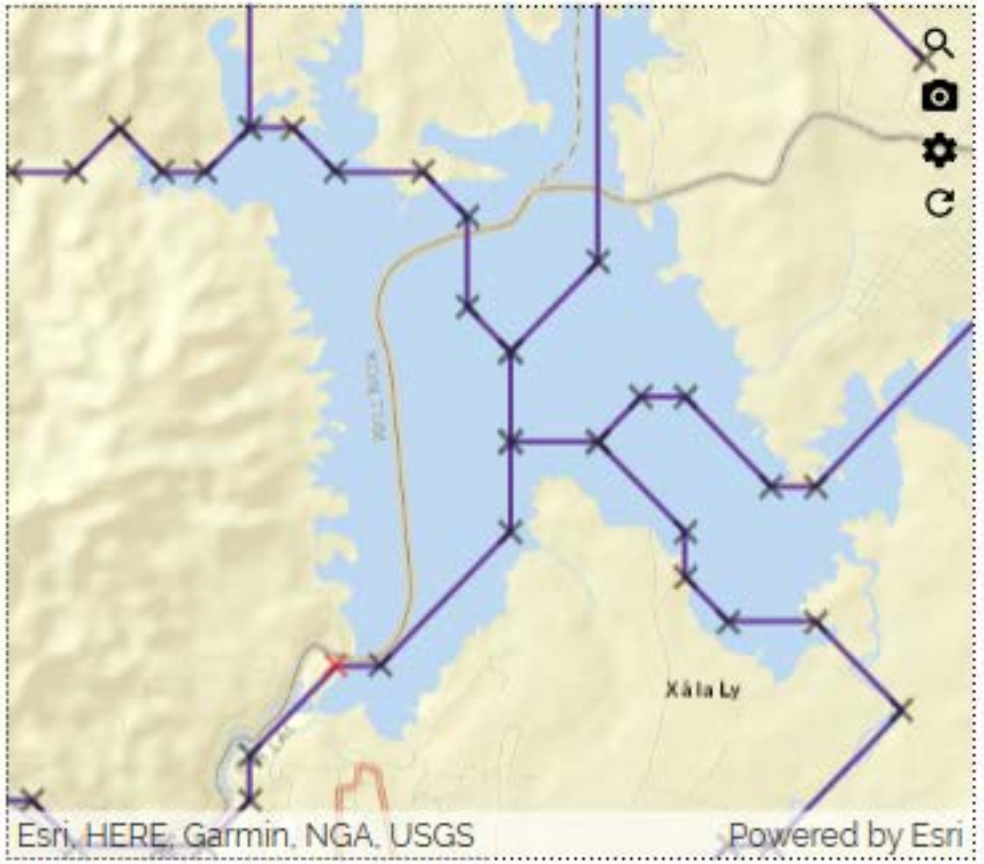
●●○○○○○○○○ (0.25)
Basin Condition
Channel Modification
(0.33)
Connectivity
(0.33)
Land Cover Naturalness
(0.33)

[1] Import Vector River Network



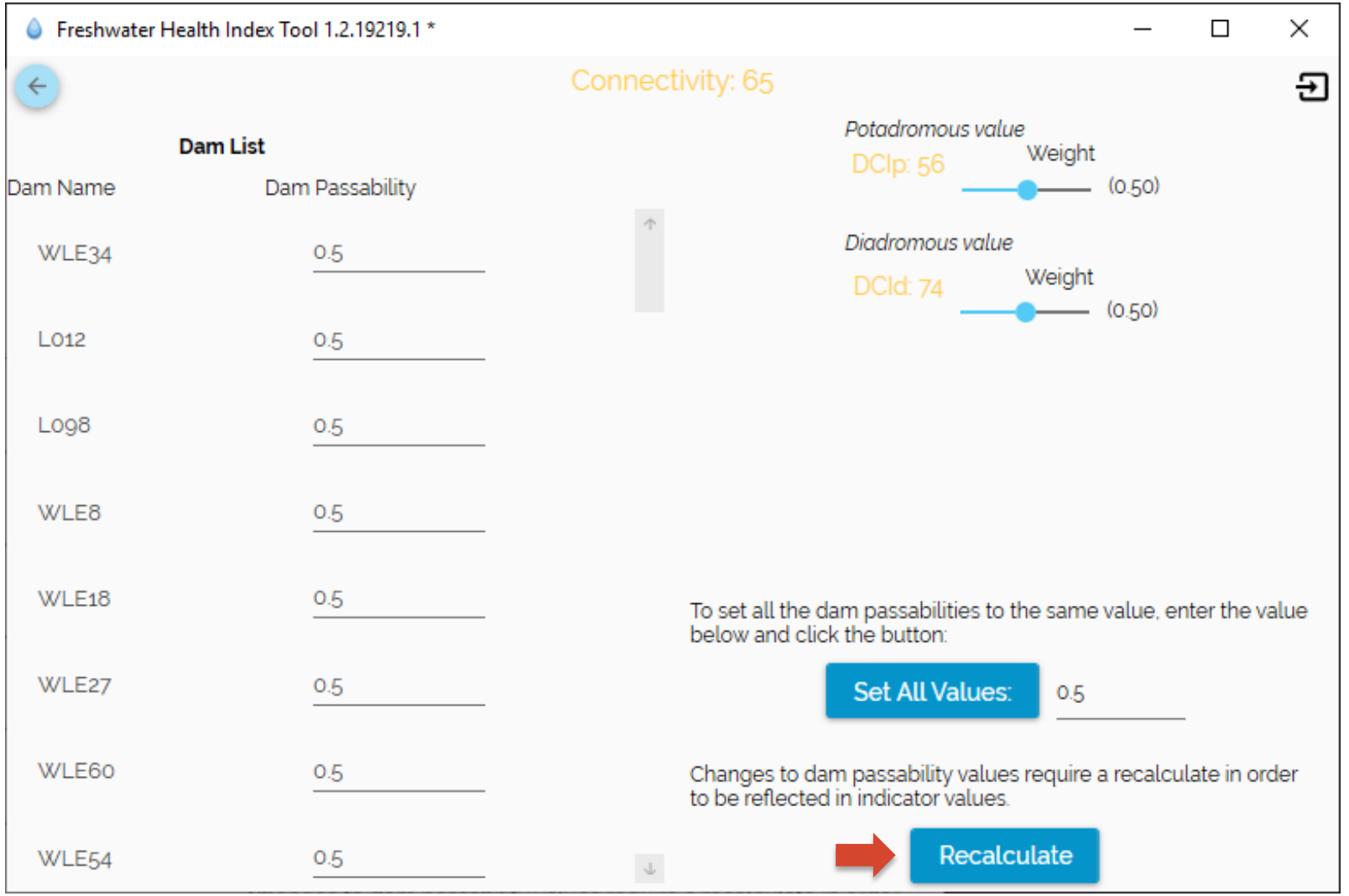
[2] Import Vector Barrier Location

You have imported your river network. The average length of a reach is 0.1m the maximum is 0.4 m and the minimum is 0.0m. with 2115 total reaches.
There are 59 dams in this river network.

