Socioeconomic Impact Evaluation for Near Real-Time Flood Detection in the Lower Mekong River Basin

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Introduction

Flood events pose a severe threat to communities in the Lower Mekong River Basin. The combination of population growth, urbanization, and economic development exacerbate the impacts of these events. Damage assessments are frequently used to quantify the economic losses in the wake of storms. These assessments are critical for understanding the effects of flooding on the local population, and for informing decision-makers about future risks. Remote sensing systems provide a valuable tool for monitoring flood conditions and assessing their severity more rapidly than traditional post-event evaluations. The frequency and severity of extreme flood events are projected to increase, further illustrating the need for improved flood monitoring and impact analysis.

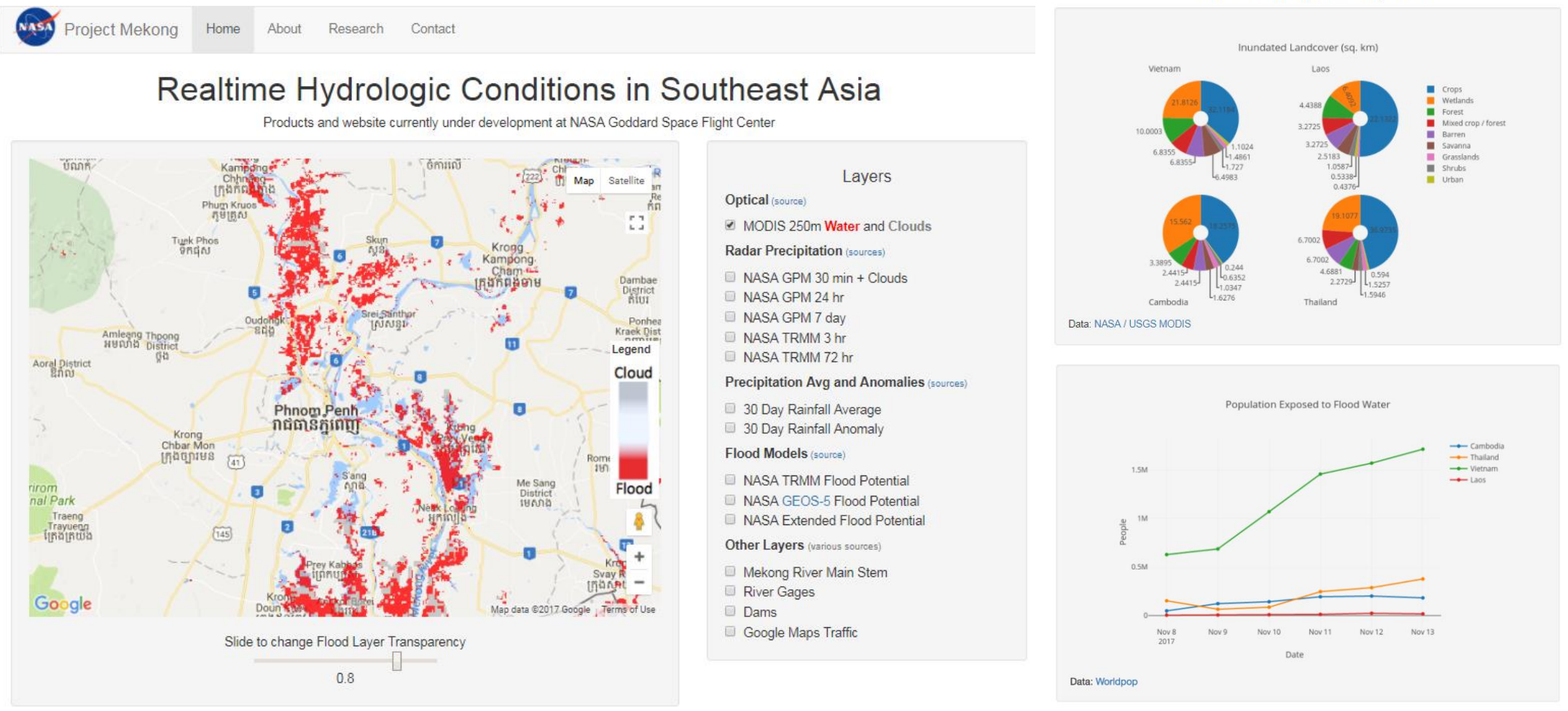


Figure 1. Project Mekong web application (Ahamed and Bolten, 2017). MODIS-derived surface flooding indicated in red while gray pixels represent masked clouds. Image taken November 13, 2017.

2011 Southeast Asia Flood

Flood events between August and October, 2011, caused widespread damage across the Mekong Basin. Flooding extent from this event is shown in Figure 2 below. This study uses the 2011 Southeast Asia floods as a case study to determine the feasibility of near real-time damage assessments across the wider Mekong Basin.

