THA 2022 26-28/01/2022

Integrated Groundwater and Socio-Economic Vulnerability Analysis to Identify Potential Risk of Water Stress

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USGS science for a changing world

NexView

Pilot study to support natural resource **decision-making**

Cross-disciplinary analysis of **groundwater and socio-economic resources**

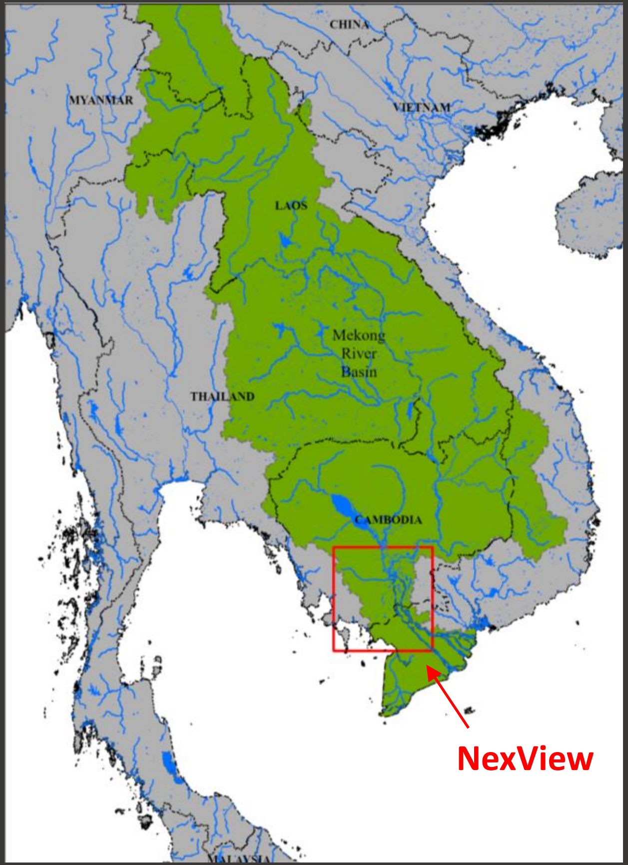
Risk assessment using climate change scenarios

Measure of **adaptive capacity** to respond to risk

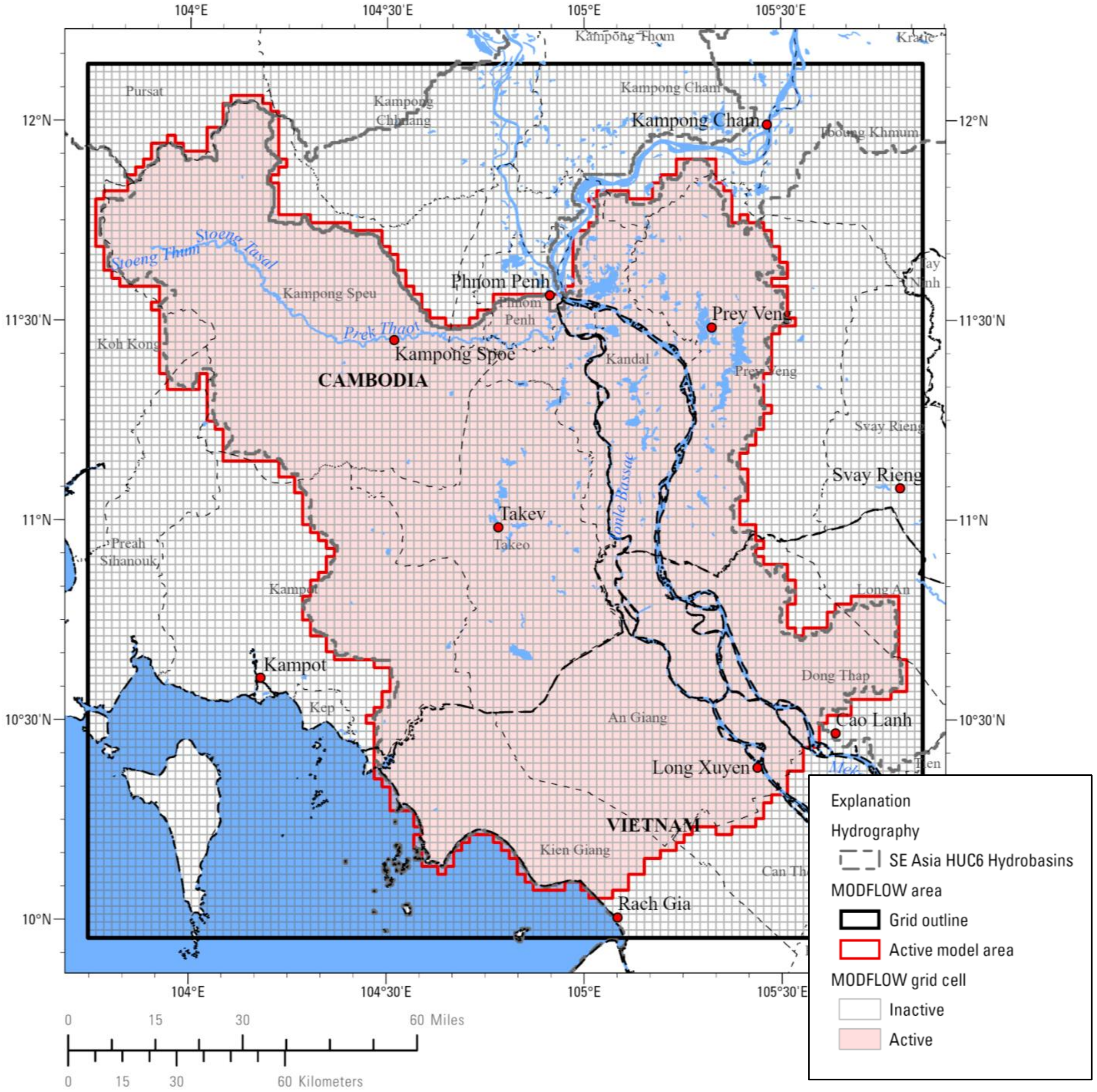
pact building local promise.


Overview
Vulnerability Framework
Groundwater
Risk Exposure
Socio-economic
Risk Sensitivity & Response

STUDY AREA



CHINA
MYANMAR
VIETNAM
LAOS
Mekong River Basin
THAILAND
CAMBODIA
NexView



104°E
104°30'E
105°E
105°30'E
12°N
11°30'N
11°N
10°30'N
10°N
Kampong Cham
Phnom Penh
Prey Veng
Kampong Spoe
CAMBODIA
Takev
Svay Rieng
Kampot
Cao Lanh
Long Xuyen
VIETNAM
Rach Gia
0 15 30 60 Miles
0 15 30 60 Kilometers
Explanation
Hydrography
SE Asia HUC6 Hydrobasins
MODFLOW area
Grid outline
Active model area
MODFLOW grid cell
Inactive
Active

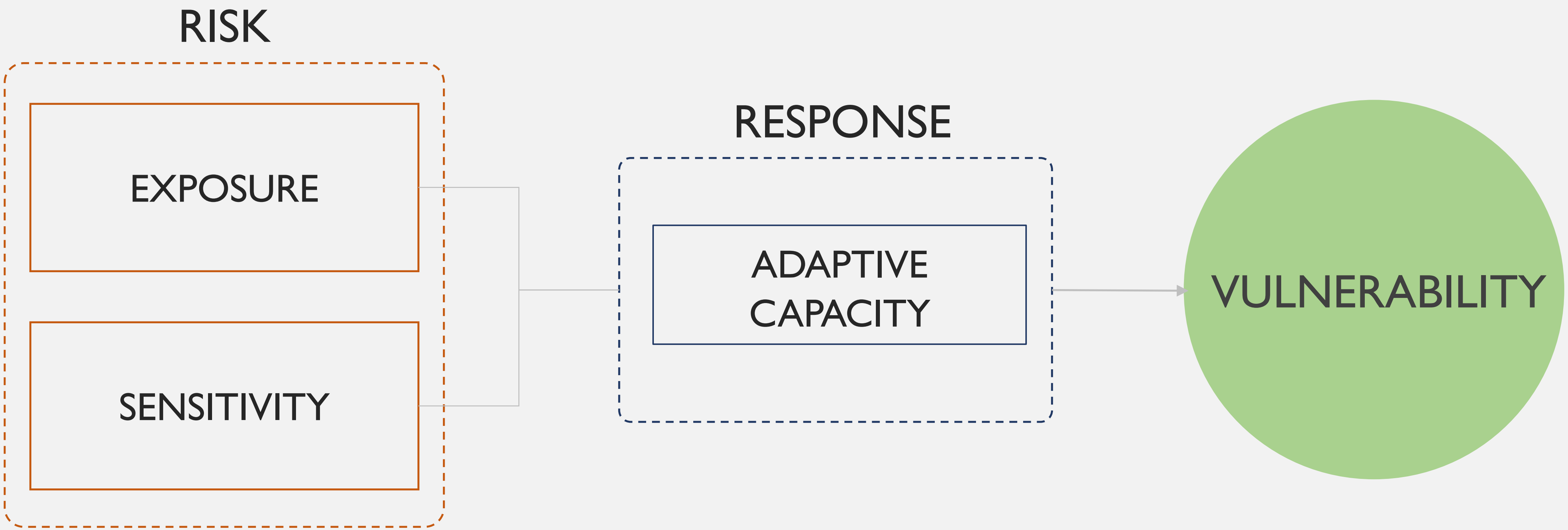
GOALS

GROUNDWATER MODEL

+

SOCIO-ECONOMIC MODEL

VULNERABILITY FRAMEWORK



CALCULATING RISK

EXPOSURE

Defined as: degree of change in the level of groundwater experienced in an area

Calculated as: the relative change in groundwater level under different climate scenarios (MODFLOW)

The *more* groundwater declines, the *higher* the exposure.

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The *more* groundwater declines, the *higher* the exposure.