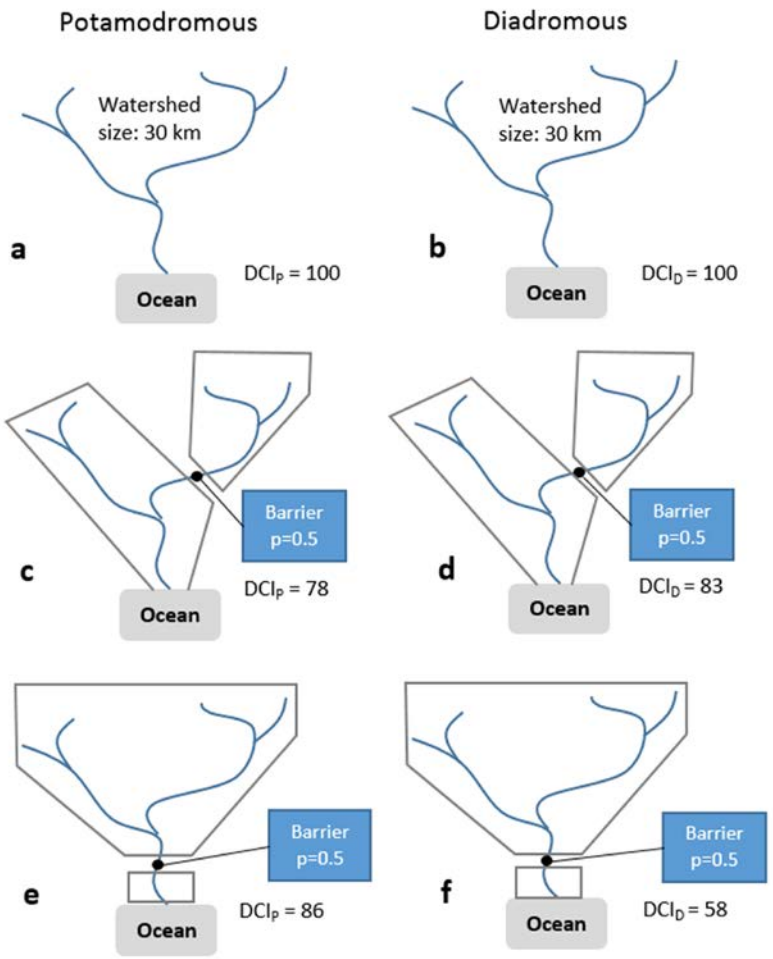


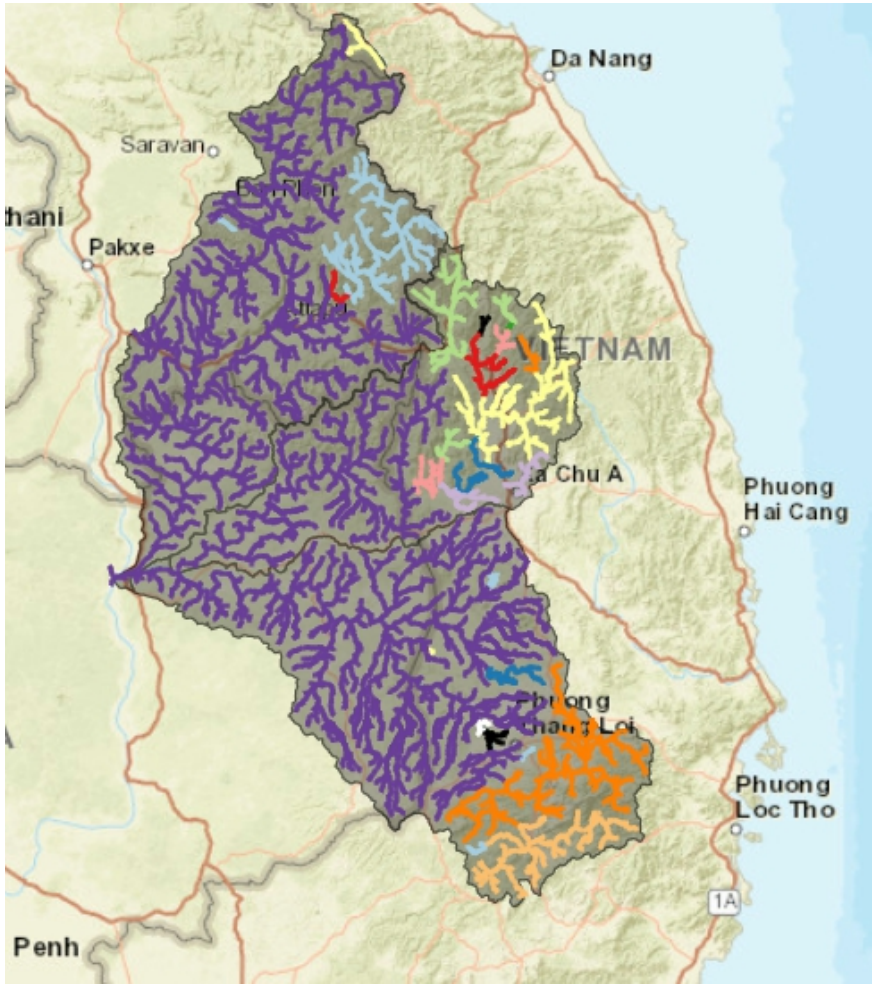
Cancel Back Done

[3] Apply “Passability” for Structures



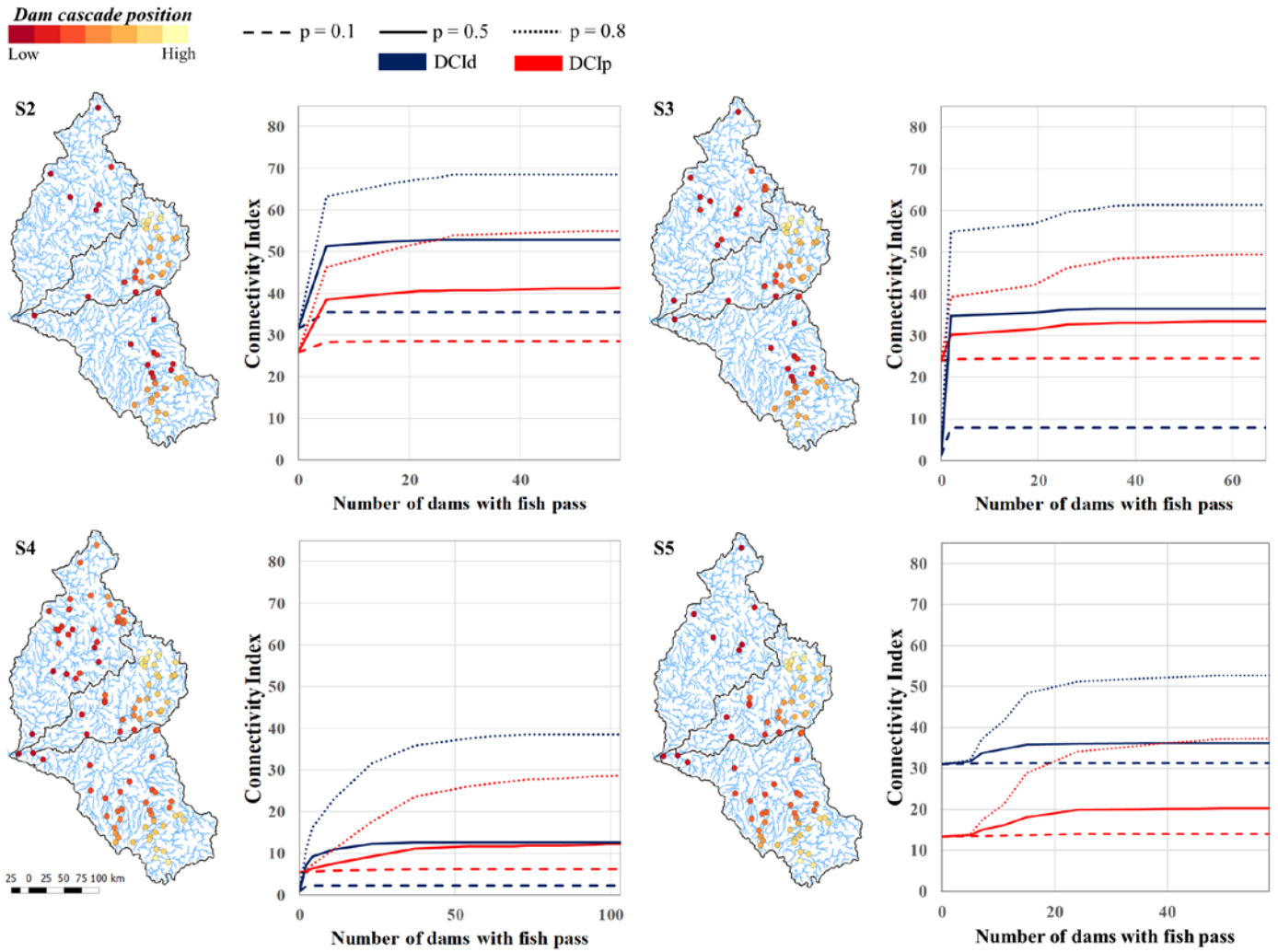
Dendric Connectivity Index





