Watershed - scale water supply and demand assessment of Tigum - Aganan - Jaro Watershed, Iloilo, Philippines by coupling the SWAT and WEAP models

Mayzonee V. Ligaray , PhD

Elaine Claire M. Macaspac, Kean Michael F. Cabigao , and Richard Cornelio

Environmental Hydrology Laboratory, Institute of Environmental Science & Meteorology
University of the Philippines Diliman

A Daloy Project by the World -Wide Fund for Nature Philippines
Funded by the Coca -Cola Foundation Philippines Inc.

INTRODUCTION

WATER RESOURCES IN THE PHILIPPINES

Water resources

- **Prone to changes** in climate and environment.
- **Increasingly stressed** due to an increase in demand.
- **Poorly managed** due to
  - Improper implementation of the water security framework
  - Inadequate resources
  - Not enough man-power

- There is a need for an efficient water resources management scheme.

Water shortage

Flooding

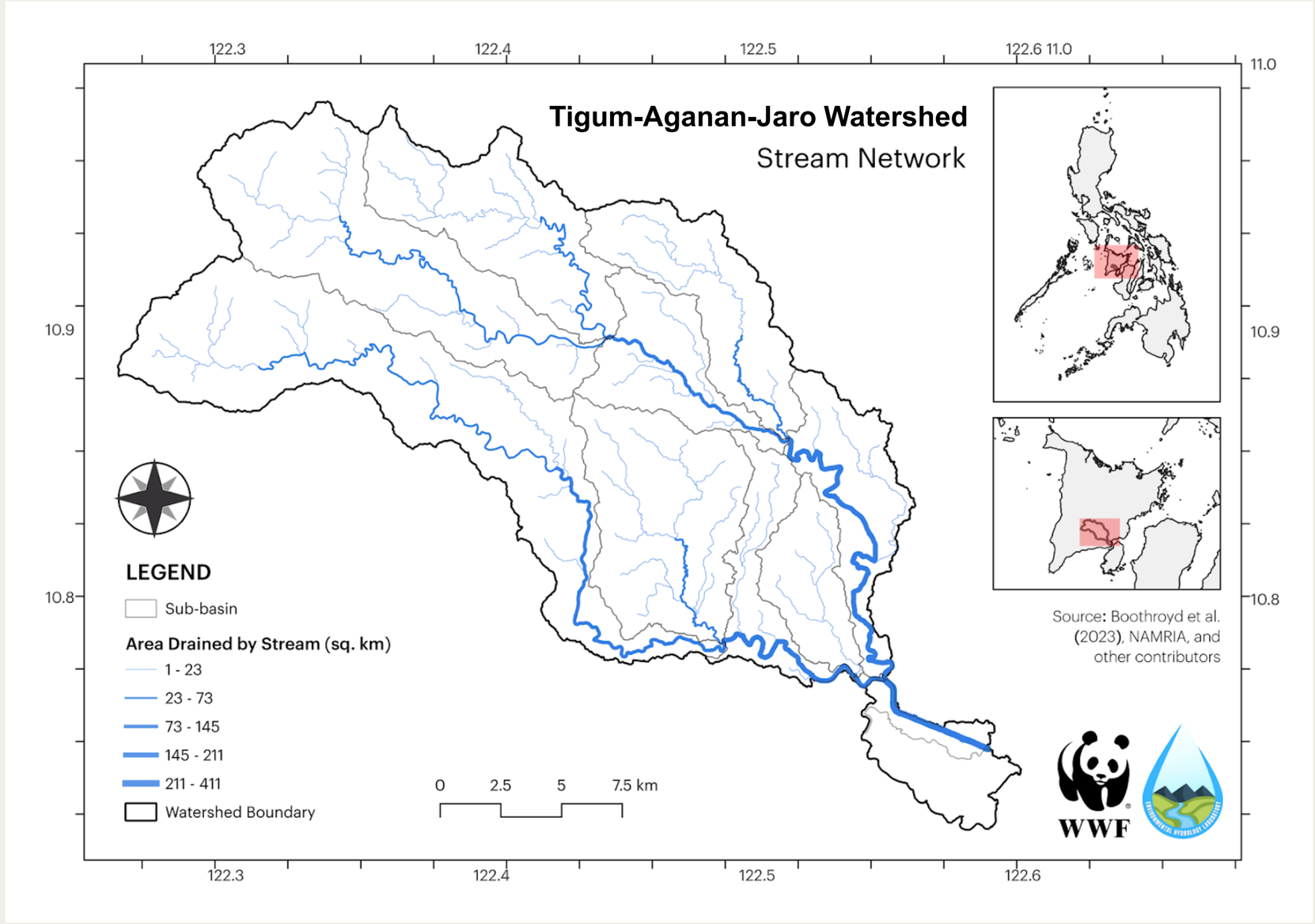
Contamination

Drought

Streamflow variations

Erosion

TIGUM - AGANAN - JARO WATERSHED



OBJECTIVES

General:

To project future water supply and demand until 2030 and 2060, and determine the gaps between supply and demand.

Specific:

- To characterize the watershed hydrology.
- To assess the current and future (2030 and 2060) status of the water supply and demand.
- To determine the impacts of climate change scenarios on the current and future water supply.

METHODOLOGY

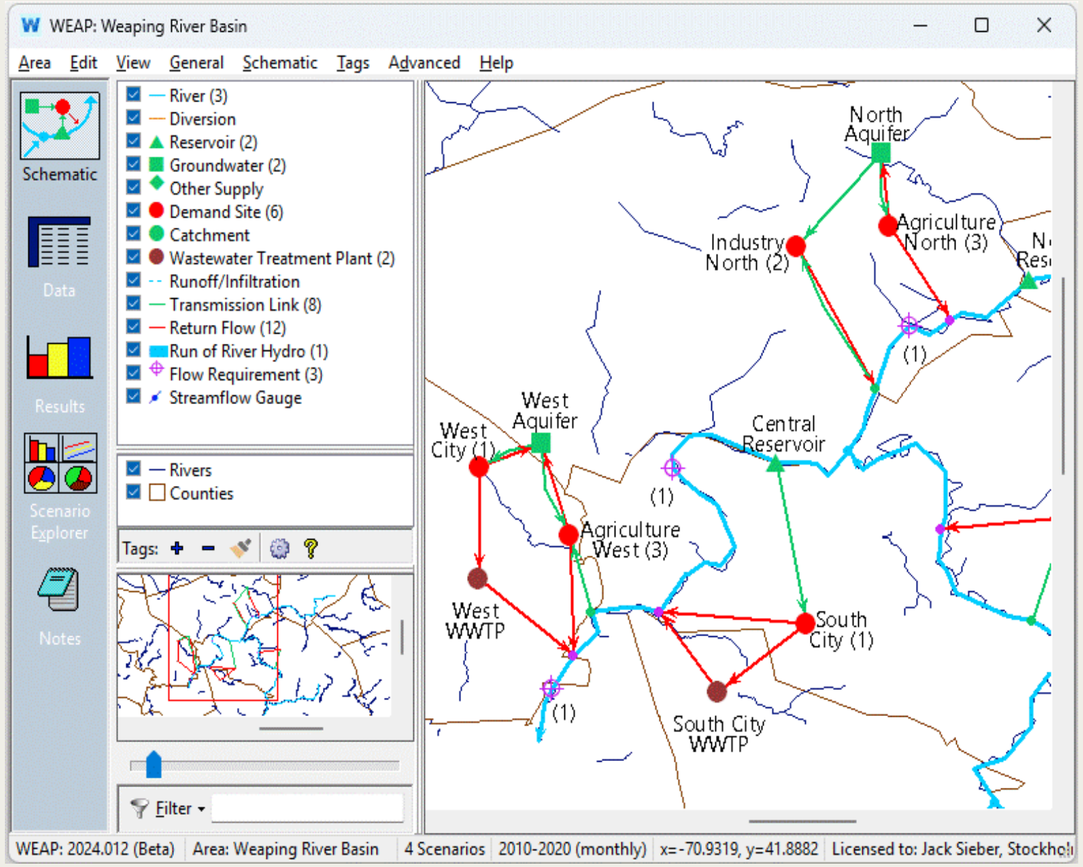
Data requirements:
Topography, Landuse/Land cover, Soil, Weather, Streamflow, Population and Socioeconomic Activities, Water sources and usage, etc.