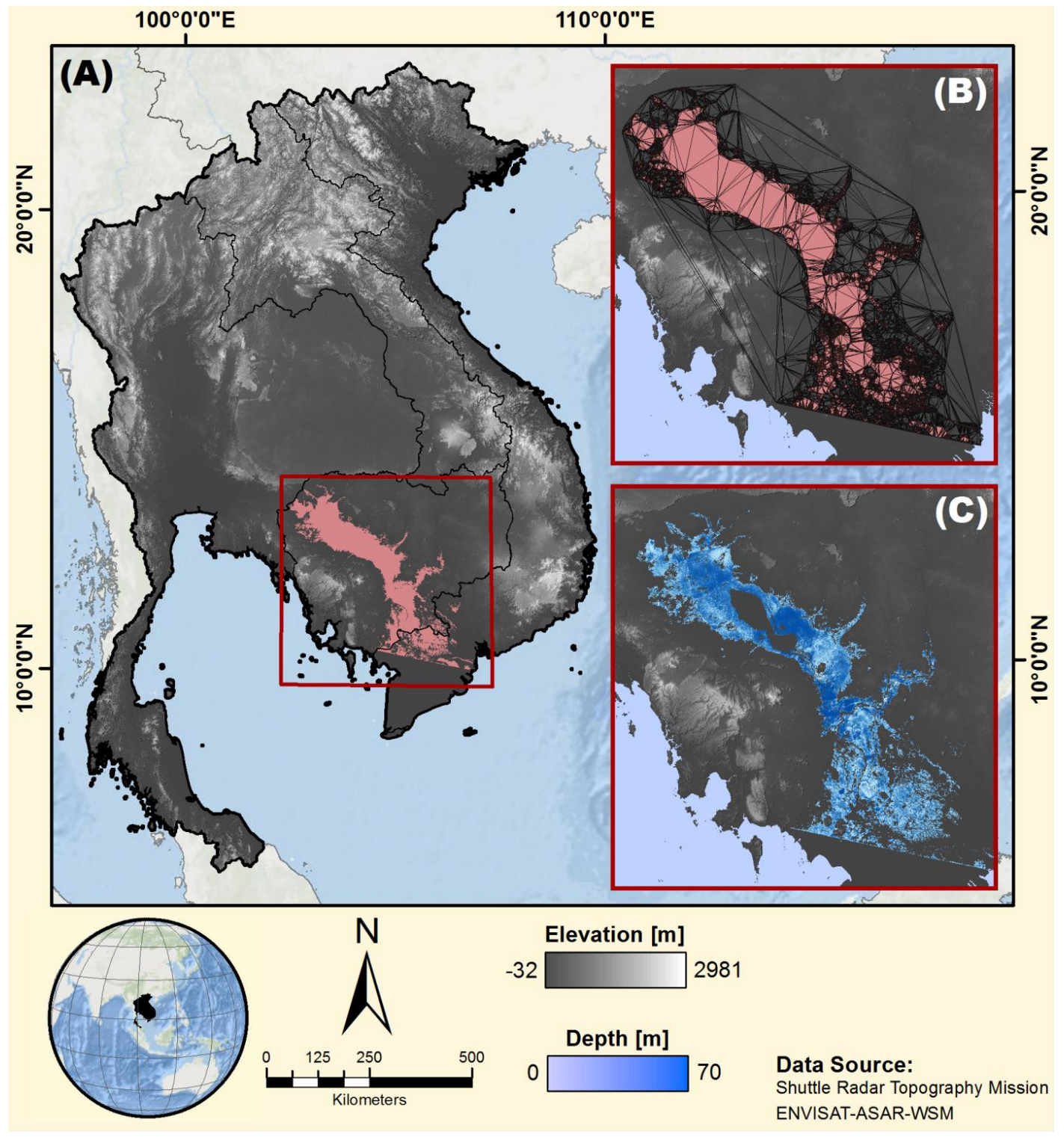


Figure 2. (A) Mekong region showing extent of 2011 Flood Event;
(B) Flood extent overlaid with Triangular Interpolated Network (TIN);
(C) Depth raster generated by subtracting underlying ground elevation from flood water surface.

