

Towards a Global High-Resolution Inundation Map: African continent application

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Presentation Outline

- **Intro:** Global wetland inventories
- **Objective**
- **Methods:** Downscaling with topographic inundation probabilities
- **Results:** Downscaled inundation maps
- **Follow-up:** Global mapping progress & customization
- **Application:** Mekong basin ecosystem connectivity
- **Conclusion**

Intro: Global wetland area

Adapted from MEA – Inland
Water Systems Chapter
(Finlayson et al. 2005)

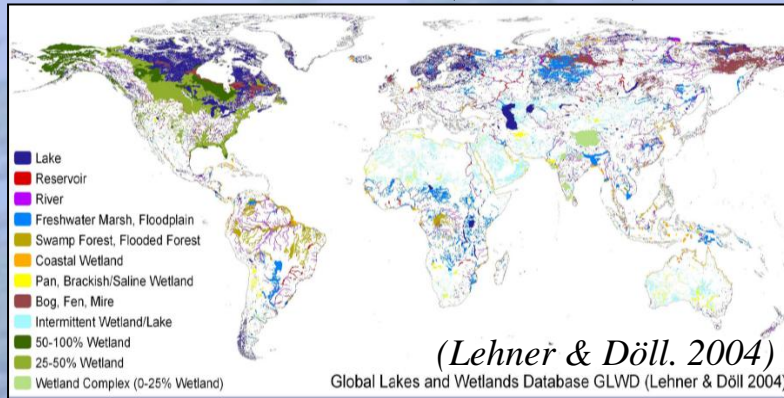
**Bottom-up
compilation of inventories**

**Aggregation of
existing global maps**

Geopolitical Region	GROWI: Global Review of Wetland Resources <i>(Finlayson et al. 1999)</i>	GLWD: Global Lakes and Wetlands Database <i>(Lehner and Döll, 2004)</i>
	<i>(thousand km²)</i>	
Africa	1,247	1,314
Asia	2,043	2,856
Europe	2,580	260
Neotropics	4,149	1,594
North America	2,416	2,866
Oceania	358	275
Total Area	~ 12,792	~ 9,167
+ Lakes and Rivers	+ 0	+ 2670
	12792	11846
+ Max. Fractional classes	+ 0	+ 952
Reviewed Area	12792	12798

Intro: Global Spatial Inventories

Global Lake & Wetland Database (GLWD)

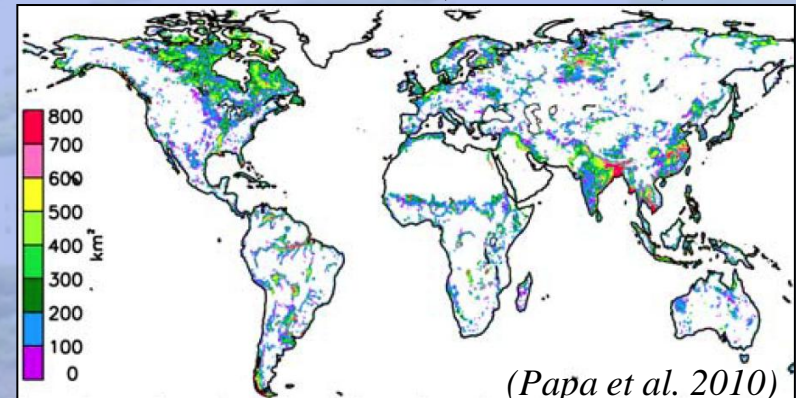


Maximum wetland extent.

Aggregation of global datasets creates inconsistencies.

Compounds errors from source data.

Global Surface Water Extent Dataset (GSWED)



Monthly cell inundated fraction.

Generated from multi-satellite method.

Coarse res. doesn't distinguish distinct waterbodies nor detects low inundation fractions.

Intro: Inventorying Challenges

Conventional approaches struggle to produce a complete global wetland inventory:

- Aggregation of regional map:**
Definition inconsistencies and untraceable errors.
- Remote sensing imagery:**
Spatial VS Temporal resolution trade-off.

A novel approach is required to circumvent these methodological hurdles.

Research Objective

Produce a global inundation extent map:

-High spatial resolution

for conservation applications

-Based on actual observations

for continued monitoring

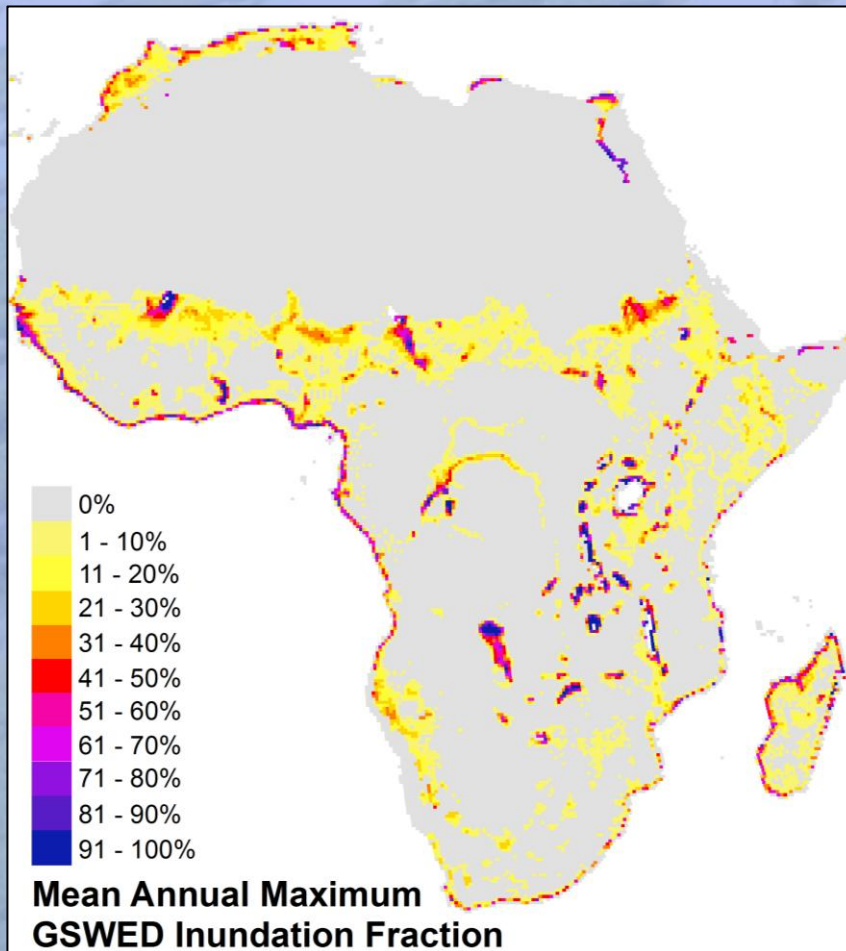
-Globally consistent

for comparison across regions

Methods: Available Global Datasets

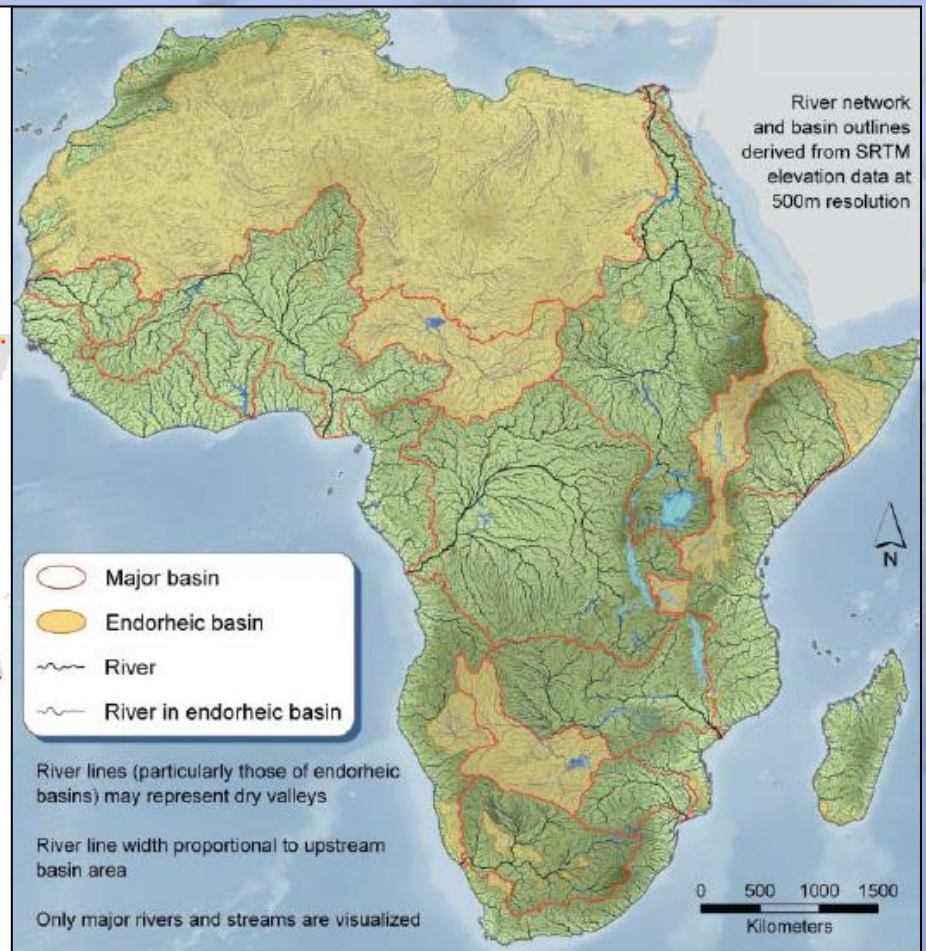
GSWED - Global Surface Water Extent Dataset

(Papa et al. 2010)



HydroSHEDS

(Lehner et al. 2008)



Methods: Available Global Datasets

GSWED - Global Surface Water Extent Dataset

(Papa et al. 2010)

HydroSHEDS

(Lehner et al. 2008)

Inundated fraction
of cell (%)

Topographic &
Hydrographic

River network
and basin outlines
derived from SRTM
elevation data at
500m resolution

0% ~ 27 km at equator

~ 500 m at equator

1 - 10%
11 - 20%
21 - 30%
31 - 40%
41 - 50%
51 - 60%
61 - 70%
71 - 80%
81 - 90%
91 - 100%

