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Evaluating the Impact of Climate Change on Water Availability in Cidanau Watershed, Banten Province of Indonesia

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INTRODUCTION

- **Climate change (CC)** has been accelerated by the increase in **greenhouse gas emissions** which is responsible for **global warming** (IPCC,2019)
- **CC** might propagate increased **water demands and water shortages** caused by population growth and economic development through changes in **rainfall magnitude and variability**
- Competition among different users is heightened by the gap between **water demand and supply capacity** that exist in many regions of the world. (Exposito et al, 2020)

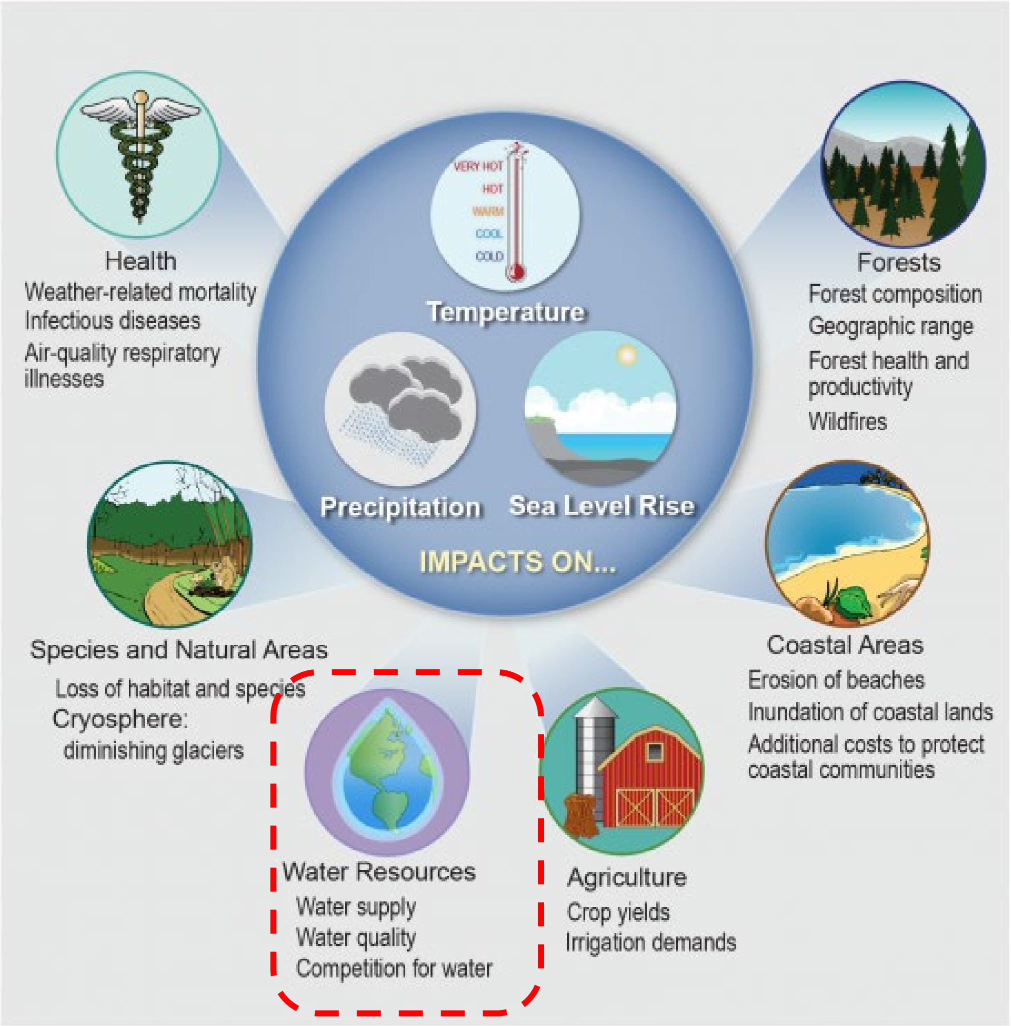
Source :https://education.nationalgeographic.org/resource/global-warming

Source : California Department of Water Resource, 2021

INTRODUCTION

- Examining CC impact on **water availability** is hence crucial, particularly matters relating to the sustainable development of CC **adaptation and strategies of resilience**. (Erler et.al., 2019)
- **SWAT** is one of the mathematical models that could help to **simulate the hydrological processes** occurring in a watershed and predict future hydrological responses **under climate change**.

