International WaterCentre

Asian Water Development Outlook 2020: KD4 Environmental Water Security

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Overview of KD4 – environmental water security

“The environmental water security indicator assesses the health and pressures on rivers, wetlands and groundwater systems and measures progress on restoring aquatic ecosystems to health on a national and regional scale”

- What is river health and what defines a healthy aquatic ecosystem system?
- Many definitions and benchmarks of an “unhealthy” and “healthy” aquatic ecosystem system
    - Safe water for human skin contact or safe to drink without treatment?
    - Safe for vulnerable native fish species or only robust species (e.g. tilapia)?

Ecosystem health and water security

Good environmental management ensures healthy ecosystems provide ecosystem services that increase water security

Bad environmental management reduces ecosystem services provided by a healthy aquatic system

Good environmental management generally also contributes to food security

Ecosystem services that increase water security

A headwater stream in Puerto Rico

[Freshwaters Illustrated](https://vimeo.com/162427775)
https://vimeo.com/162427775

Ecosystem services that increase water security

A headwater stream in Puerto Rico

- Abundant shrimp clean the water
  - Filtering and sweeping

Freshwaters Illustrated
https://vimeo.com/162427775

Ecosystem services that increase water security

A headwater stream in Puerto Rico

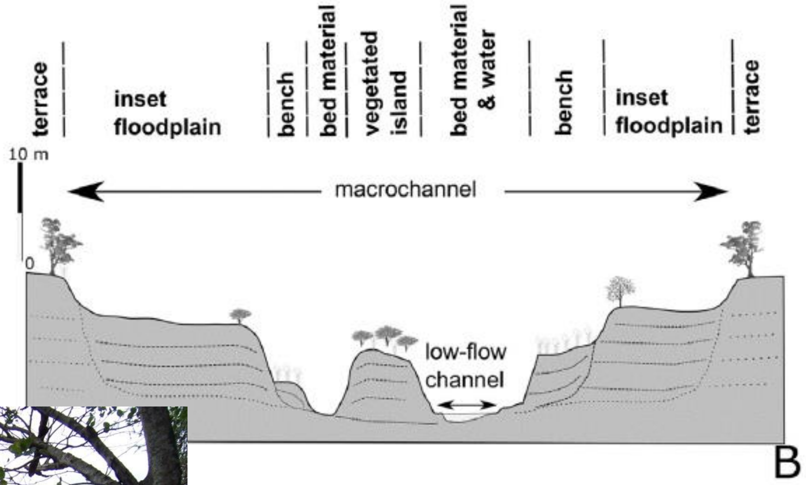
The shrimp “clean up the water, filter feeding out a lot of organic material and turning it into shrimp which turns it into fish food…and they’re working 24 hours a day 7 days a week at no cost…”

“For this system to work in the mountains and for water quality to be available to the public outside the forest, outside the mountains, have to have connectivity, for shrimp to migrate upstream and downstream.”

[Freshwaters Illustrated](https://vimeo.com/162427775)
https://vimeo.com/162427775

Poor environmental management that decrease water security

- October 2013 – Brisbane water supply hours away from shut down because of sedimentation due to poor catchment management



A “healthy” stream

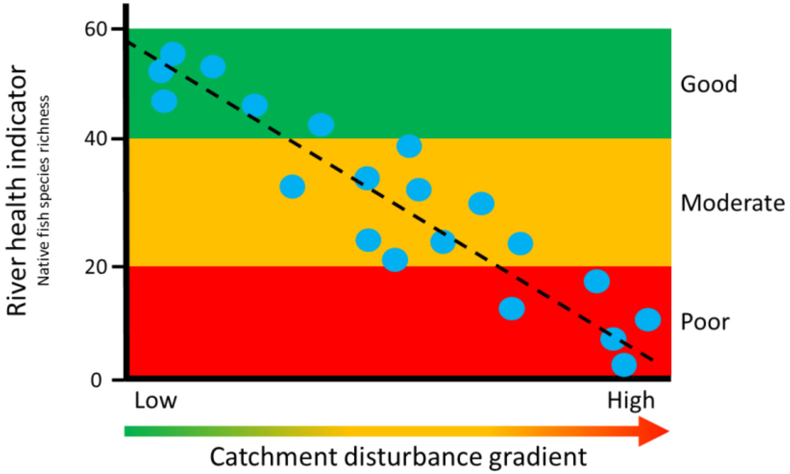
- Few stressors
  - Limited agricultural activity
  - Intact catchment and riparian vegetation
  - Unaltered flow regime
- Ecological outcomes
  - Nutritious algal growth
  - Good water quality
  - Diverse micro-habitats
  - High species richness

An “unhealthy” stream

- Many stressors
  - Increased nutrient inputs from fertiliser
  - Catchment and riparian vegetation removed
  - Altered hydrology from upstream dam
- Ecological outcome
  - Algal bloom in stagnant water
  - Poor water quality
  - Deeply incised channel with limited fish habitat
  - Reduced species richness

Quantifying aquatic ecosystem health

- Usually requires significant effort to define and monitor
  - Example indicators of river health from South-East Queensland, Australia
    - Fish
    - Macro-invertebrates
    - Ecosystem processes
    - Water quality
    - Instream nutrients
  - Each respond to ecosystem changes that impact a river and indicate the change in the “health” of the river
  - In other parts of Australia, different collections indicators are used
    - Difficult to obtain comparable observed data within countries, let alone across countries.



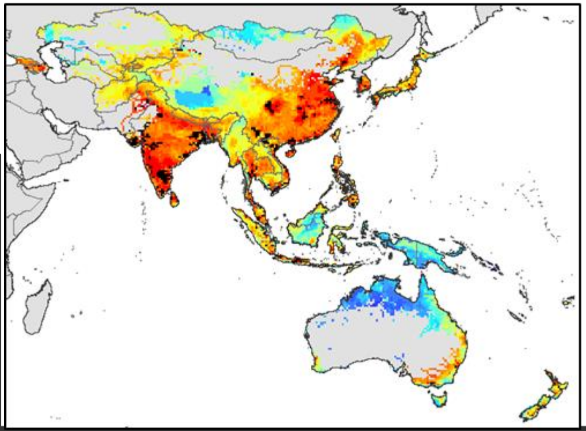
Challenges for KD4 across AWDO countries

- Several challenges exist for KD4 to assess "the health of rivers and measures progress on restoring rivers and ecosystems to health"
  - Lack of consistent river health indicator data available within and between countries.
  - Different expectations of what constitutes an acceptably "healthy" river