Major basin
Endorheic basin
River
River in endorheic basin

Monthly
1993 to 2004

Static
snapshot of 2000

River lines (particularly those of endorheic basins) may represent dry valleys

River line width proportional to upstream basin area

Only major rivers and streams are visualized

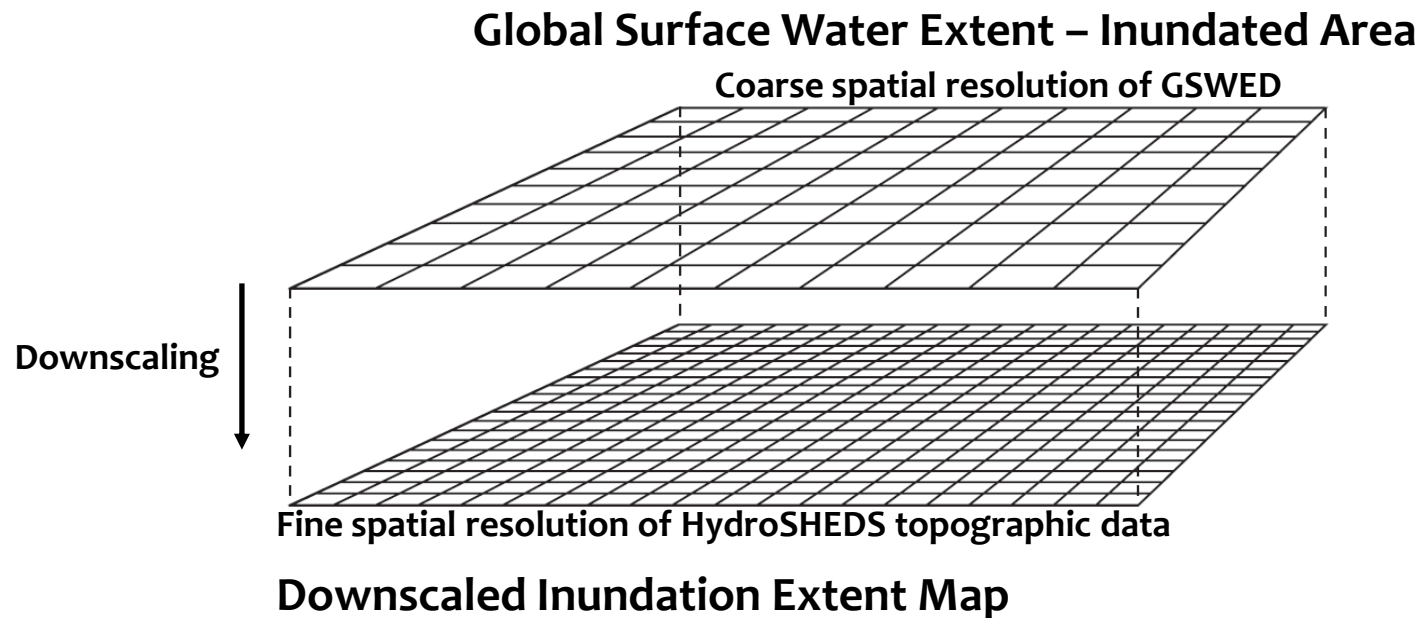
500 1000 1500
Kilometers

Mean Annual Maximum
GSWED Inundation Fraction

Method: Topographic Downscaling

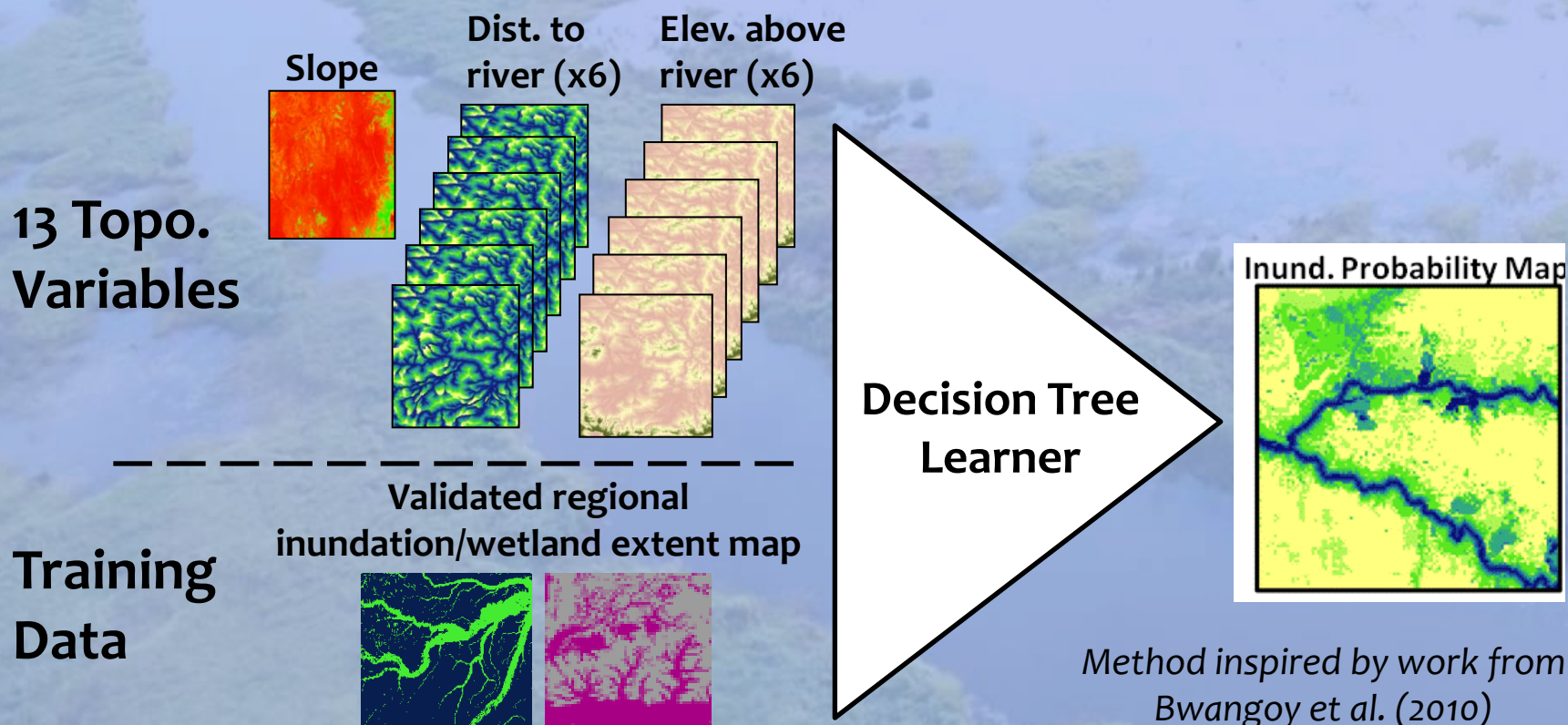
Downscale GSWED inundated area to finer resolution of HydroSHEDS.

Use topographic information to allocate inundated area to high-resolution pixels.



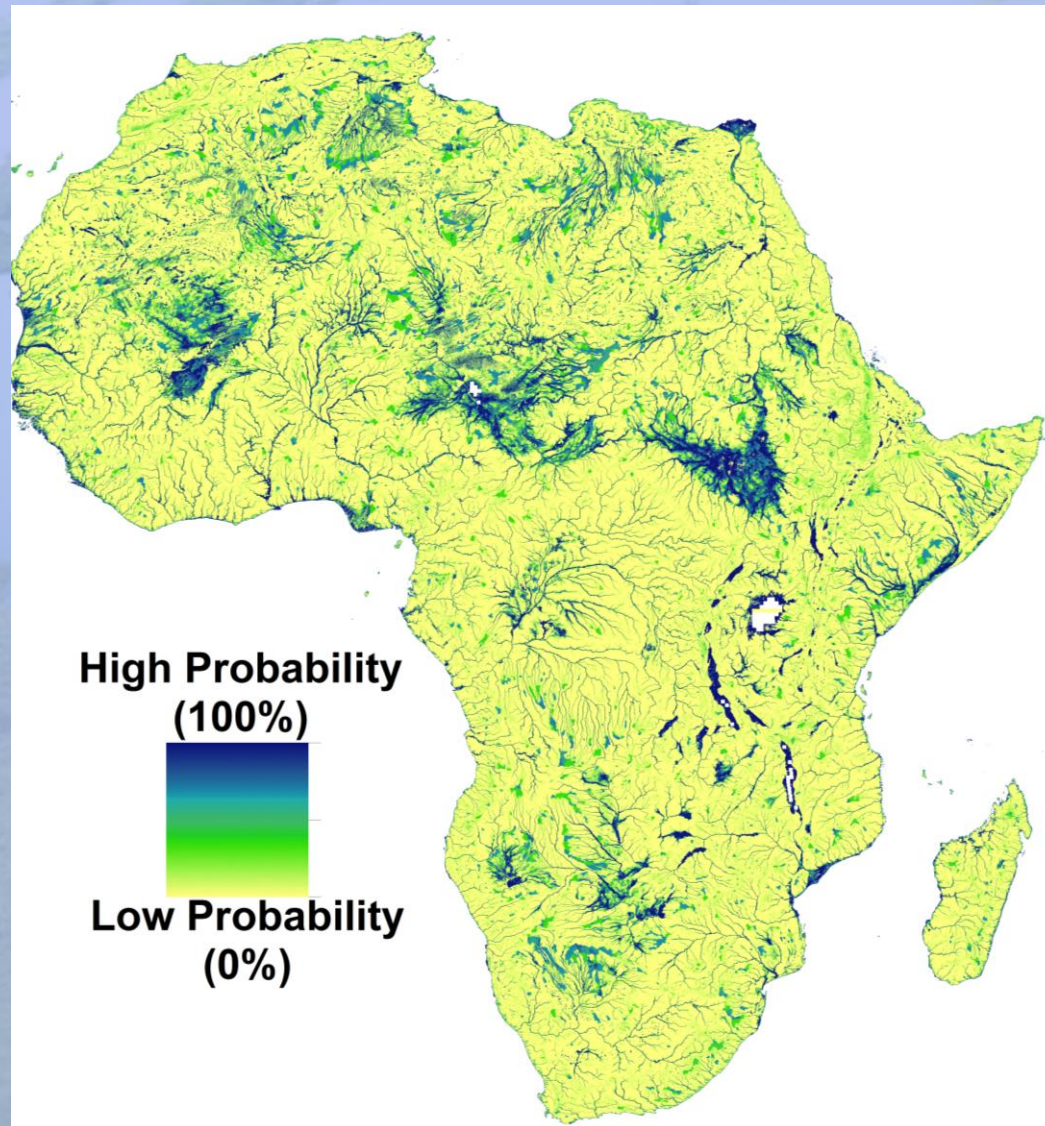
Methods: Inundation Probabilities

The predictive information of inundation occurrence from topography summarized into **topographic inundation probabilities.**