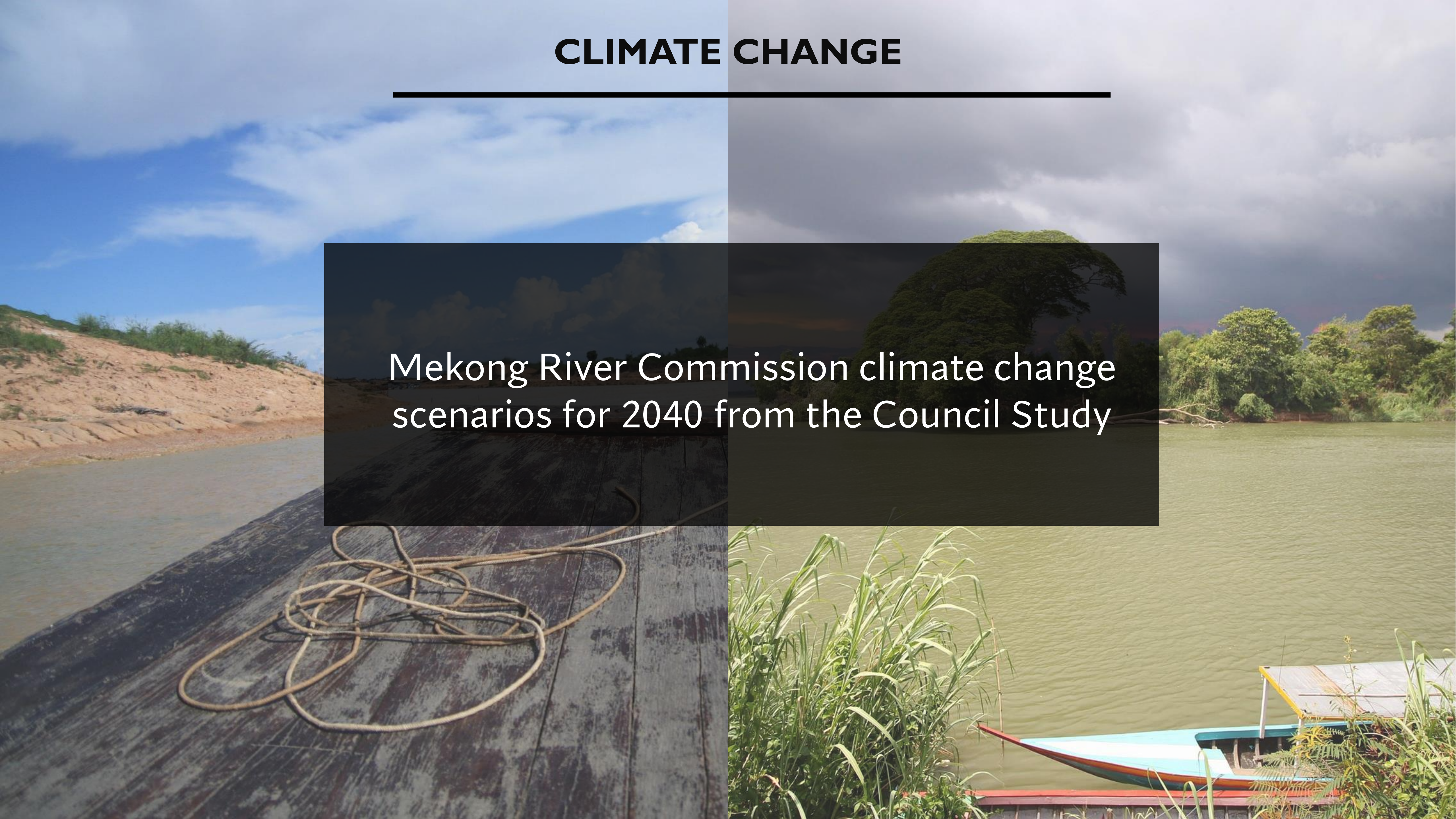
SENSITIVITY

Defined as: A community's dependence on freshwater to maintain livelihoods and human populations

Calculated as: the total water needs for humans, livestock and agriculture

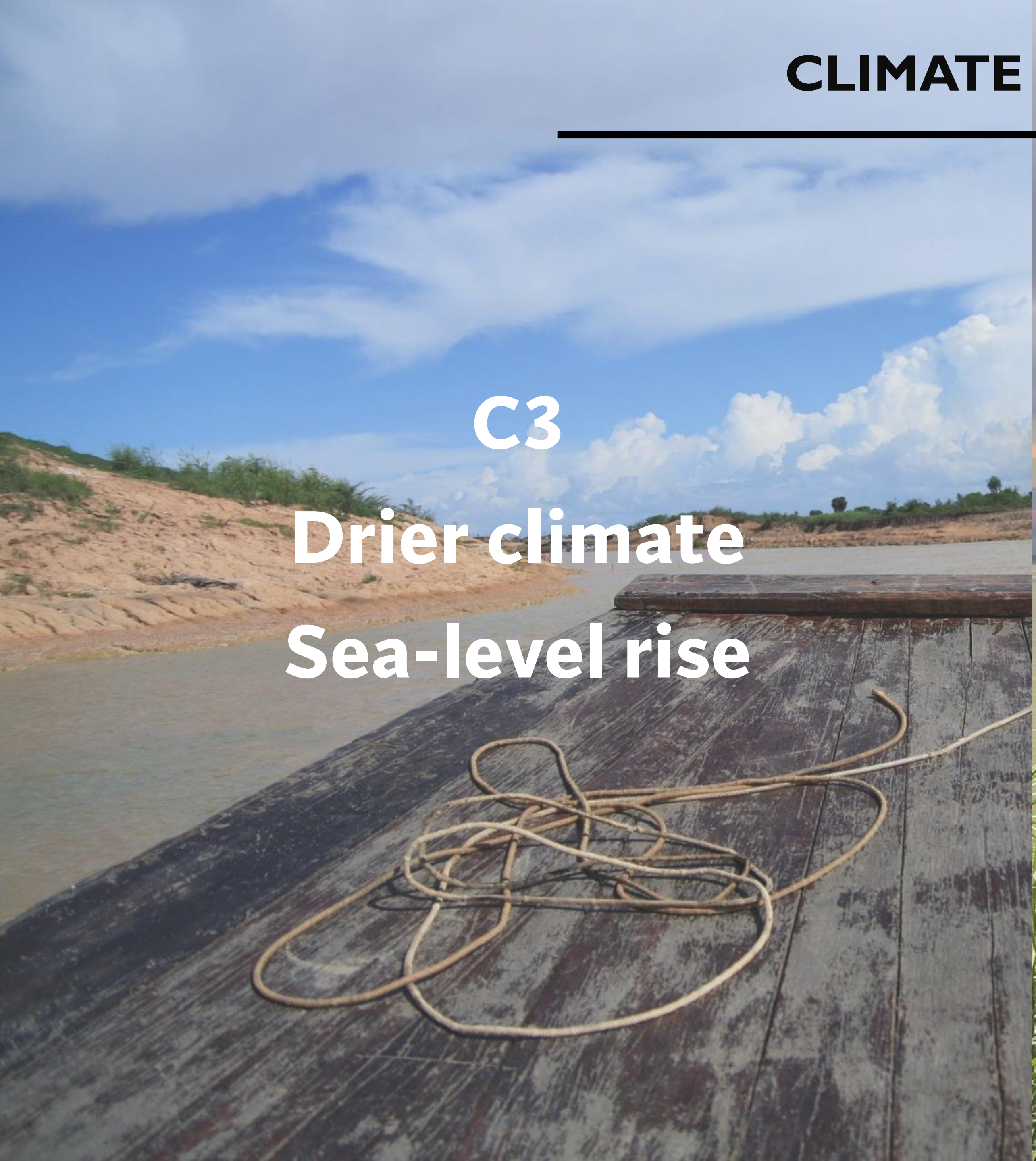
The *more* water needed, the *higher* the sensitivity.

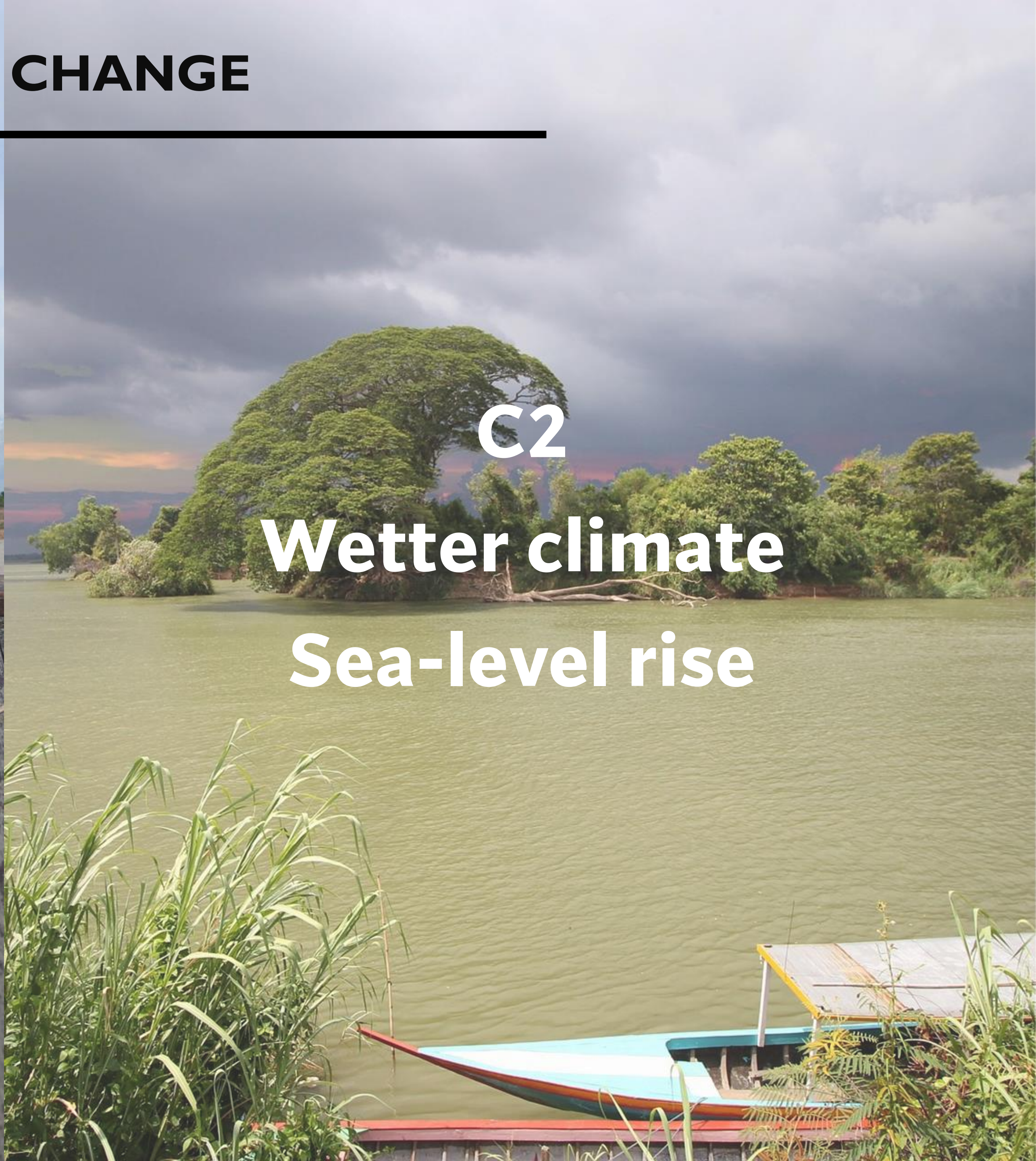
CLIMATE CHANGE



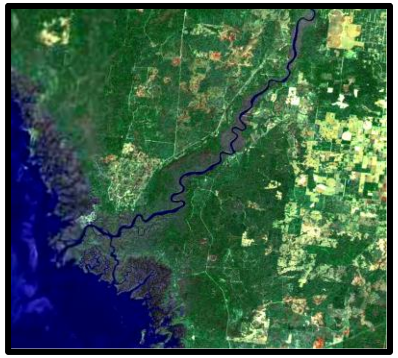
Mekong River Commission climate change scenarios for 2040 from the Council Study

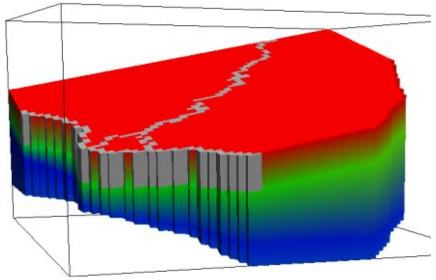
CLIMATE CHANGE

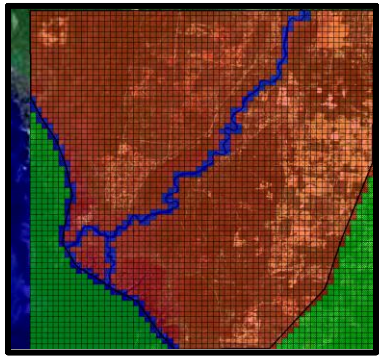


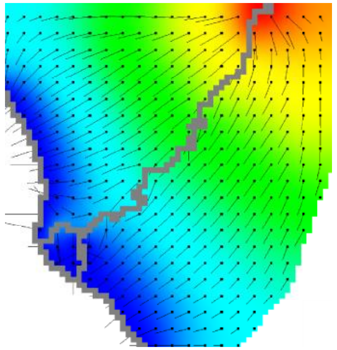


A Numerical Groundwater Flow Model









Real-world system → Hydrogeologic and conceptual models → Model input → Model output

Real-world system

- How will the model be used?
- What processes are most important?