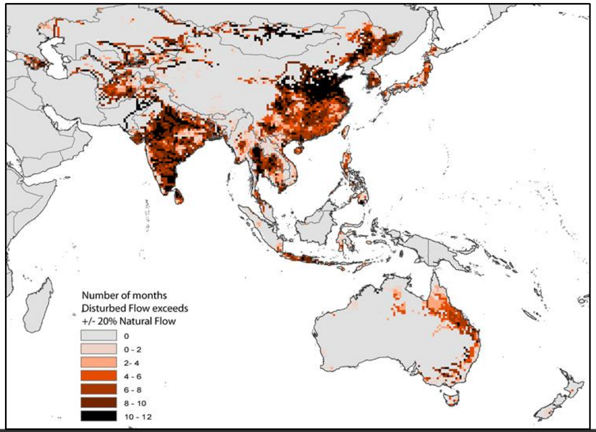
Methodology and datasets for KD4 in AWDO 2016

- To overcome these challenges we previously relied on surrogate indicators and models
  - River health index
    - Statistical model estimating impact of urban development, agricultural and general economic activity
  - Hydrologic alteration
    - Ensemble of five global hydrology models quantifying changes to river flow
  - Governance of the environment
    - Four indicators of country level governance, collated by Yale University

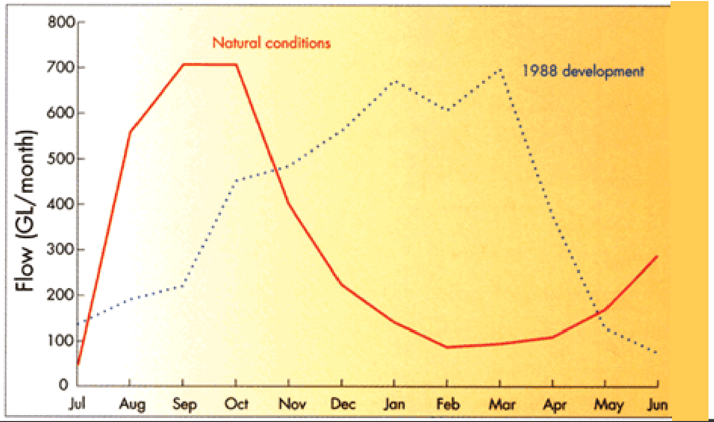
River Health Index



Hydrologic alteration



Example altered hydrograph



Limitations of KD4 methodology – AWDO 2016

- Statistical model for River Health Index does not directly measure river health
  - RHI can be viewed as a *risk map* that identifies areas of greatest pressure on river health

- Statistical model of River Health Index does not account for mitigation efforts
  - RHI provides guidance on where to invest in restoration measures (a key component of the definition of KD4), such as riparian restoration and environmental flow management that can offset impacts on river health

AWDO 2020 – new sub-indicators for KD4

- To overcome these challenges and develop a holistic indicator of the health and pressures on ecosystems in the region we use two Indices, each with several sub-indicators
  - The **Catchment and Aquatic System Condition Index** is a synthesis of the following sub-indicators
    1. Riparian tree cover loss
    2. Groundwater depletion
    3. Hydrological alteration
    4. Coastal sedimentation
  - The **Environmental Governance** index brings together the following sub-indicators from Yale Environmental Performance Index
    1. Wastewater treatment
    2. Terrestrial protected areas – percentage of land area that is protected in the country
    3. Sustainable nitrogen management index – nitrogen use efficiency to quantify how much nitrogen enters the environment

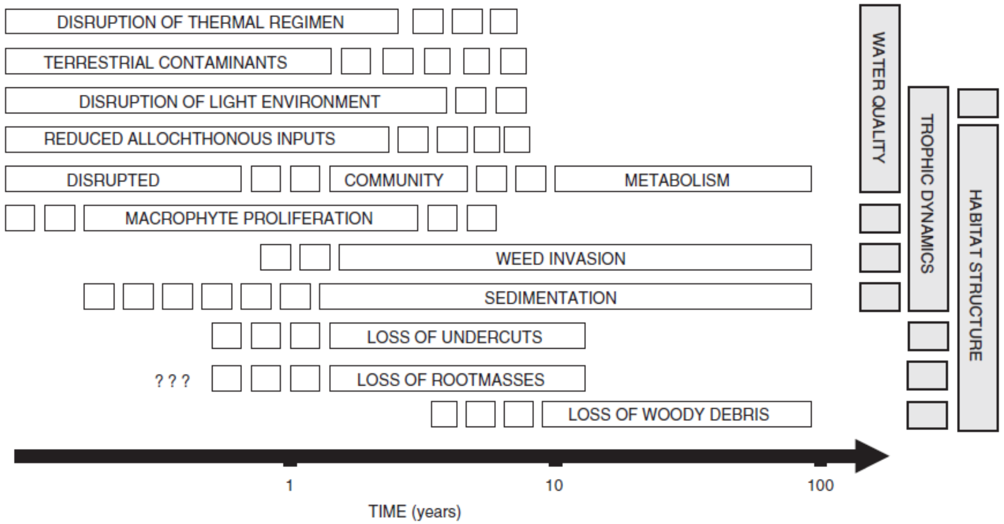
Catchment and Aquatic System Condition Index

- The index is a synthesis of the following sub-indicators
  1. Riparian tree cover loss
     - Known influence on aquatic ecosystem condition
  2. Groundwater depletion
     - Direct measurement of sustainability of groundwater extraction
  3. Hydrological alteration
     - Known influence on aquatic ecosystem condition
  4. Coastal sedimentation
     1. Indicator of unsustainable catchment management and impact of development of dams

- Quantify the extent and trend of tree cover loss within 100m of river channels and wetlands in each country

Importance of the riparian zone to the conservation and management of freshwater fish: a review

Bradley J. Pusey[A,B] and Angela H. Arthington[A]



POLICY DIRECTION

Journal of Applied Ecology BRITISH ECOLOGICAL SOCIETY

Riparian buffers in tropical agriculture: Scientific support, effectiveness and directions for policy