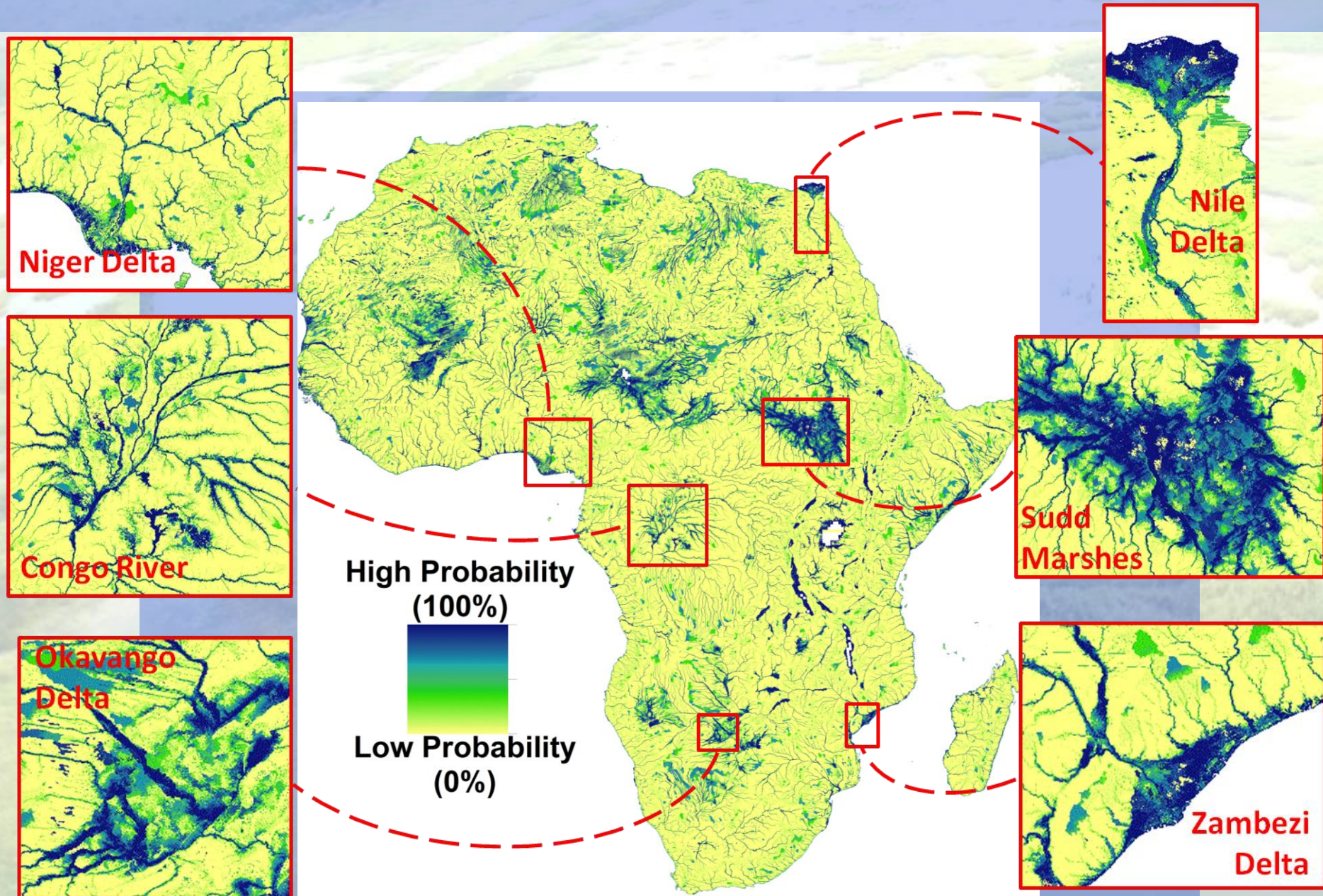


Method inspired by work from Bwangoy et al. (2010)

Methods: Inundation Probabilities

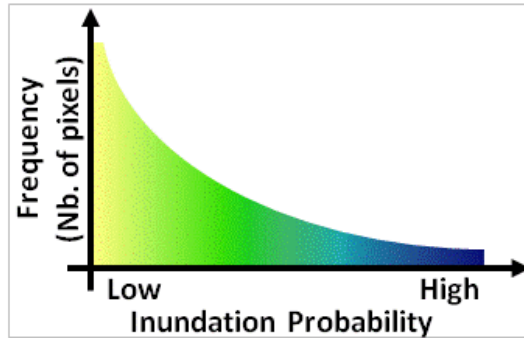
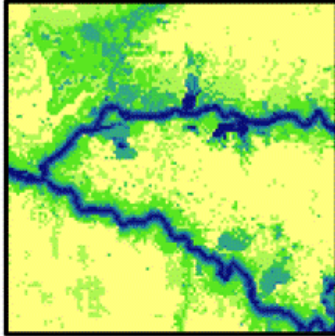


Methods: Inundation Probabilities



Methods: Probability Thresholding

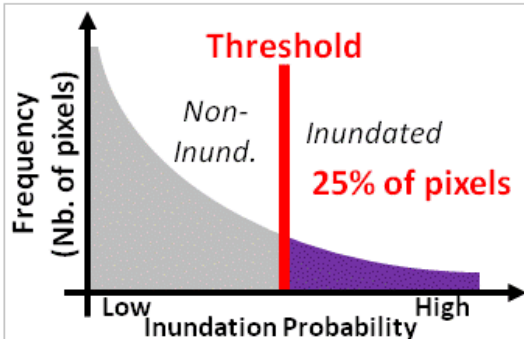
Inund. Probability Map



GSWED Inund. Fraction

Time #1

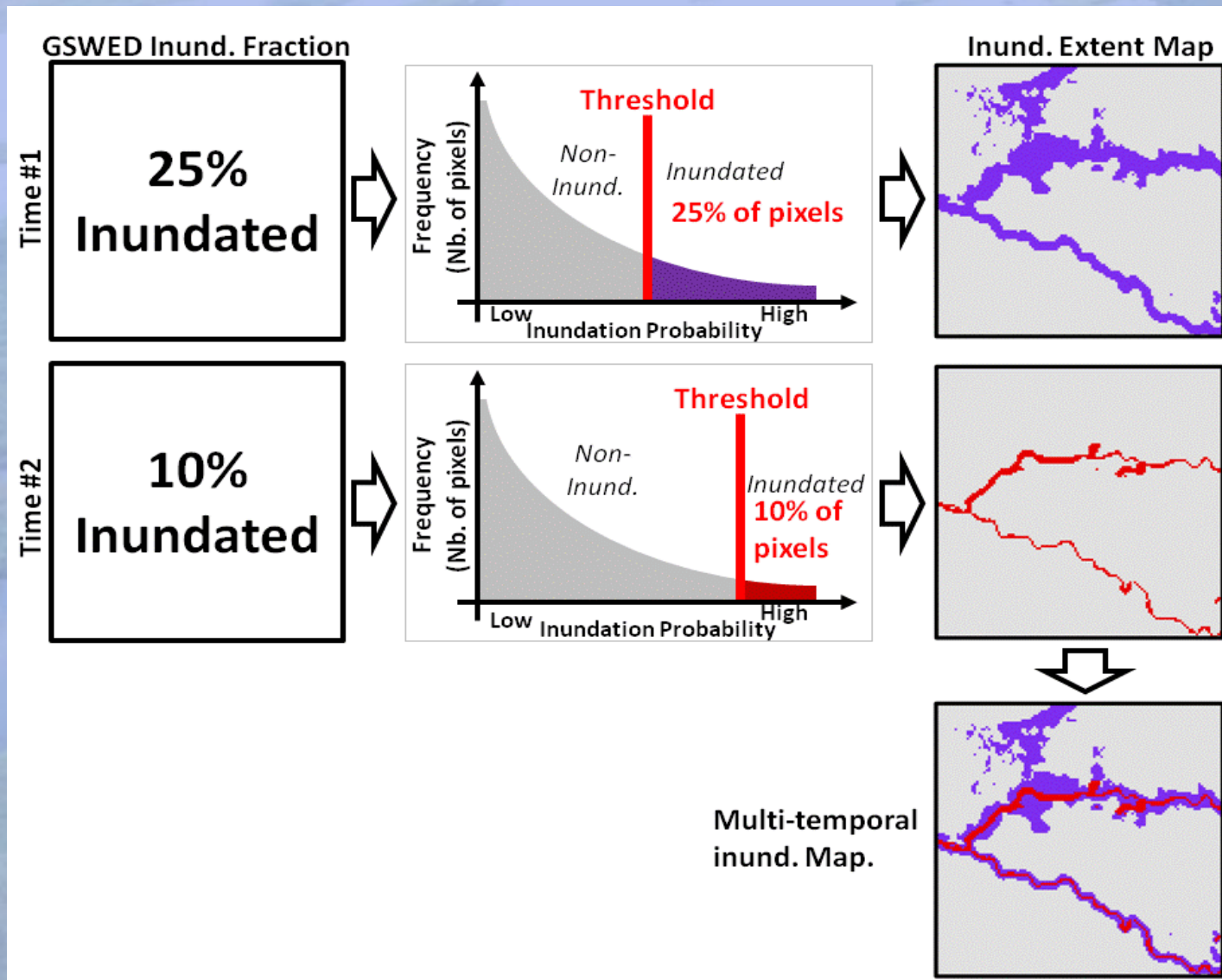
**25%
Inundated**



Inund. Extent Map

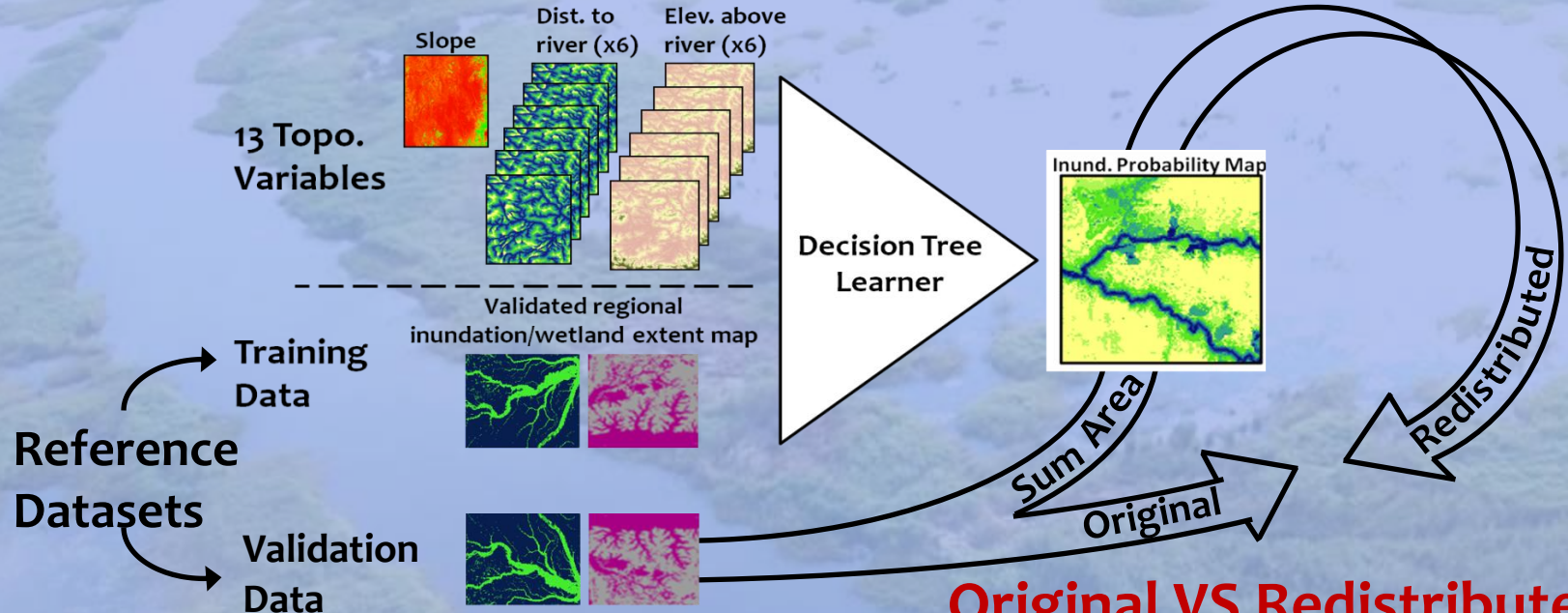


Methods: Probability Thresholding



Methods: Downscaling Accuracy Validation

Evaluates spatial distribution of downscaled inundation from probability map over validation areas.