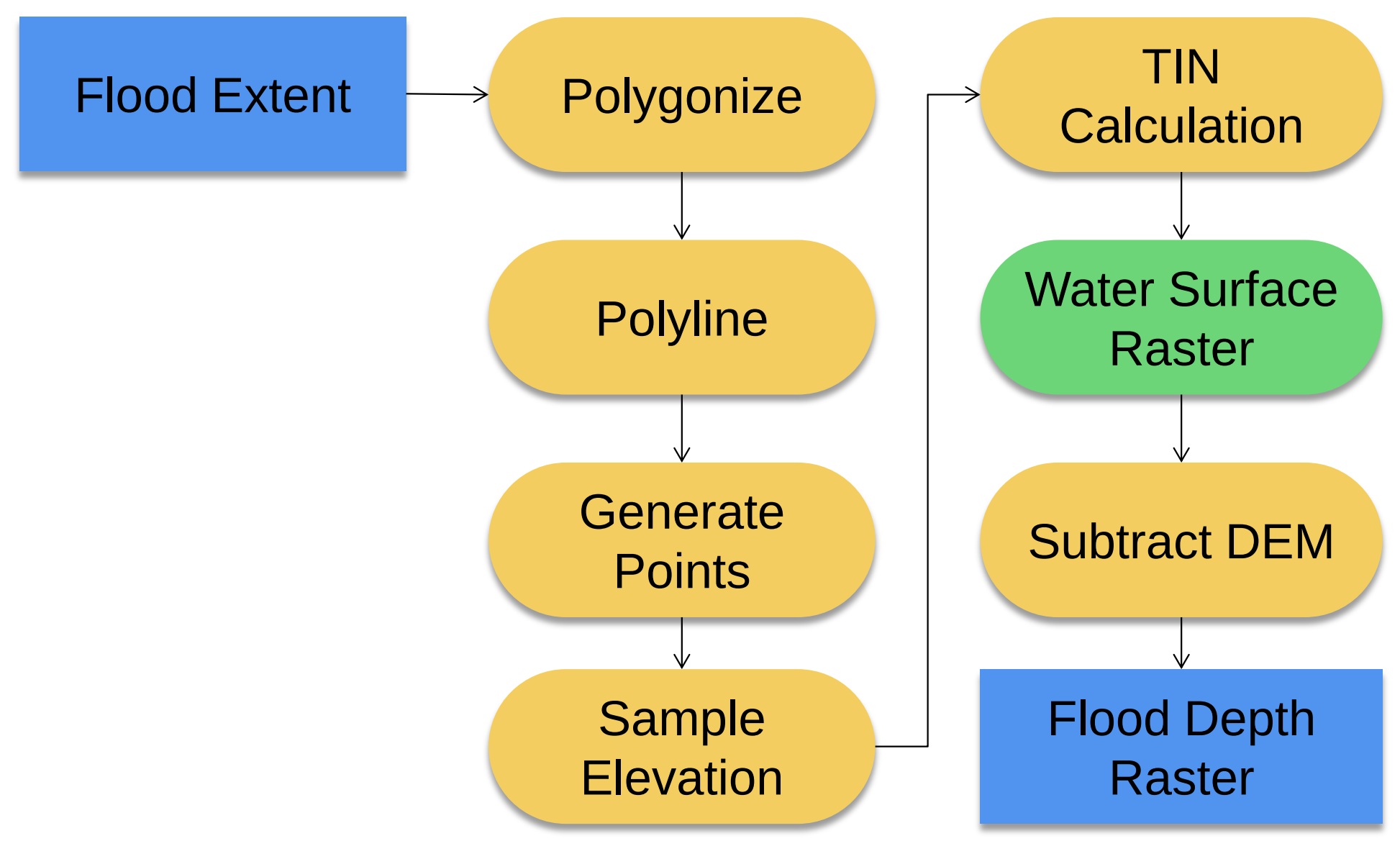
Objectives

Here we implement and improve on a socioeconomic impact assessment for flood damages in the Mekong Basin. For this study, we have three objectives:

1. **Use the 2011 Southeast Asia flood event as a case study to perform a feasibility analysis of near real-time impact assessment.**
2. **Develop a damage model that includes updated land cover and improved estimates of infrastructure damages.**
3. **Integrate impact assessment methodology into existing near real-time flood detection platform to visualize damages.**

Methodology

Depth Determination



Flood Extent → Polygonize → Polyline → Generate Points → Sample Elevation → TIN Calculation → Water Surface Raster → Subtract DEM → Flood Depth Raster

Figure 3. Schematic for estimating flood inundation depth. Flood extent from ENVISAT-ASAR Wide Swath Mode (WSM) was processed using the method described in Cham et al. (2015).