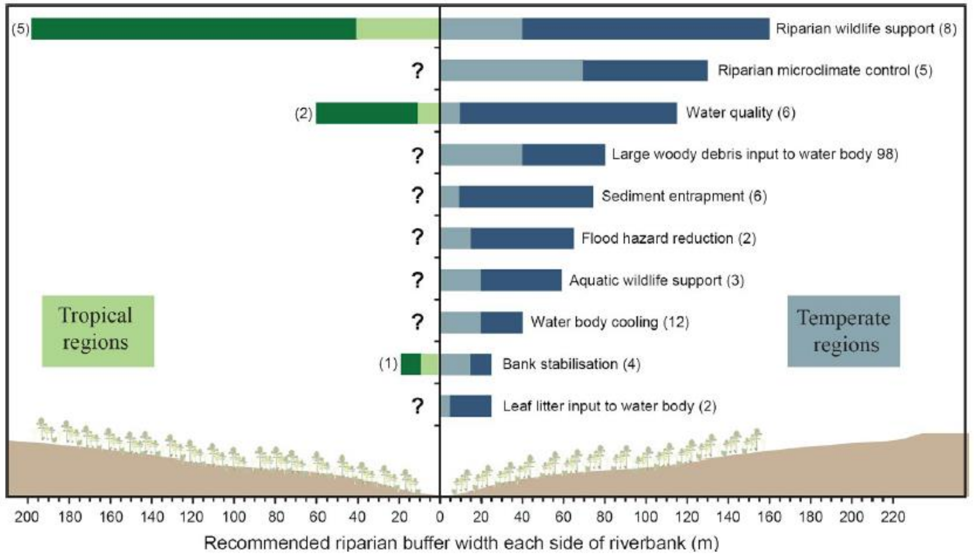
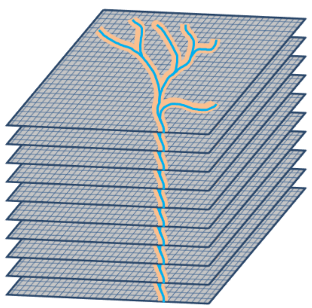


FIGURE 1 Minimum (light shading) and maximum (dark shading) riparian buffer widths recommended to protect riparian functions in

The Catchment and Aquatic System Condition Index: Riparian tree cover loss

- Quantify the extent and trend of tree cover loss within 100m of river channels and wetlands in each country
    - Hansen et al. (2013) High-resolution global maps of 21st-century forest cover change, *Science*, **342**.
- Calculate the approximate area (km^2) of annual tree cover loss from 2001-2018:
    - within 100m of the permanent water bodies (rivers and wetlands) and
    - within the maximum extent of inundated areas plus 100m around this extent.
- Annual losses are converted to the percentage of total riparian forest that has been lost
    - The first sub-score is derived from the total riparian forest loss
- Calculate the proportion of forest that was lost in the last five years
    - The second sub-score is derived from the proportion lost in the last five years.



Annual riparian forest loss

Extent of annual riparian forest loss

Year	Loss (km^2)
2001	100
2002	200
2003	150
...	
2016	400
2017	290
2018	450

Proportion of total riparian forest

Year	FL/TF
2001	0.42
2002	0.43
2003	0.32
...	
2016	2.23
2017	1.9
2018	1.18
Total lost	16.5%

Sub-score 1:
Percentage of lost riparian forest

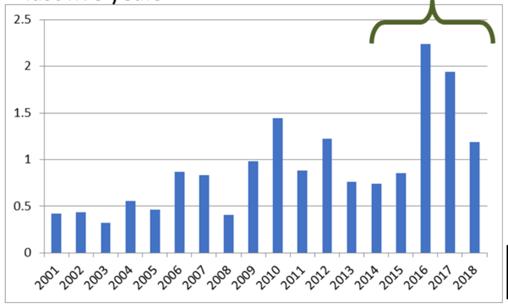
Percentage lost	Sub-indicator score
<22	5
(22.1,36)	4
(36.1,54)	3
(54.1,71)	2
>71	1

Sub-score 1:

16.5	5

Sub-score 2:
Proportion of total lost in last five years

$$\sum_{i=2015}^{2018} FL_i \Big/ \sum_{i=2001}^{2018} FL_i$$



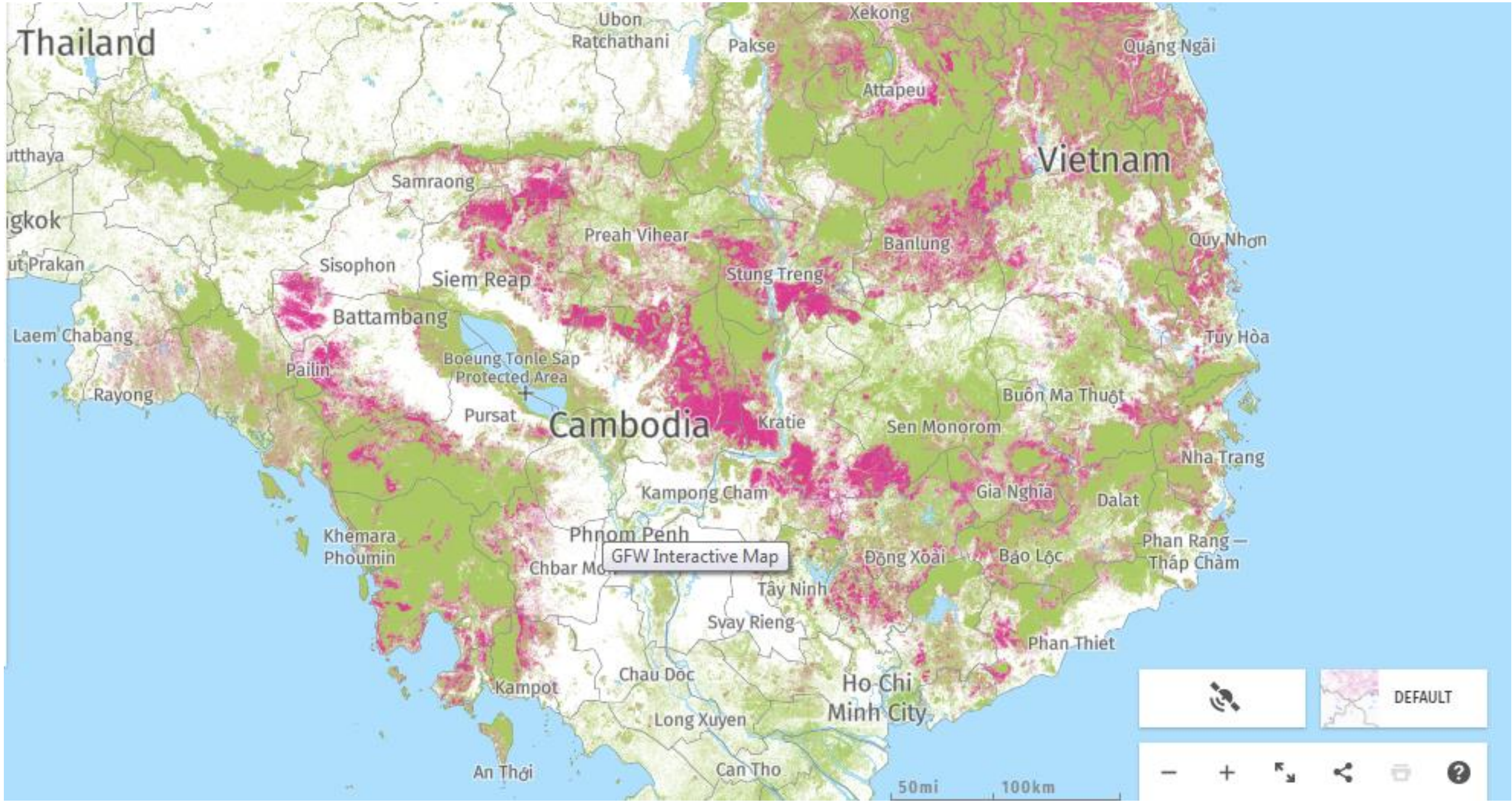
$6.9/16.5 = 0.42$

Proportion in last five years	Sub-indicator score
<0.22	5
(0.221,0.36)	4
(0.361,0.54)	3
(0.541,0.71)	2
>0.71	1