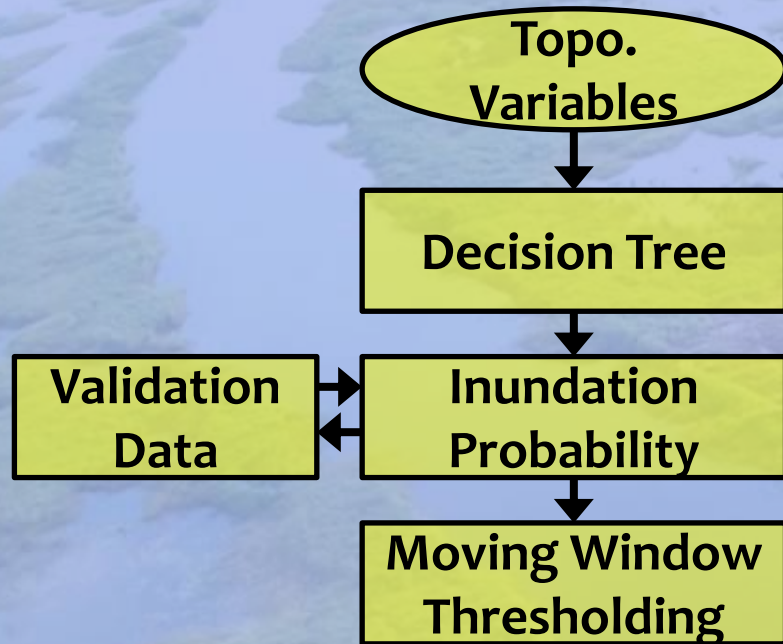
Accuracy metrics:

- Producer Accuracy: 84.3%
- Overall Accuracy: 92.3%
- Kappa Index: 80.1%

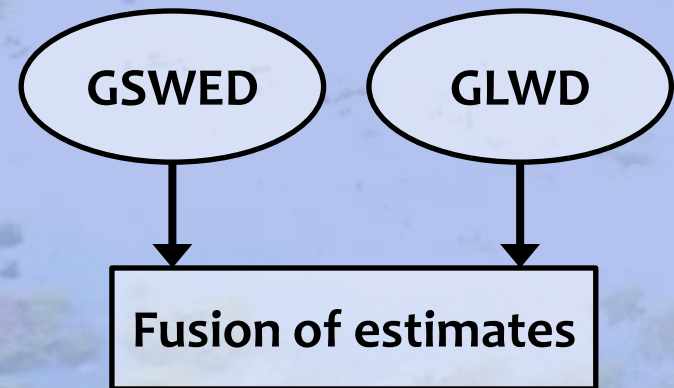
Original VS Redistributed of equal inundated area compared

Methods: Recap.

Topographic Downscaling *(Spatial Distribution error)*



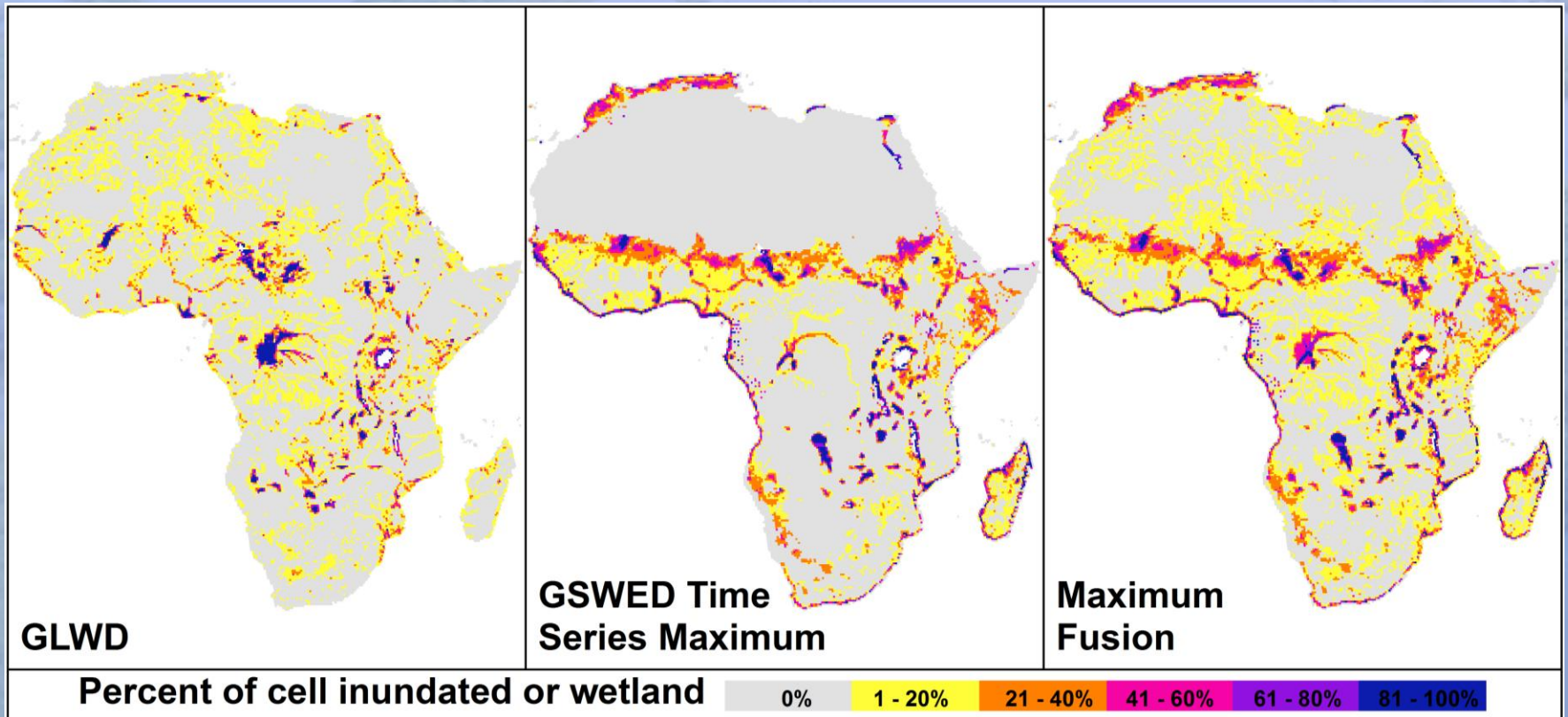
Inundation estimates *(Inundation area error)*



Downscaled Inundation Map

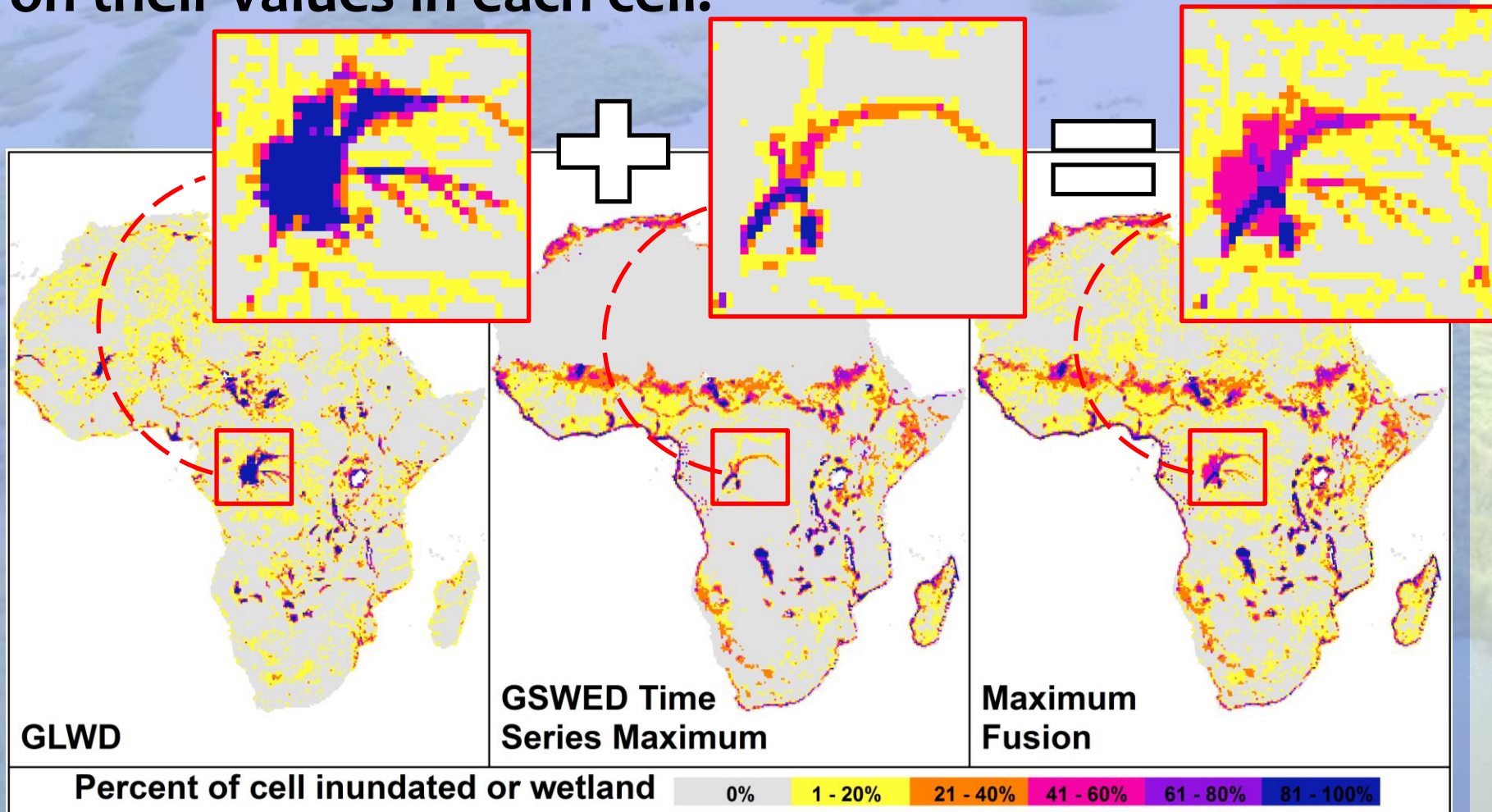
Methods: Fusion of GLWD & GSWED

Inundated area from GLWD & GSWED merged, based on their values in each cell.