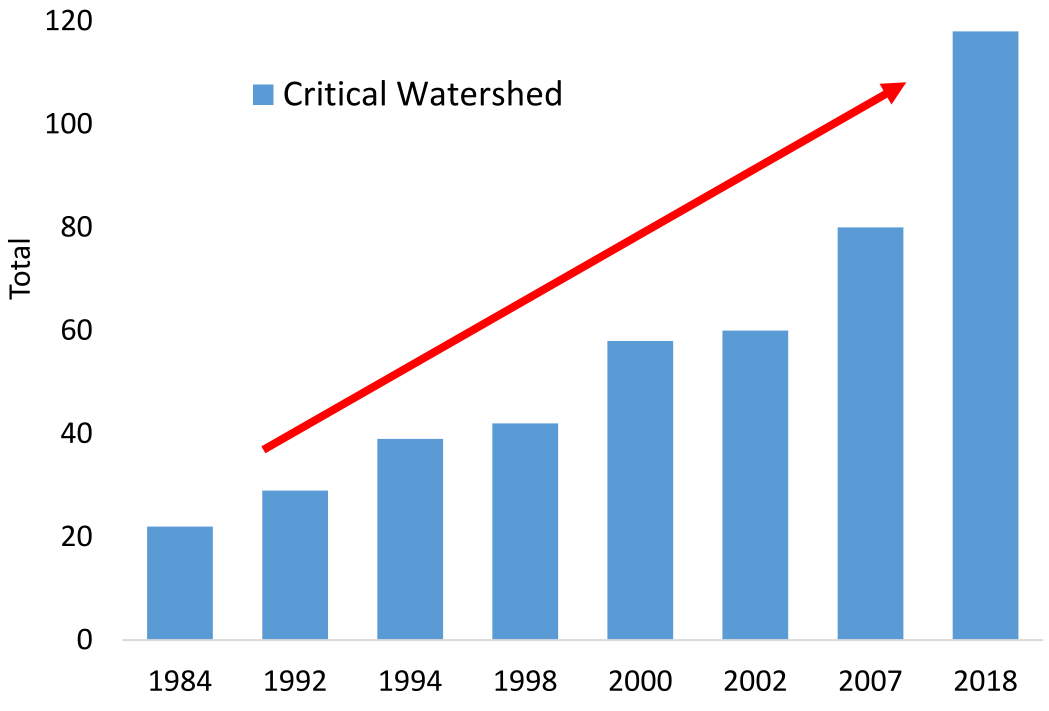
Potential Effects of Climate Change



Source : US. Global Change Research Program,2022
(Figure source: adapted from Phillipe Rekacewicz UNEP/GRID-Arendal 2012, "Vital Climate Graphics" collection19)

Issues of Indonesia 2020s

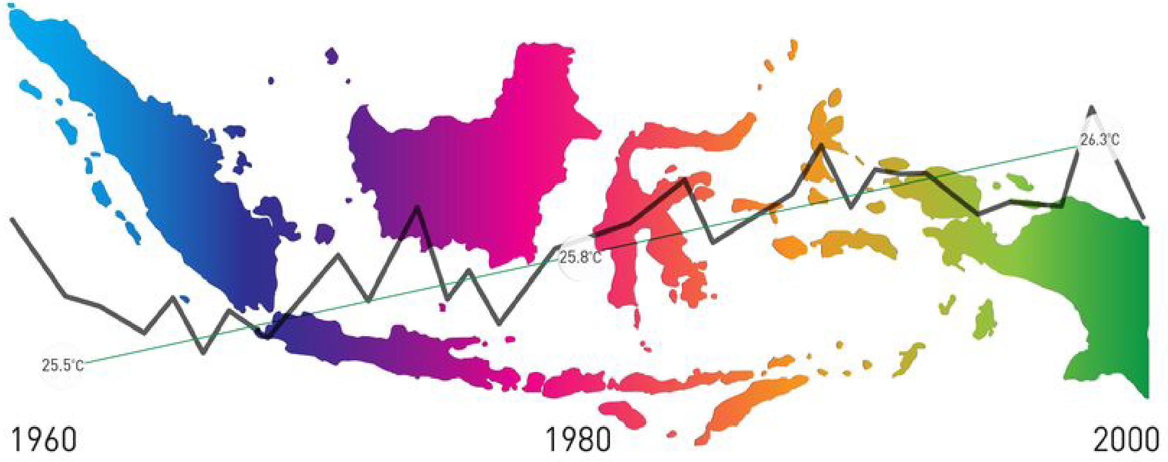
Trend of critical watershed in Indonesia



Source : Ministry of Env. and Forestry of Indonesia, 2018

Indonesia's climate change vulnerability

Indonesia is the world's largest archipelago comprising over **17,508 ISLANDS.** Covering an area of about **790 million** hectares with a total coastline length of **95.181 KM** and a land territory of about **200 million** hectares.