Hydrogeologic and conceptual models

- Hydrogeologic understanding
- Understand and describe important groundwater processes

Model input

- Spatial extent and time period
- Hydrogeologic properties
- Representation of aquifer stress

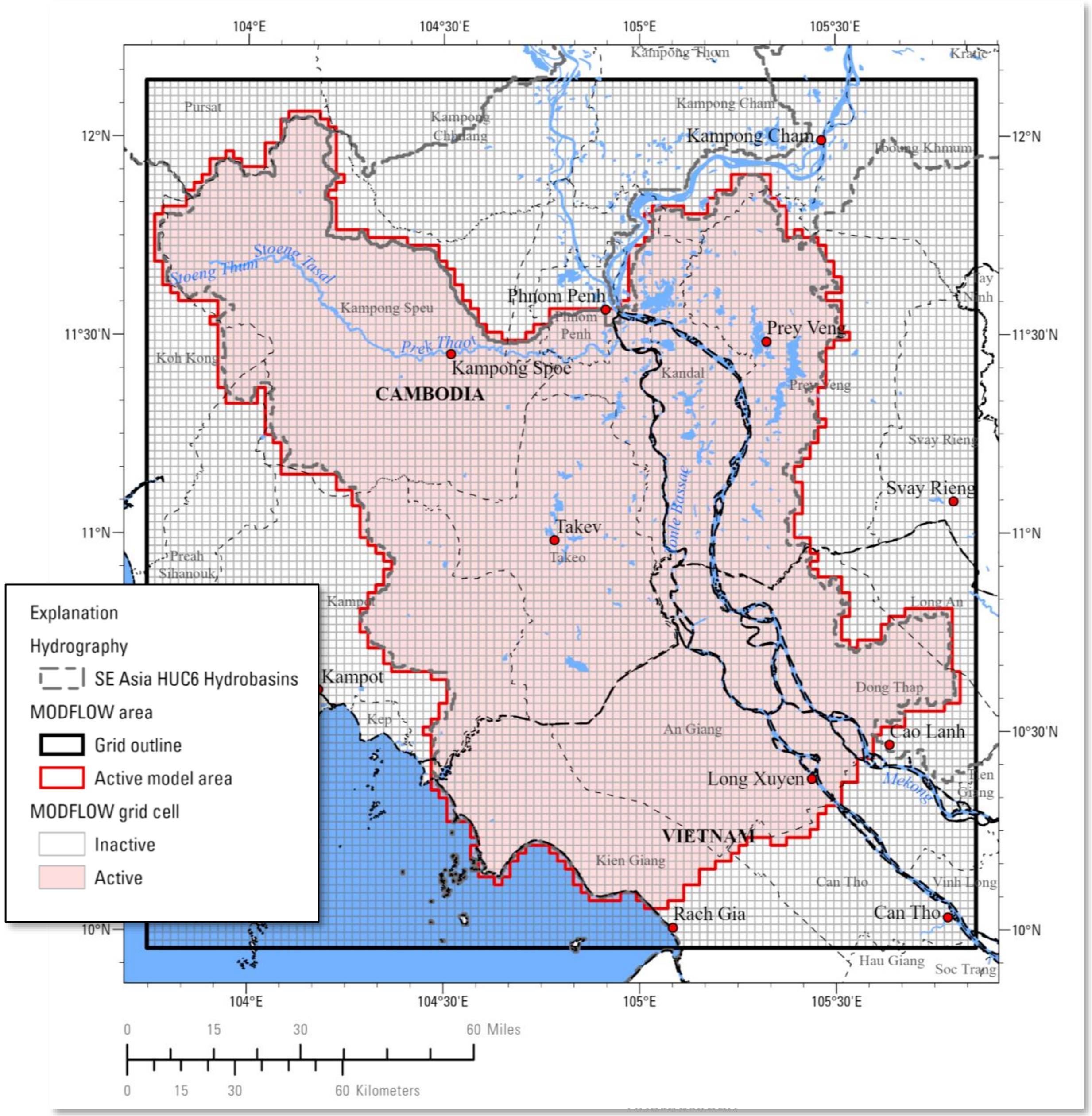
Model output

- Simulation of system behavior in space and time
- Simulation of potential future scenarios

USGS
science for a changing world

Model Design

- USGS MODFLOW-6
- Spatial extent and time period
  - Mekong River Basin between Phnom Penh, Cambodia and Cao Lanh, Vietnam
  - Predevelopment (steady-state)
  - Time-varying conditions (1991-2010):
    - Historical
    - Future scenarios (20 years)
  - Stress periods: three months long
    - Two per dry season (Nov. – Apr.)
    - Two per wet season (May – Oct.)

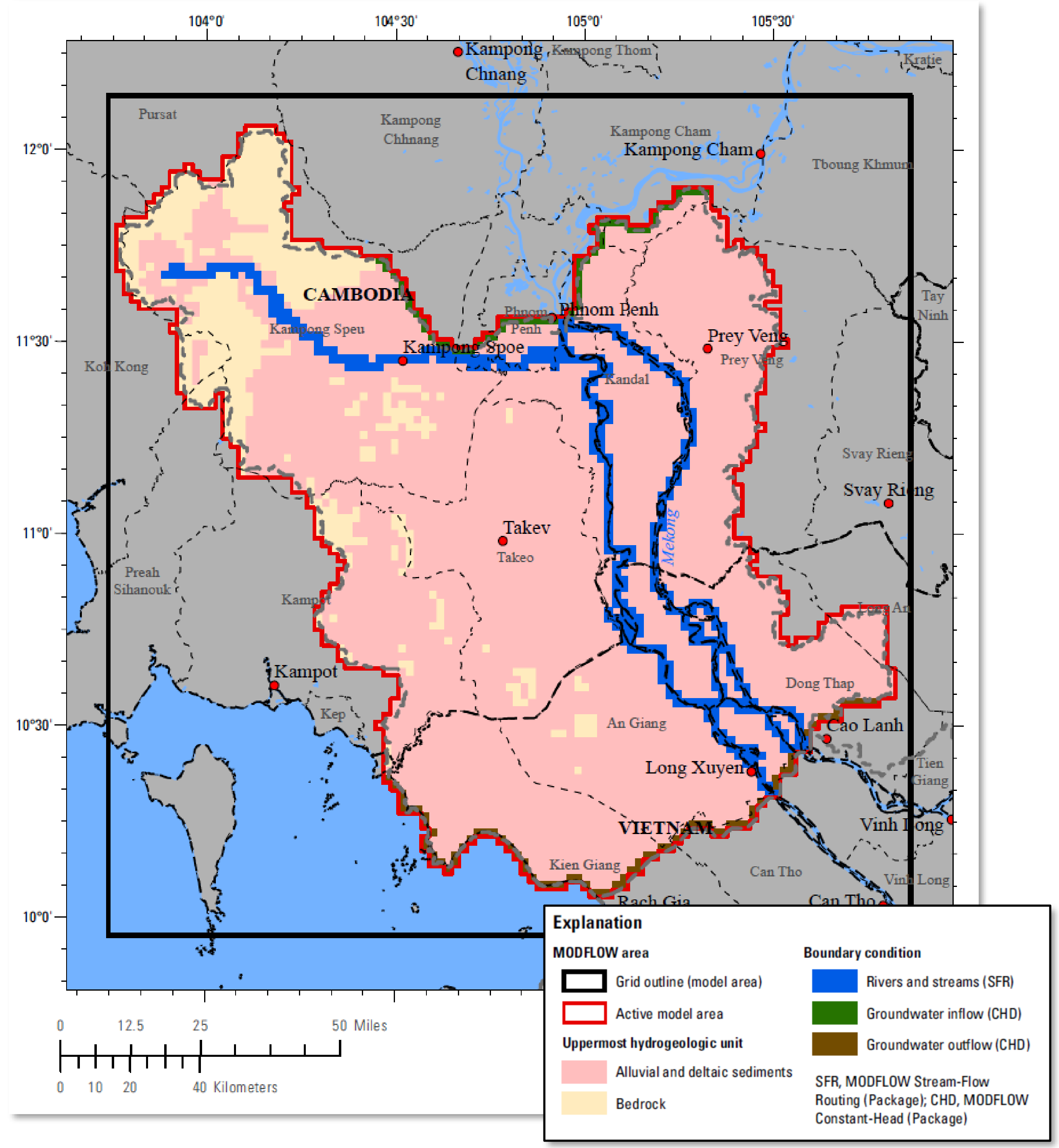


Conceptual Understanding

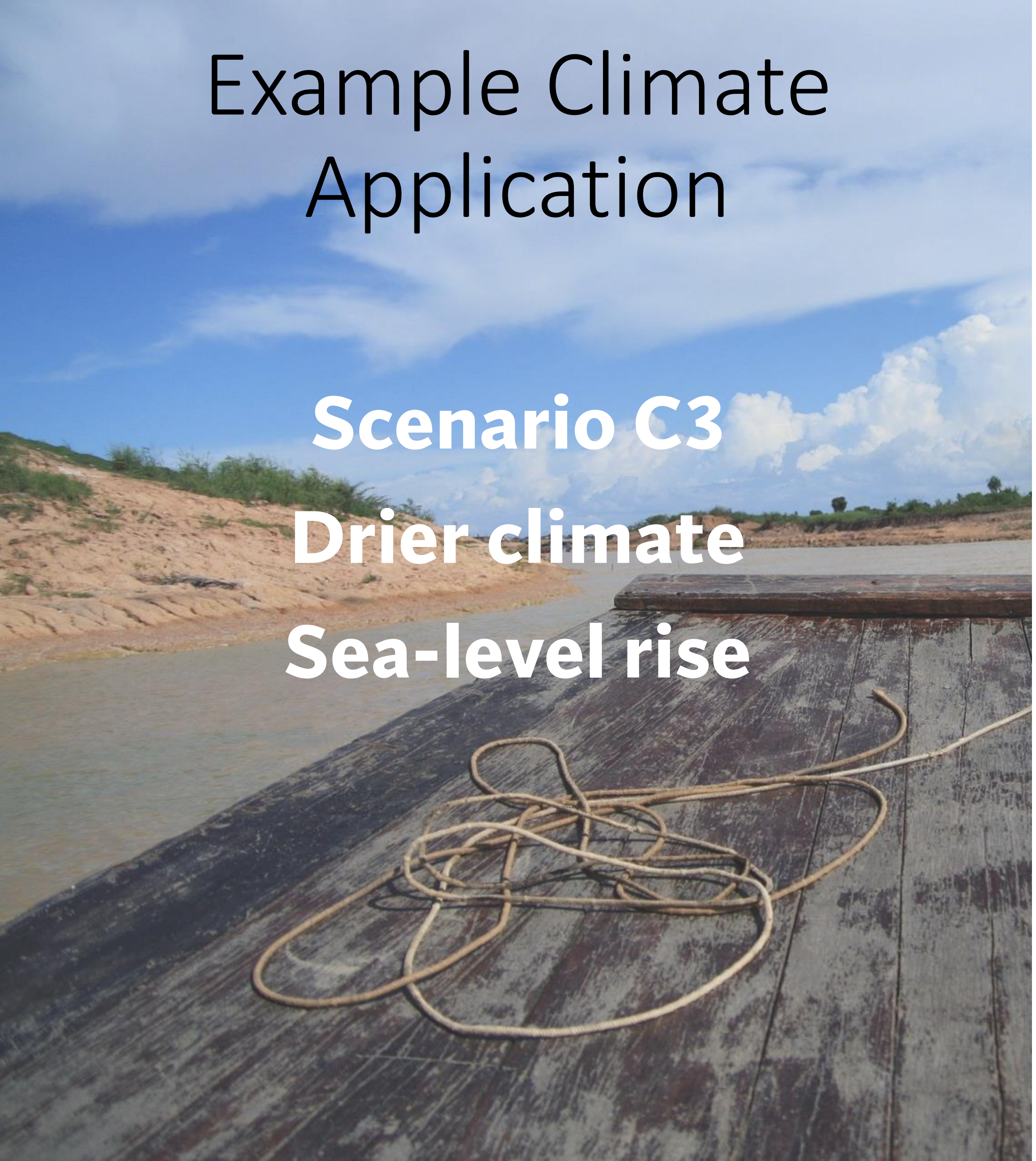
- Hydrogeologic understanding
  - Layers 1–5: delta aquifer and confining units
  - Layers 6: bedrock aquifers
  - Used geologic maps define initial layering and extent
  - Uniform hydrogeologic properties
- Understand and describe important groundwater processes
  - Streamflow
  - Connection between rivers and aquifers
  - Recharge
  - Evapotranspiration
  - Groundwater pumping*
  - Salt-water intrusion*
  - Land subsidence*