Water Supply, Sediment Load, and Climate Change Scenarios:
The Soil and Water Assessment Tool (SWAT Model) was used to assess the water supply (baseline and climate change scenarios). This is a watershed model that can give us the available water in a watershed.

Water Supply and Demand Projections and Management Recommendations:
The Water Evaluation And Planning (WEAP) Model was used to compare the water supply and demand as well as management scenarios and project them to 2030 and 2060.

METHODOLOGY

WEAP Model: Water Evaluation And Planning System



- Developed by the Stockholm Environment Institute (SEI) in 1988
- It aims to be a flexible, integrated, and transparent planning tool for evaluating the sustainability of **current water demand and supply patterns** and exploring alternative long-range scenarios.
- Aral Sea as its first major application.

METHODOLOGY

SWAT Model

- Data collected
  - Topography
  - Landuse/land cover
  - Soil
  - Weather
- Model Simulation
  - Streamflow
- Sensitivity analysis
- Calibration (2001-2010)
- Validation (2011-2020)

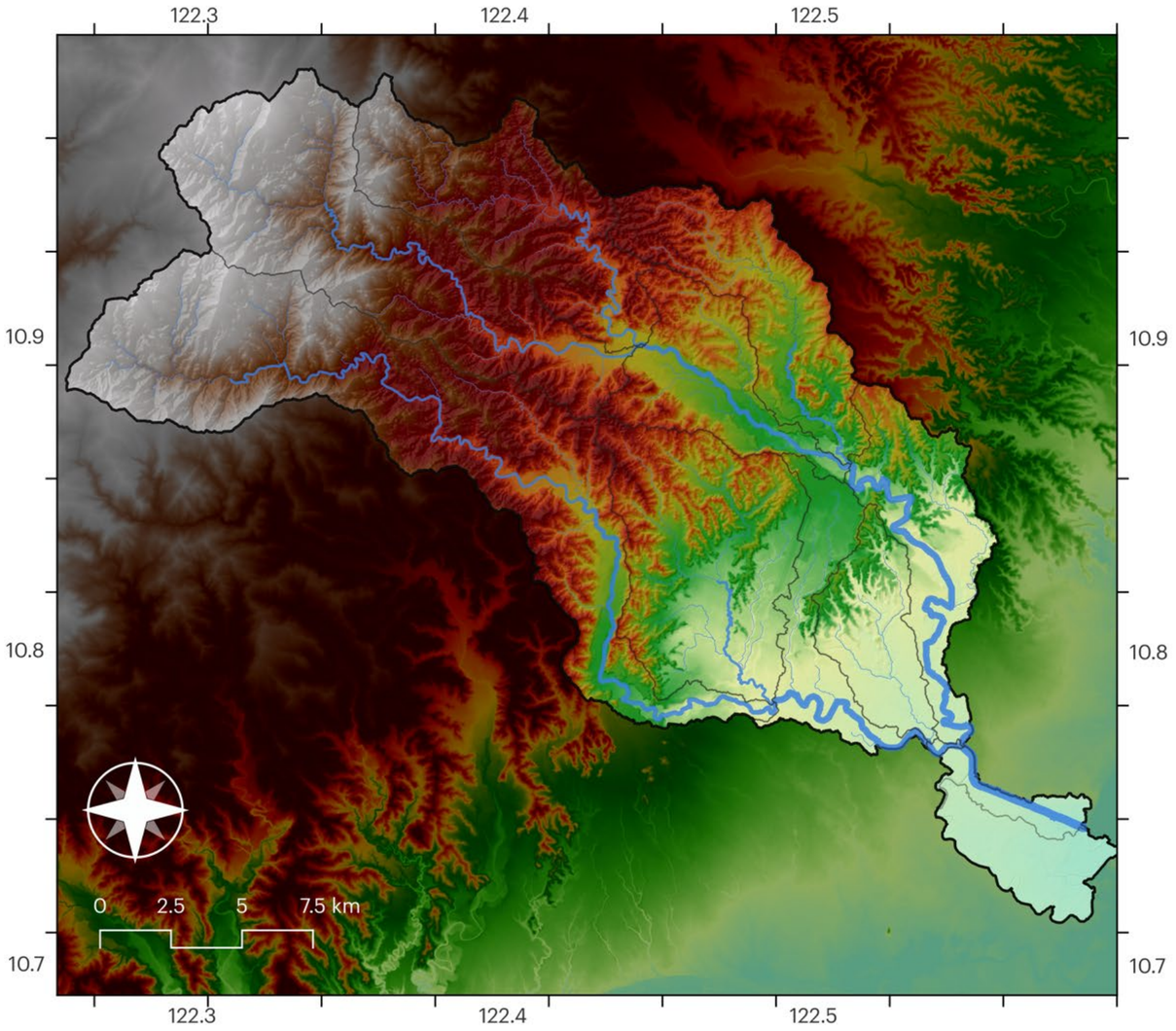
WEAP Model

- Water supply
  - SWAT simulated streamflow
  - Groundwater recharge
- Water demand
  - Population data

Application

- Water supply and demand assessment
- Climate change scenarios
  - Water balance components

Data collected



Jaro Watershed
Elevation Map

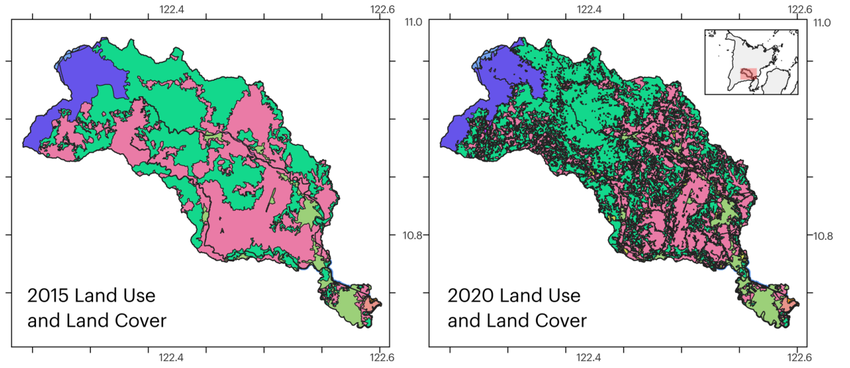
LEGEND

Area Drained by Stream (sq. km)
- 1 - 23
- 23 - 73
- 73 - 145
- 145 - 211
- 211 - 411
- Sub-basins
- Watershed Boundary

Interferometric Synthetic Aperture Radar (IfSAR)
Digital Terran Model (5-m)
1,526.02
0