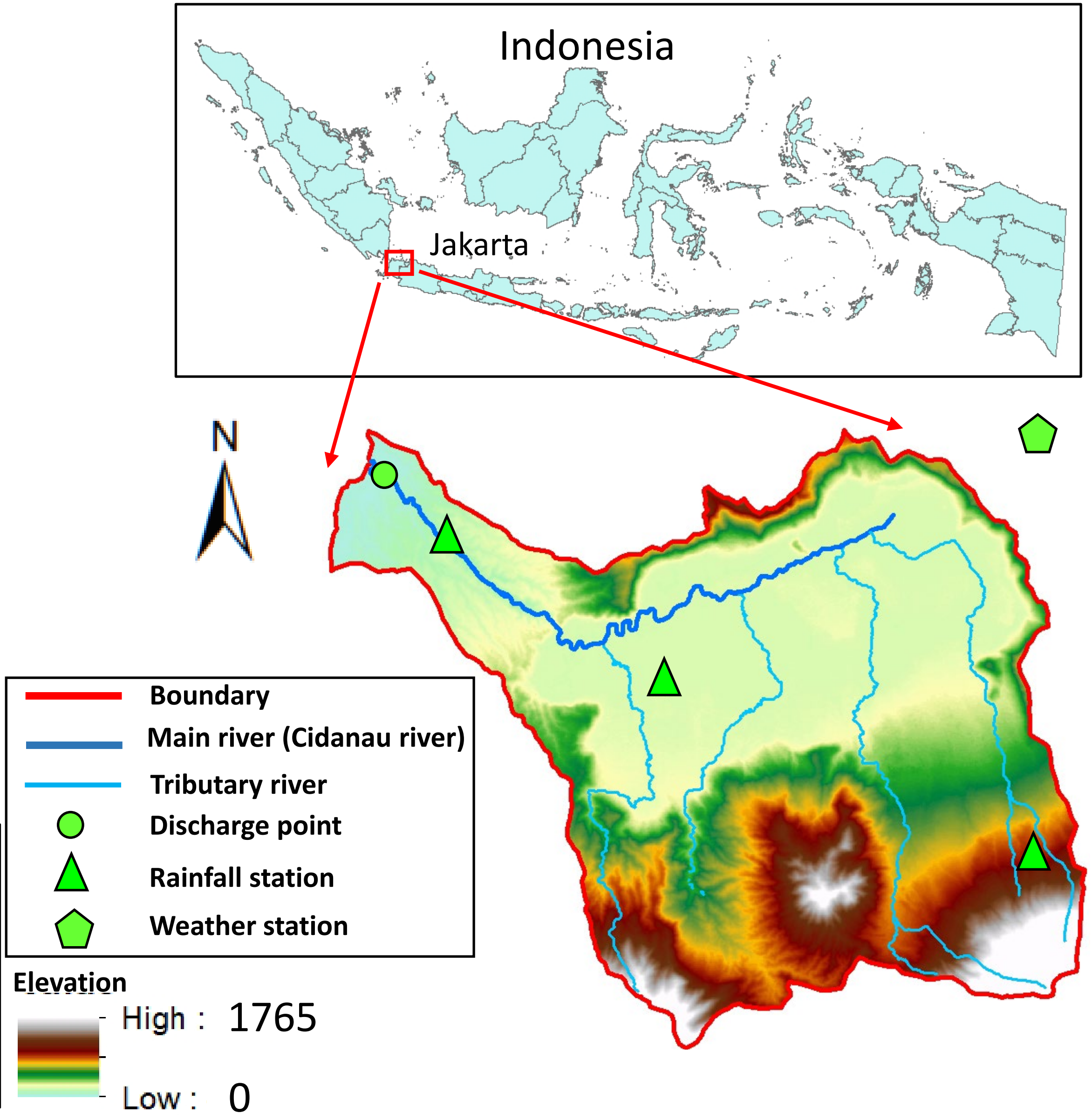
With its situation, Indonesia is **highly vulnerable** to the adverse impacts of climate change. Data collected on the average temperature variation across the entire region of Indonesia for the past years shows a trend of increasing temperature level.

Indonesia has 450 watersheds, but 118 watersheds are in critical condition (Ministry of Env. and Forestry of Indonesia, 2018)

Indonesia is highly vulnerable to climate change impacts, including extreme events such as floods and droughts, shifts in rainfall patterns and increasing temperature (Disaster Management Agency of Indonesia, 2021)

Study Area : Cidanau Watershed

- Cidanau river, located in Banten Province, around 120 km from Jakarta capital of Indonesia, is **main source** to **supply water needs** for domestic and industrial sectors at Cilegon city.
- Total area : Approx. 22.620 Ha
- Climate : Tropical rainforest, moonson
- Temperature : 21 – 33^{o} C
- Precipitation : ave. 2000-3000 mm/year
- Altitude : 0 - 1765 m



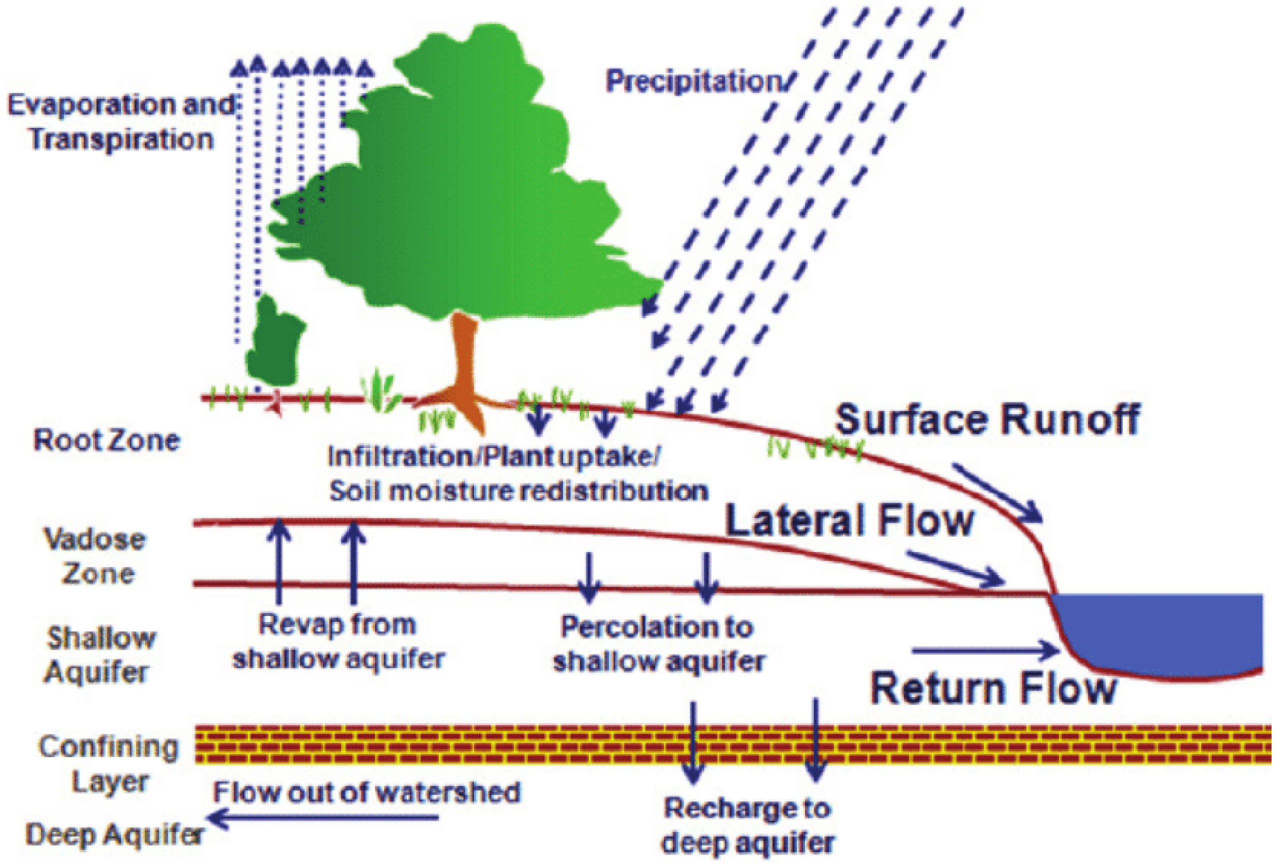
Previous study : 1978-2018 The daily average temperature changed 0.79^{o}C, annual rainfall decreased by 5.3 mm/year, driest condition was in 1997 with annual rainfall 1115 mm (Setiawan *et.al* , 2019)