Sub-score 2:

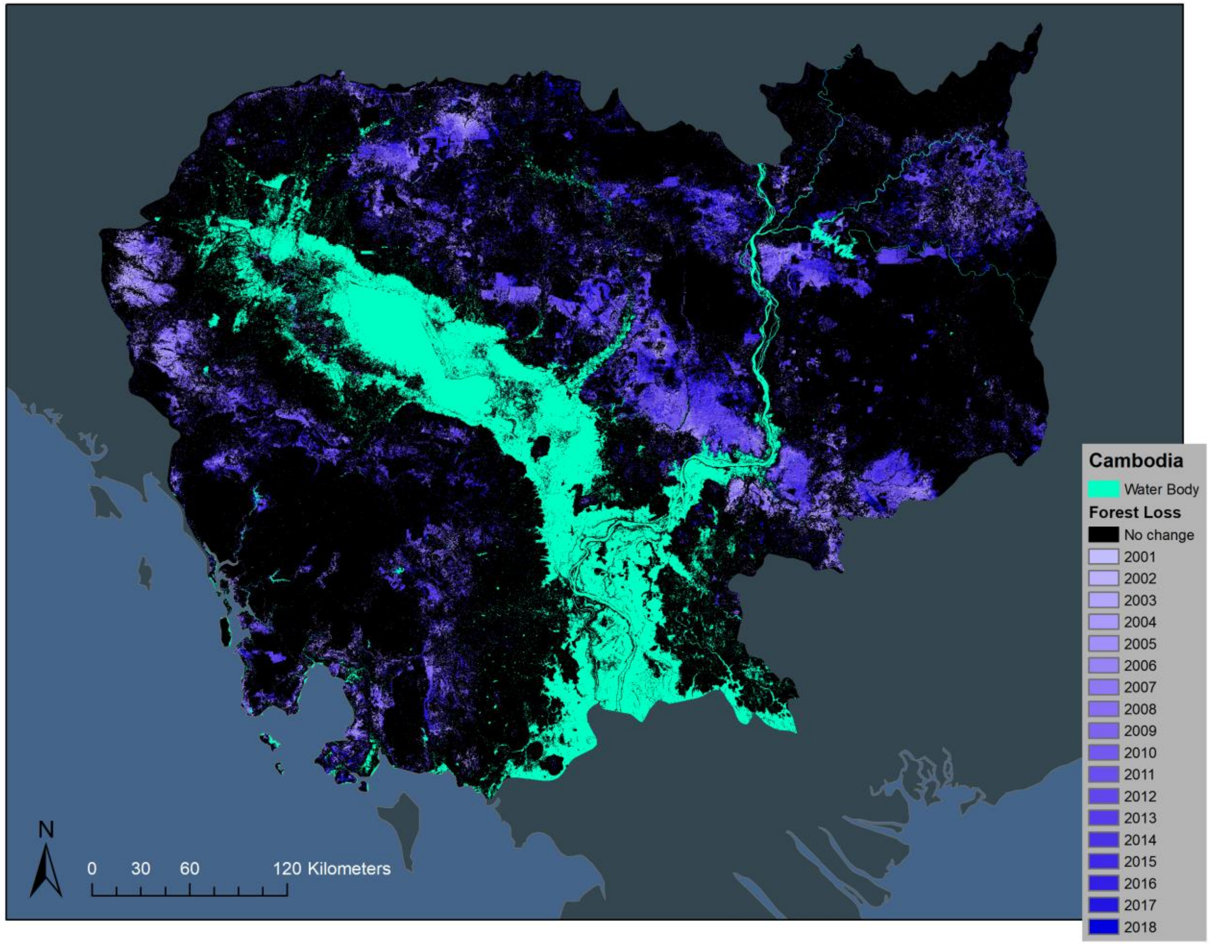
0.42	3

Forest loss: 2000, 2007, 2012, 2018



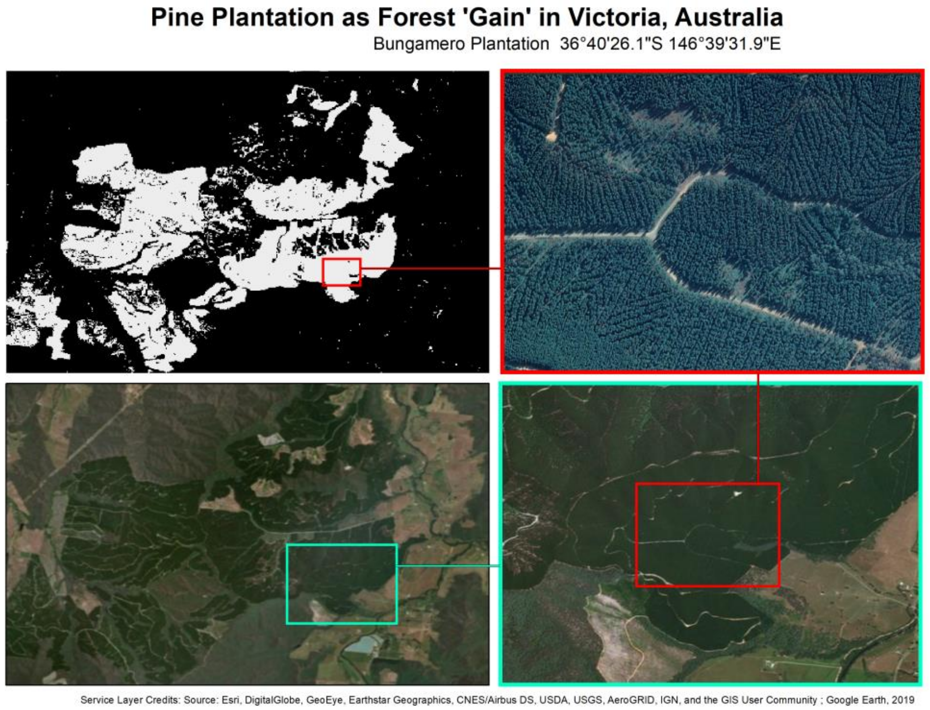
Forest loss and maximum inundation extent in Cambodia