Source: Boothroyd et al. (2023), NAMRIA, and other contributors

WWF



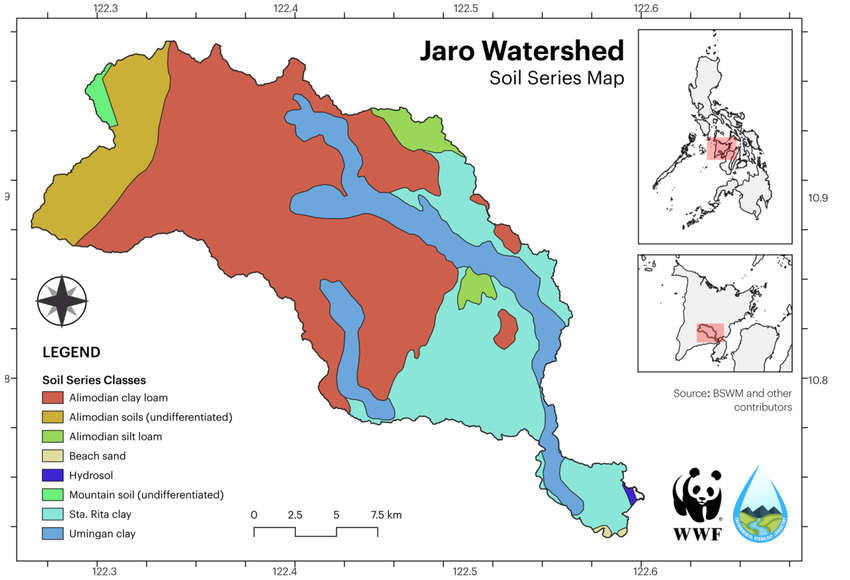
Jaro Watershed
0 2.5 5 7.5 10 km

WWF

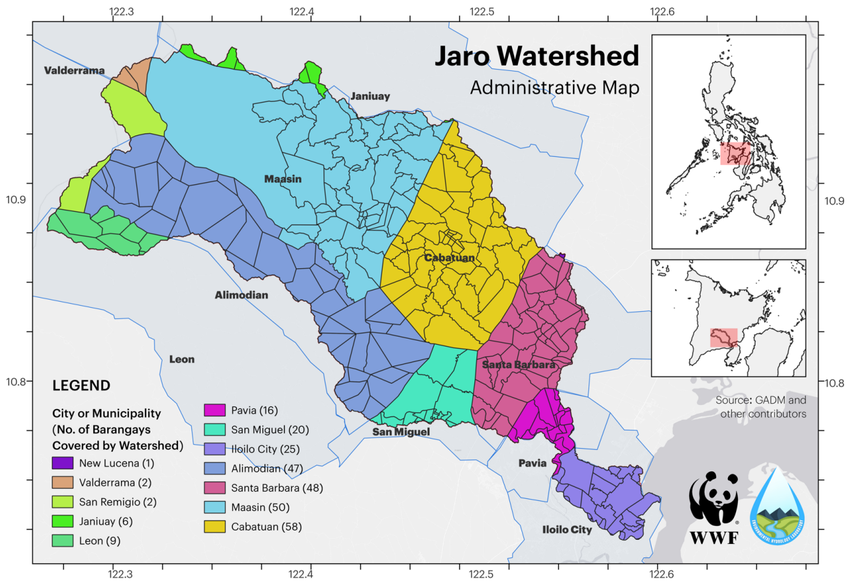
Source: ESA, NAMRIA, and other contributors

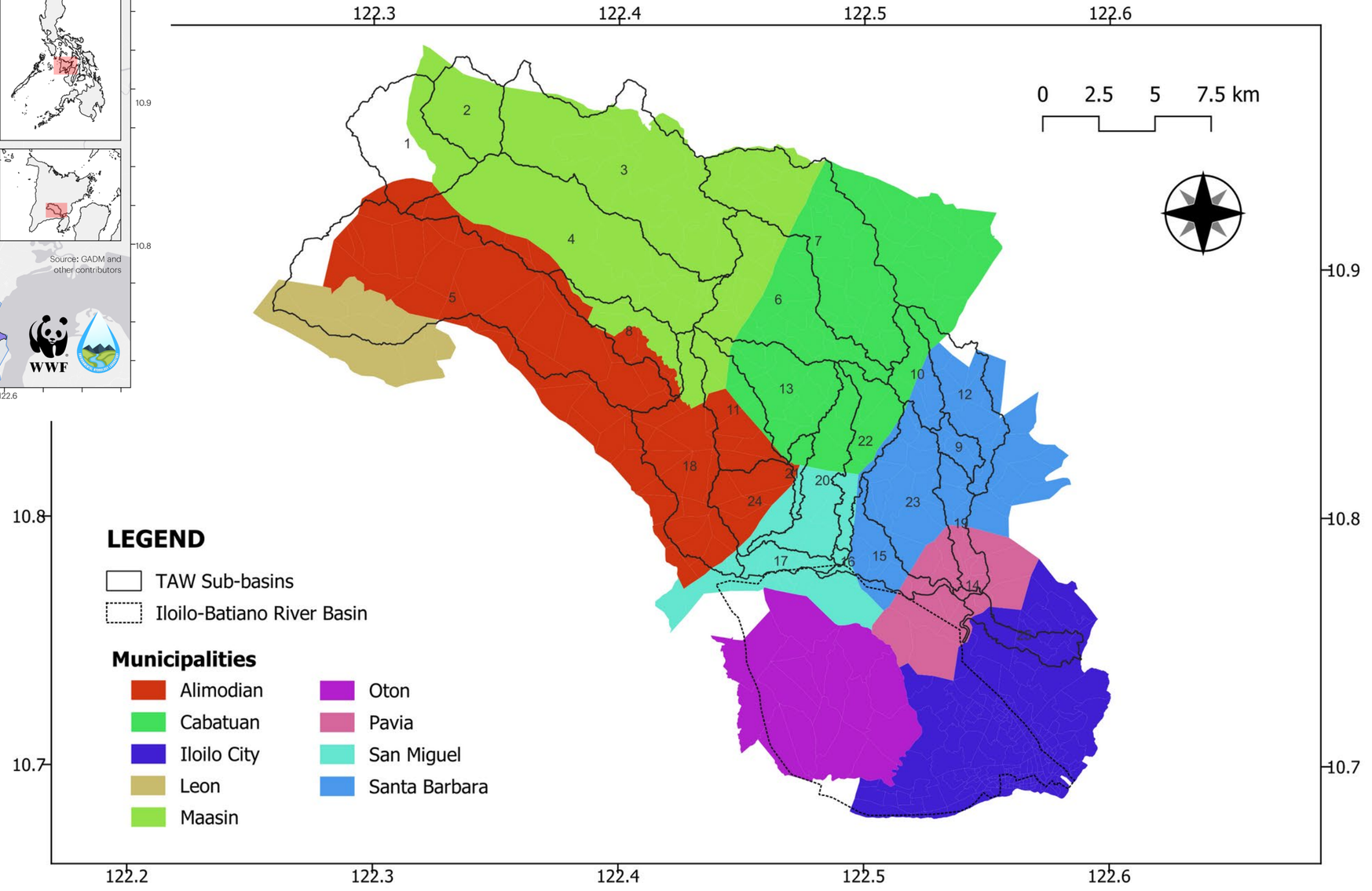
LEGEND

Land Use/Cover Classes
- Annual Crop
- Brush/Shrubs
- Built-up
- Closed Forest
- Fishpond
- Grassland
- Inland Water
- Mangrove Forest
- Open Forest
- Open/Barren
- Perennial Crop



Sub-basins of the Tigum -Aganan Watershed overlaid with the administrative map





WATERSHED HYDROLOGY CHARACTERISTICS

- **Very slow recharging of groundwater** , large volumes of water moving out of the watershed, most likely due to the soil types of the watershed (predominantly clay). Land management is also a major factor in affecting the available water of the watershed.

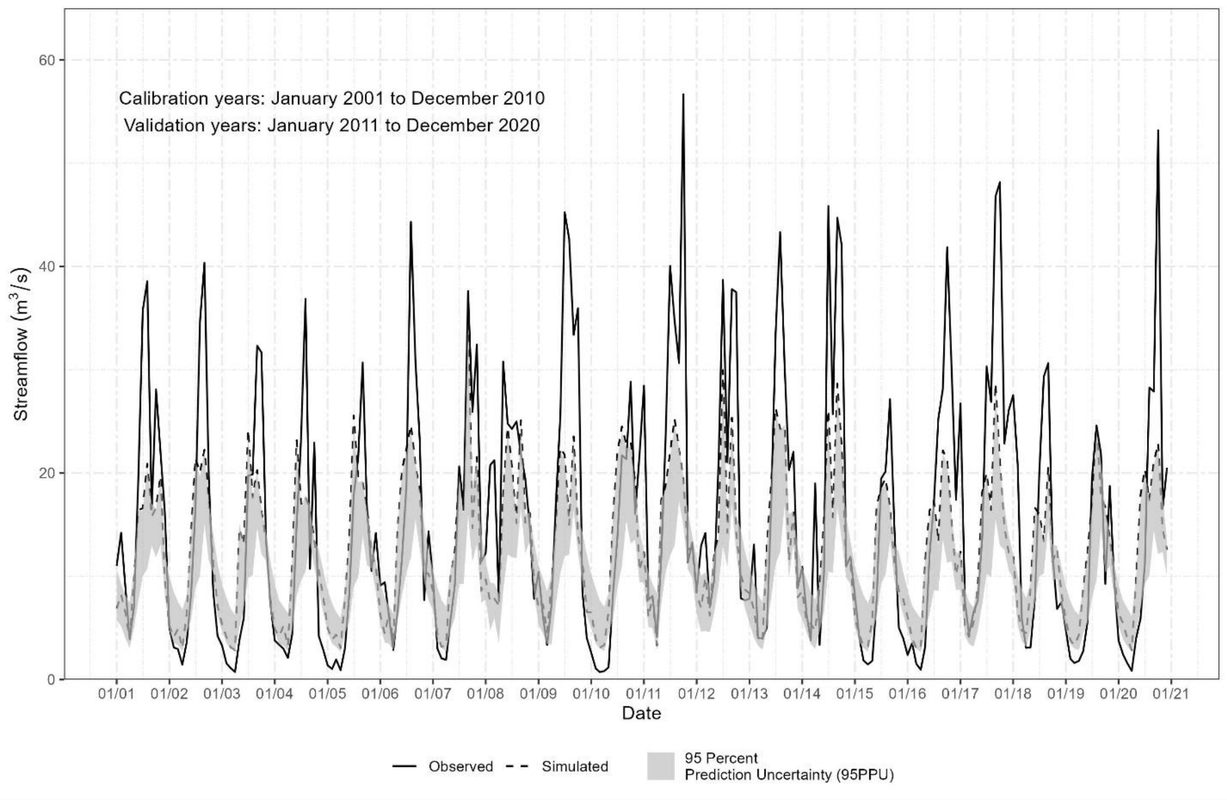
- Critically **high surface runoff** (>83% of total runoff), which could imply flood risks