Model Input

- Representation of aquifer stress
  - Interaction with streams
    - Time variable streamflow
  - Spatially uniform recharge:
    - Time variable
    - Approximately 16 percent of precipitation
  - Spatially uniform maximum potential evapotranspiration:
    - About 1.5 meters per year
  - Groundwater inflow and outflow



Example Climate Application



Scenario C3

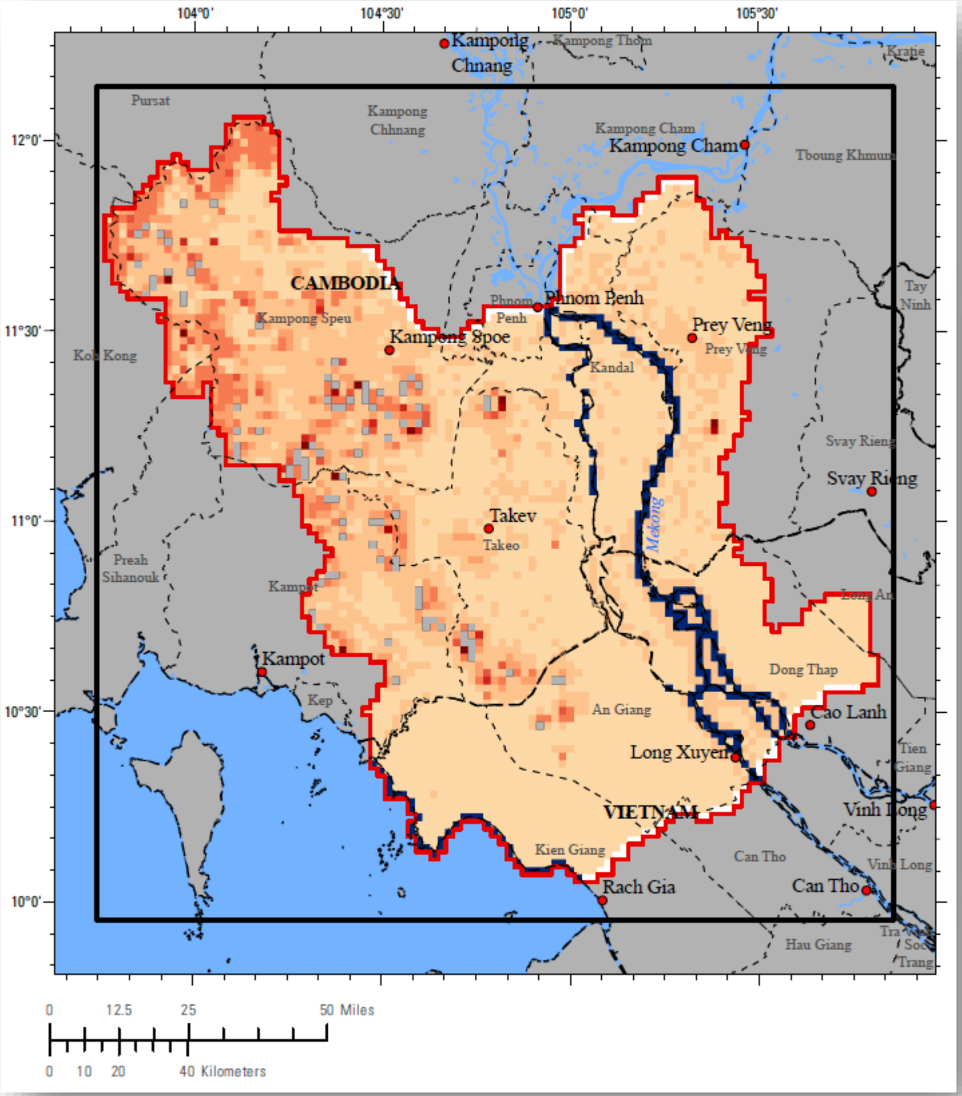
Drier climate

Sea-level rise

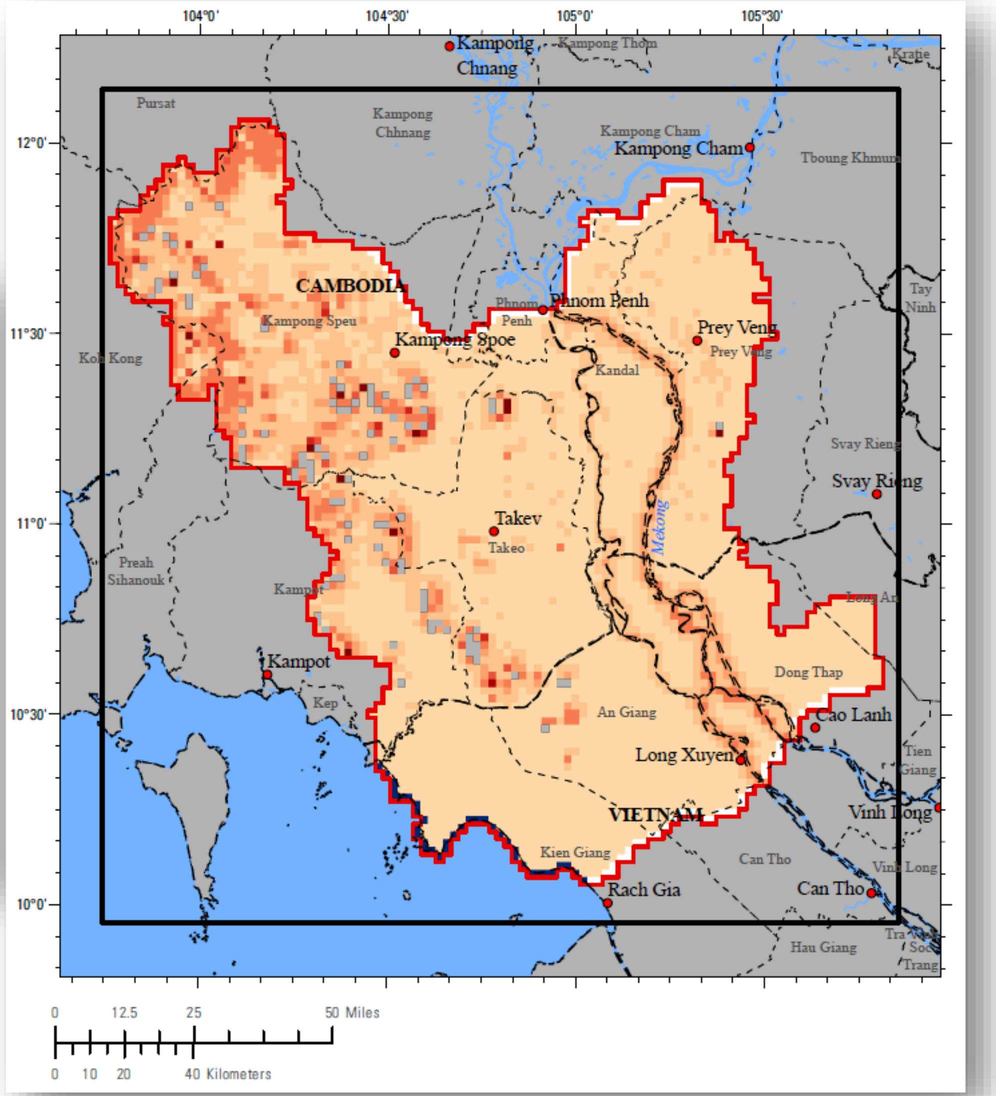
- Changes applied to model
  - Adjusted monthly recharge
  - Adjusted monthly streamflow at Phnom Penh
  - Sea-level rise
- Example analyses of model results
  - Calculate relative water level change

Simulated water level declines (exposure)

Dry season



Wet season



Explanation

Water level decline, as a percent of saturated thickness

- -3 to 0
- 0
- 0 to 1
- 1 to 5
- 5 to 10
- 10 to 20
- 20 to 40
- 40 to 60
- 60 to 80
- 80 to 100

CALCULATING SENSITIVITY

WATER NEEDS

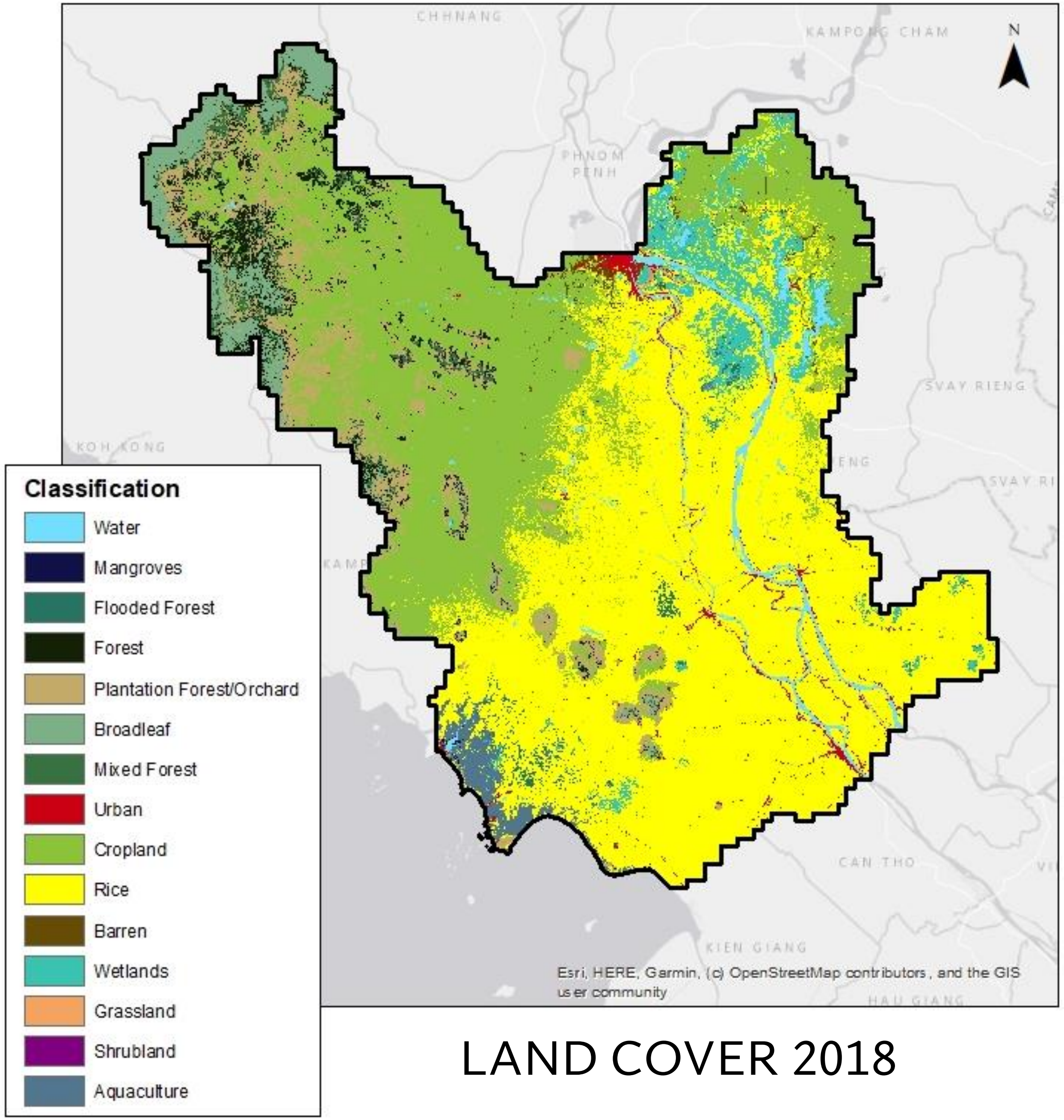
CALCULATING SENSITIVITY

WATER NEEDS

Human Needs
Rural / urban population

Livestock Needs
Buffalo, cattle, pigs, poultry

Agriculture Needs
Rice, maize, sugar cane, cassava, cashew, mango, etc.