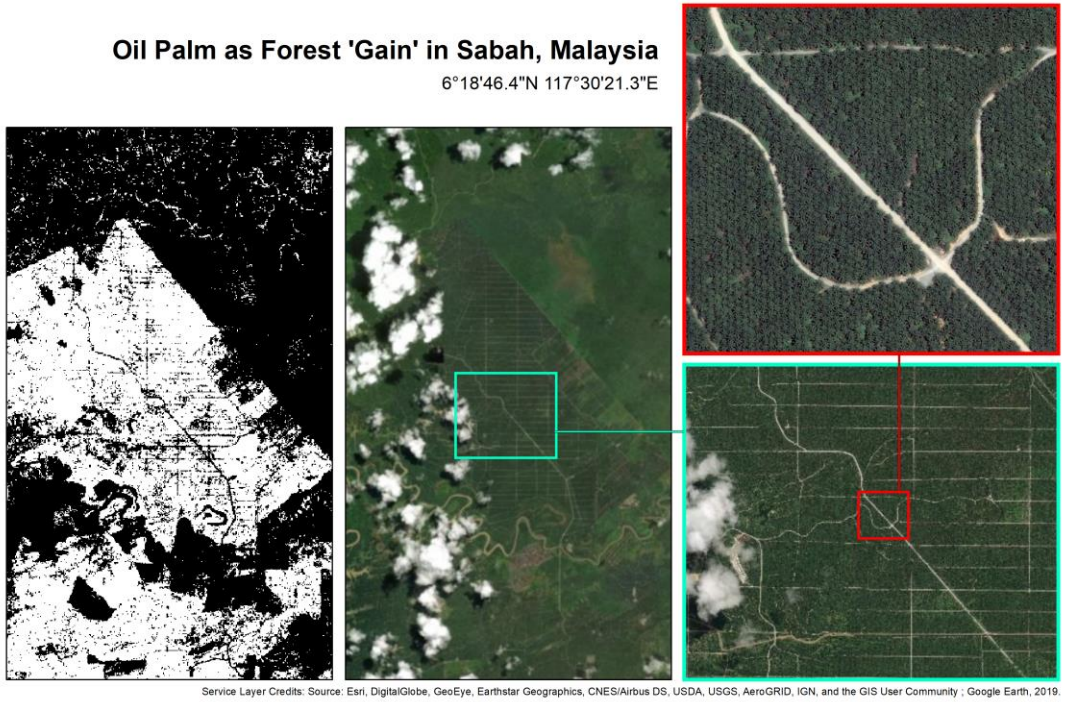
	Total Riparian forest			
	5243.51			
	Area lost (KM)	Percentage lost		
2001	25.79	0.49		
2002	16.01	0.31		
2003	31.77	0.61		
2004	36.77	0.70		
2005	20.10	0.38		
2006	60.53	1.15		
2007	41.05	0.78		
2008	30.06	0.57		
2009	69.63	1.33		
2010	88.85	1.69		
2011	59.17	1.13		
2012	90.70	1.73		
2013	30.59	0.58		
2014	37.11	0.71		
2015	29.82	0.57		Loss in last five years
2016	115.39	2.20		5.13
2017	70.29	1.34		
2018	16.26	0.31		
Total losses	869.91	**16.59**		**0.31**
	Sub-scores	**5**		**4**



European Commission Global Surface Water Data (Pekel et al. 2016)

- Why not use forest gain?
  - Forestry plantations in general and oil palm plantations in particular have been shown to have a range of adverse impacts on aquatic ecosystem health (Gharibreza et al., 2013; Juen et al, 2016).





Catchment and Aquatic System Condition Index

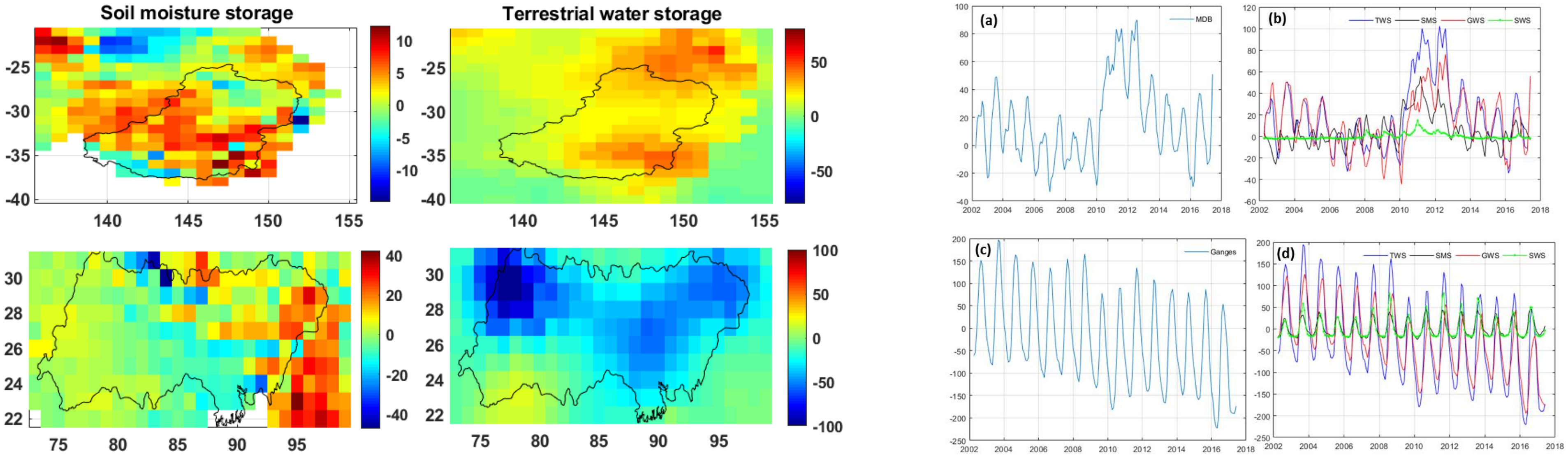
- The index is a synthesis of the following sub-indicators

1. Riparian tree cover loss
   - Known influence on aquatic ecosystem condition
2. Groundwater depletion
   - Direct measurement of sustainability of groundwater extraction
3. Hydrological alteration
   - Known influence on aquatic ecosystem condition
4. Coastal sedimentation
   1. Indicator of unsustainable catchment management and impact of development of dams

- Extract key components from the Gravity Recovery and Climate Experiment (GRACE) to determine trends in groundwater storage
  - Unsustainable groundwater use is a long-term problem in itself, however, also key effects on aquatic ecosystems