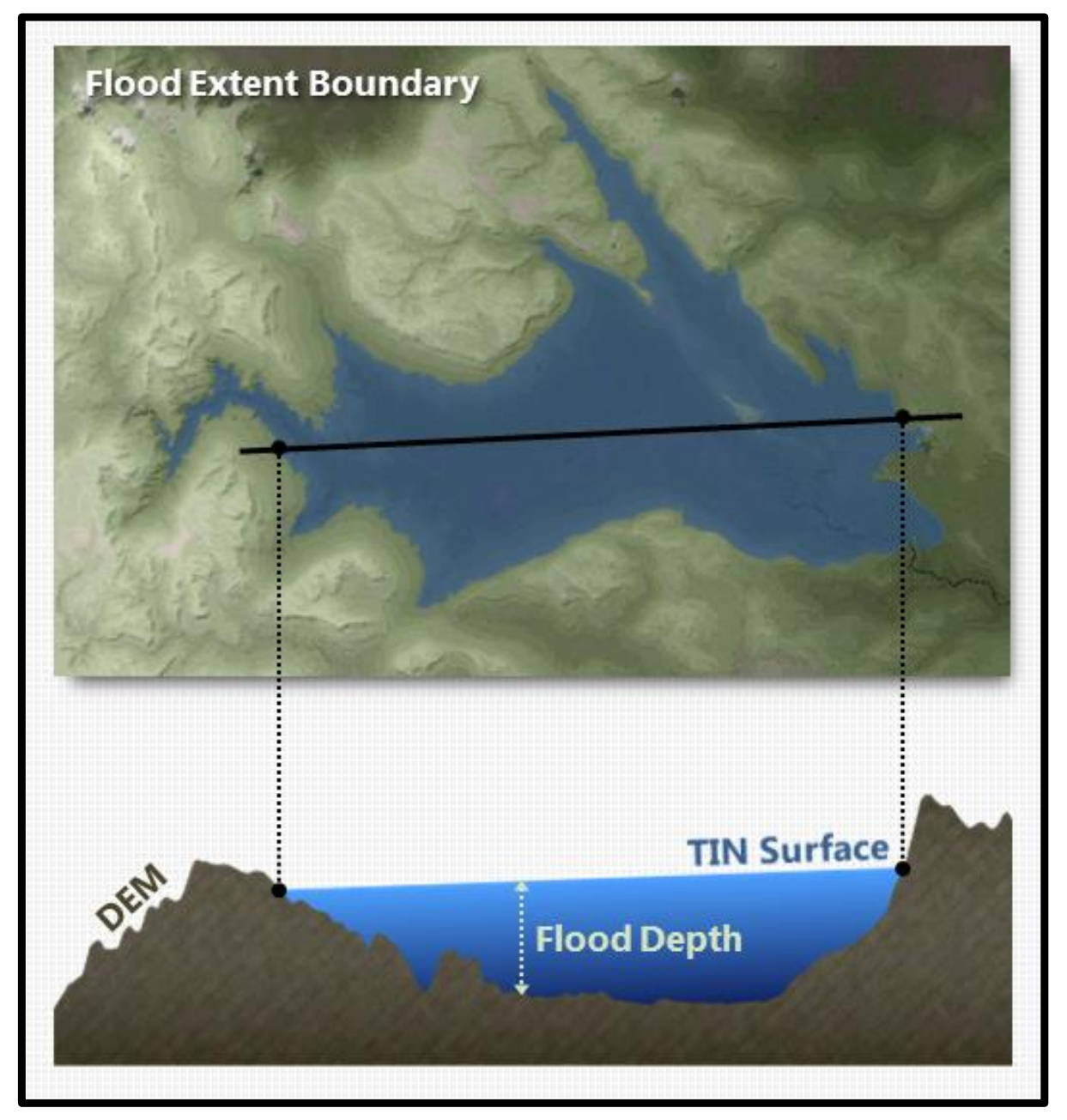


Figure 4. Cross-section illustration of inundation depth estimations. Top panel shows how flood extent is mapped to underlying digital elevation model (bottom panel) to produce a flood surface. Figure adapted from Cham et al. (2015).