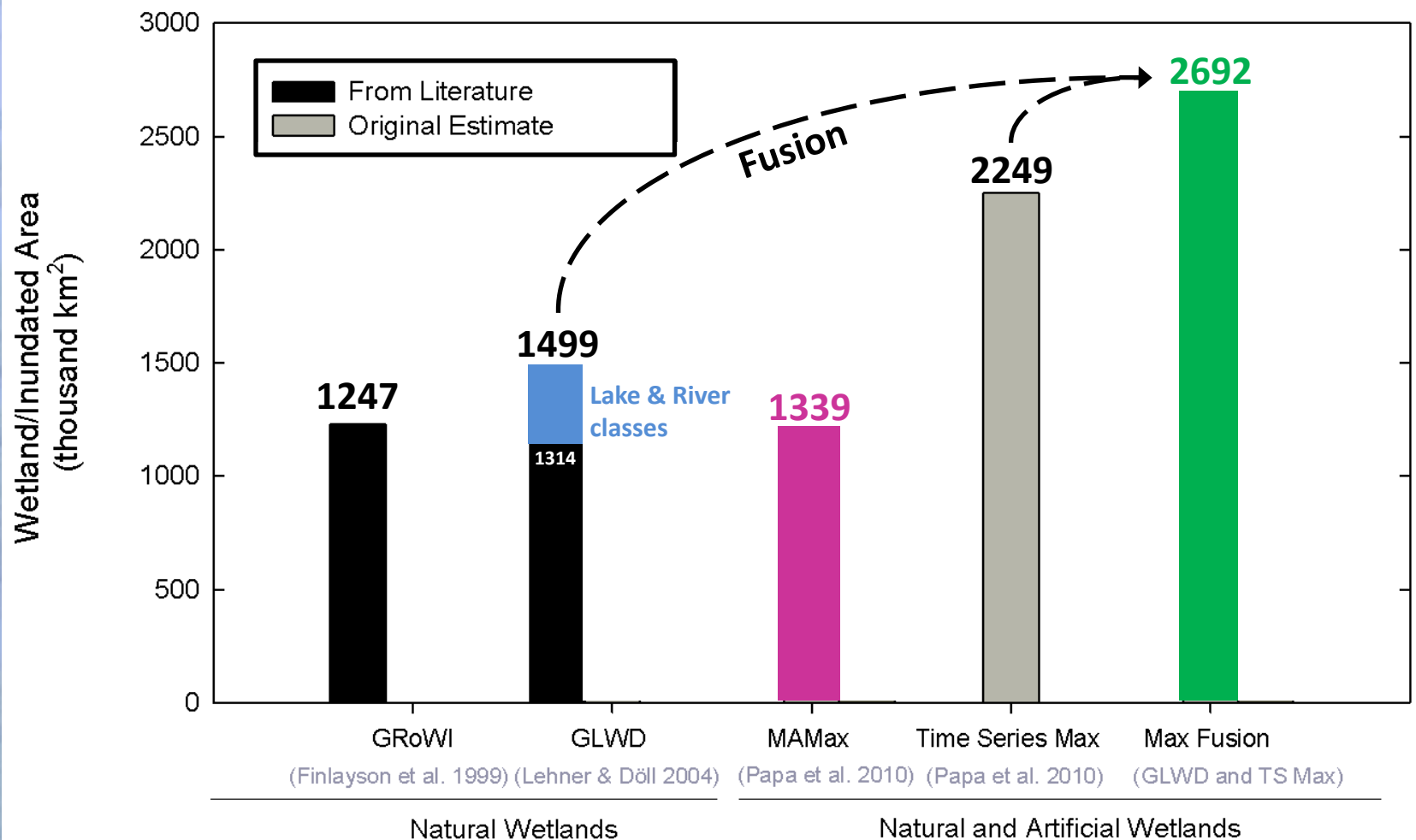


Methods: Fusion of GLWD & GSWED

Inundated area from GLWD & GSWED merged, based on their values in each cell.



Methods: Africa Total Wetland Area

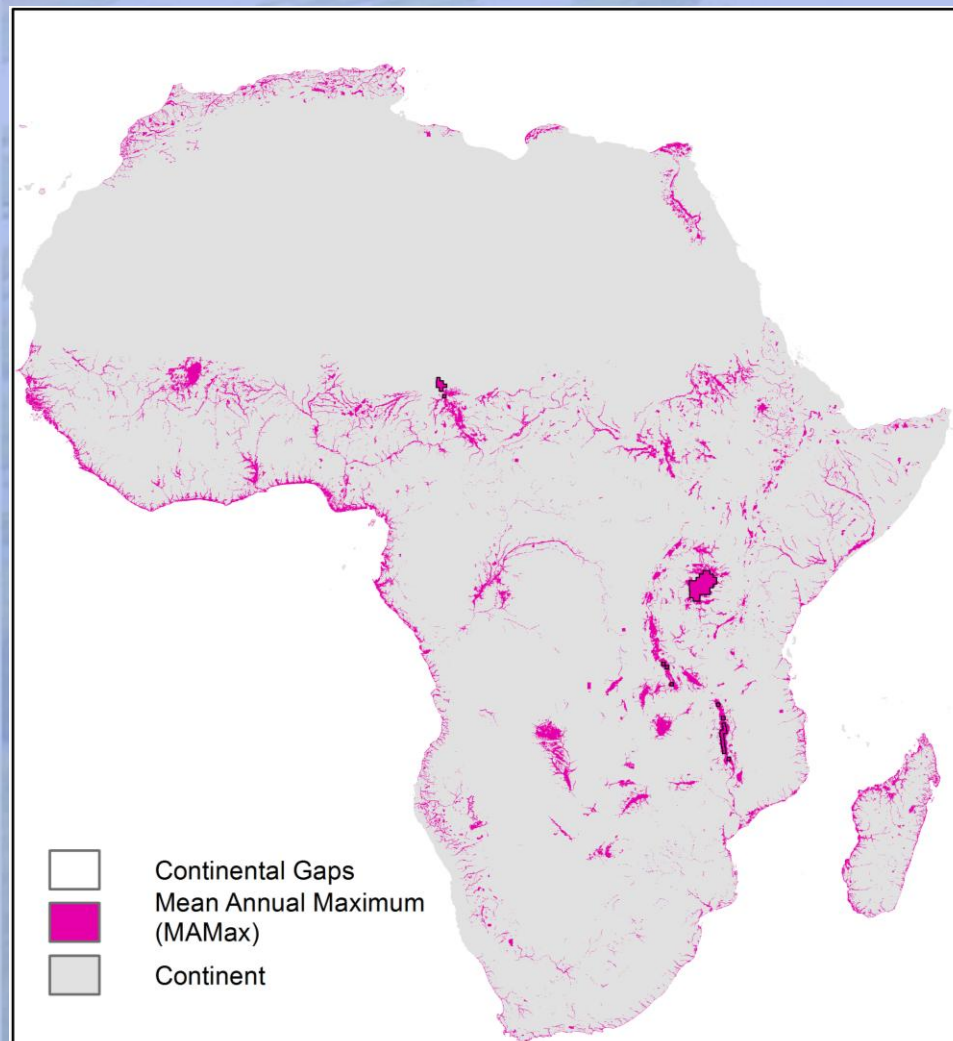


Note: artificial inundation from irrigated rice paddies account for 8.7 thousand km² over the continent.

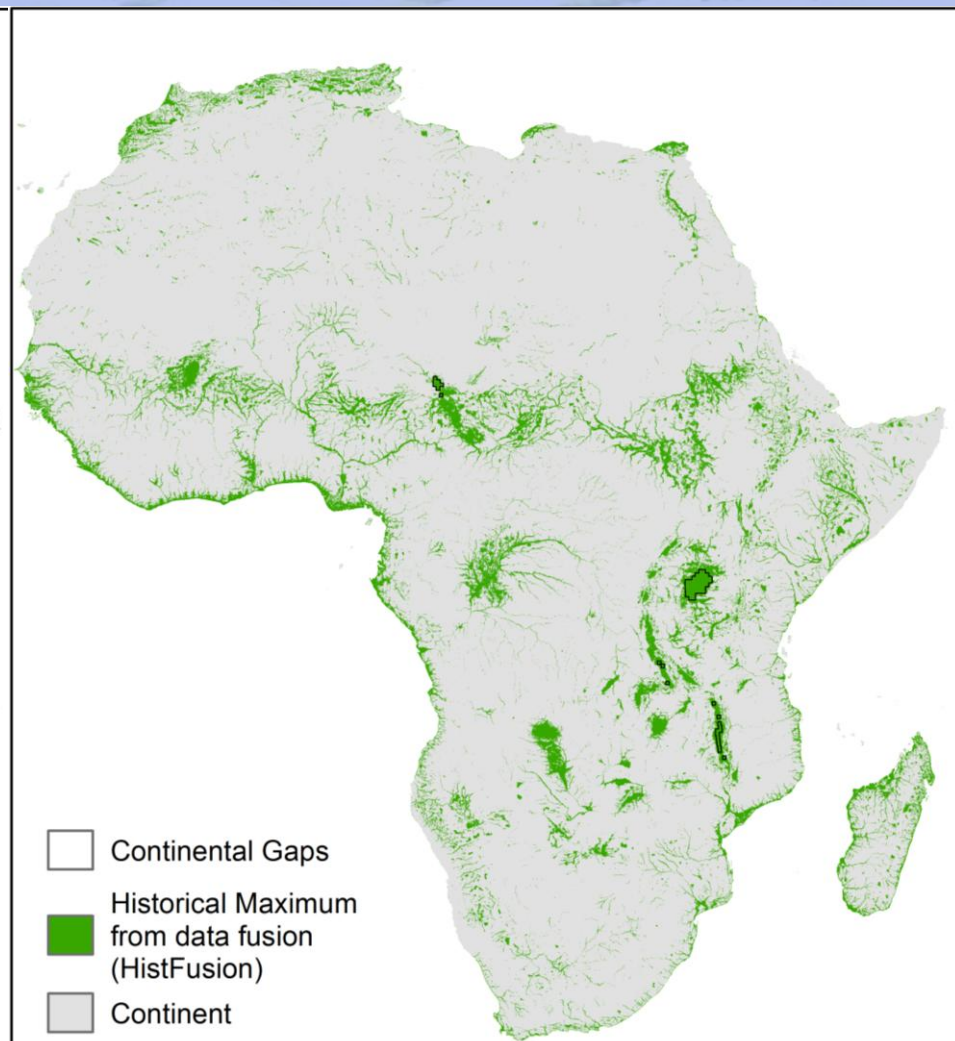
Results: Downscaled Inundation Maps

Mean Annual Maximum

Fusion Maximum



MAMax Moving Window Thresholding (MWT)

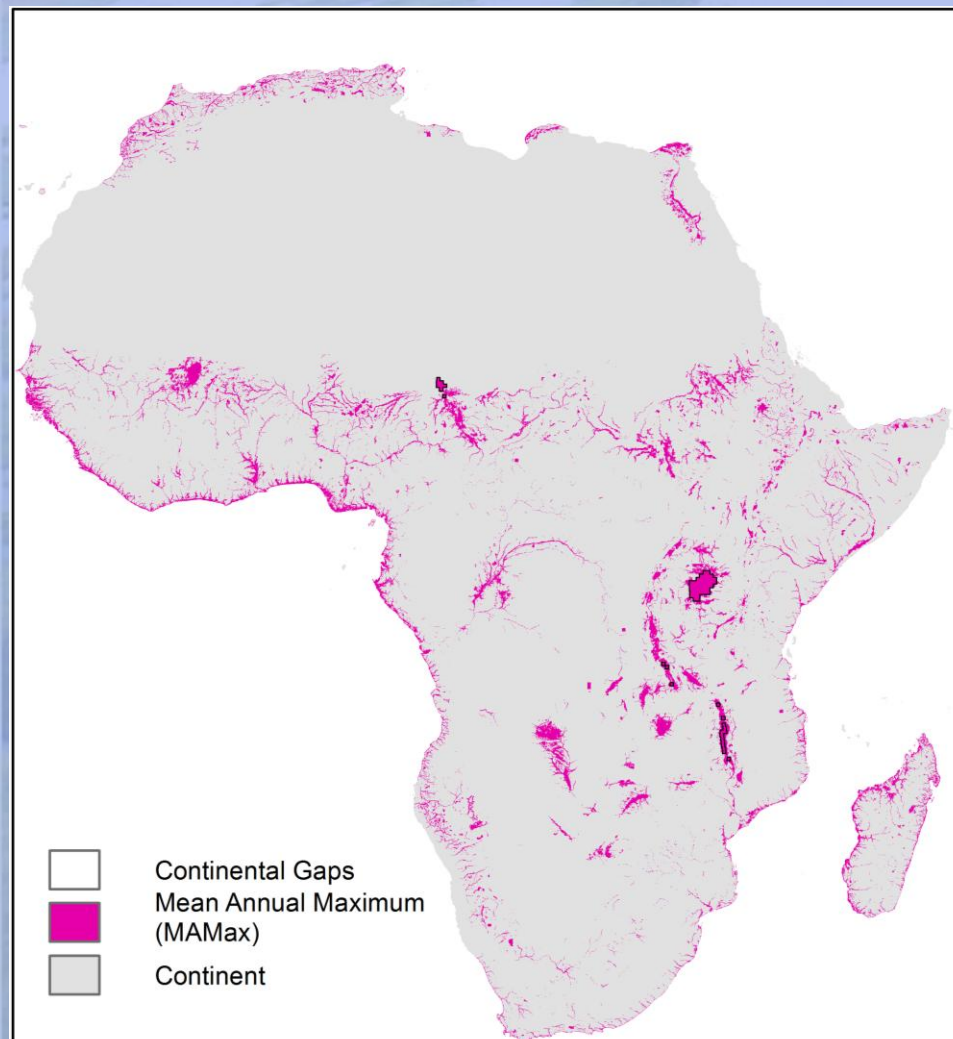


Moving Window Thresholding (MWT)