LAND COVER 2018

DATA USED

- SERVIR-Mekong Land Cover Maps
- WorldPop - Human population distribution raster
- GeomWiki – Livestock distribution raster
- Census Reports (Human Population and Agricultural) from KHM and VN

HUMAN WATER NEEDS

HIGH

MODERATE

LOW

SENSITIVITY

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Buffalo, cattle, sheep, pigs, poultry

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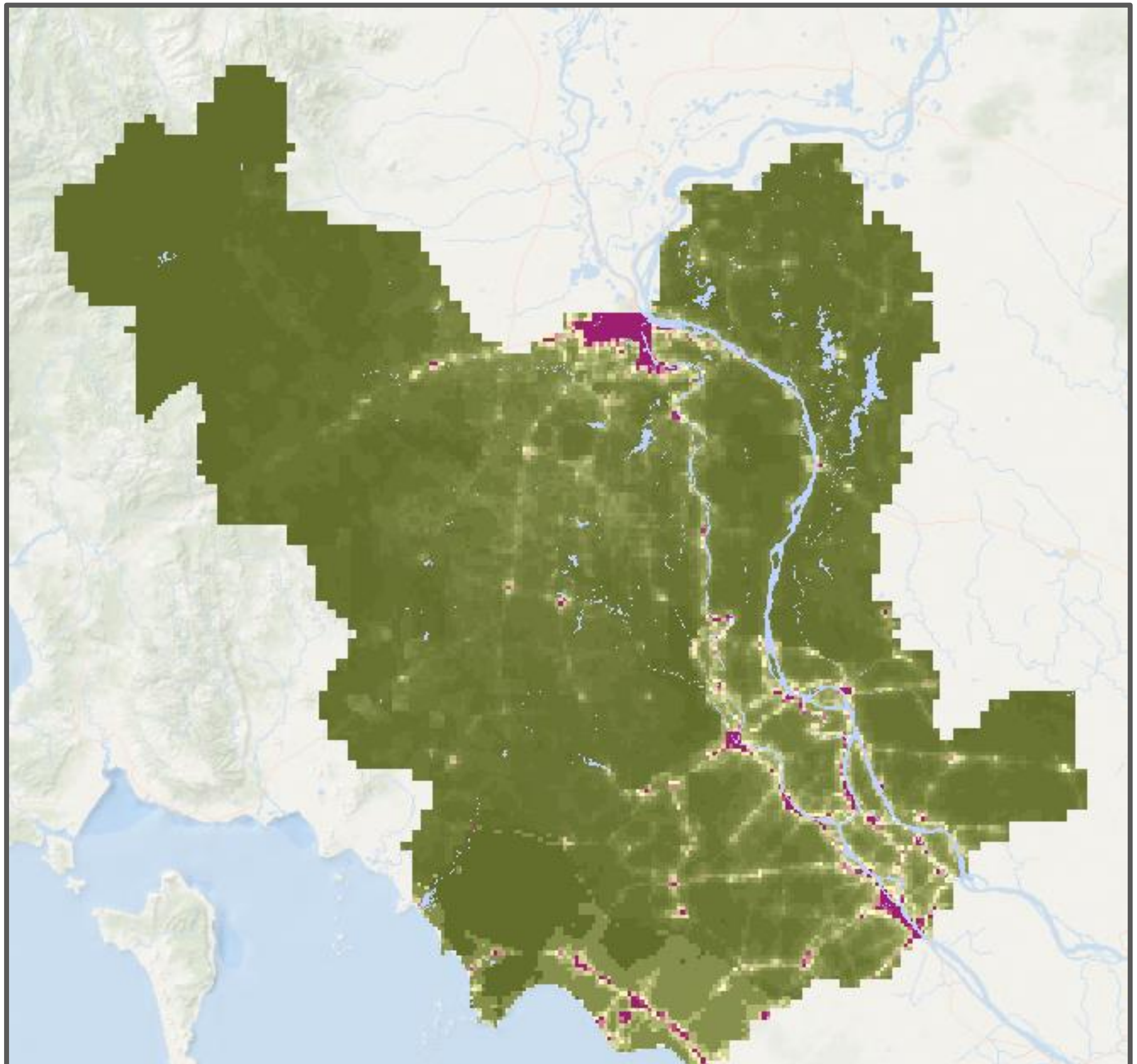

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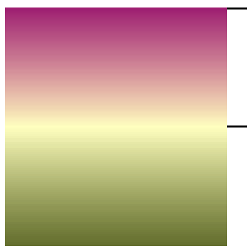
LIVESTOCK WATER NEEDS



SENSITIVITY

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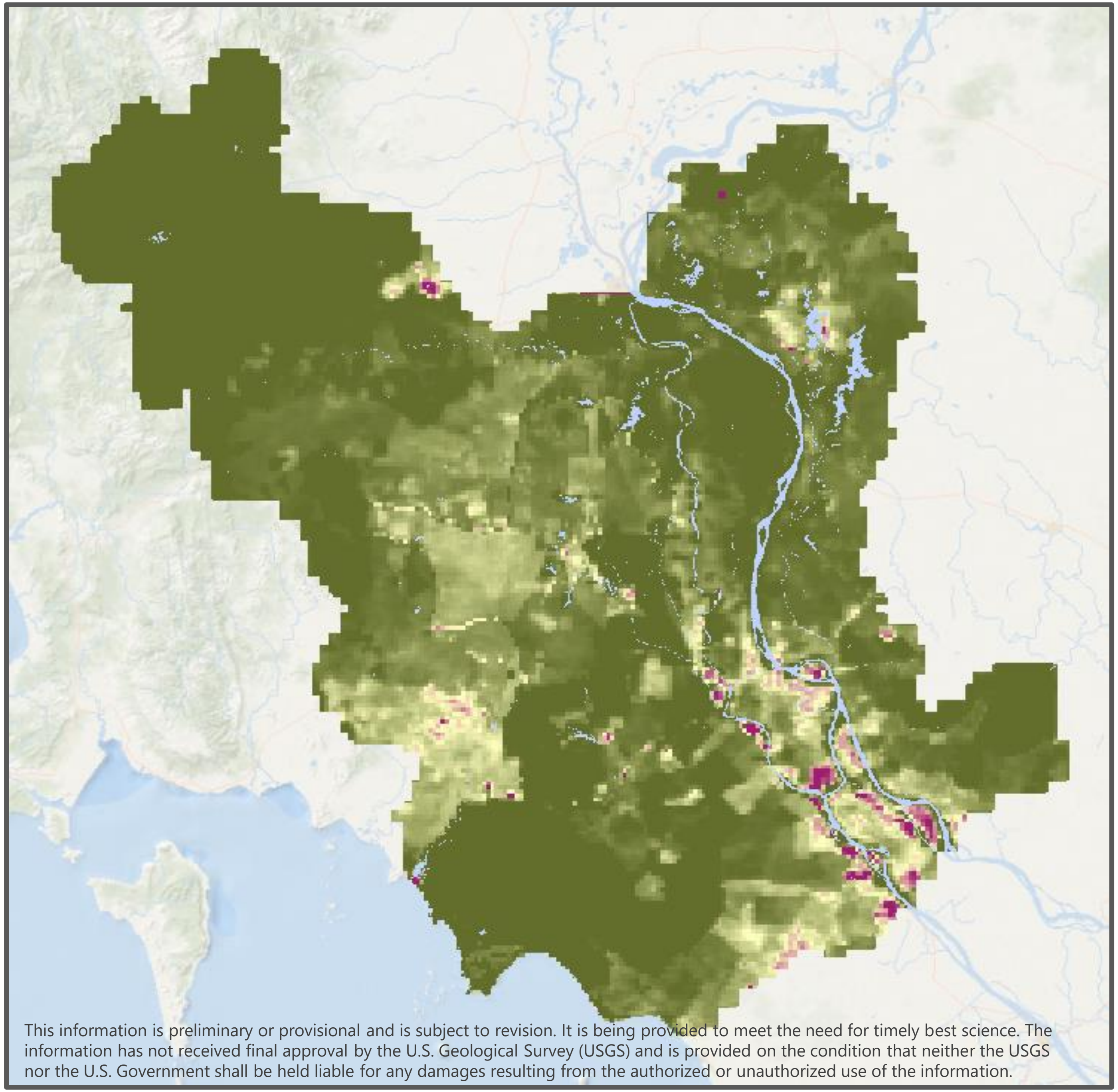
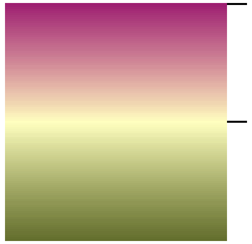


AGRICULTURE WATER NEEDS



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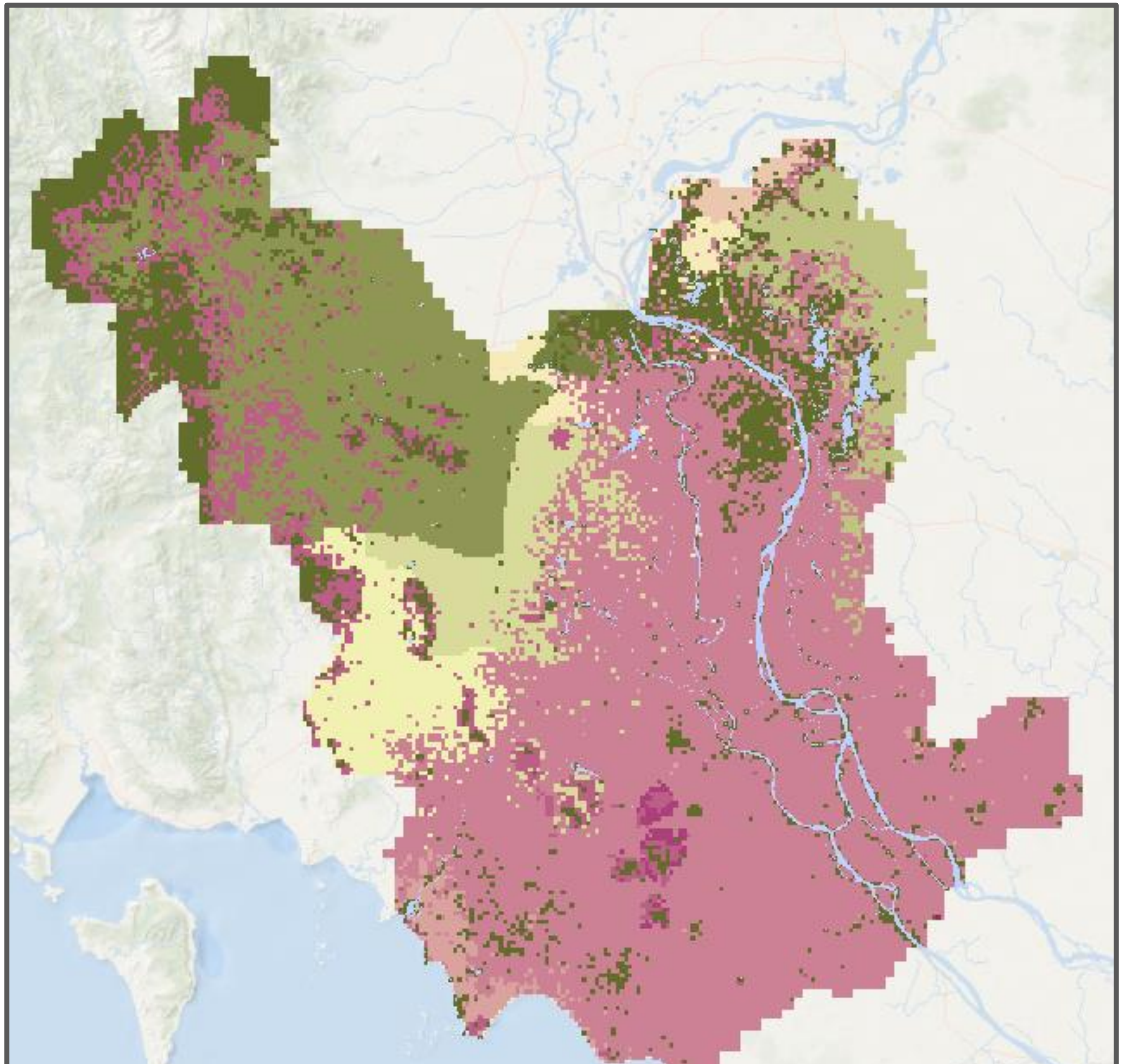