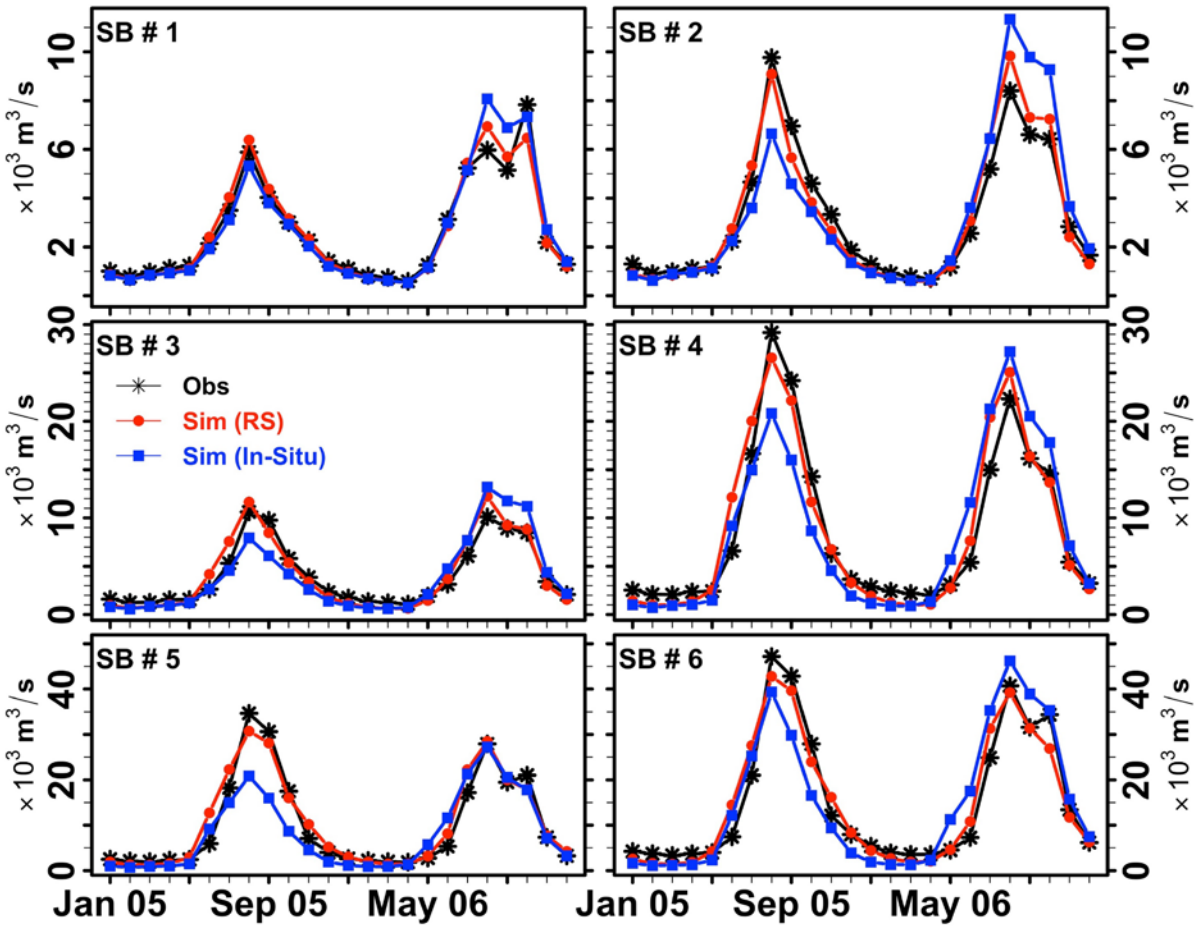
Reference: Cote, David, Dan G. Kehler, Christina Bourne, and Yolanda F. Wiersma. 2009. "A New Measure of Longitudinal Connectivity for Stream Networks." Landscape Ecology 24 (1): 101–13.