Land Use / Land Cover & Infrastructure

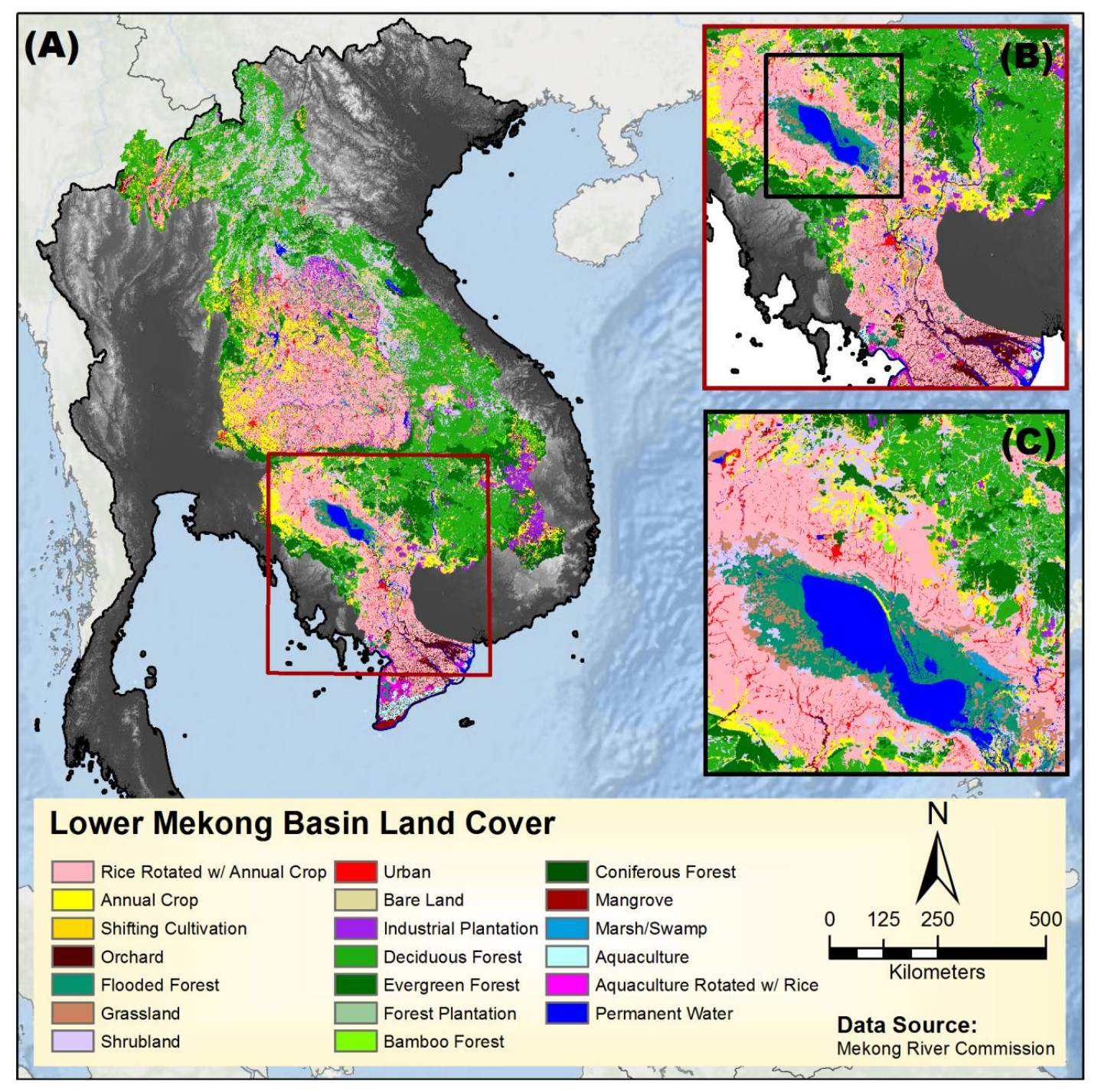


Figure 5. (Left) Land use / land cover map used in the case study. Map produced by Mekong River Commission at 30-meter resolution.

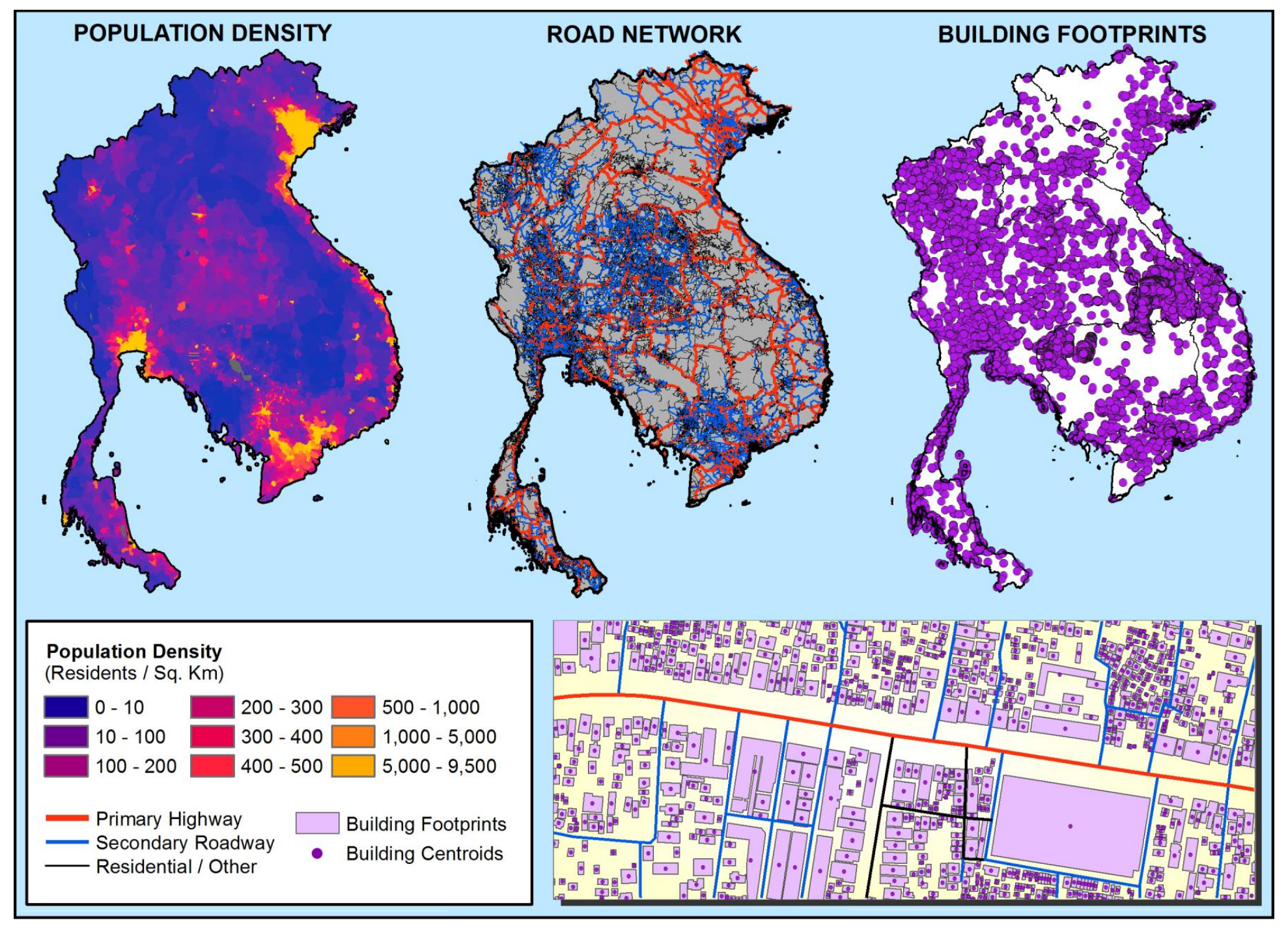


Figure 6. (Right) Infrastructure components of damage analysis. Population density data from NASA Socioeconomic Data and Applications Center (SEDAC) was used to classify regions as 'urban' vs. 'rural'. Roads data from gROADS (SEDAC) indicates locations of Primary, Secondary, and residential roadways. Building Footprints and Centroids were collected using open-source data from OpenStreetMap.