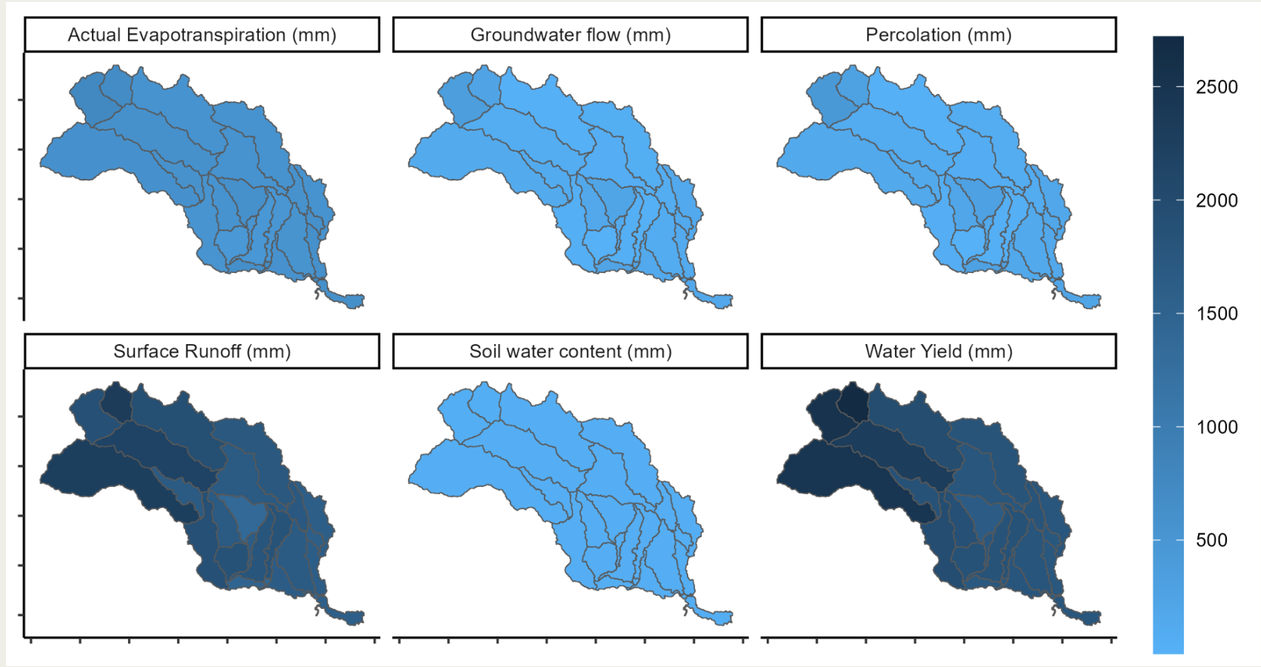
- Historical trend of **sedimentation is increasing in uplands** and is projected to increase in the future. This will affect the cost for river management and water treatment and, eventually, cost of water.

WATERSHED HYDROLOGY CHARACTERISTICS

Parameter Name	Definition	t-Stat	P-Value	Rank
1:R__CN2.mgt	SCS runoff curve number	42.08	0.00	1
11:V__GW_DELAY.gw	Groundwater delay	-12.54	0.00	2
3:V__ESCO.hru	Soil evaporation compensation factor	5.39	0.00	3
10:V__ALPHA_BF.gw	Alpha factor for groundwater recession curve	2.64	0.01	4
2:R__SOL_AWC(..).sol	Available water capacity of the soil layer	-2.06	0.04	5
5:V__GWQMN.gw	Threshold depth of water in shallow aquifer for return flow to occur	-1.78	0.08	6
9:R__SLSUBBSN.hru	Average slope length	-1.71	0.09	7
14:R__SOL_Z(..).sol	Depth from soil surface to bottom of layer	-1.57	0.12	8
6:V__GW_REVAP.gw	Groundwater “revap” coefficient	0.71	0.48	9
12:R__SOL_BD(..).sol	Moist bulk density	0.59	0.56	10
8:R__OV_N.hru	Manning's "n" value for overland flow	0.52	0.60	11
7:V__REVAPMN.gw	Threshold depth of water in shallow aquifer for “revap” to occur	0.45	0.65	12
15:R__SURLAG.bsn	Surface runoff lag coefficient	0.45	0.66	13
13:R__SOL_K(..).sol	Saturated hydraulic conductivity	0.41	0.68	14
4:V__EPCO.hru	Plant uptake compensation factor	0.09	0.93	15