Indicators & Scenarios



Reference: Shaad et al (2018)."Evaluating the sensitivity of dendritic connectivity to fish pass efficiency for the Sesan, Srepok and Sekong tributaries of the Lower Mekong." Ecological Indicators 91: 570-574.

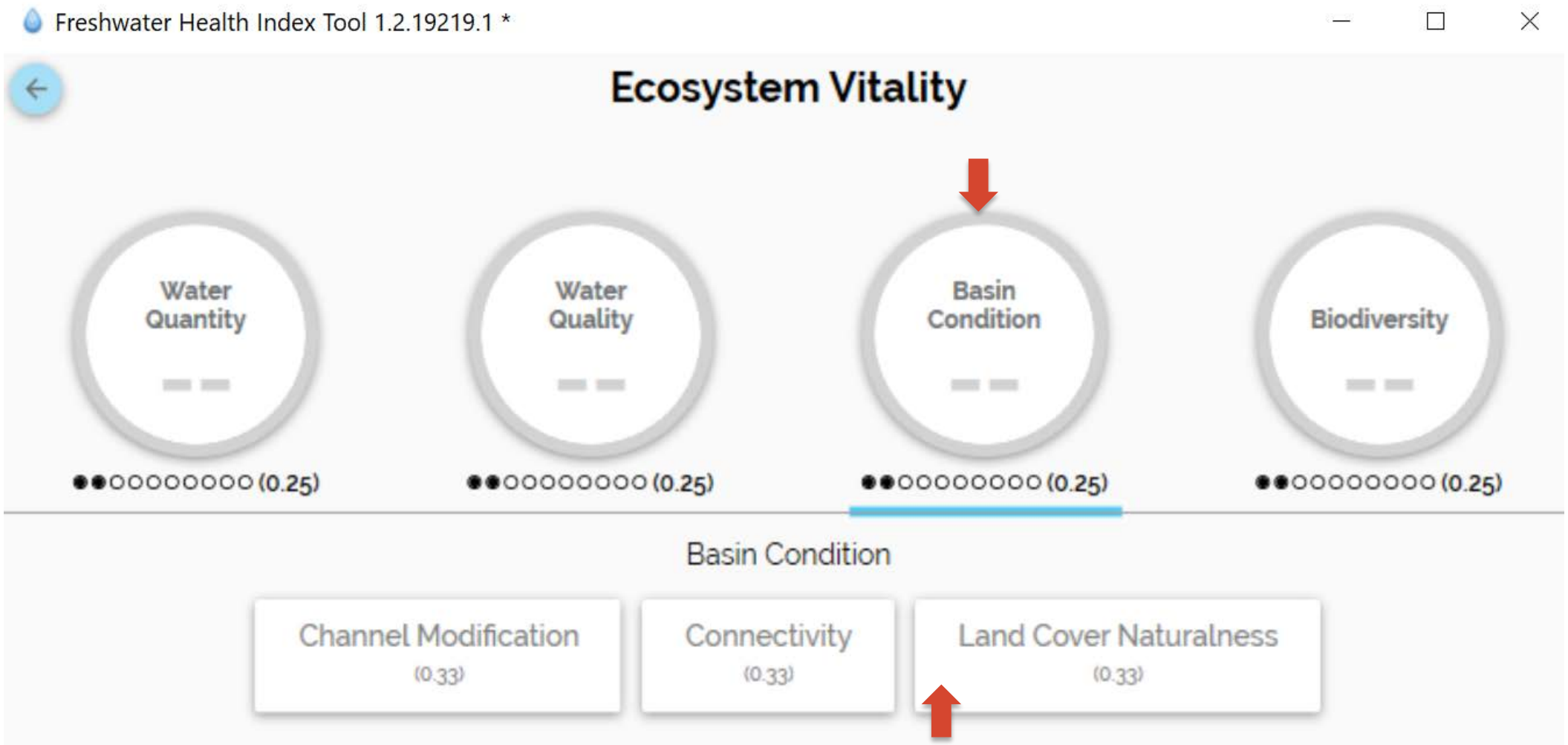
Hydrological Modelling Using Satellite-Based Earth Observations



- NASA has worked to calibrate and validate a hydrological model leveraging the proper utilization of available in situ and satellite-based Earth observations.
- These models attempt to compensate for insufficient coverage by local gauge data