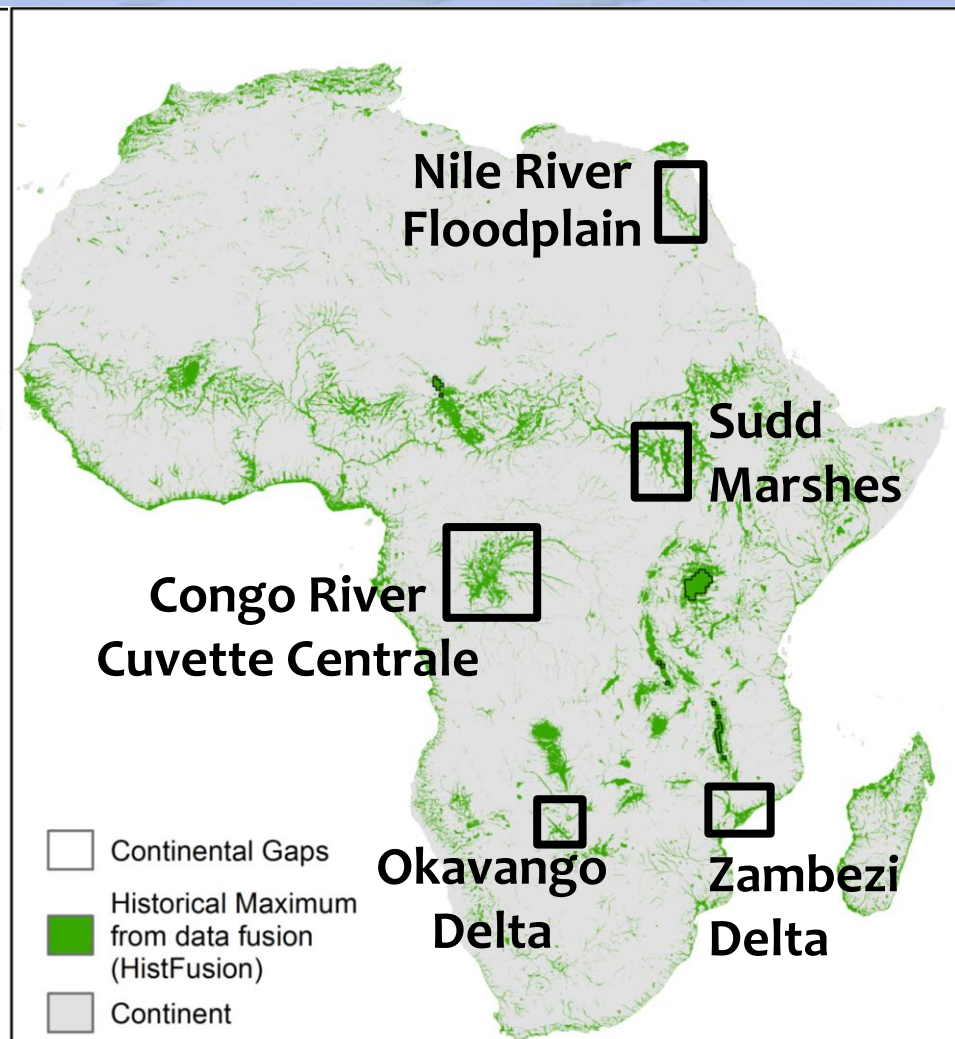
Results: Downscaled Inundation Maps

Mean Annual Maximum

Fusion Maximum

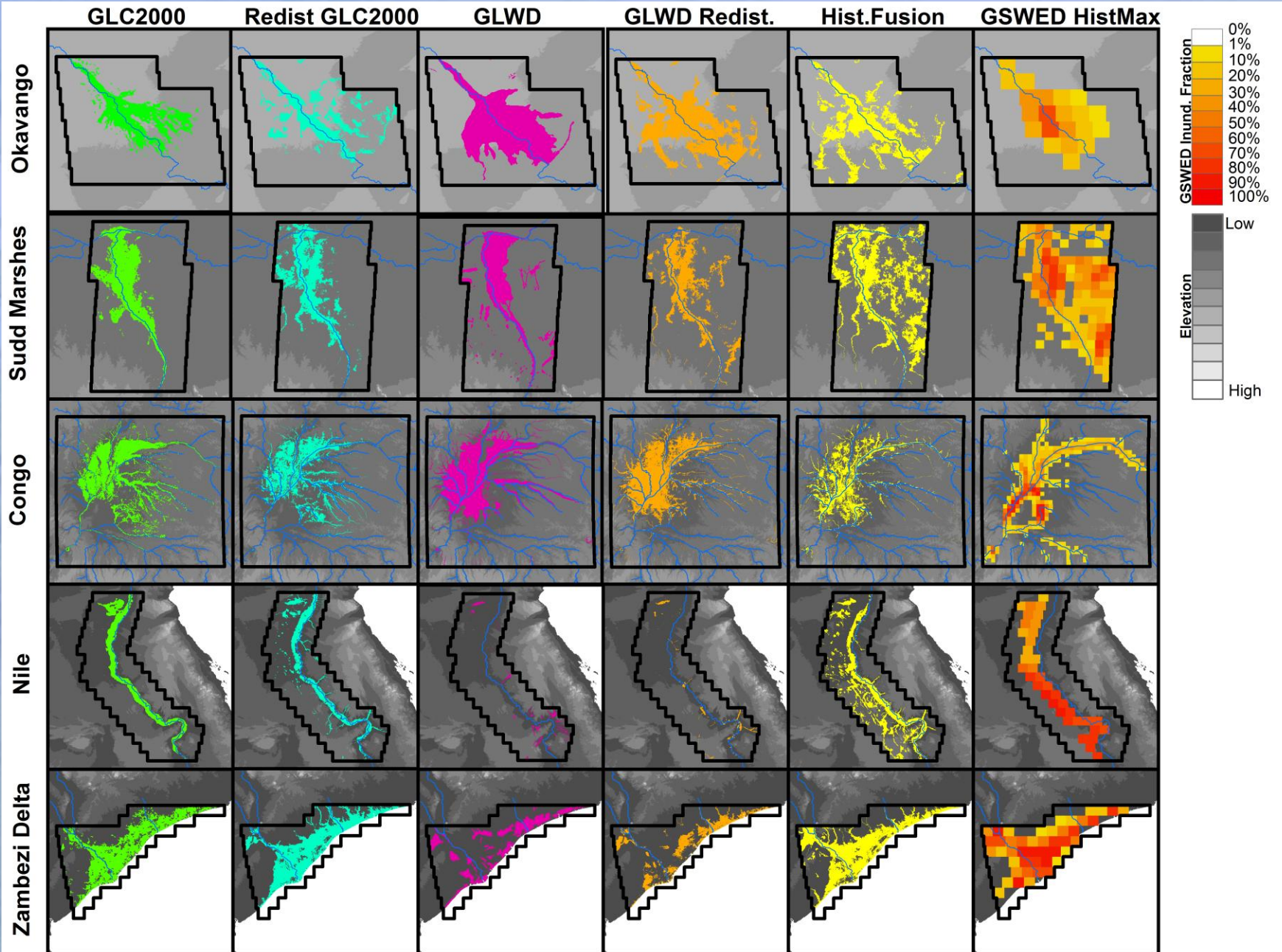


MAMax Moving Window Thresholding (MWT)

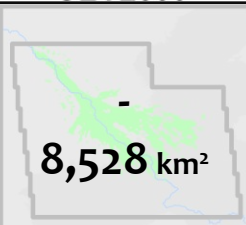
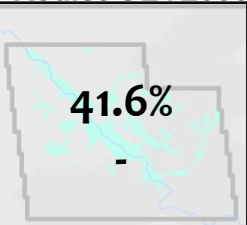
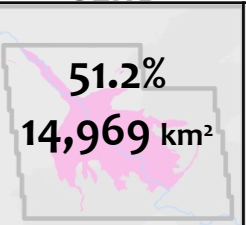
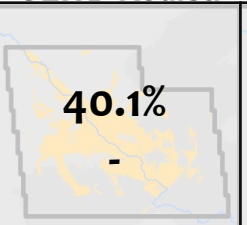
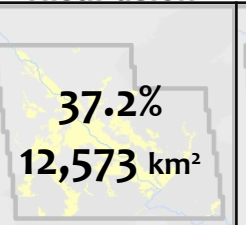
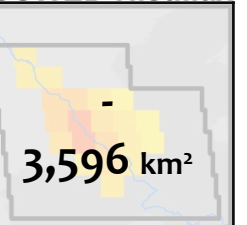

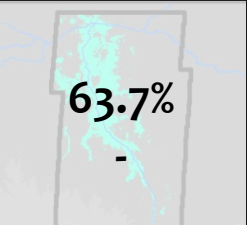
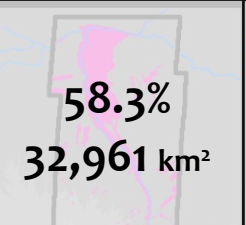
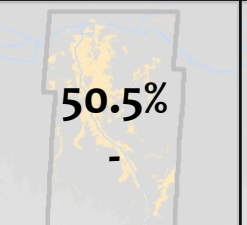
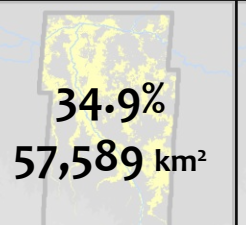
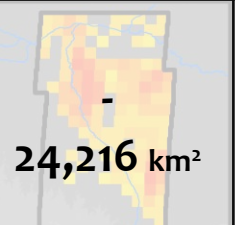

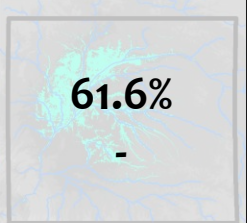
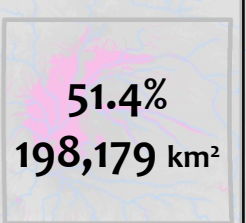
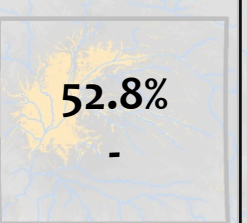
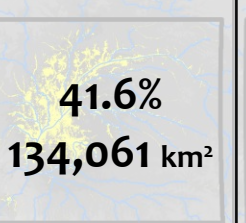
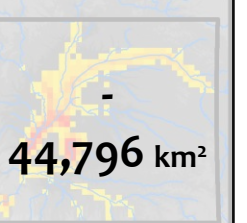