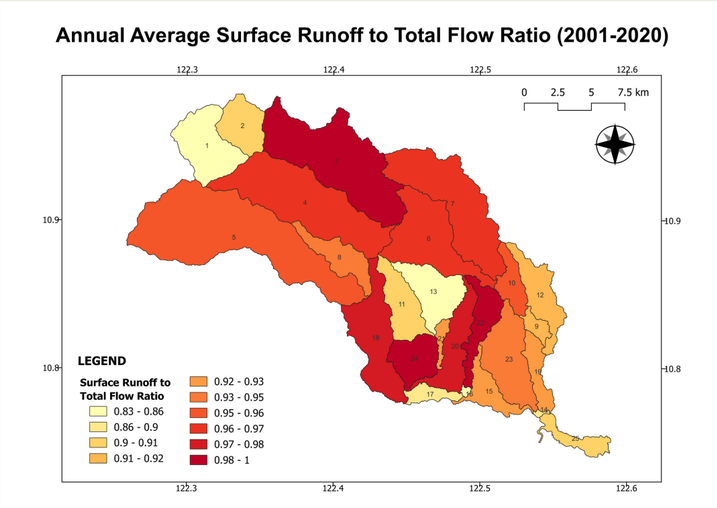
WATERSHED HYDROLOGY CHARACTERISTICS



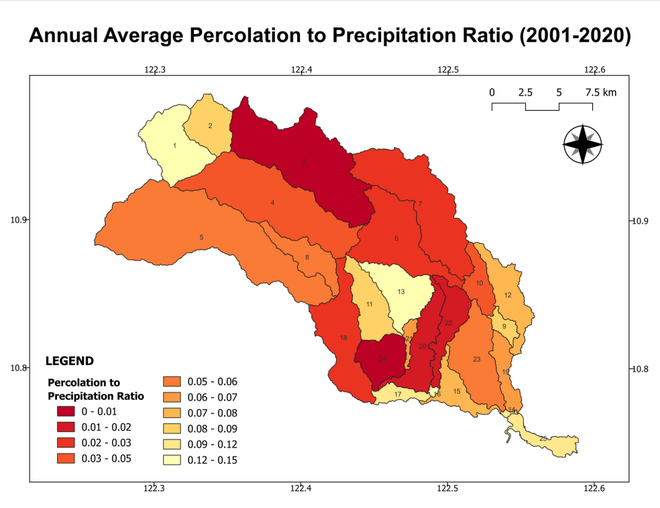


WATERSHED HYDROLOGY CHARACTERISTICS

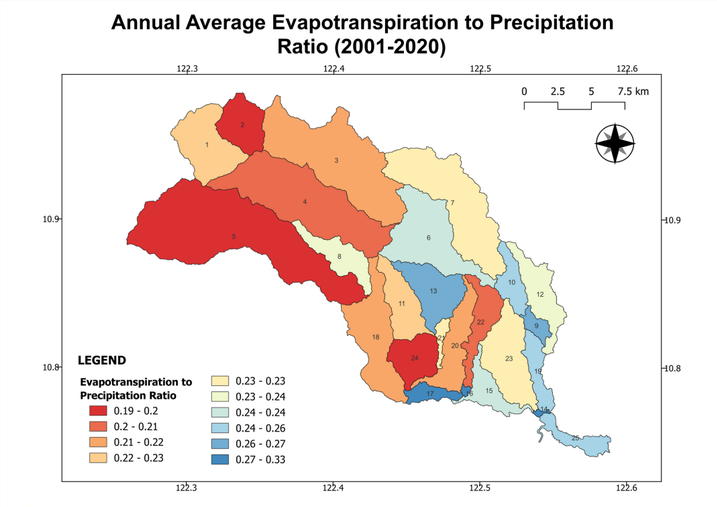
- Surface runoff/Total flow ratio is high (>0.80)
- Groundwater ratio may be low
- Water yield may be excessive
- Surface runoff may be excessive
- Historical trend of sediment load is increasing



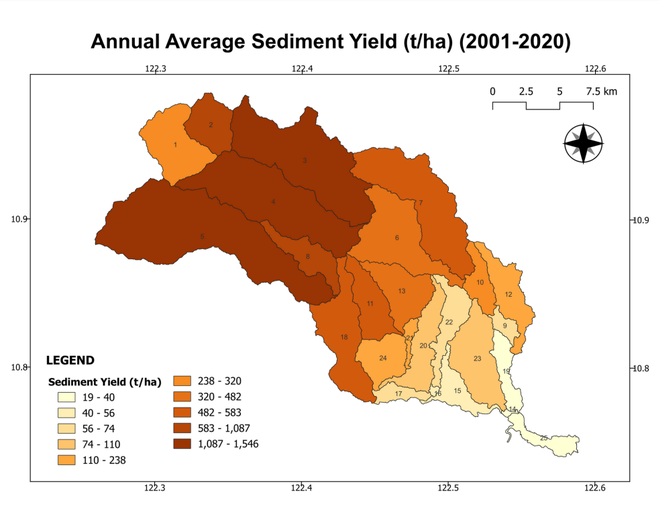
>0.80, more water goes out of the watershed



<0.20, less water goes to aquifers



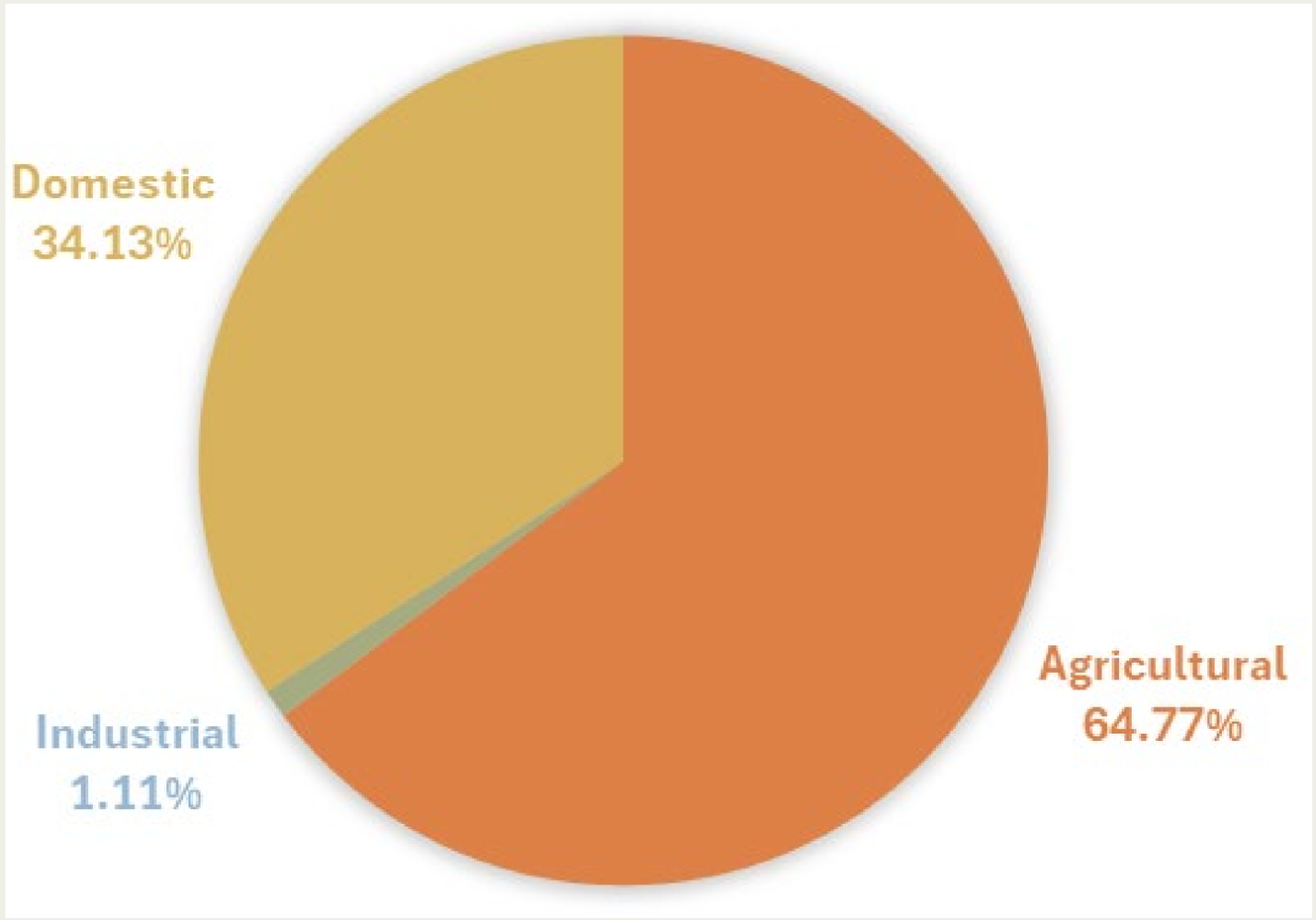
>0.20, less water goes back to environment from vegetation and soil



Upland yields an average of 50% of the sediments

WATER SUPPLY AND DEMAND ASSESSMENT

CURRENT WATER DEMAND PER SECTOR



Domestic

- Population within the watershed (from PSA) x water use rates (from MIWD)