OBJECTIVES

- **Developing hydrological modeling** using SWAT Model including calibration and validation for estimating water availability in Cidanau watershed, Banten Province of Indonesia
- **Analyzing climate change projection** under scenarios of CO2 emission, combination scenarios between **SSP** (Shared Socioeconomic Pathways) and Representative Concentration Pathways (**RCP**)
- **Evaluating** the **impact of climate change** on water availability under scenarios SSP1-2.6, SSP2-4.5, and SSP5-8.5 in 2040-2060

METHODOLOGY

Hydrological Modeling using SWAT



Source : SWAT 2012

- Open source software USDA-ARS
- Physically based
- Semi distributed model
- Continuous timescale (daily time step)
- Divides catchment into sub-catchment and then further into HRU (Hydrological Response Units)

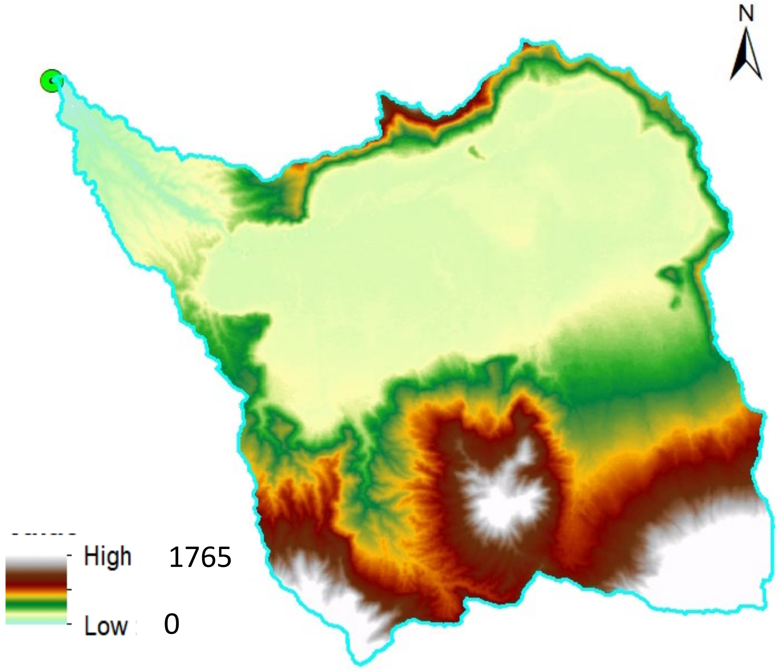
The hydrological cycle simulation is based on: **Water balance equation :**

$$SW_t = SW_o + \sum_{i=1}^{t} R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}$$

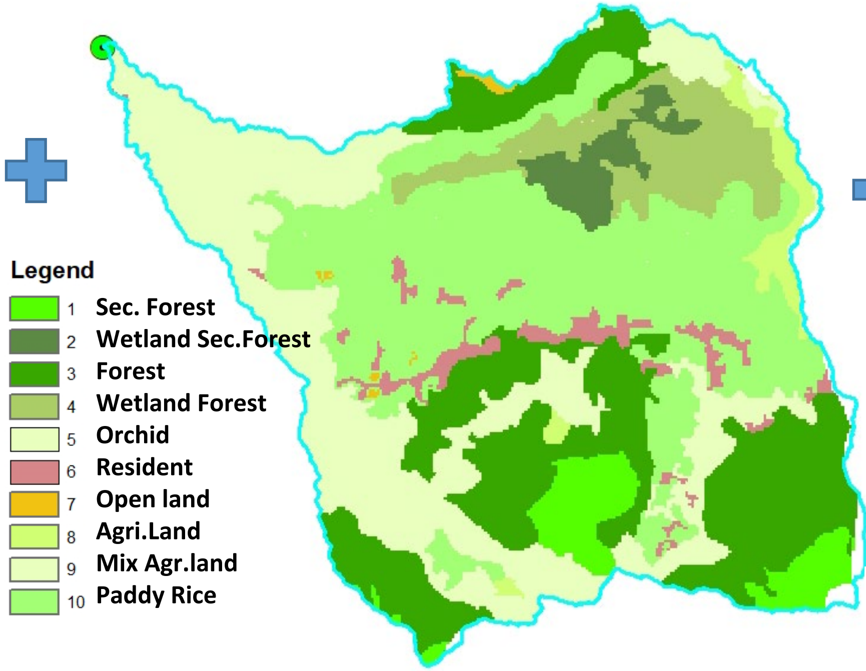
SWt : final soil water content; SWo : initial soil water content
Rday : precipitation ; Qsurf : surface runoff ;
Ea : evapo-transpiration; Wseep : water entering unsaturated zone;
Qgw : amount of return flow