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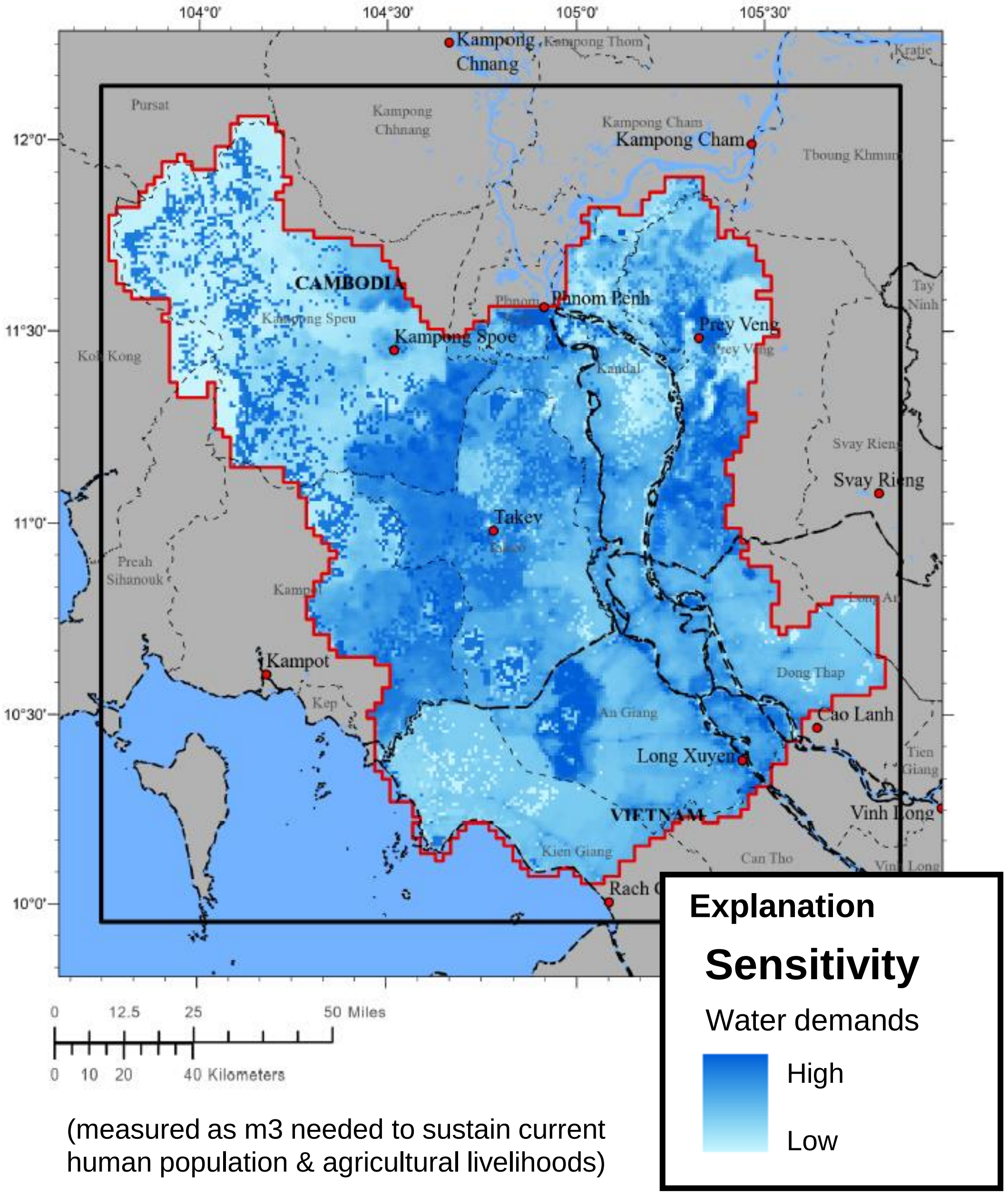

(measured as m3 needed to sustain current human population & agricultural livelihoods)

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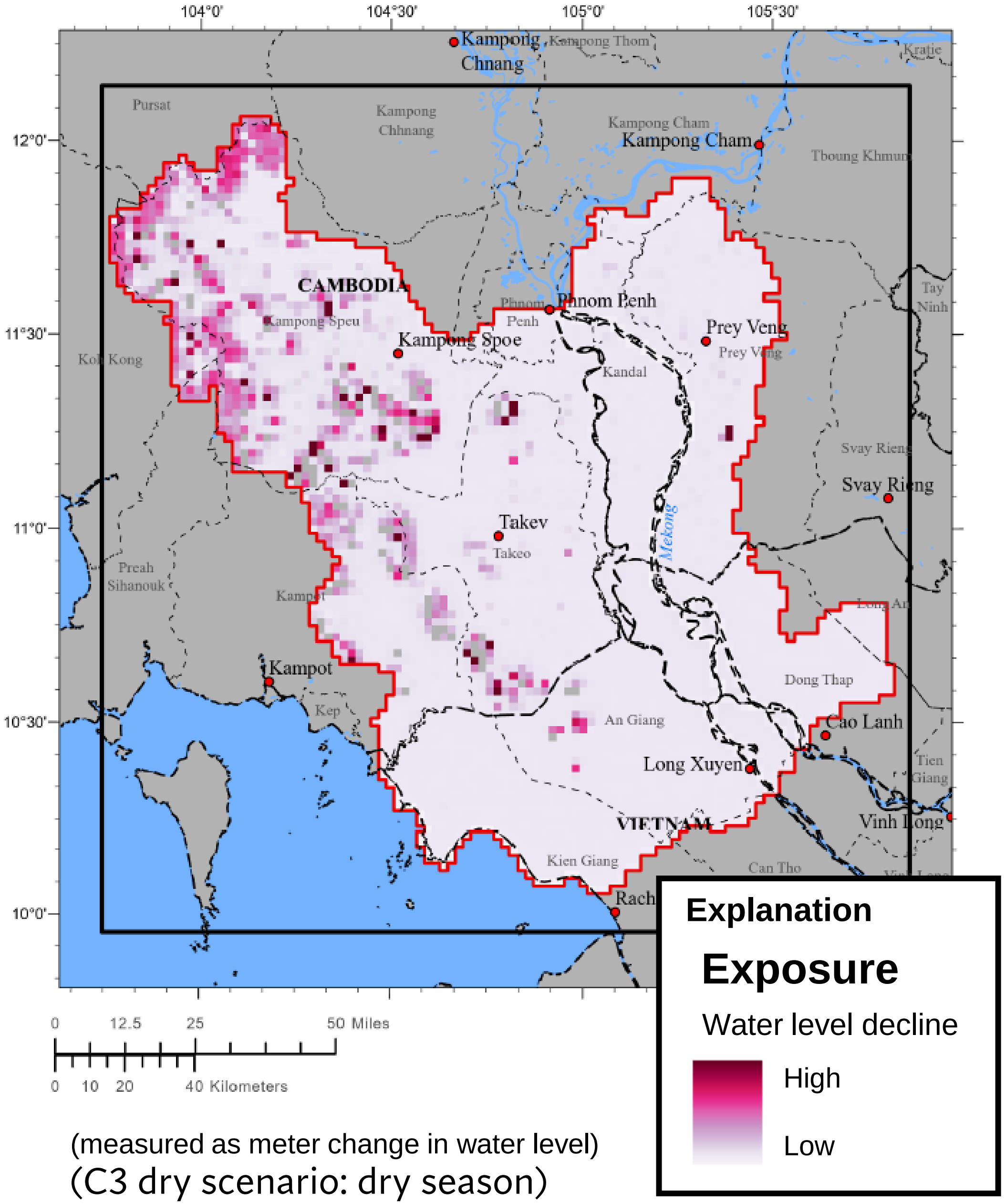
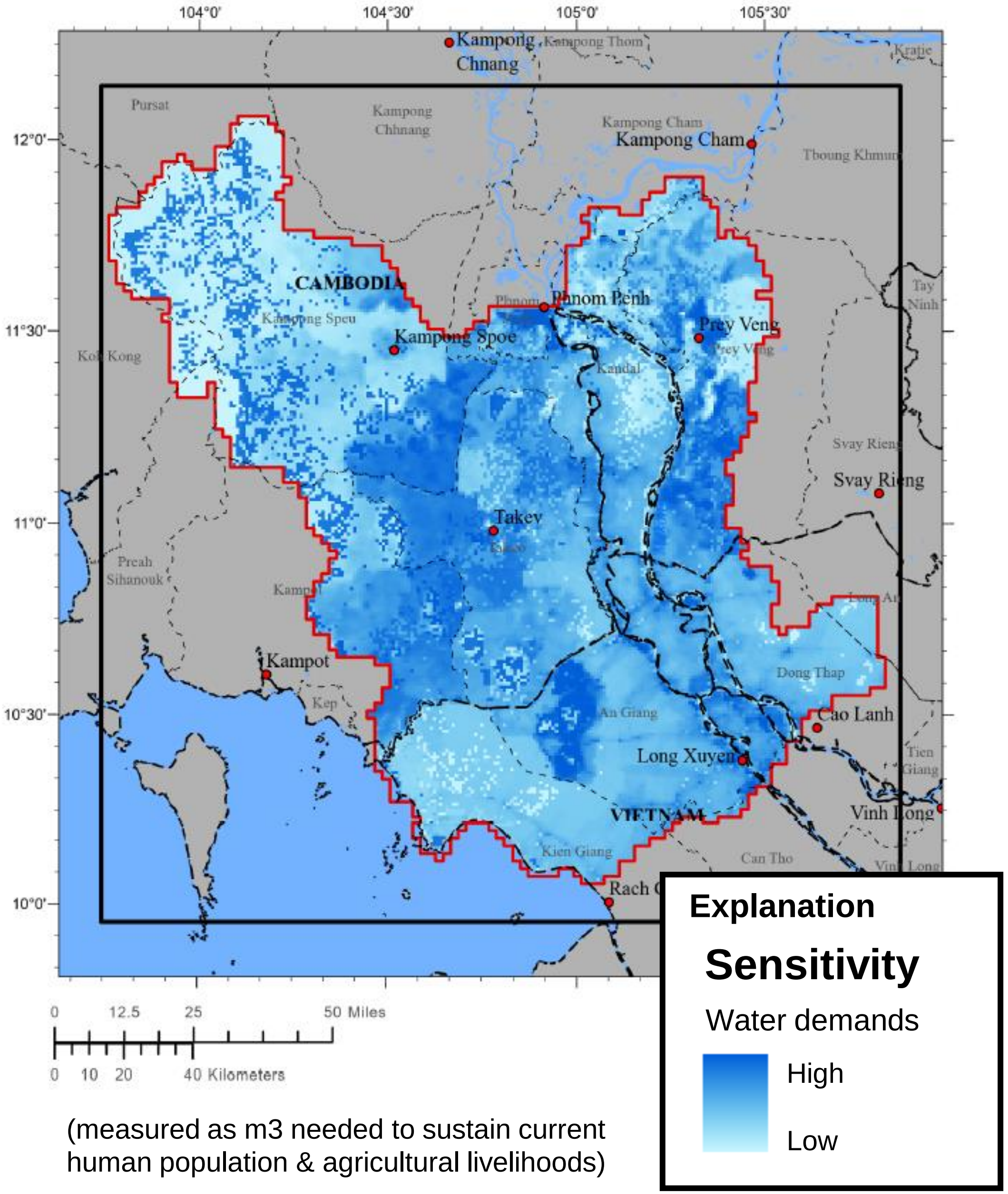