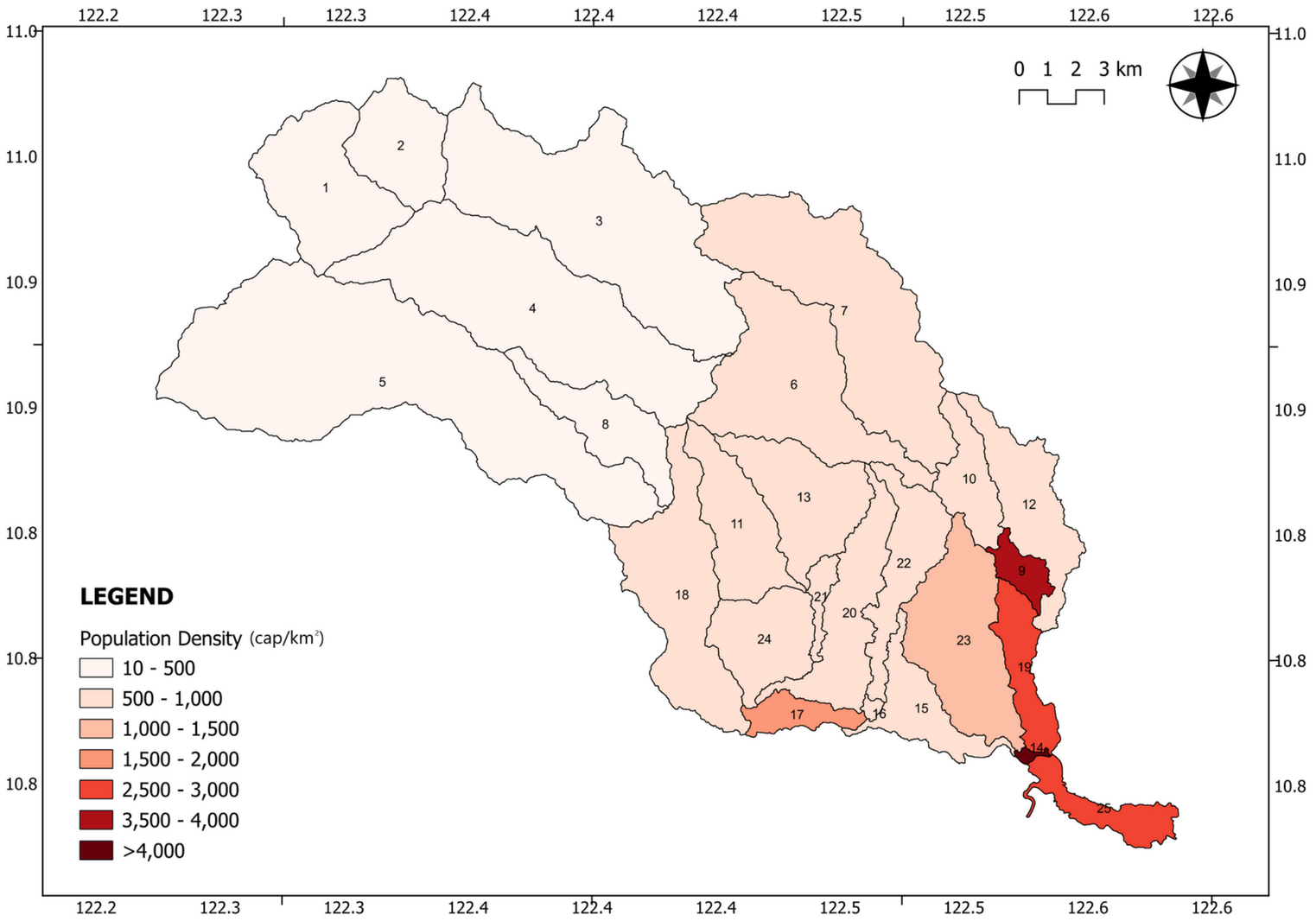
Industrial

- Only 6 industries were included (data from NWRB water permits)
- Does not include commercial entities (e.g., restaurants and hotels)

Agricultural

- Only includes Aganan RIS and Sta. Barbara RIS (data from NIA)

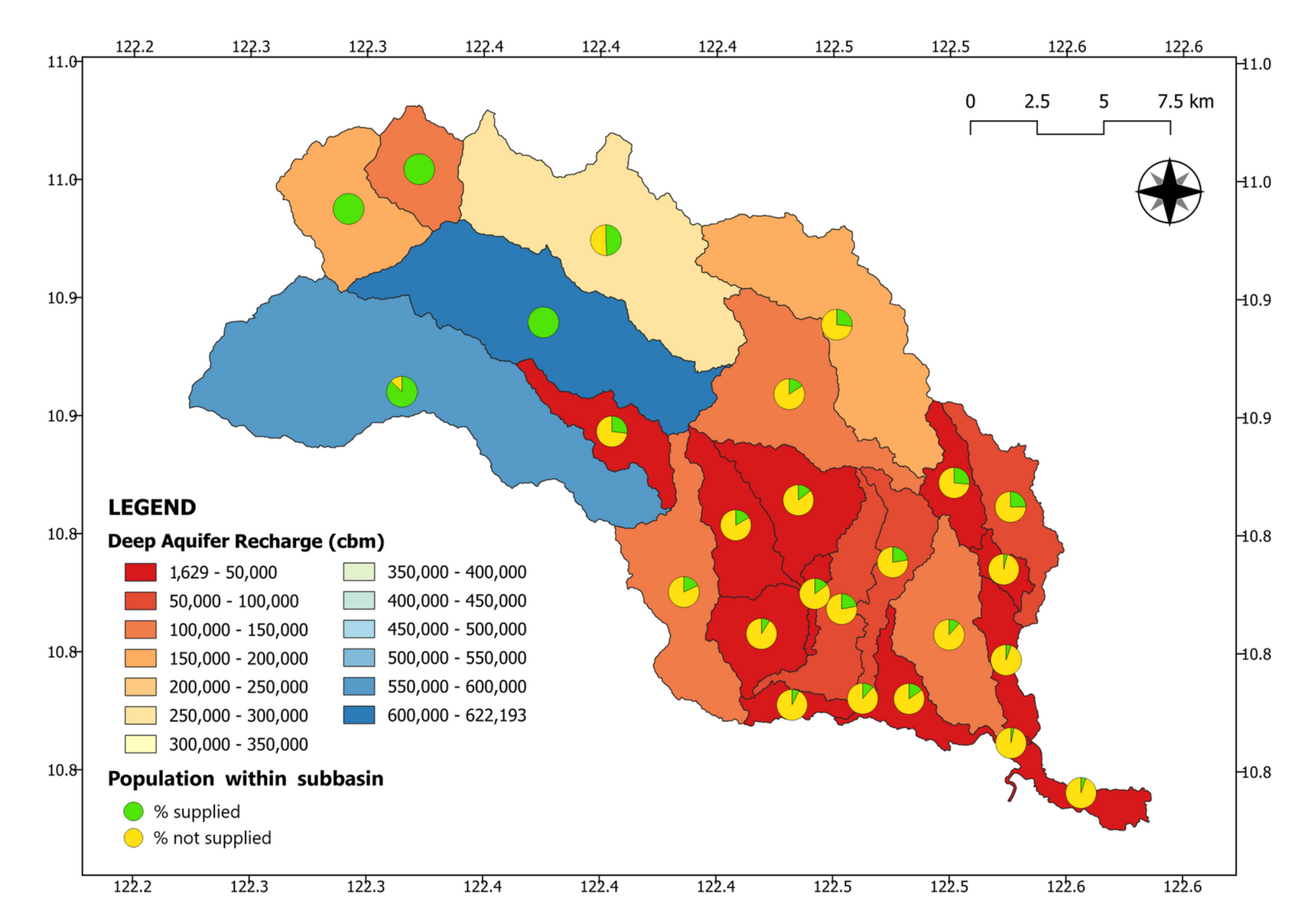
POPULATION WITHIN THE WATERSHED



More densely populated areas are more prone to water stress due to higher competition and groundwater extraction