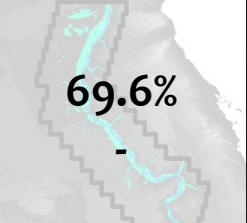
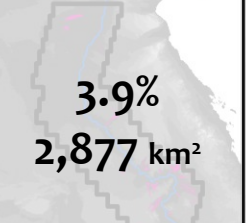
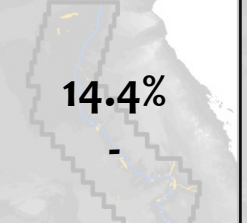
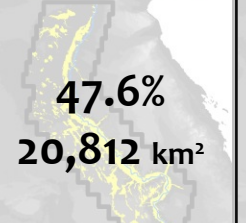
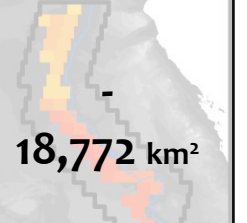

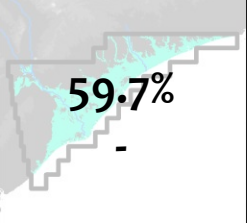
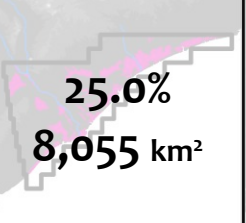
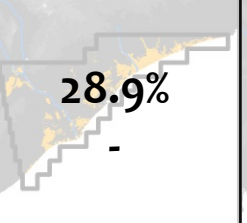
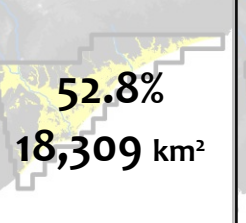



Moving Window Thresholding (MWT)

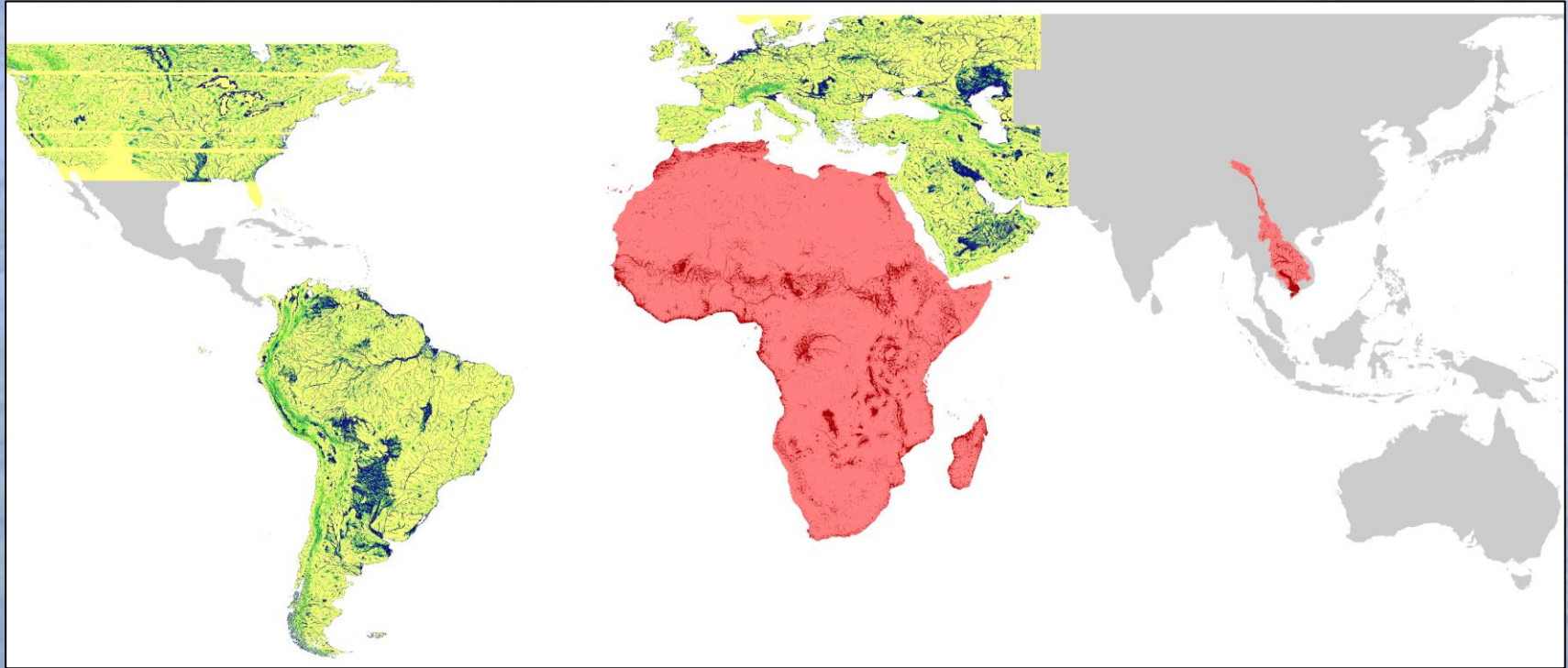
Results: Study Sites



Results: Study Sites Metrics

	GLC2000	Redist GLC2000	GLWD	GLWD Redist.	Hist.Fusion	GSWED HistMax	
Okavango	 - 8,528 km ²	 41.6% -	 51.2% 14,969 km ²	 40.1% -	 37.2% 12,573 km ²	 - 3,596 km ²	Kappa Index of Agreement (%) & Inundated Area (km ²)
Sudd Marshes	 - 31,331 km ²	 63.7% -	 58.3% 32,961 km ²	 50.5% -	 34.9% 57,589 km ²	 - 24,216 km ²	
Congo	 - 143,256 km ²	 61.6% -	 51.4% 198,179 km ²	 52.8% -	 41.6% 134,061 km ²	 - 44,796 km ²	
Nile	 - 12,475 km ²	 69.6% -	 3.9% 2,877 km ²	 14.4% -	 47.6% 20,812 km ²	 - 18,772 km ²	
Zambezi Delta	 - 16,660 km ²	 59.7% -	 25.0% 8,055 km ²	 28.9% -	 52.8% 18,309 km ²	 - 7,396 km ²	

Follow-up: Global Mapping Progress



-  : Inundation Extent Map
-  : Inundation Probabilities
-  : Not Mapped

Follow-up: Product Customization

Method designed for different resolutions.

Temporal Resolution

Current: Mean Annual Maximum
Historical Maximum (from Fusion)