(measured as meter change in water level)
(C3 dry scenario: dry season)

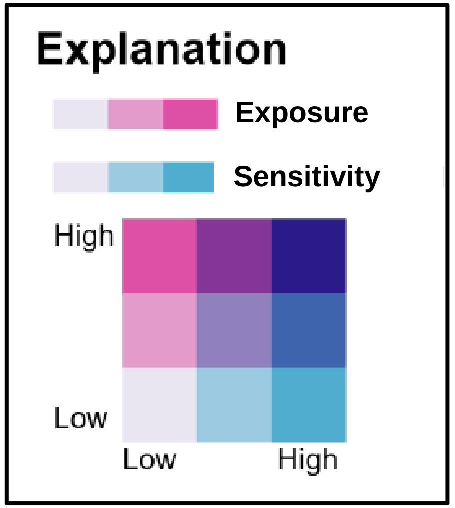


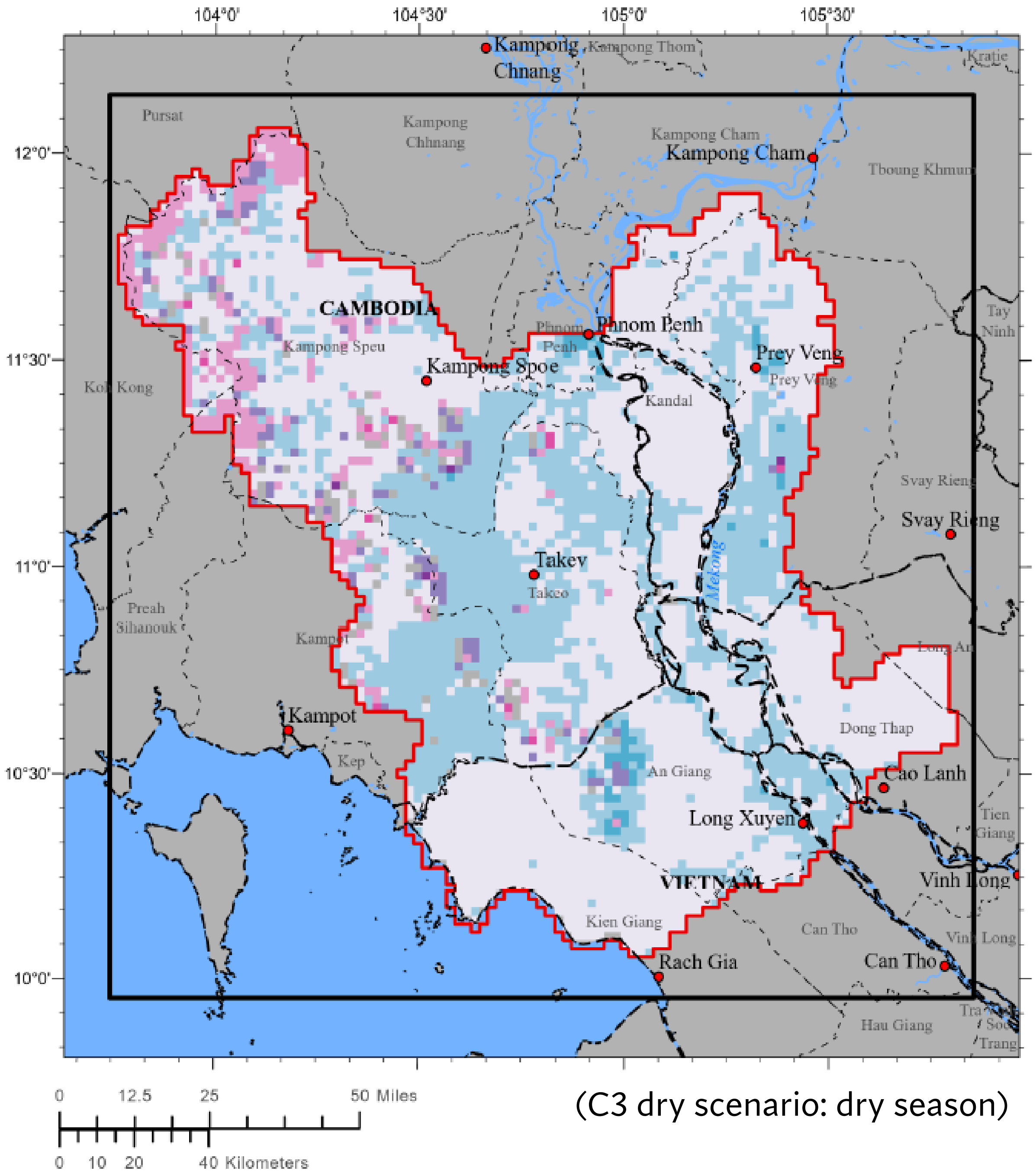
(measured as m3 needed to sustain current human population & agricultural livelihoods)

IDENTIFYING RISK

Risk = Exposure + Sensitivity

- Areas with **high** exposure and **high** sensitivity are most at risk (**dark purple**)
- Areas with **high** exposure and **low** sensitivity (**pink**) *or* **low** exposure and **high** sensitivity (**blue**) have moderate risk
- Areas with **low** exposure and **low** sensitivity have low risk levels (white)





(C3 dry scenario: dry season)

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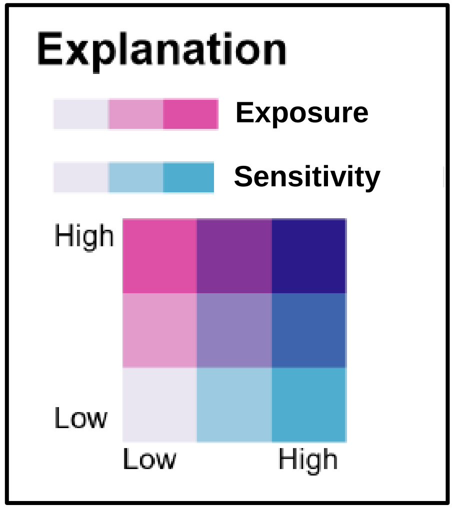

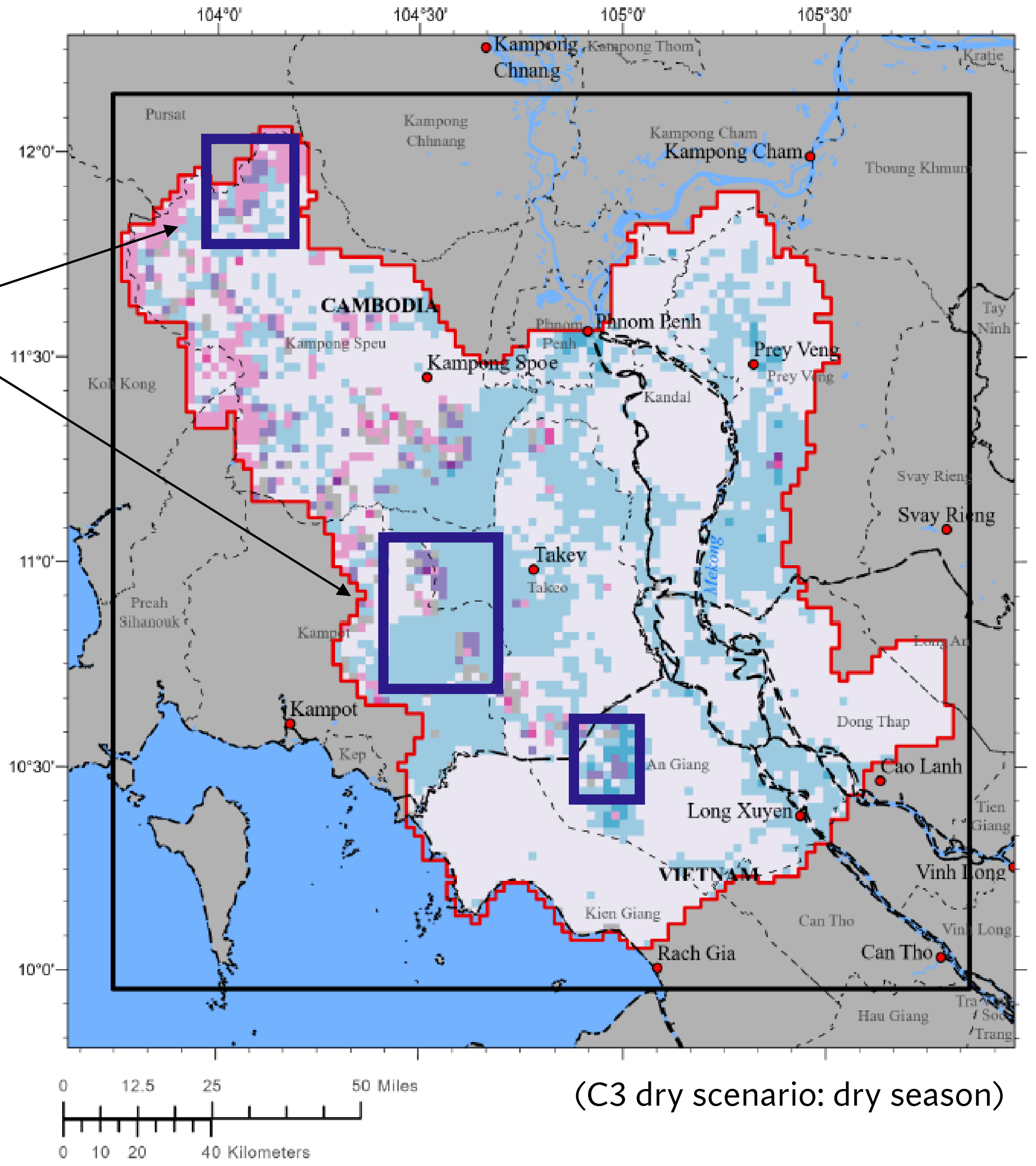

(C3 dry scenario: dry season)