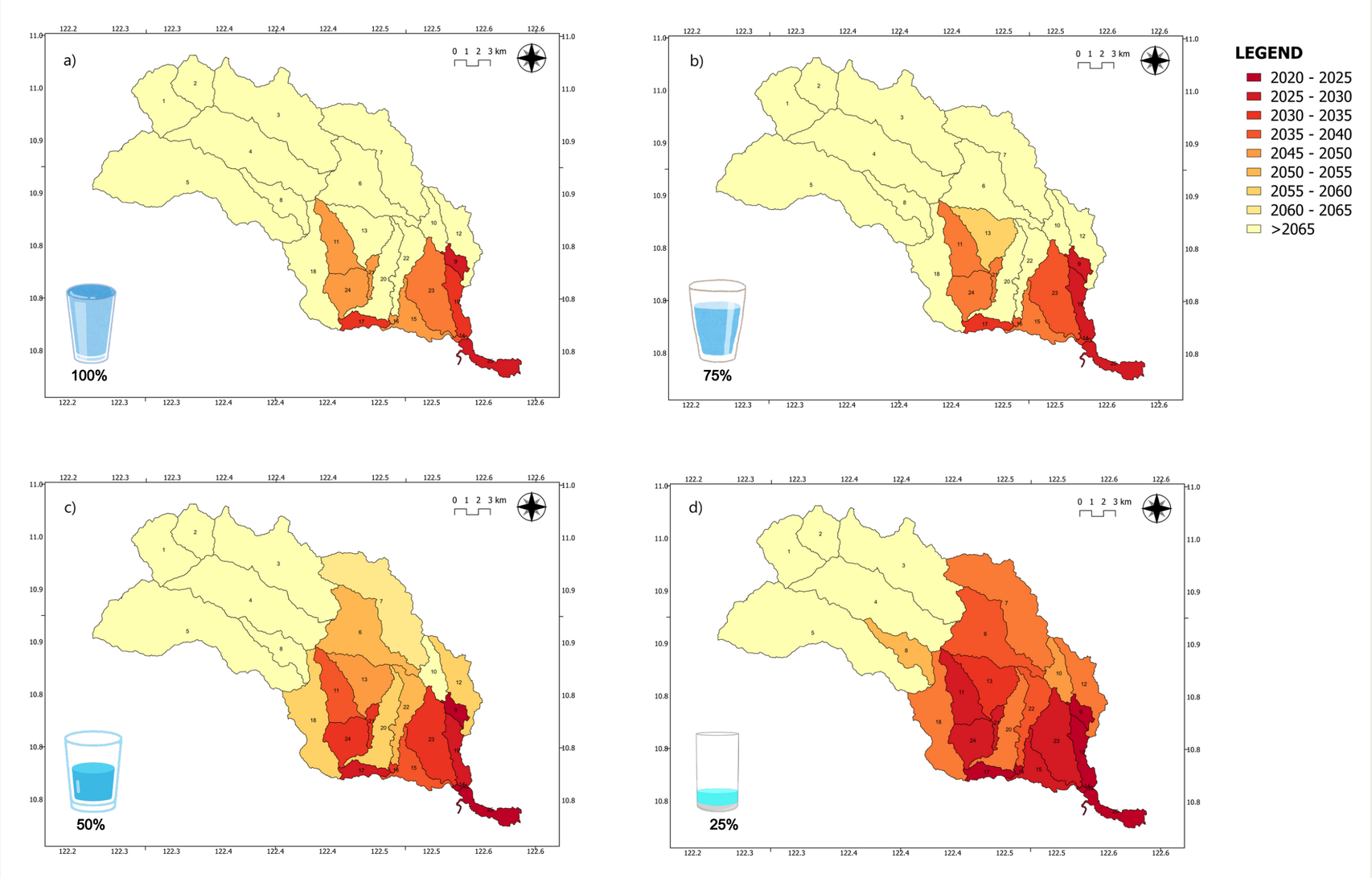
Most densely populated: **Parts of Pavia, Sta. Barbara and Iloilo City**

POPULATION SUPPORTED BY CURRENT RECHARGE RATES



TOTAL DEEP AQUIFER DEPLETION

Lowlands (parts of Iloilo City, Pavia, Sta. Barbara and San Miguel) are more prone to having **total deep aquifer depletion between 2025 to 2060**



UNMET DEMAND

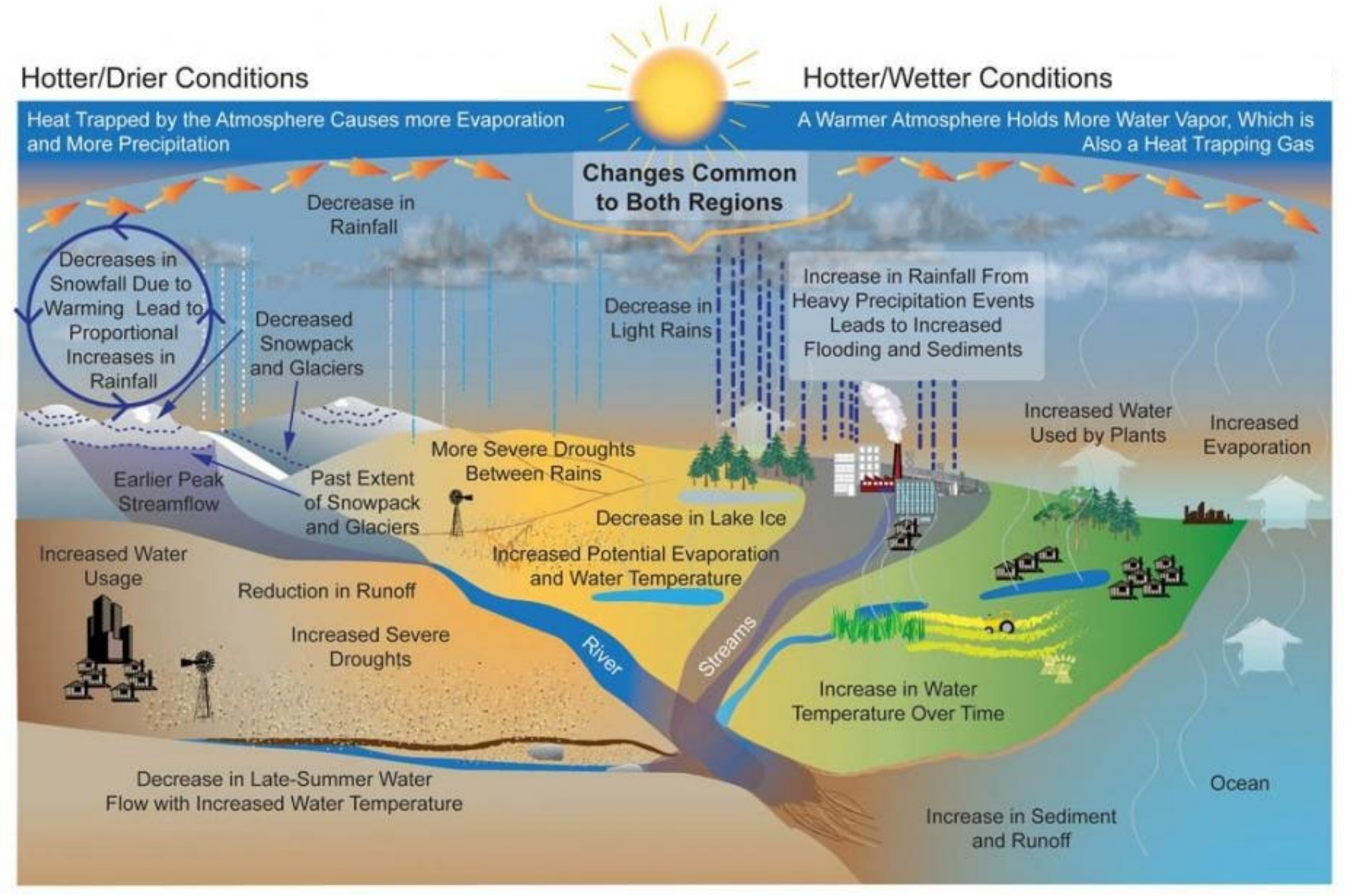
Up to..

39% of the population within the watershed is projected to experience extreme water stress by **2030** .

80% of the population within the watershed is projected to experience extreme water stress by **2060** .