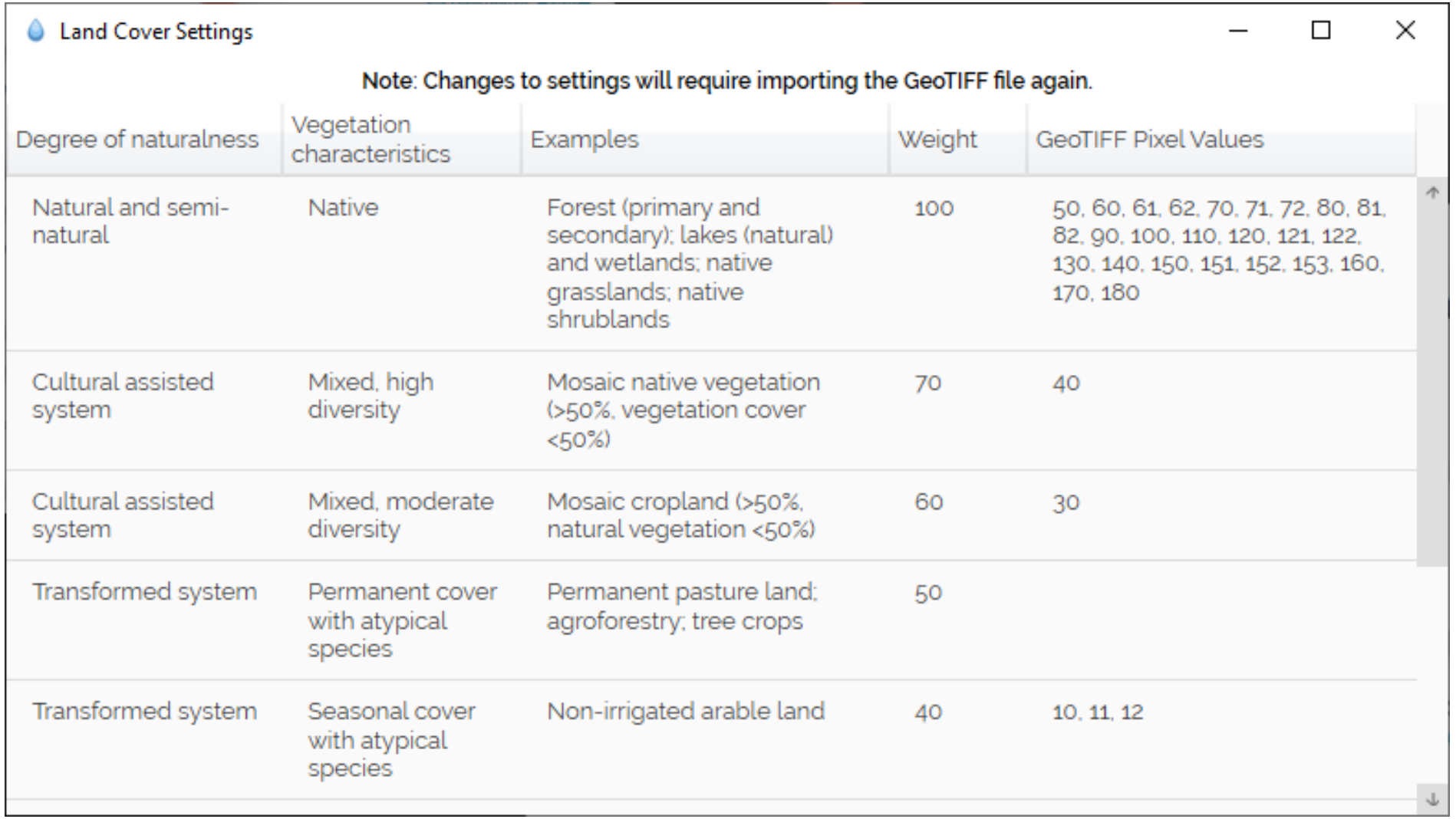
Reference: Mohammed, I.N. et al (2018). Improved Hydrological Decision Support System for the Lower Mekong River Basin Using Satellite-Based Earth Observations. Remote Sensing, 10 (6), 885

Drainage Basin Condition: Land Cover Naturalness



Reference: Machado, A. 2004. An index of naturalness. Journal for nature conservation, 12(2):95-110.

[1] Map Landcover Raster to “Degree of Naturalness”

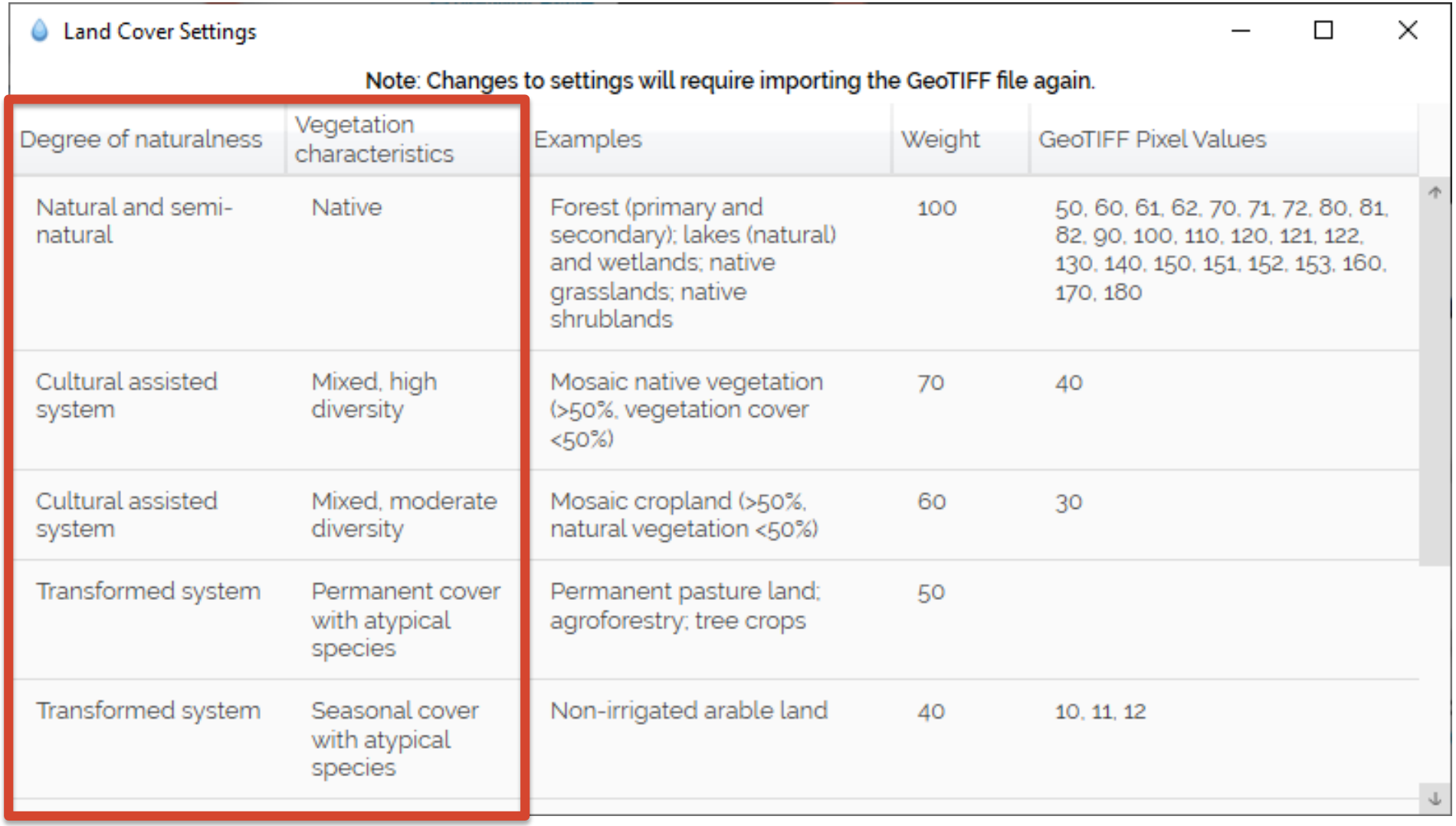


Land Cover Settings

Note: Changes to settings will require importing the GeoTIFF file again.