Murray-Darling Basin

Ganges-Brahmaputra Basin



Goddard Earth Sciences Data and Information Services Center (GESDICS) (http://grace.jpl.nasa.gov/data/gldas/)
Gravity Recovery and Climate Experiment (GRACE) for the period 2002-2016 (data files accessed at http://icgem.gfz-potsdam.de/ICGEM/shms/monthly/csr-rl05/)

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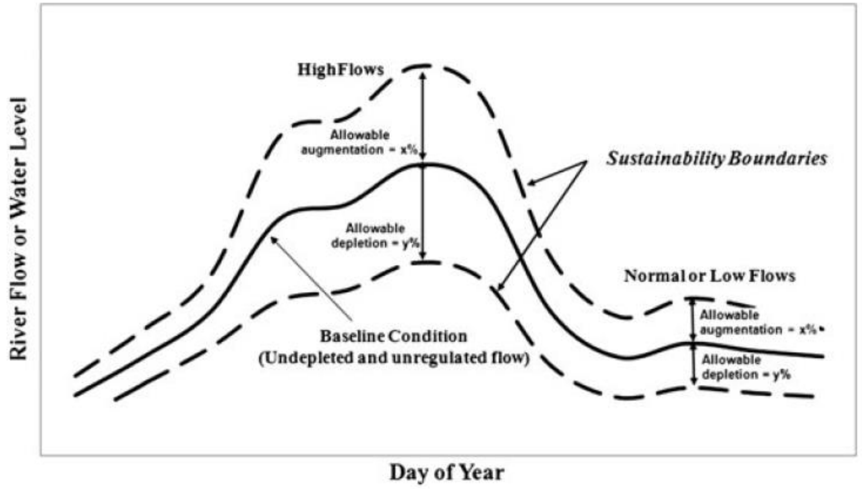
- The indicator for hydrologic alteration uses modelled river flow from the water balance model runs using the TerraClimate data of monthly climate forcings (Abatzoglou, et al 2018)

RIVER RESEARCH AND APPLICATIONS
River Res. Applic. **28**: 1312–1321 (2012)

A PRESUMPTIVE STANDARD FOR ENVIRONMENTAL FLOW PROTECTION

B. D. RICHTER,[a*] M. M. DAVIS,[b] C. APSE[c] and C. KONRAD[d]

- The monthly river flow is considered "hydrologically altered" if flows are more than 20% different from pristine
  - developed as a presumptive indicator of "moderate to major" ecological impact on river systems (Richter et al. 2012)



Catchment and Aquatic System Condition Index: Hydrological alteration

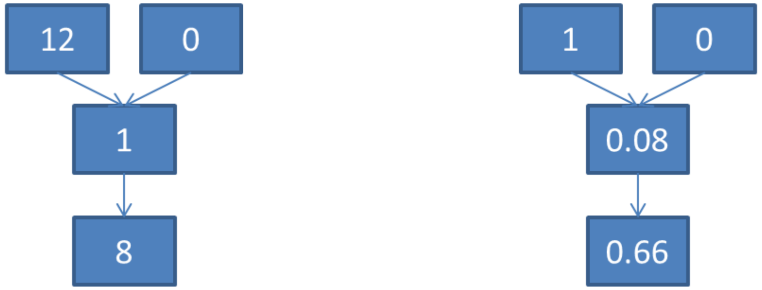
- Proportion of grid cells with flowing water in a country where observed monthly discharge is more than 20% different from pristine discharge weighted by the number of months this occurs
  - Less stringent that AWDO 2016.

Average proportion	Sub-indicator score
<0.22	5
(0.221, 0.36)	4
(0.361, 0.54)	3
(0.541, 0.71)	2
>0.71	1

Hypothetical country with a single river comprised of four pixels

Number of months actual flow in each pixel is >20% different from natural flow

Proportion of months actual flow in each pixel is >20% different from natural flow



Score is average of proportion of months in each pixel where flow is altered:

$(0 + 1 + 0.08 + 0.66)/4 = 0.435$

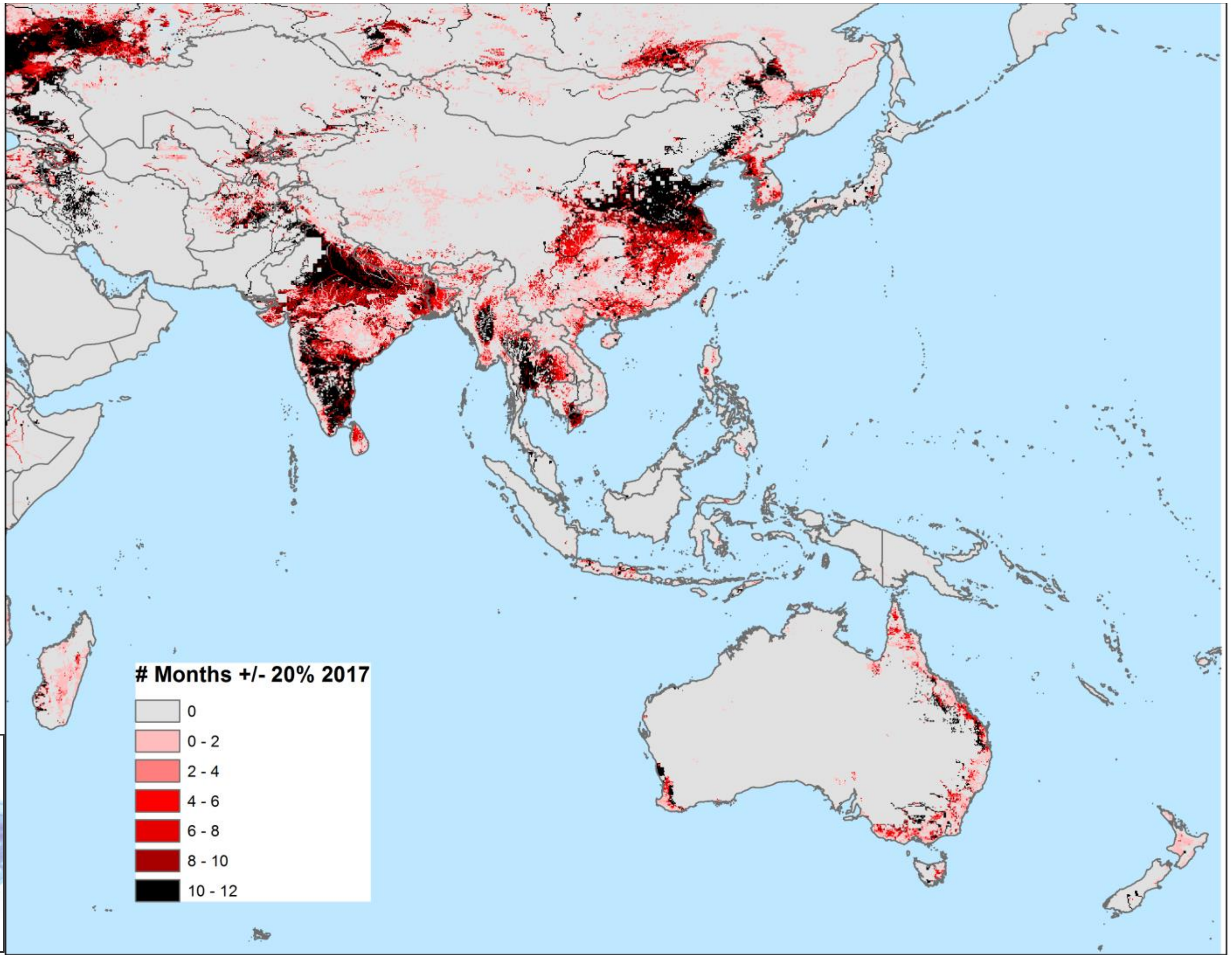
Catchment and Aquatic System Condition Index: Hydrological alteration