Damage Model

$$S = \sum_{i=1}^{n} a_i n_i S_i$$

where:
α_i = damage factor category, i
n_i = number of units in category, i
S_i = maximum damage per unit in category, i

"Standard Method"
(Kok et al. 2005)

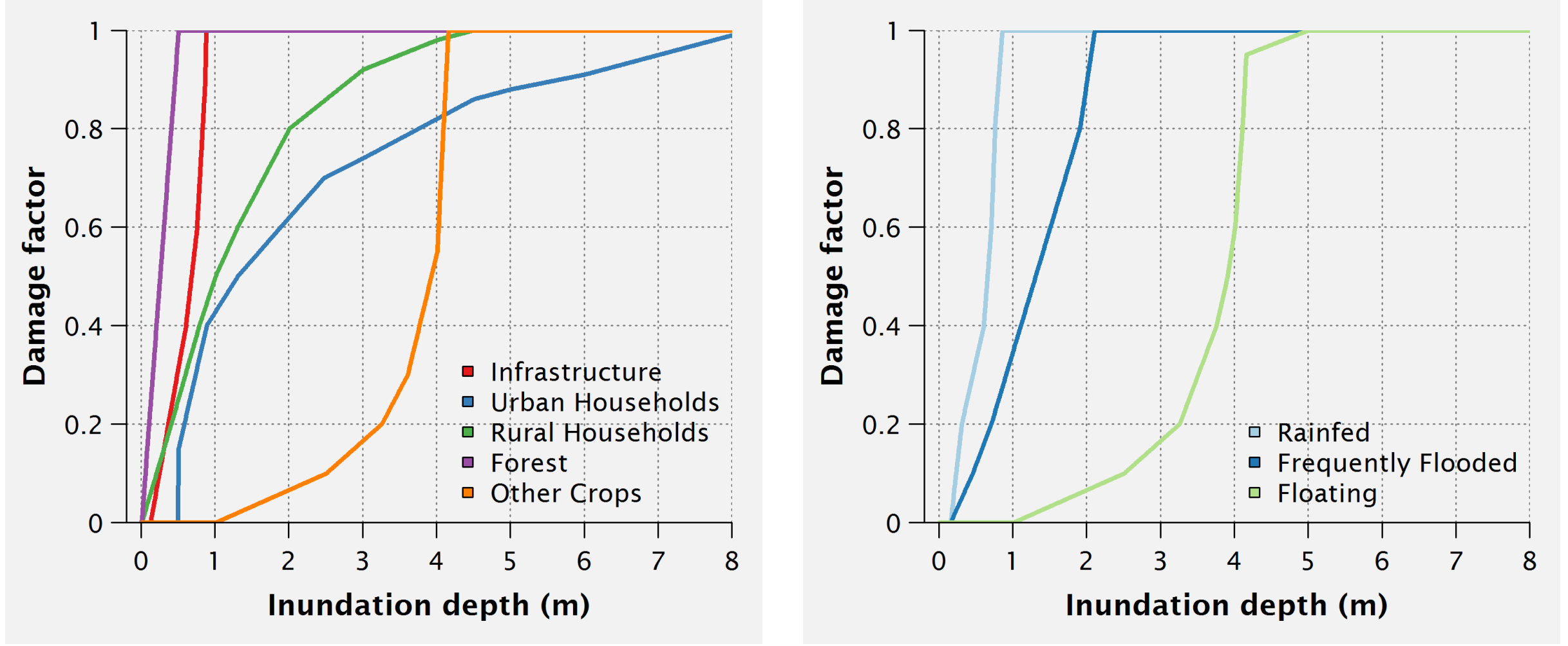
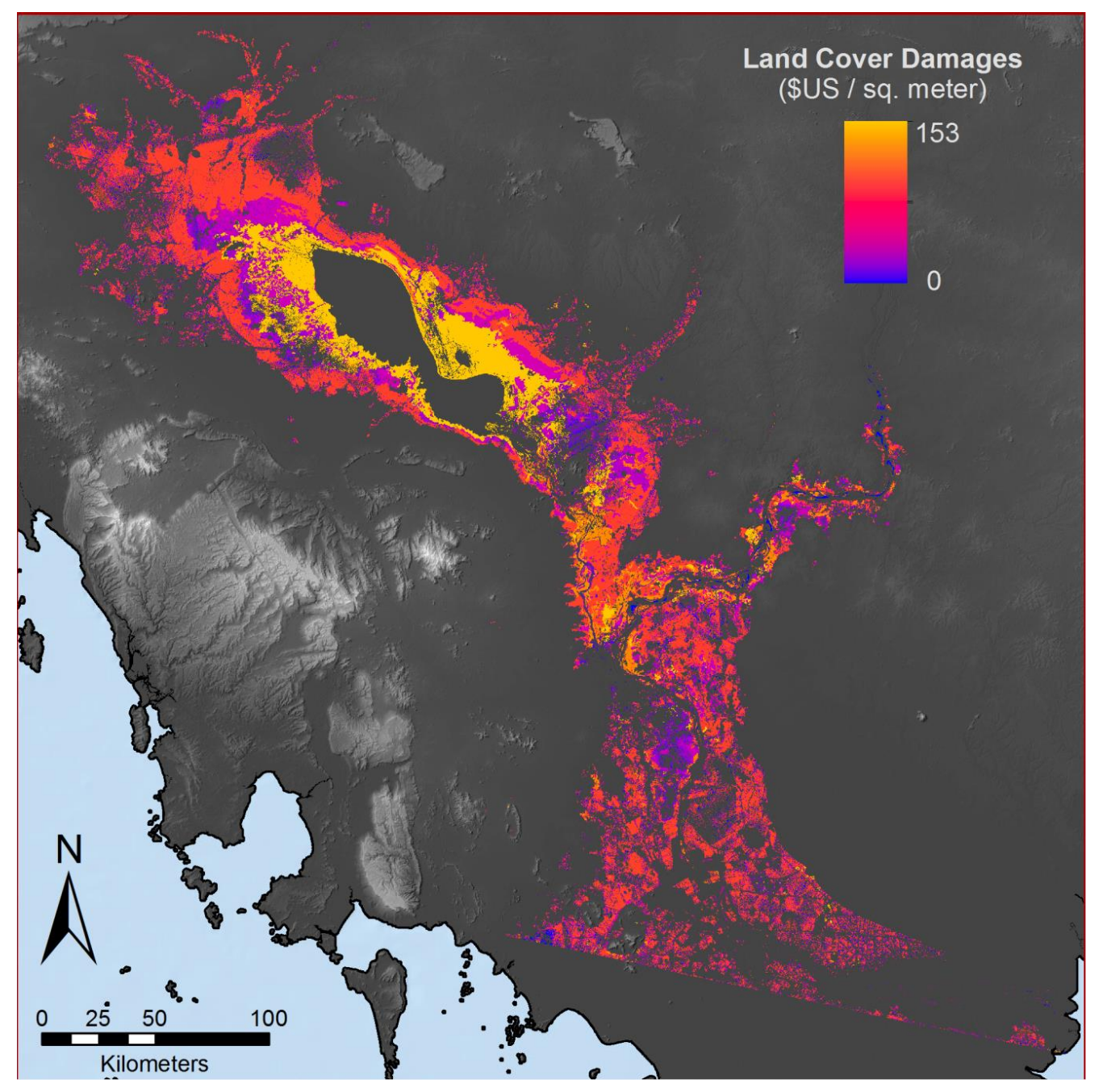