METHODOLOGY

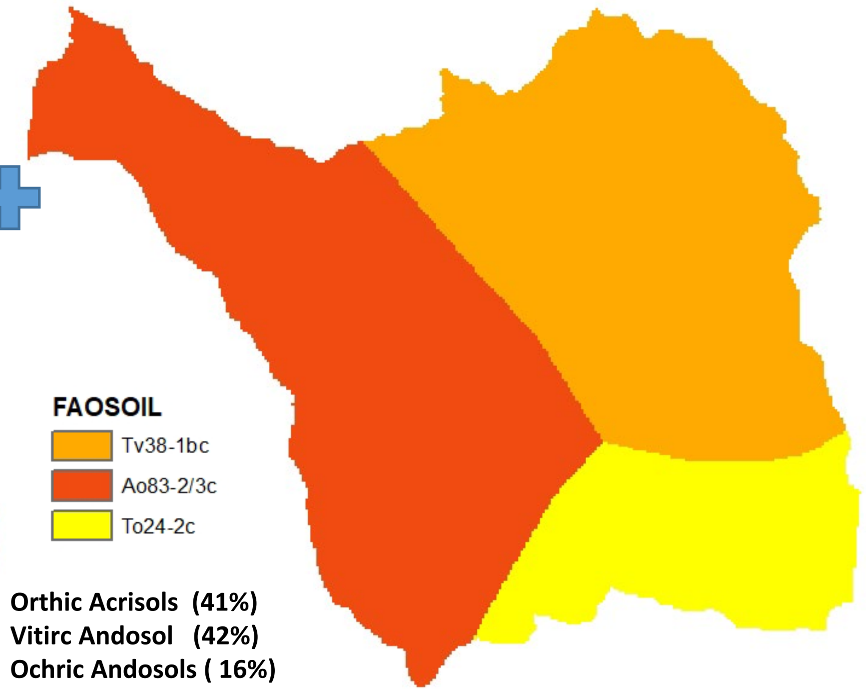
SWAT Model Input and Setup



DEM for watershed delineation (Source DEM: Geospatial Agency of Indonesia, 2018)



Landuse maps for HRU Generation (Source : Ministry of Environmental and Forestry of Indonesia, 2019)



Soil Map for HRU Generation (Source : FAO, https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/faounesco-soil-map-of-the-world/en)