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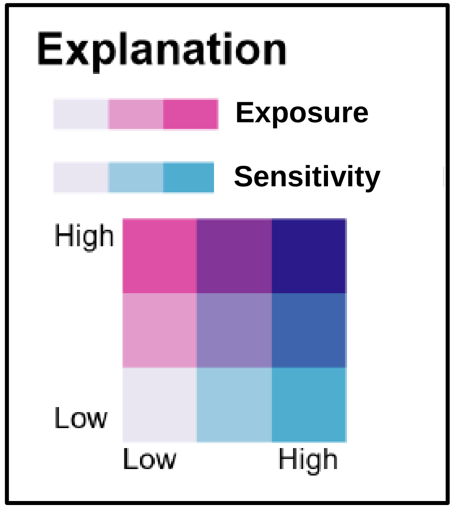
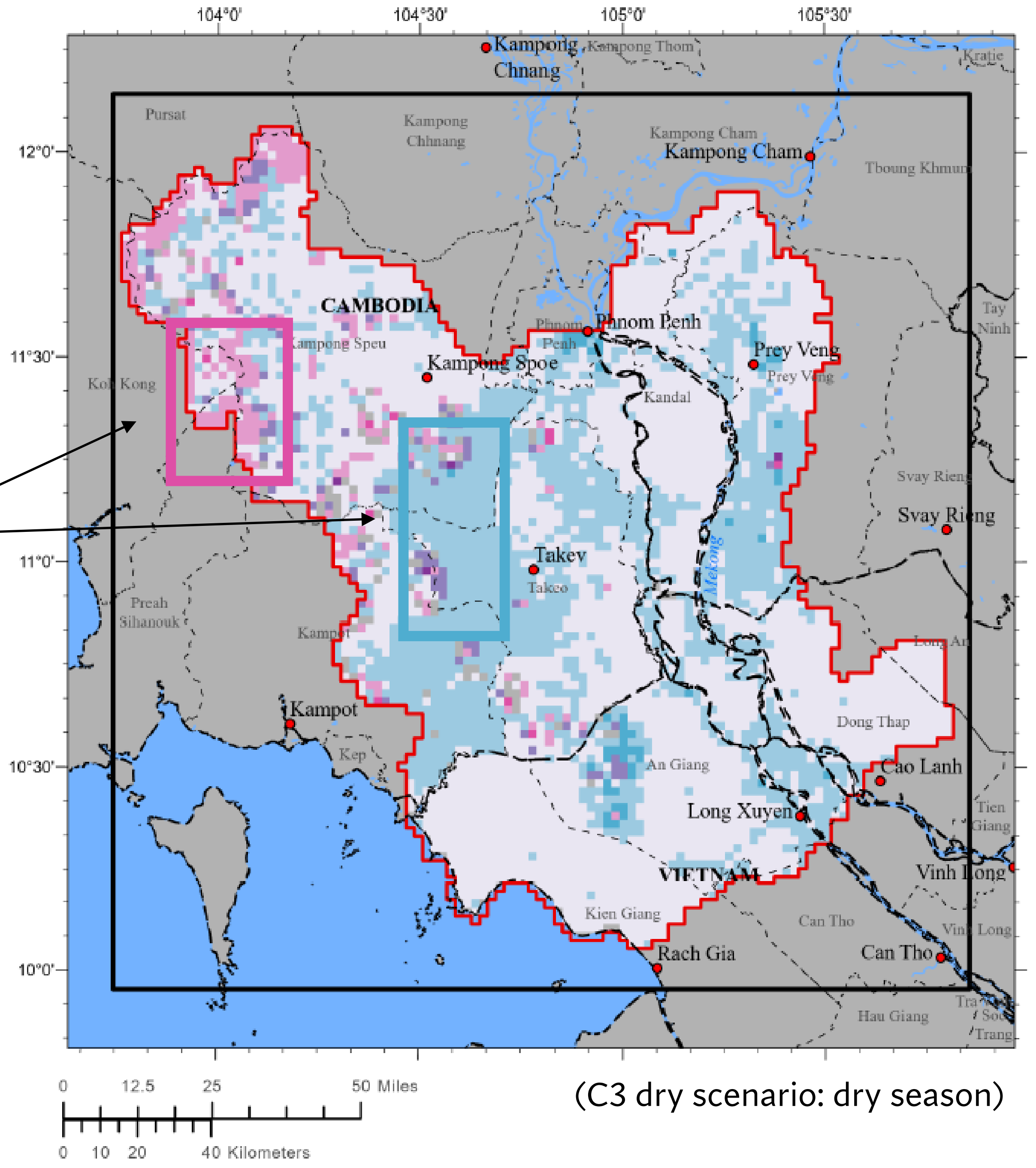
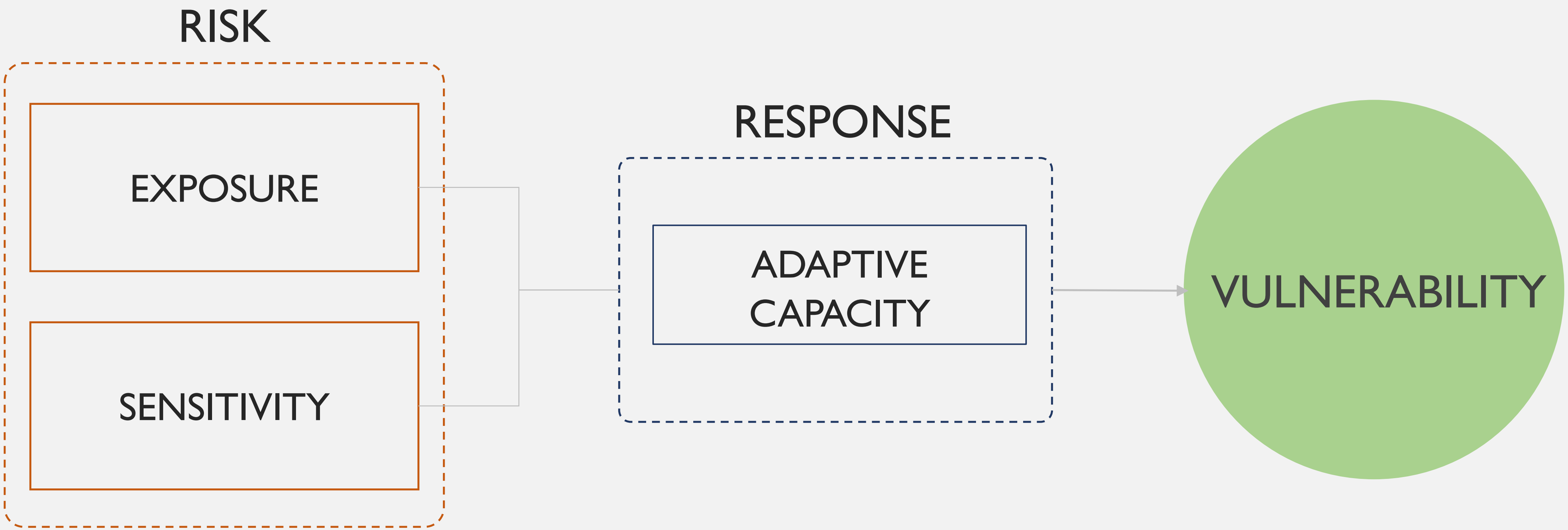


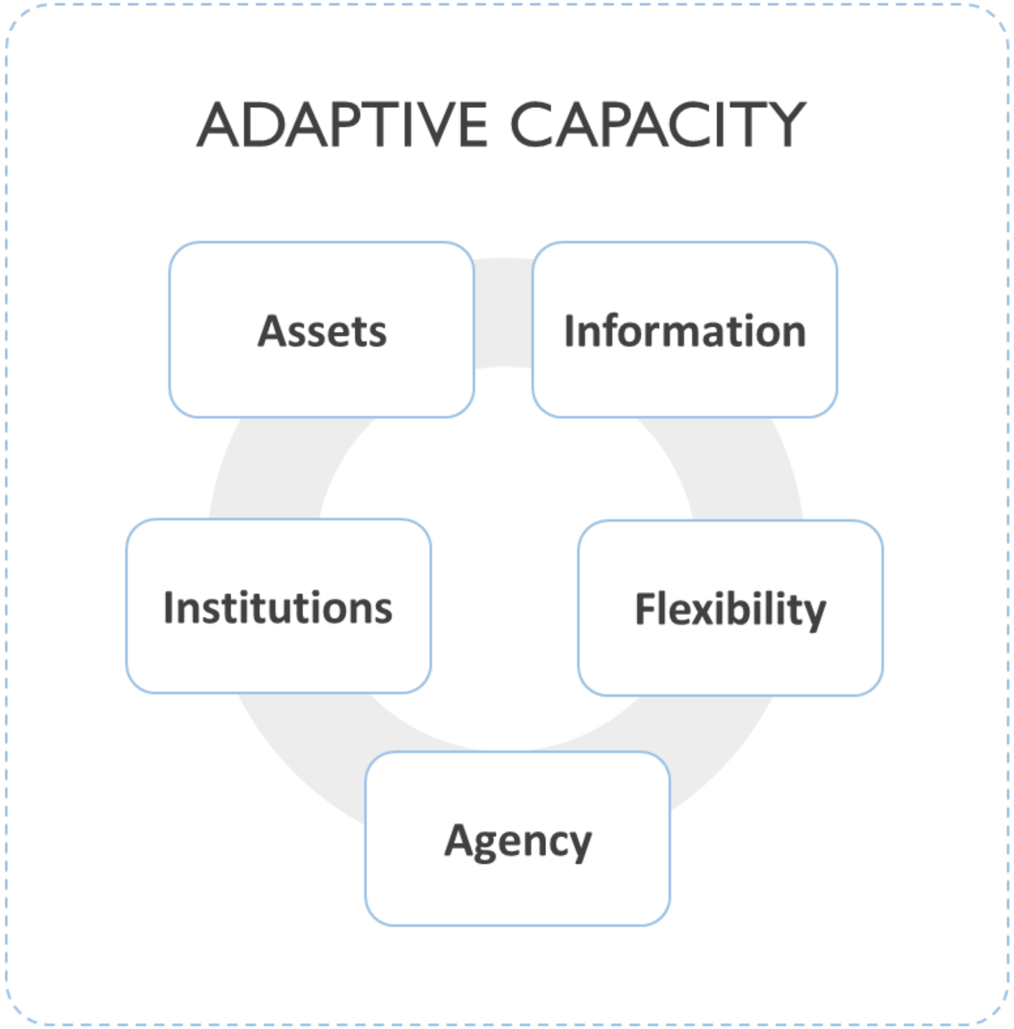


(C3 dry scenario: dry season)

VULNERABILITY FRAMEWORK



5 COMPONENTS OF ADAPTIVE CAPACITY



Framework adapted from Brooks et al 2003 and Cinner et al 2019

1. ASSETS
The financial, technological, and service resources that people have access to

2. INFORMATION & LEARNING
The ability to generate, absorb, and process new information

3. FLEXIBILITY
The opportunities available to adapt or change

4. INSTITUTIONS & SOCIAL ORGANIZATION
The way society is organized, including formal and informal relationships, and existence of appropriate institutions that enable cooperation, collective action, knowledge sharing and fair access and entitlements to key assets and capital

5. AGENCY
The power and freedom to leverage and mobilize the other aspects of adaptive capacity

ADAPTIVE CAPACITY INDICATORS & THE SDGS

AC: Assets
- Clean drinking water
- Sanitation
- Electricity

AC: Information & Learning
- % population with secondary education
- % population as trained workers
- Literacy rate

AC: Agency
- Gender inequality index

AC: Assets
- % population with centrally managed drinking source
- % population with flush toilets

AC: Flexibility & Institutions
- Employment rate
- Access to bank account

CHALLENGES + FUTURE STEPS

Integrating multiple spatial scales
- Combining risk & adaptive capacity

Inability to collect field data due to COVID-19
- Socio-economic data
- Limits to collaboration

Improvements to groundwater model
- Include groundwater pumping
- Update hydrogeology
- Simulate surface and groundwater management scenarios


Thank you.

EXTRA SLIDES

Adaptive Capacity Component (# indicators)	Specific Indicator
Asset Base (7)	Labor force as % of population
	Employment rate
	Malnutrition under 5 years
	Birth life expectancy
	Electrification rate
	Sanitation services
	Water provider
Information & Learning (4)	Literacy rate
	Secondary education
	Trained worker rate
	Access to information (internet)
Flexibility (3)	% income from agriculture
	Number of markets per person
	Net migration
Institutions/Social organization (3)	% membership in cooperative, farmer assoc.
	Access to extension agents
	Access to bank
Agency (1)	Gender equality index*

(Disclaimer: This is an example. Figure does not represent real data.)