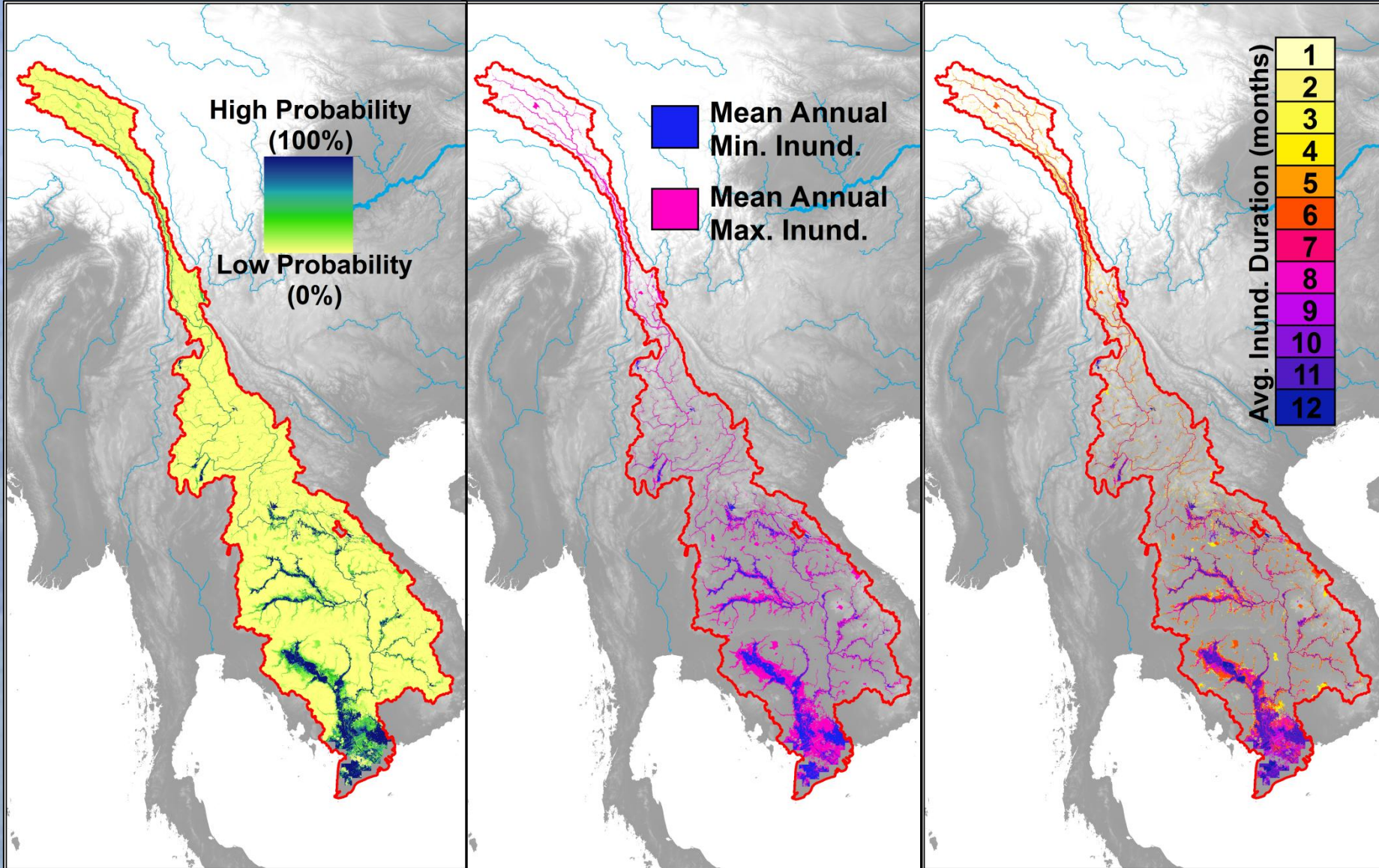
Minimum: Monthly

Spatial Resolution

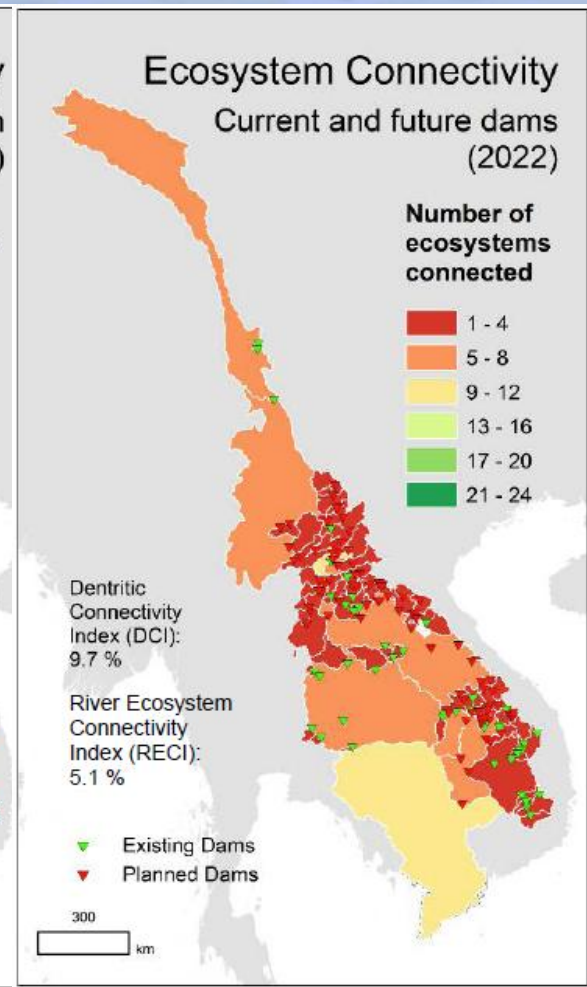
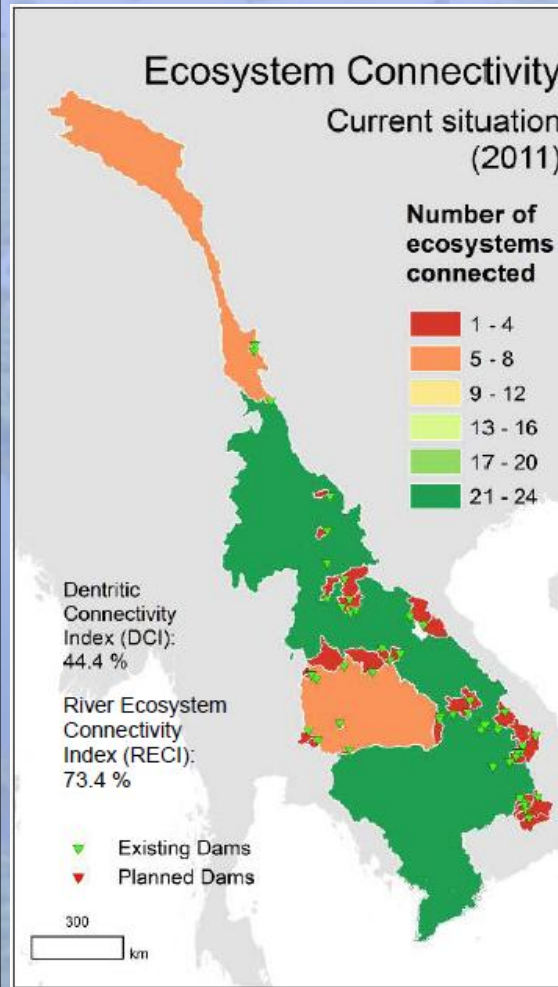
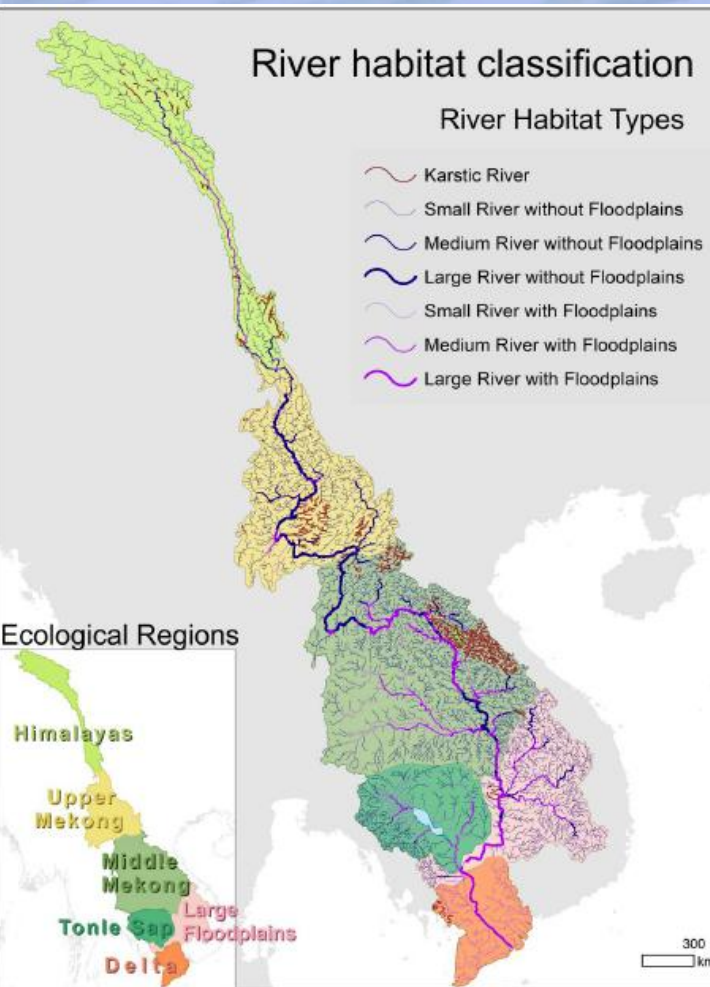
Current: 500m

Reproducible at: 90m or 1000m

Application: Mekong Basin Inundation



Application: Mekong Basin Connectivity



(Lehner et al., in prep)

Conclusion

Provides improved wetland baseline inventory

- Superior spatial res. than other global inventories
- Globally consistent, quantified accuracy.

Much room for improvement in future

- Cannot distinguish natural from artificial inundation
- Monthly temporal variations depends on GSWED
- Possibility to improve map accuracy with:
 - Additional reference data
 - Downscaling method optimization
 - Improved inundation GSWED estimates.

Thank You !

Questions ?



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Literature Cited

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- Lehner, B., Grill G., Ouellet-Dallaire C., Fluet-Chouinard, E., in prep.,** Ecosystem fragmentation and flow regulation in the Mekong River Basin due to past and future dam development:
- Mayaux, P., Bartholomé, E., Fritz, S. & Belward, A., 2004.** A new land-cover map of Africa for the year 2000", *Journal of Biogeography*, vol. 31(6), pp. 861-877.
- Papa, F., Prigent, C., Aires, F., Jimenez, C., Rossow, W. B. & Matthews, E., 2010.** Multi-Satellite Remote Sensing of Global Surface Waters Extent, 1993-2004. *Journal of Geophysical Research*, vol. 115(D12111), pp.1-17.

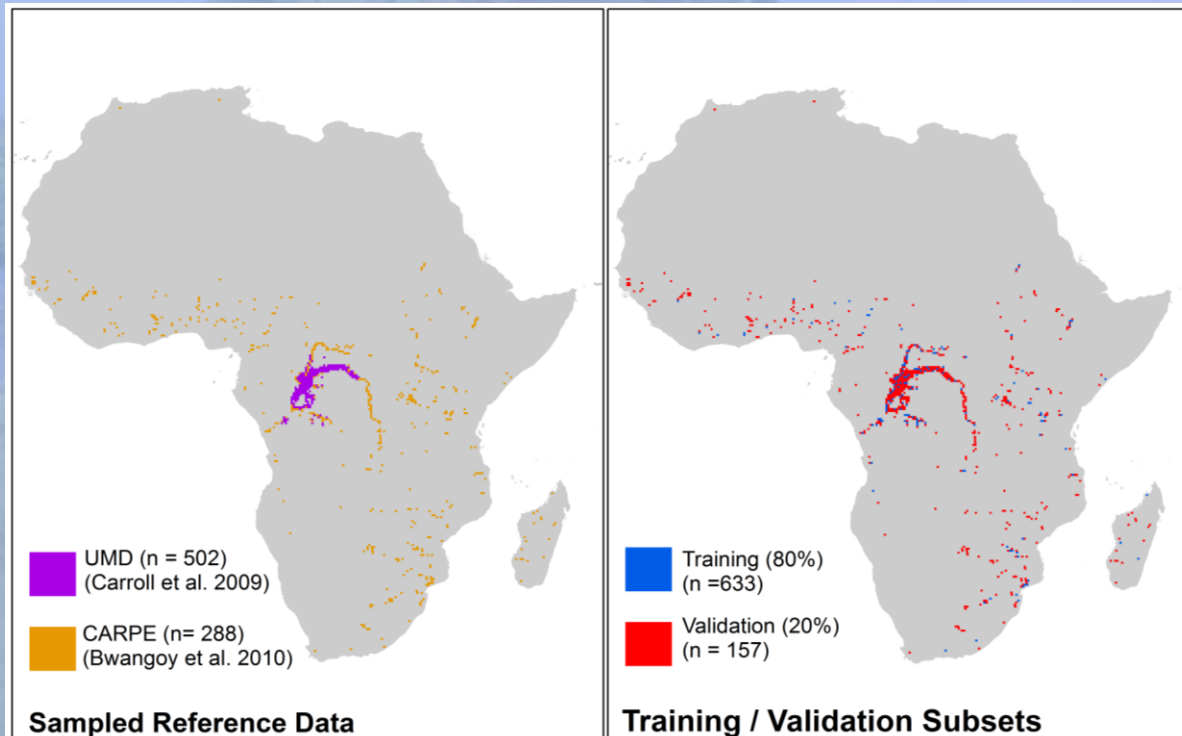
Extra Slides

Reference Data (for train/valid.)

Moving Window Thresholding

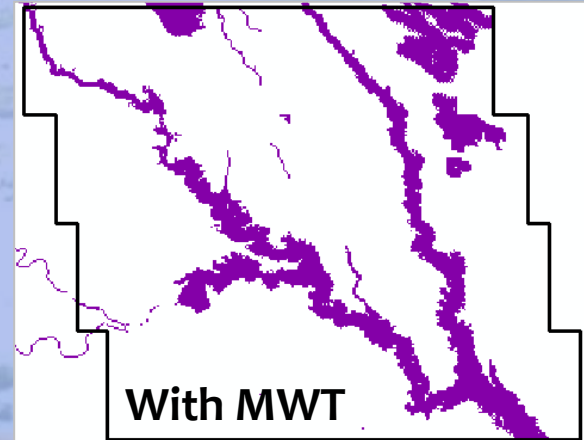
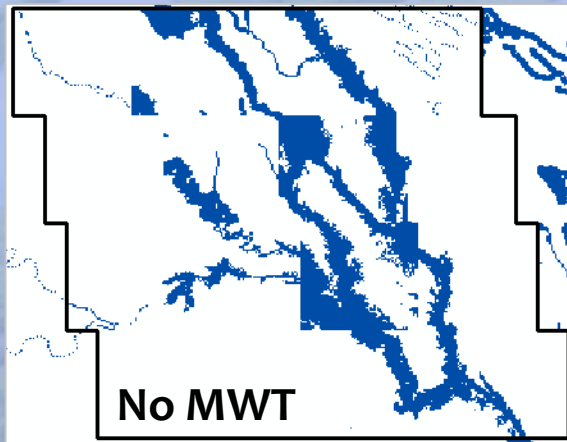
Reference Data

Data Source	Region	Wetland/Inundation Definition
University of Maryland – Water Mask (UMD) (Carroll et al. 2009)	African Continent	Open water bodies from the SWBD (Slater et al. 2006) combined with MODIS remote sensing (Carroll et al. 2009).
Central Africa Regional Program for the Environment (CARPE) – Congo Wetland Map (Bwangoy et al. 2010)	Central Congo Basin	General wetland definition, to distinguish from non-wetland upland forests. Map produced from thresholding of wetland probabilities from remote sensing and topographic indices.

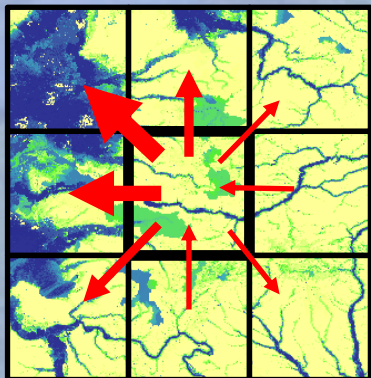


Methods: Moving Window Thresholding

Thresholding on single tiles creates linear features at the borders.



MWT eliminates linear features by reallocating inundated area.



Reallocation of inundated area among adjacent cells based on probabilities of each cell.

Reallocation does not significantly alter total inundated area.