Number of Subbasins: 27 Number of HRUs: 80

METHODOLOGY

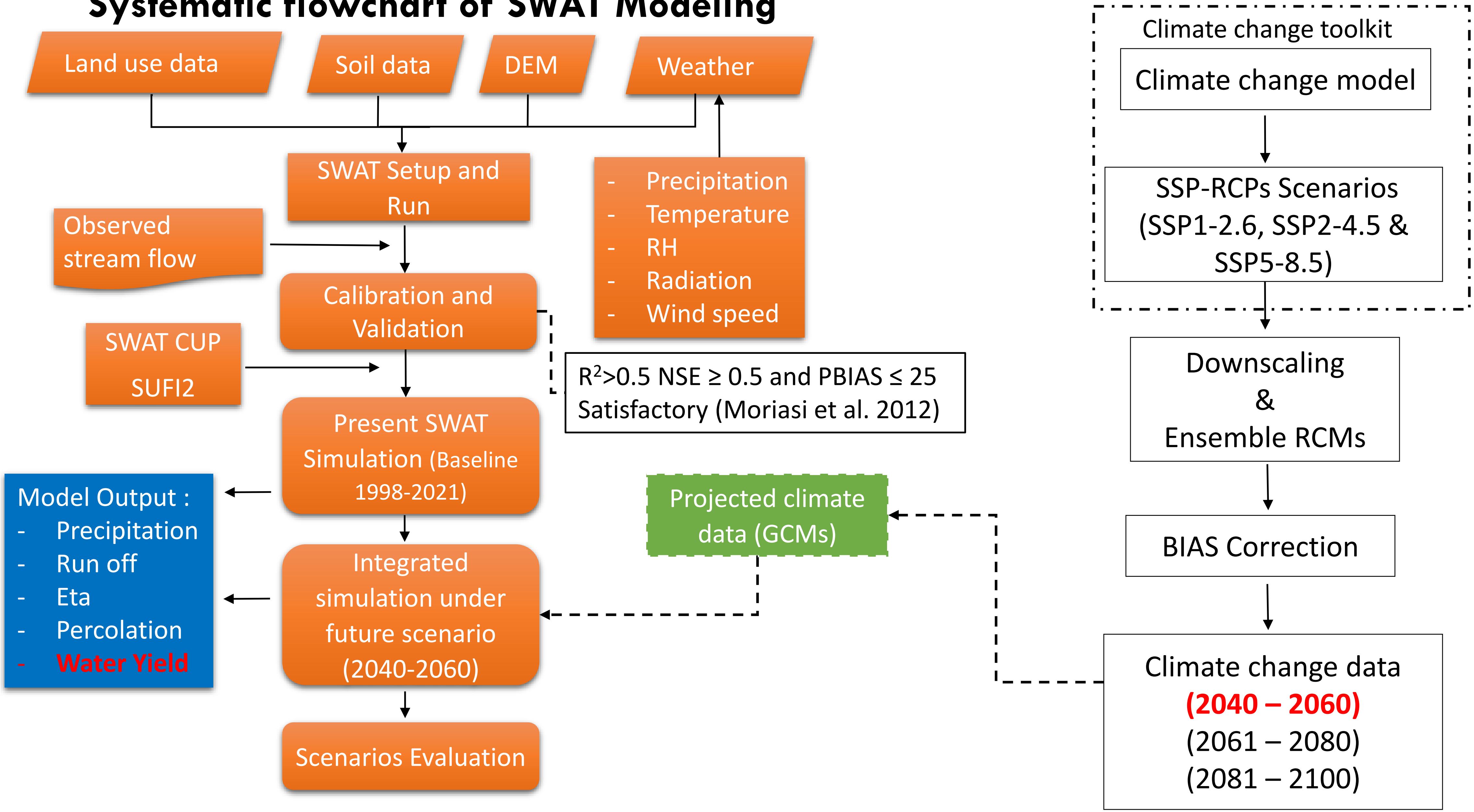
Data Inputs

- **Spatial data**: Digital Elevation Model (DEM), Landuse, and Soil Map.
- **Weather data** (2000-2021) : Max and Min Temperature, Relative Humidity Wind speed, and Solar Radiation (Source: Meteorology, Climatology, and Geophysical Agency of Indonesia). Daily Precipitation (Source: Ministry of Public Works of Indonesia)
- **Streamflow data**, observed in daily (2000-2021). Source : PT. Krakatau Tirta Industry, tbk (State-owned enterprises of Indonesia)
- **Climate change projection** using **CMIP6** (2040-2060): Four climate models ACCES-CM2(Australia),CMCC-ESM2 (Italy),INM-CM4-8 (Russia),MIROC-ESL2 (Japan) with scenarios SSP1-RCP2.6, SSP2-RCP4.5 and SSP5-RCP8.5). Source : European Centre for Medium-Range Weather Forecasts (ECMWF)

METHODOLOGY

Systematic flowchart of SWAT Modeling

Process of climate change projection

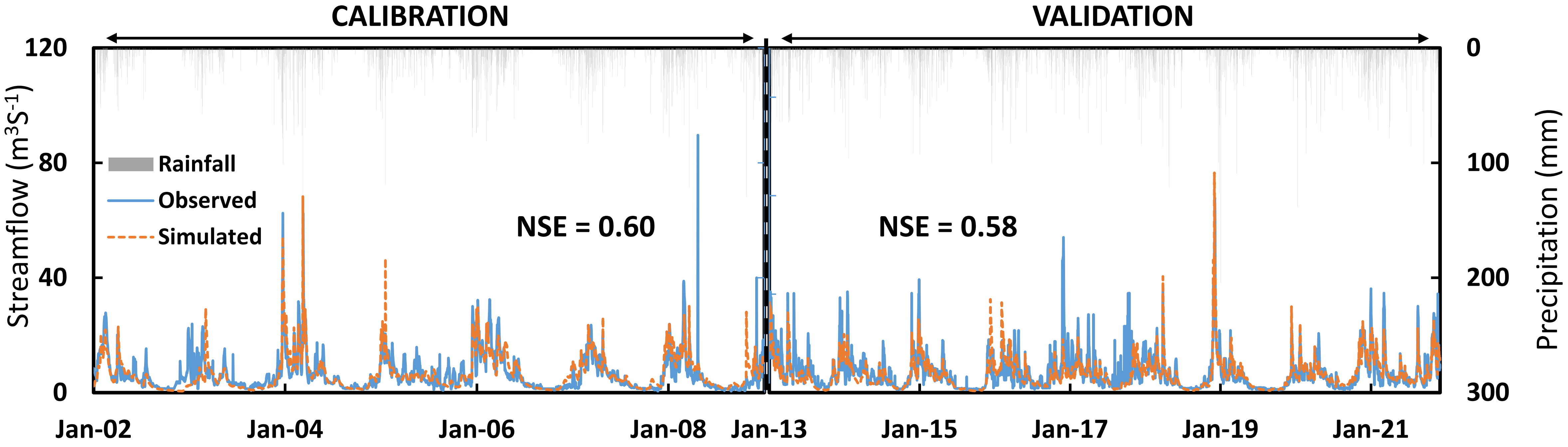


Methodology

Climate change simulation process in SWAT model

- Calibrate and validate the SWAT model with SWAT CUP
- Prepare **projected climate data** in the same way as historical data
- In ArcSWAT, Edit Weather data and stations -> Module **create pcp1.pcp, tmp1.tmp., file.cio.**
- Copy the new pcp1, tmp1, and file.cio (from ArcSWAT project TxtINOut Folder) into SWAT-CUP Project Folder.
- Open SWATCUP project file, input Par_inf.txt and edit the **CO_2 (CO_2.sub) concentration in the future (Min-Max)** then leave all the other parameters as before.
- Make **an iteration** with calibrated ranges and with as many **simulations as before** using No_Observation program to extract the variables of interest.