Figure 7. Damage factor curves for different land utility categories used in this study. Left panel shows agricultural and infrastructure curves digitized from Chen (2007). Right panel shows rice-specific for three varieties.

Table II. Maximum Damage Values used in this study.

Land Utility	USD/m^2	Source
Agriculture		
Rice, totally destroyed	0.078	*Leenders et al. (2009)*
Crop, totally destroyed	0.109	
Other Plants, totally destroyed	0.147	
Rice, partially destroyed	0.027	
Crop, partially destroyed	0.030	
Other Plants, partially destroyed	0.030	
Fishery		
Farm. Ponds and paddy fields	0.639	*Leenders et al. (2009)*
Shrimp and shell fish	1.706	
Freshwater fish	0.048	
Infrastructure		
Urban area	29	*Giang et al. (2009)*
Rural area	22	
Provincial road	80	
National road	400	
Railway	1000	
Other crops	0.02	
Forest	0.84	

Results



Description	Area (km^2)	Damages (USD)
Rice - 1 crop/yr	12,192.01	809,581,660
Mixed Annual Crops	1,425.17	129,237,367
Cleared before 2010	35.36	3,209,493
Orchard	242.66	6,585,287
Flooded Forest	3,113.91	2,543,914,840
Grassland/Sparse Vegetation	1,767.45	44,782,083
Deciduous Shrubland	1,155.41	28,755,228
Urban	205.91	888,217,376
Barren - Rock Outcrops	67.85	0
Industrial Plantation	1.30	32,003
Deciduous Broadleaved	7.15	5,048,014
Evergreen/ Broadleaved	2.18	1,613,848
Forest Plantation	0.00	0
Bamboo Scrub/Forest	11.09	9,130,890
Coniferous Forest	0.00	0
Mangrove	1.71	962,455
Marsh/Swamp	493.05	13,617,733
Aquaculture	5.99	224,727
Aquaculture Rotated with Rice	17.56	298,482