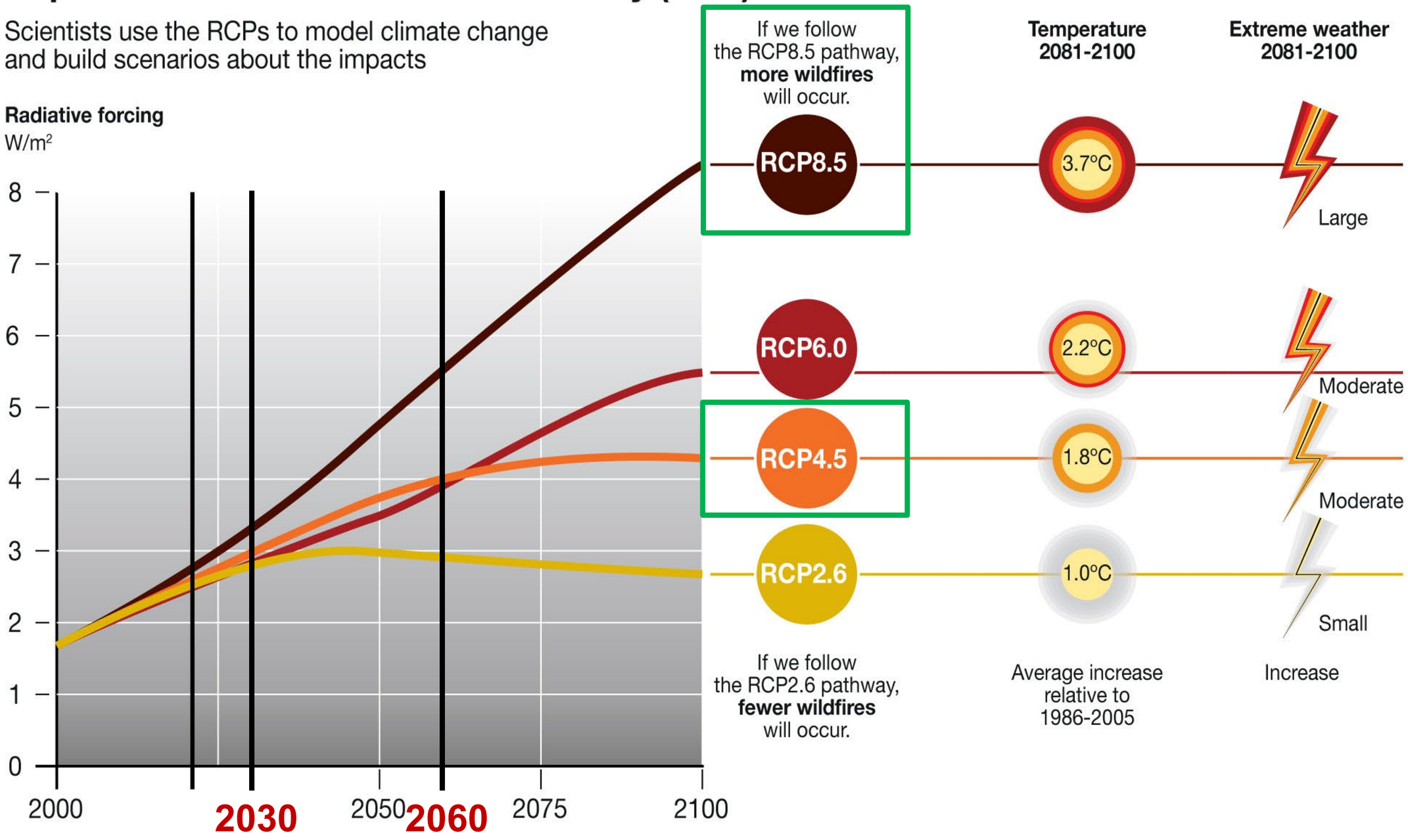
CLIMATE CHANGE

CLIMATE CHANGE



Representative Concentration Pathway (RCP)

Scientists use the RCPs to model climate change and build scenarios about the impacts



GRID-Arendal/Studio Atlantis, 2021

IMPLICATIONS TO WATER BALANCE

Precipitation and Water Yield

- **Wetter rainy seasons** , more pronounced in RCP 8.5 conditions
- Increase in water yield → during rainy season due to **increase levels of precipitation**

Evapotranspiration

- **More water is being lost** to the atmosphere due to increase in temperature
- **Decreased soil moisture and infiltration capacity** , affecting groundwater recharge and agricultural productivity

Soil Water Content

- RCP 4.5 → decrease soil water content
- RCP 8.5 → increase in soil water content
- **Too much or too little soil moisture can negatively affect vegetation** (water stress or waterlogging)

IMPLICATIONS TO WATER BALANCE

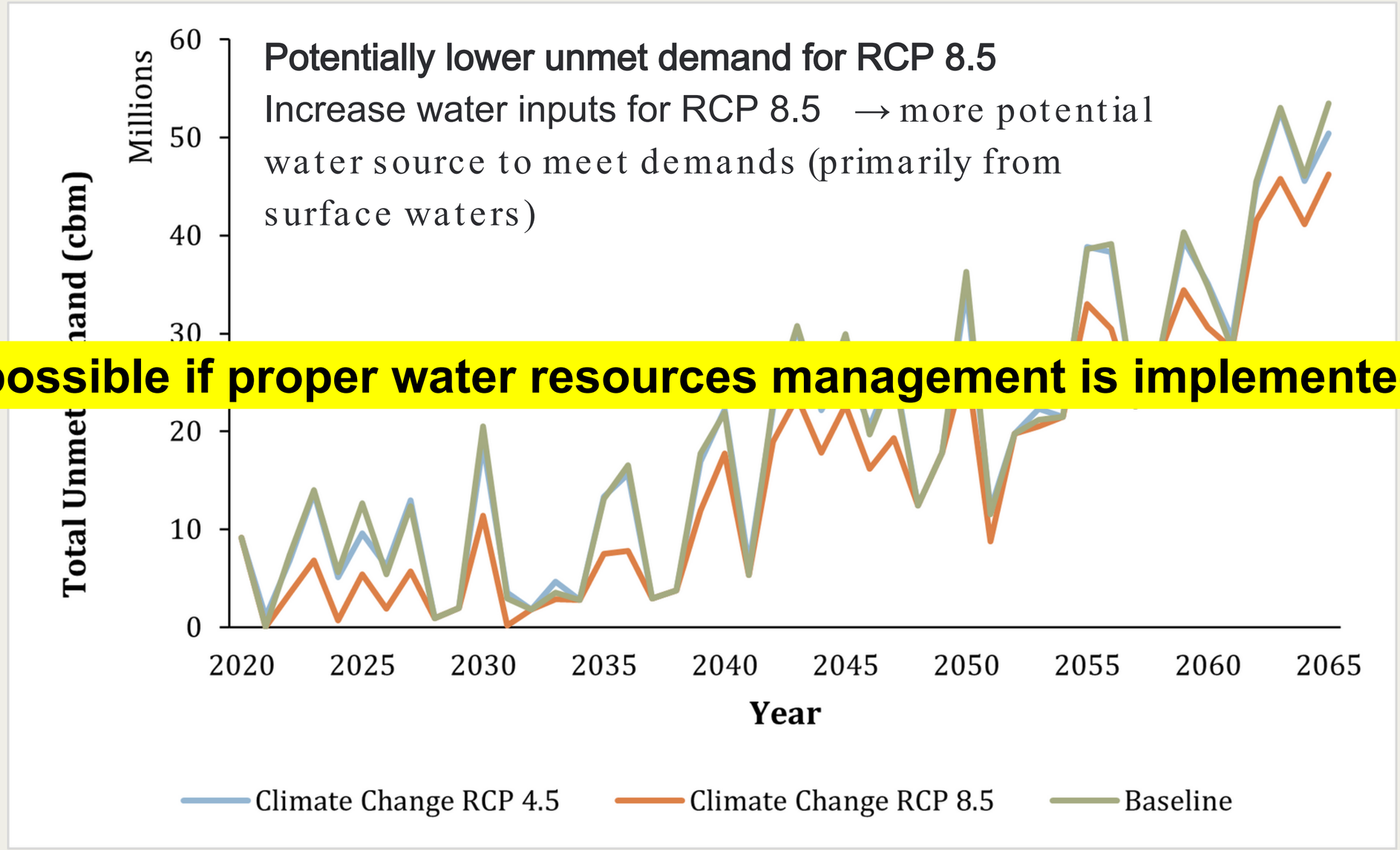
Percolation and Groundwater Flow

- Increased flow of water underground due to increased precipitation
- Does not necessarily mean increased groundwater recharge

Surface Runoff

- **Immensely heightened flood risks** , especially during wet season
- **Can lead to greater soil erosion** , stripping fertile topsoil from agricultural land

OVERVIEW: EFFECT ON WATER SUPPLY AND DEMAND



Only possible if proper water resources management is implemented now.

Conclusion

- Hydrologic Assessment of Tigum-Aganan Watershed
  - Slow replenishment of groundwater, high volume of water readily exits the watershed via surface runoff (flood risk)
  - Uplands have high sediment load which can impact cost of water
- Water Supply and Demand
  - The water demand of most subbasins are unmet.
  - 2030: 39% of population will experience water insecurity
  - 2060: 80% of population will experience water insecurity
- Climate Change Scenarios
  - Potentially lower unmet demand for RCP 8.5: Increase water inputs → primarily from surface waters

Thank you

Visit us at **https://pages.upd.edu.ph/ehydrolab**