RESULTS AND DISCUSSIONS



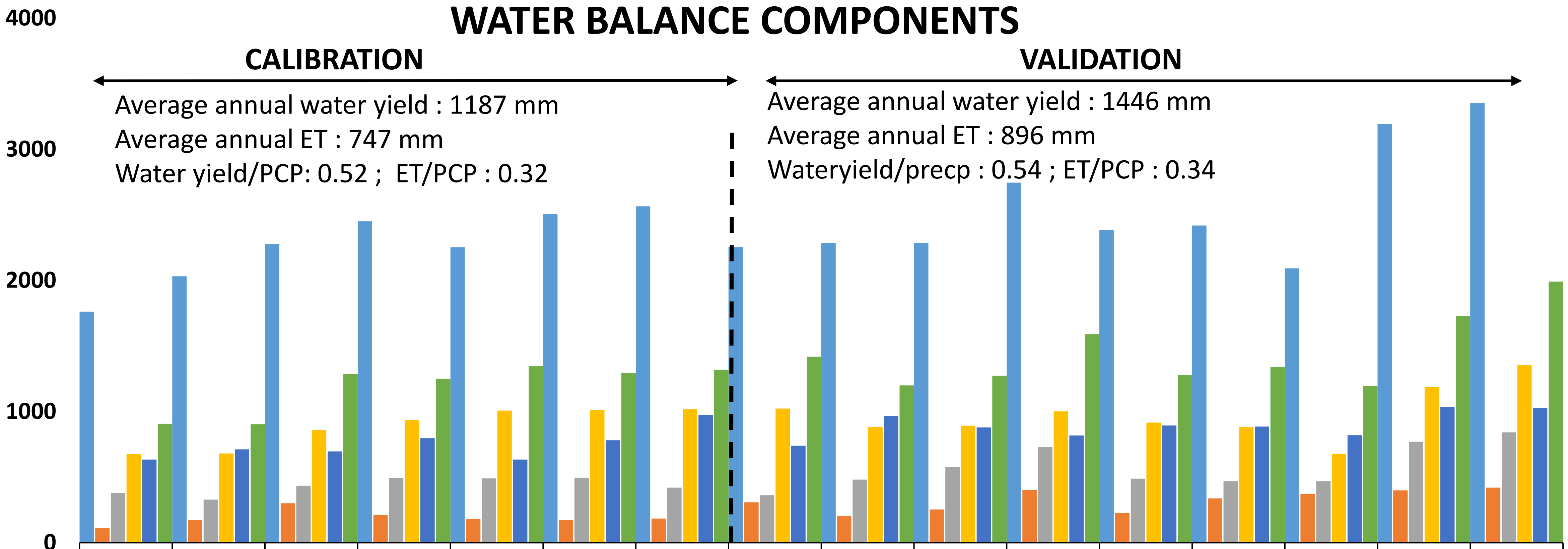
MODEL PERFORMANCE

INDICATORS	CALIBRATION	VALIDATION
R^2	**0.61**	**0.59**
PBIAS	**3.90**	**7.90**
KGE	0.74	0.72
p-factor	0.83	0.86
p-factor	1.28	1.28

The most sensitive parameters of streamflow :

- Curve number factor (**CN2.mgt**) ↓
- Effc. hydrlc. conductivity main channel (**CH_K2.rte**) ↑
- Deep aquifer percolation fraction (**RHRG_DP.gw**) ↑
- Saturated hdrylc. Conductivity (**SOL_K.sol**) ↓
- Soil Evaporation compensation factor (**ESCO.hru**) ↓
- Baseflow alpha factor (**ALPHA_BF.gw**) ↑