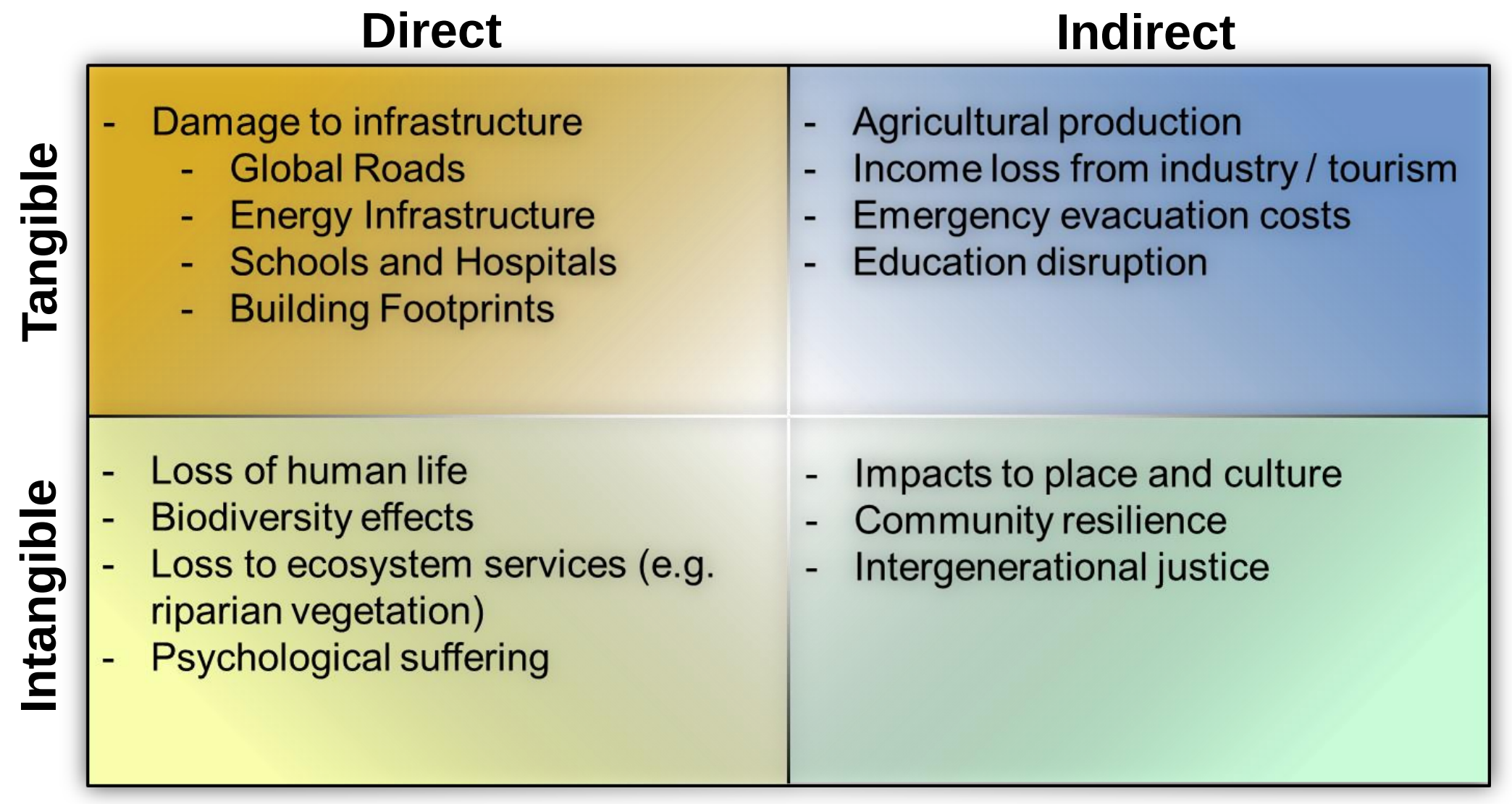
- Case study results show how damages can be calculated on a per pixel basis and re-projected to be viewed spatially.
- Locations directly around the Tonle Sap Lake indicate the largest damages, due to the comparatively high maximum damage value (S_i) for forests, and the presence of the 'Flooded Forest' land cover around the lake.

Figure 8. Results of damage assessment for land cover categories. Scale bar represents severity of damages in USD / m^2.

Table II. Land utility with total affected area and estimated damages.

Discussion

- The 2011 Southeast Asia Flood event provides a valuable case study for evaluating flood impacts.
- Inundation depth estimates, using the method described in Cham et al. (2015), can be produced quickly and provide a critical input for damage model.
- Updated land use / land cover maps improve our understanding of impacts to crops and other vegetation.
- Flood depth and damage estimates still require validation from primary literature.
- Future work will integrate damage model with existing near real-time flood detection platform, Project Mekong.



	Direct	Indirect

Tangible	- Damage to infrastructure
	  - Global Roads
	  - Energy Infrastructure
	  - Schools and Hospitals
	  - Building Footprints
		- Agricultural production
		- Income loss from industry / tourism
		- Emergency evacuation costs
		- Education disruption

Intangible	- Loss of human life - Biodiversity effects - Loss to ecosystem services (e.g. riparian vegetation) - Psychological suffering	- Impacts to place and culture - Community resilience - Intergenerational justice

Figure 9. Flood impacts matrix illustrating areas for future socioeconomic damage valuations.

Conclusions

- Floods cause significant threats to many communities in southeast Asia.
- Near real-time flood detection systems can be a critical resource to government agencies or first responders in the wake of a disaster.
- Impact assessments can provide useful information about what regions are most impacted by flooding, particularly when generated in near real-time.
- The Dutch "Standard Method" is a practical model for estimating damages and can be readily integrated into existing flood detection platforms.
- More work is required to constrain damage values and validate depths.

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