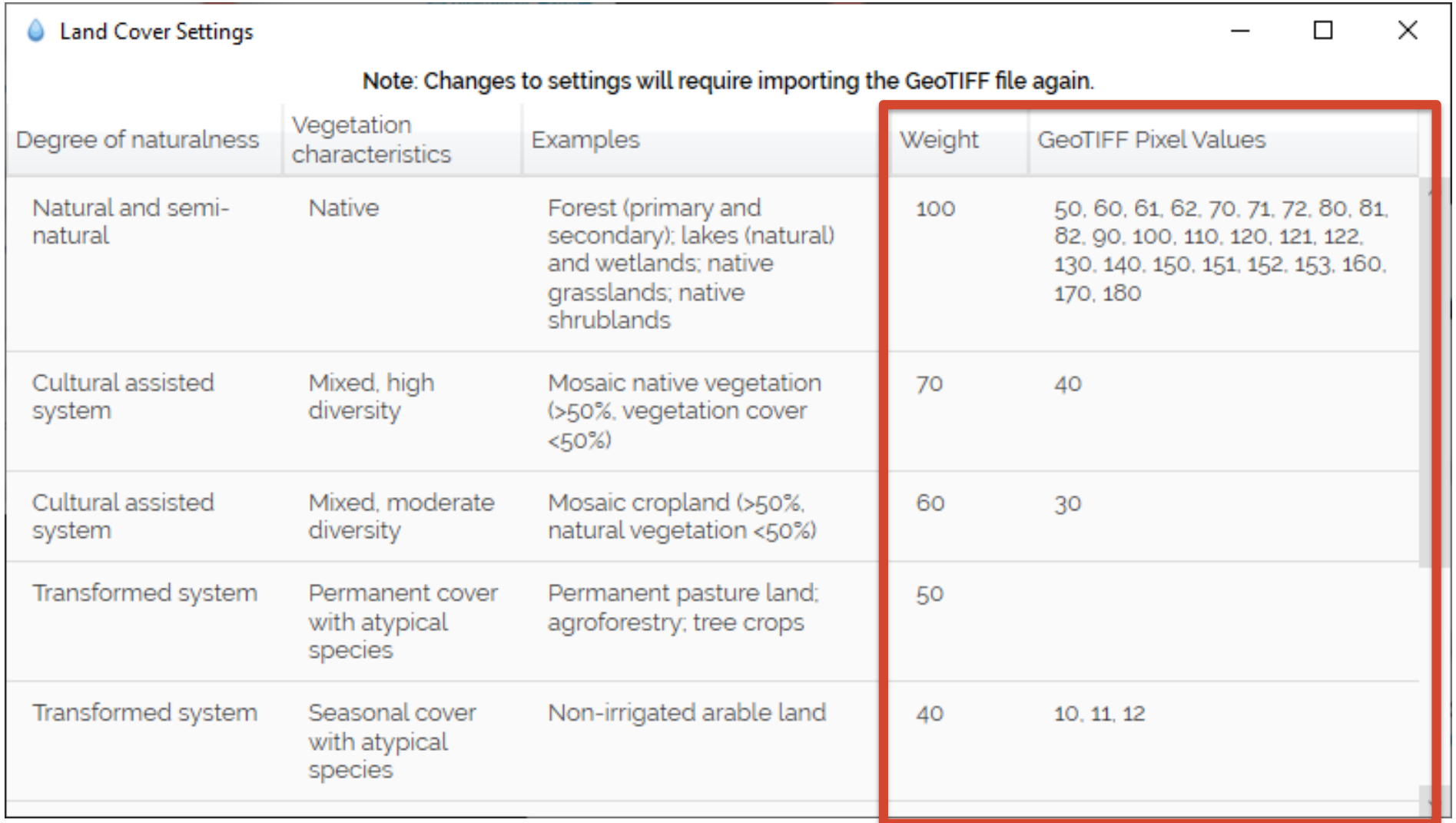
Degree of naturalness	Vegetation characteristics	Examples	Weight	GeoTIFF Pixel Values
Natural and semi-natural	Native	Forest (primary and secondary); lakes (natural) and wetlands; native grasslands; native shrublands	100	50, 60, 61, 62, 70, 71, 72, 80, 81, 82, 90, 100, 110, 120, 121, 122, 130, 140, 150, 151, 152, 153, 160, 170, 180
Cultural assisted system	Mixed, high diversity	Mosaic native vegetation (>50%, vegetation cover <50%)	70	40
Cultural assisted system	Mixed, moderate diversity	Mosaic cropland (>50%, natural vegetation <50%)	60	30
Transformed system	Permanent cover with atypical species	Permanent pasture land; agroforestry; tree crops	50	
Transformed system	Seasonal cover with atypical species	Non-irrigated arable land	40	10, 11, 12

[1] Map Landcover Raster to “Degree of Naturalness”



Degree of naturalness	Vegetation characteristics	Examples	Weight	GeoTIFF Pixel Values
Natural and semi-natural	Native	Forest (primary and secondary); lakes (natural) and wetlands; native grasslands; native shrublands	100	50, 60, 61, 62, 70, 71, 72, 80, 81, 82, 90, 100, 110, 120, 121, 122, 130, 140, 150, 151, 152, 153, 160, 170, 180
Cultural assisted system	Mixed, high diversity	Mosaic native vegetation (>50%, vegetation cover <50%)	70	40
Cultural assisted system	Mixed, moderate diversity	Mosaic cropland (>50%, natural vegetation <50%)	60	30
Transformed system	Permanent cover with atypical species	Permanent pasture land; agroforestry; tree crops	50	
Transformed system	Seasonal cover with atypical species	Non-irrigated arable land	40	10, 11, 12

[1] Map Landcover Raster to “Degree of Naturalness”