Preliminary results of flow alteration for example countries

	Average alteration	Sub-indicator score
Afghanistan	0.34	4
Armenia	0.44	3
Australia	0.26	4
Azerbaijan	0.53	3
Bangladesh	0.34	4
China, People’s Republic	0.24	4

May need to investigate alternative scoring thresholds

COMPASS
A WATER FUTURE INITIATIVE



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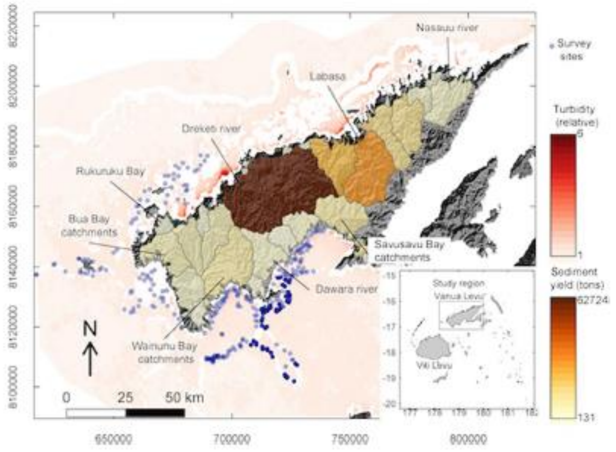
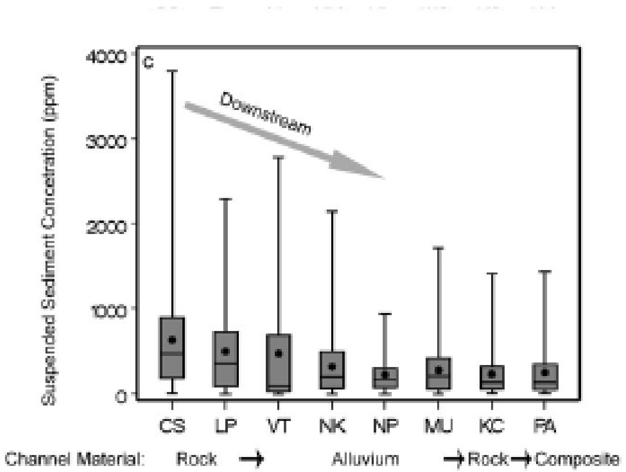
     1. Indicator of unsustainable catchment management and impact of development of dams

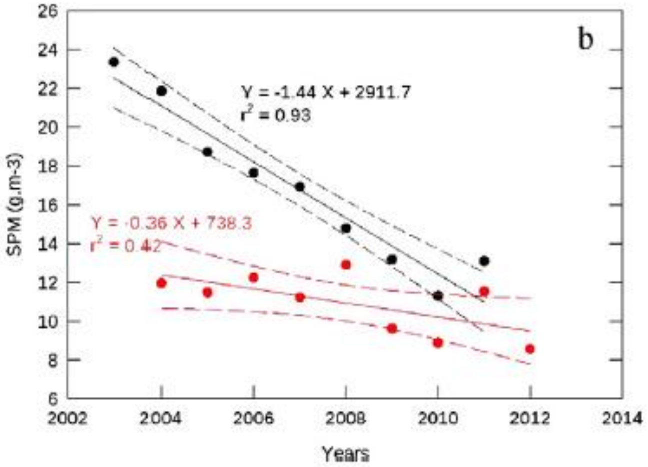
- The sub-indicator for coastal sedimentation relies on estimates of suspended particulate matter (SPM) derived from MODIS satellite imagery
  - Deforestation and agriculture are likely to increase sediment loads reaching the coast
  - Increasing dam development can decrease sedimentation as sediment loads become trapped behind reservoirs
  - Different trends may exist in different seasons



Brown et al.2017



Xue et al. 2011



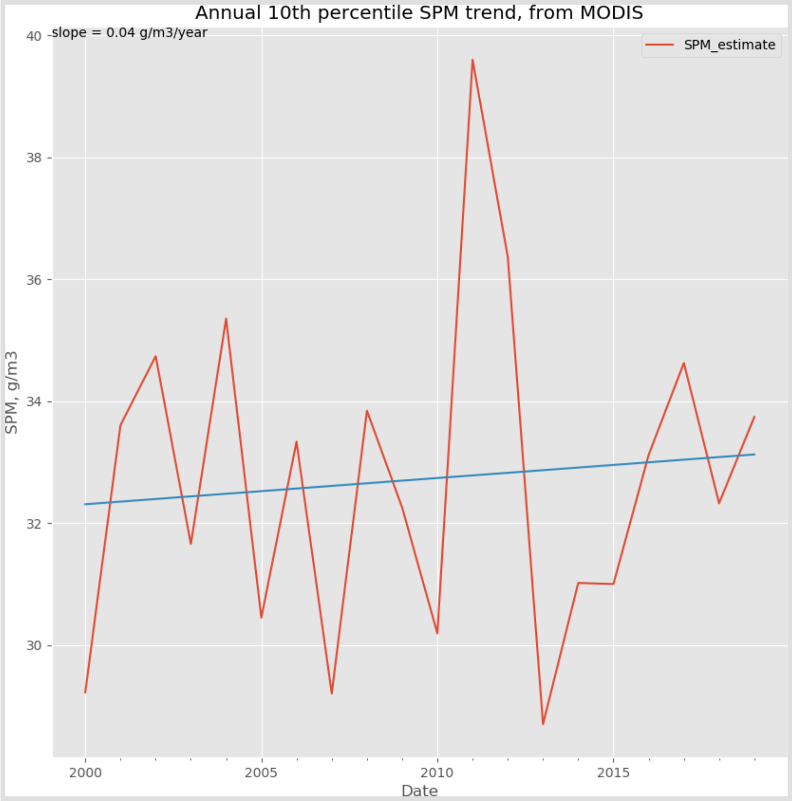
Loisel et al. 2014

Catchment and Aquatic System Condition Index: Coastal sedimentation

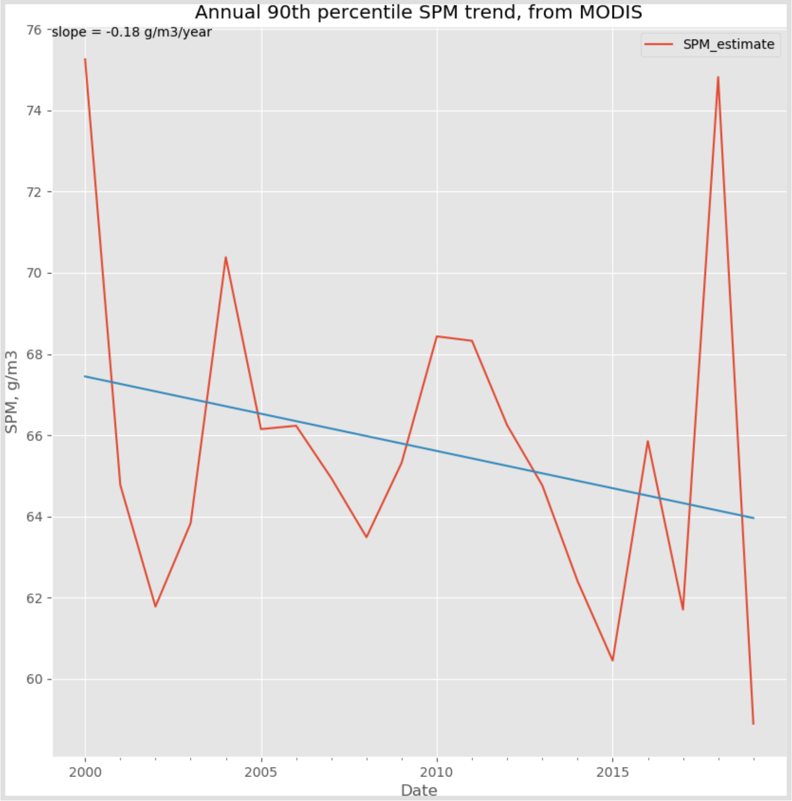
- Convert trends to standardised anomalies

Standard deviations	Score
≤-2	1
(-1.99, -1.5)	1
(-1.49, -1)	1
(-0.99, -0.5)	2
(-0.49, -0.25)	3
(-0.249, -0.1)	4
(0.09, 0)	5
(0, 0.1)	5
(0.11, 0.25)	4
(0.251, 0.5)	3
(0.51, 1)	2
>1	1

Trend of low flow sediment loads Mekong Coastal zone



Trend of high flow sediment loads Mekong Coastal zone



Environmental Governance Iindex

- The index brings together the following sub-indicators from Yale Environmental Performance Index

1. Wastewater treatment
   - Achieving higher levels of wastewater treatment will help countries reduce pressure on aquatic ecosystems from poor water quality
2. Terrestrial protected areas – percentage of land area that is protected in the country
   - Terrestrial protected areas provide healthy catchments that reduce pressure on aquatic ecosystems
3. Sustainable nitrogen management index – nitrogen use efficiency to quantify how much nitrogen enters the environment
   - More efficient agricultural practice, as quantified by this index, reduce pressures on aquatic ecosystems by reducing nutrient loads in agricultural runoff.

Percentage score (EPI)	Sub-indicator score
<22	1
(22.1, 36)	2
(36.1, 54)	3
(54.1, 71)	4
>71	5

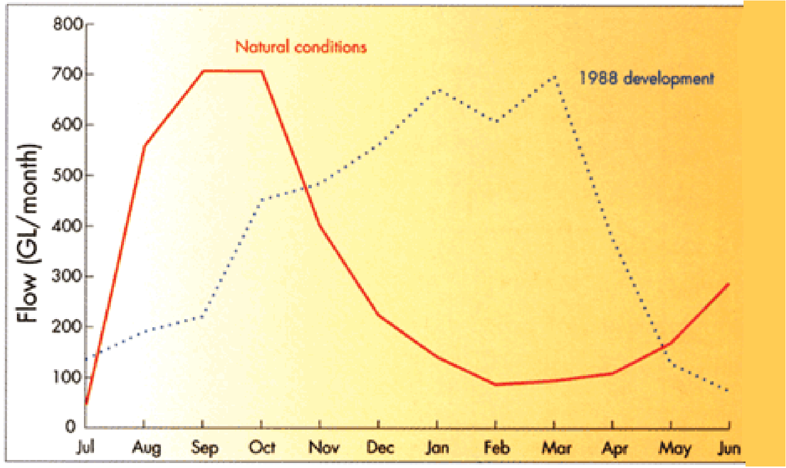
The narrative of KD4: Improving the score

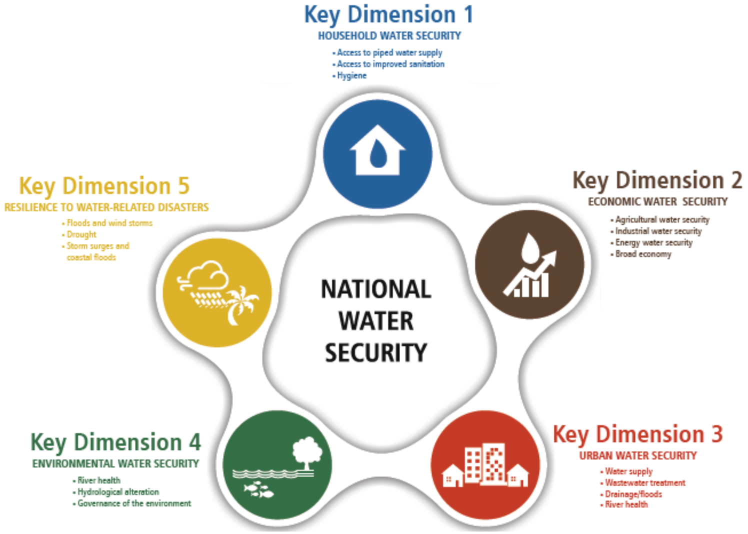
Many efforts to improve other aspects of the NWSI impact KD4

- These efforts should improve other KD scores

With better management and policy these impacts can be minimised

- Protection and restoration of riparian vegetation
- Sustainable use of groundwater
- Effective environmental flow releases
- High quality infrastructure to allow sediment flows (e.g. multi-offtake dams)





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