Degree of naturalness	Vegetation characteristics	Examples	Weight	GeoTIFF Pixel Values
Natural and semi-natural	Native	Forest (primary and secondary); lakes (natural) and wetlands; native grasslands; native shrublands	100	50, 60, 61, 62, 70, 71, 72, 80, 81, 82, 90, 100, 110, 120, 121, 122, 130, 140, 150, 151, 152, 153, 160, 170, 180
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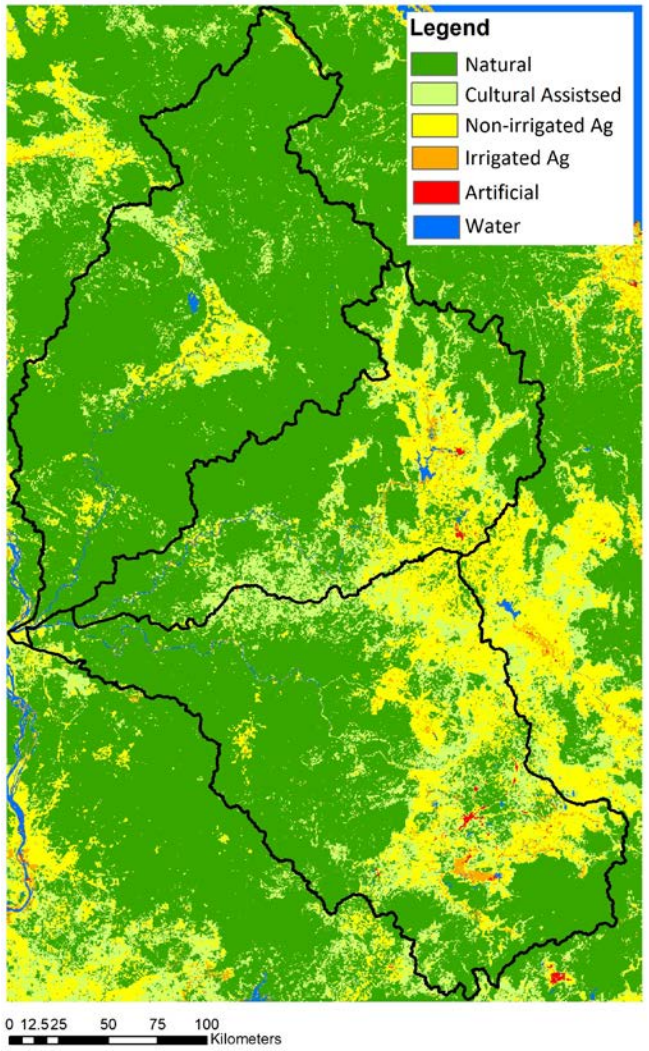
Transformed system	Permanent cover with atypical species	Permanent pasture land; agroforestry; tree crops	50	
Transformed system	Seasonal cover with atypical species	Non-irrigated arable land	40	10, 11, 12

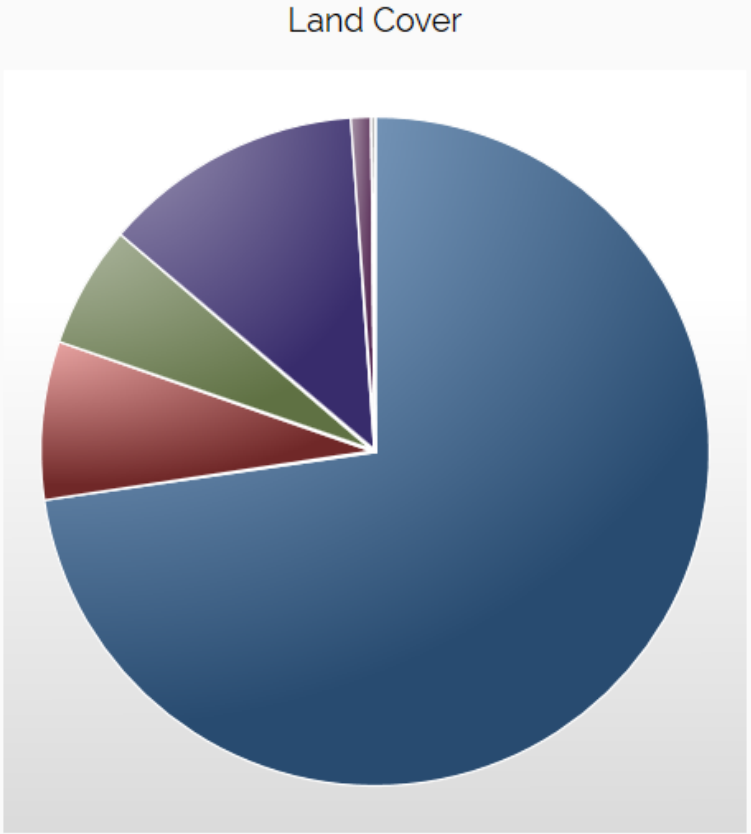
[2] Import Raster



Freshwater Health Index Tool 1.2.19219.1 *

Land Cover Naturalness: 87

Degree of naturalness / Vegetation	% Coverage
Natural and semi-natural: Native	72.7
Cultural assisted system: Mixed, high diversity	7.6
Cultural assisted system: Mixed, moderate diversity	5.9
Transformed system: Permanent cover with atypical species	0.0
Transformed system: Seasonal cover with atypical species	12.7
Transformed system: Seasonal cover with atypical species	1.0
Completely artificial: Sparse cover with grass	0.0
Completely artificial: None	0.2



Biodiversity: Species of Concern

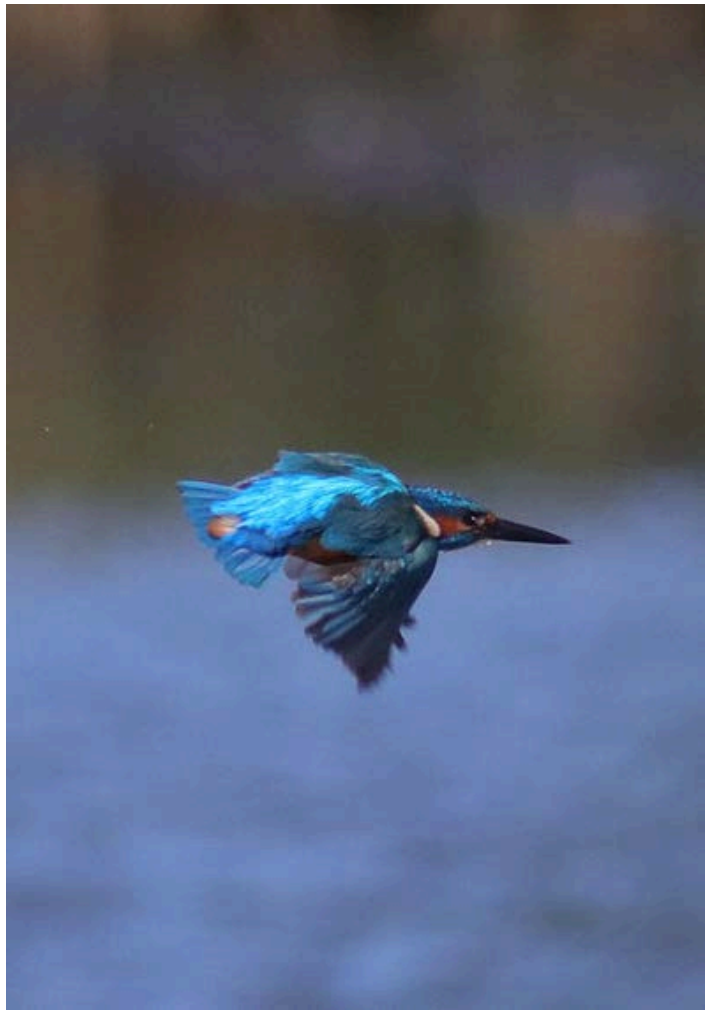


Image Credit: Kingfisher by Mark Kilner (Flickr)

- Threatened aquatic or riparian (water-dependent) species and other species of interest (such as keystone or umbrella species) that will be affected by changes in habitat condition.
- Assess species presence/absence and population trends.

3 STEP PROCESS

1. Assess **proportion of threatened and endangered freshwater species**, of the total freshwater species assessed in the basin

2. Assess **change in the number of species of concern**

3. Assess **change in population trends**

Ecosystem Services

Provisioning Services

Reliability of water supply

Biomass for consumption

Regulating Services

Flood Regulation

Deviation of water quality metrics

Sediment Regulation

Exposure to water-associated diseases

Direct tangible benefits from water-related Ecosystems

Indirect benefits and support from water-related Ecosystems

Ecosystem Services

Demand & Supply	Data Requirement
How much of the region has a gap between demand-supply?	Area Affected: Just a village or the whole province?
How often are the demands not met?	Duration Affected: Sometimes or all the time?
How large is the gap between demand and supply?	Extent of Gap: by a little or by a large amount?

Ecosystem Services

Initial estimates or diagnostic values can be derived using RS data of floods, droughts, water quality, etc.

Provisioning Services

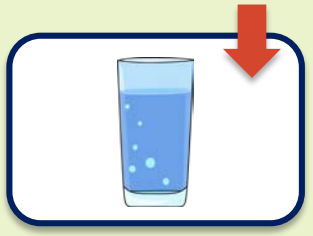
Reliability of water supply

Biomass for consumption

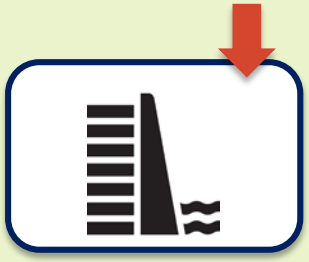
Direct tangible benefits from water-related Ecosystems

Regulating Services

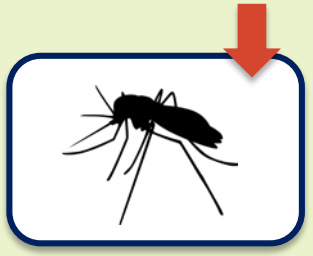
Flood Regulation



Deviation of water quality metrics



Sediment Regulation



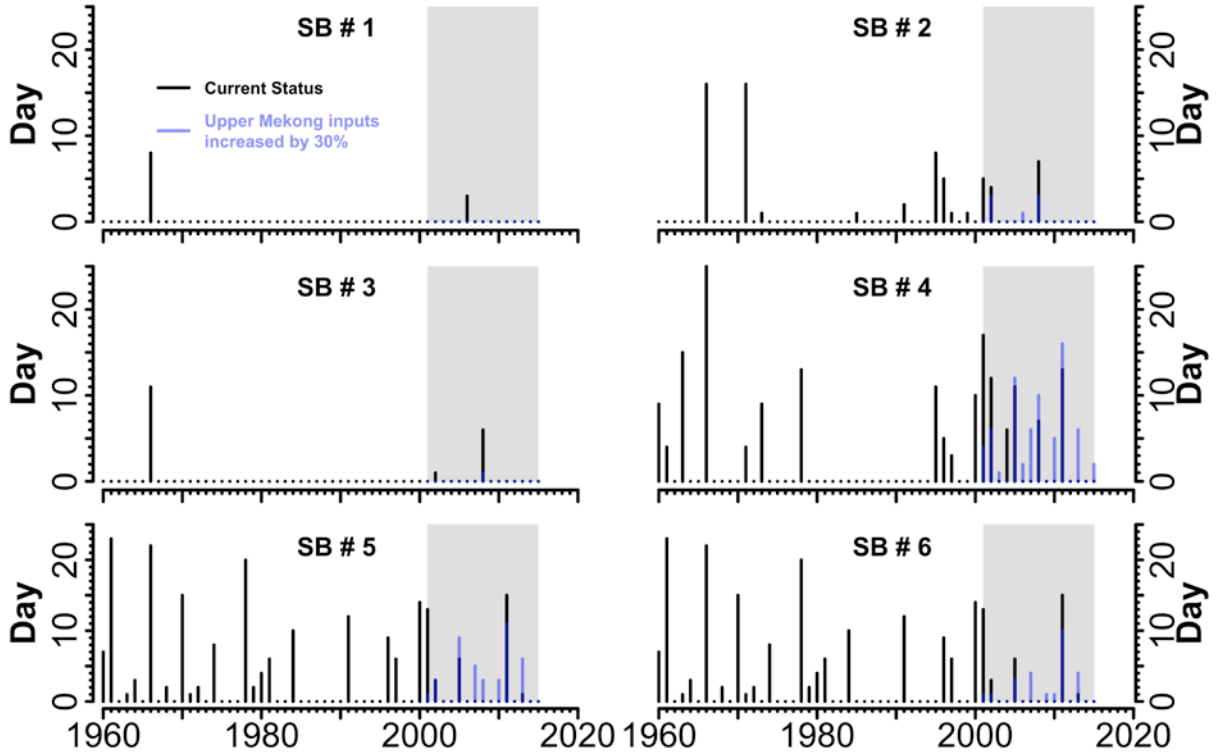
Exposure to water-associated diseases

Indirect benefits and support from water-related Ecosystems

High Flow Disturbance Analysis for the Lower Mekong River Basin

Flood Duration Analyses:

- The flood duration (in days) are the number of days when discharge equals or exceeds a threshold discharge magnitude causing floods.
- Black bars give flood duration in days for the 1960–2015 time period using observed discharges.
- Blue bars give flood duration calculated from simulated discharges with the Upper Mekong inflow increased by 30%



Reference: Mohammed, I.N. et al (2018). Satellite observations and modeling to understand the Lower Mekong River Basin streamflow variability. J. Hydrol. 564, 559-573

Summary

- Thinking of freshwater as a social-ecological system helps define water management goals beyond a narrow range of water requirement objectives and consider the inherent long and short terms trade-offs within a basin.

- The Freshwater Health Index draws on a wide range of products available via remote sensing, GIS and numerical models. These, in combination with local knowledge and data, help communicate the state of the freshwater system to stakeholders via simplified metrics.

- The FHI desktop tool is a recent effort to provide a platform to calculate and collate basin-level social-ecological indicators for freshwater.

Contacts

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- General ARSET Inquiries
  - Ana Prados: aprados@umbc.edu
- ARSET Website:
  - http://arset.gsfc.nasa.gov

National Aeronautics and Space Administration

Homework Due: Tuesday October 15th

Amber McCullum & Juan Torres-Pérez

1 October, 2019


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Thank You!