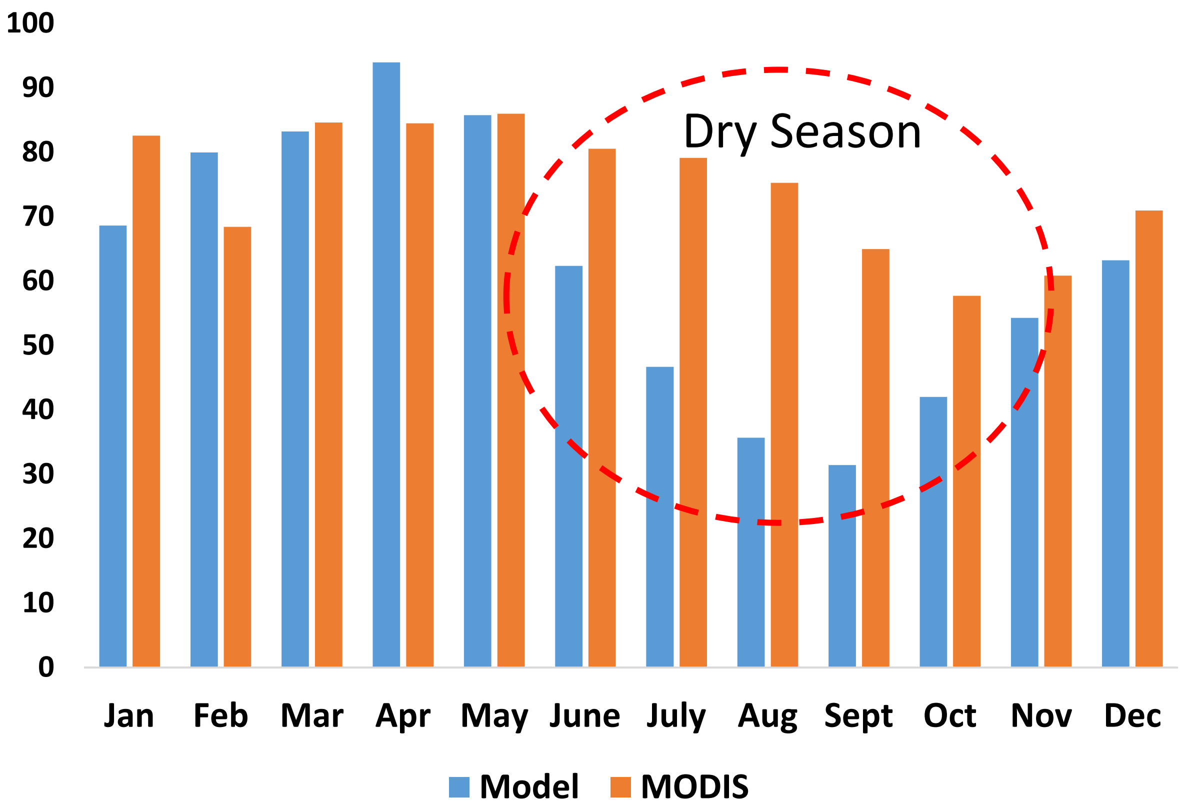
RESULTS AND DISCUSSIONS

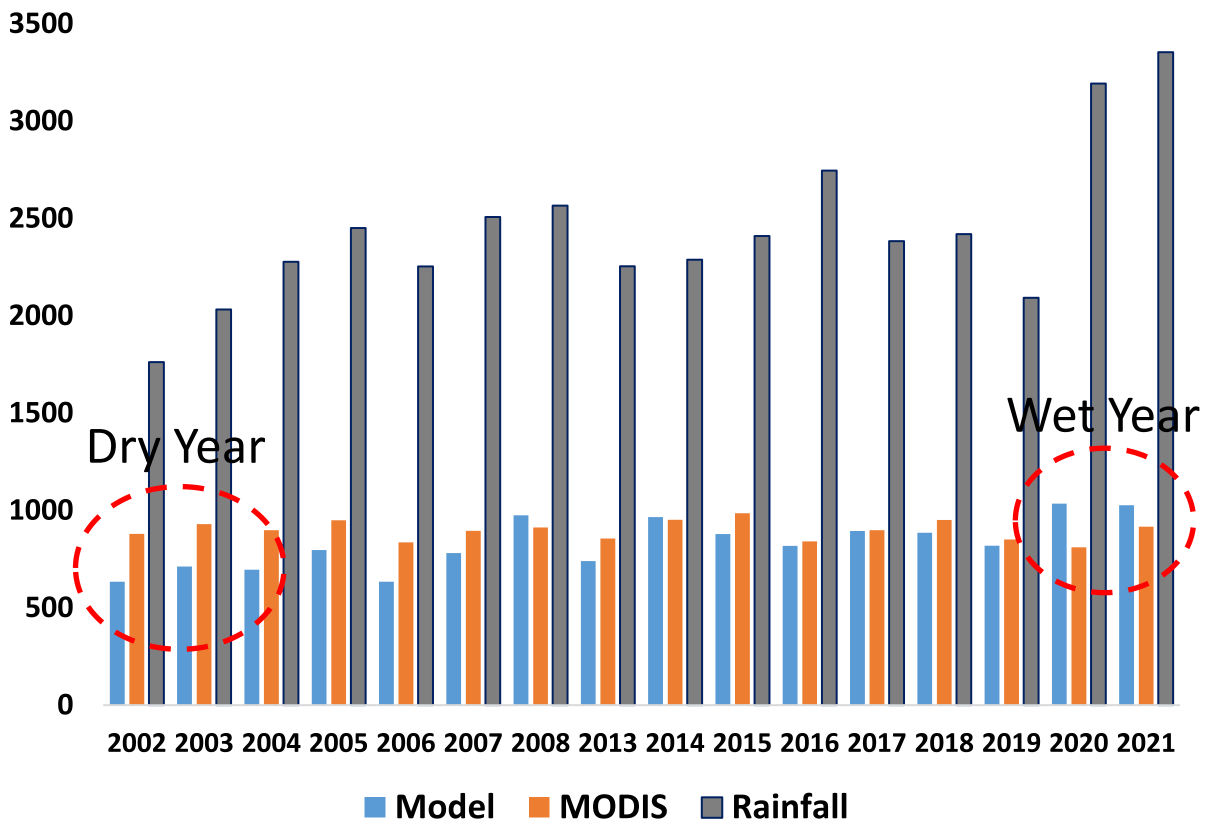


	2002	2003	2004	2005	2006	2007	2008	2013	2014	2015	2016	2017	2018	2019	2020	2021
PREC	1763	2033	2278	2451	2254	2508	2566	2254	2288	2288	2746	2383	2420	2093	3193	3354
SURQ	113	172	301	210	182	174	184	308	202	254	403	228	338	374	399	421
PERCO	381	329	435	494	491	496	420	363	482	578	729	489	469	469	770	842
LATQ	675	681	859	936	1008	1014	1019	1023	881	893	1002	917	881	679	1187	1355
ET	634	712	696	797	635	781	975	740	966	880	819	894	886	820	1035	1027
W.YIELD	907	904	1286	1251	1346	1295	1319	1419	1200	1274	1591	1277	1339	1193	1728	1991

RESULTS AND DISCUSSIONS

ACTUAL ET MODEL VS ACTUAL ET MODIS (BASE LINE)

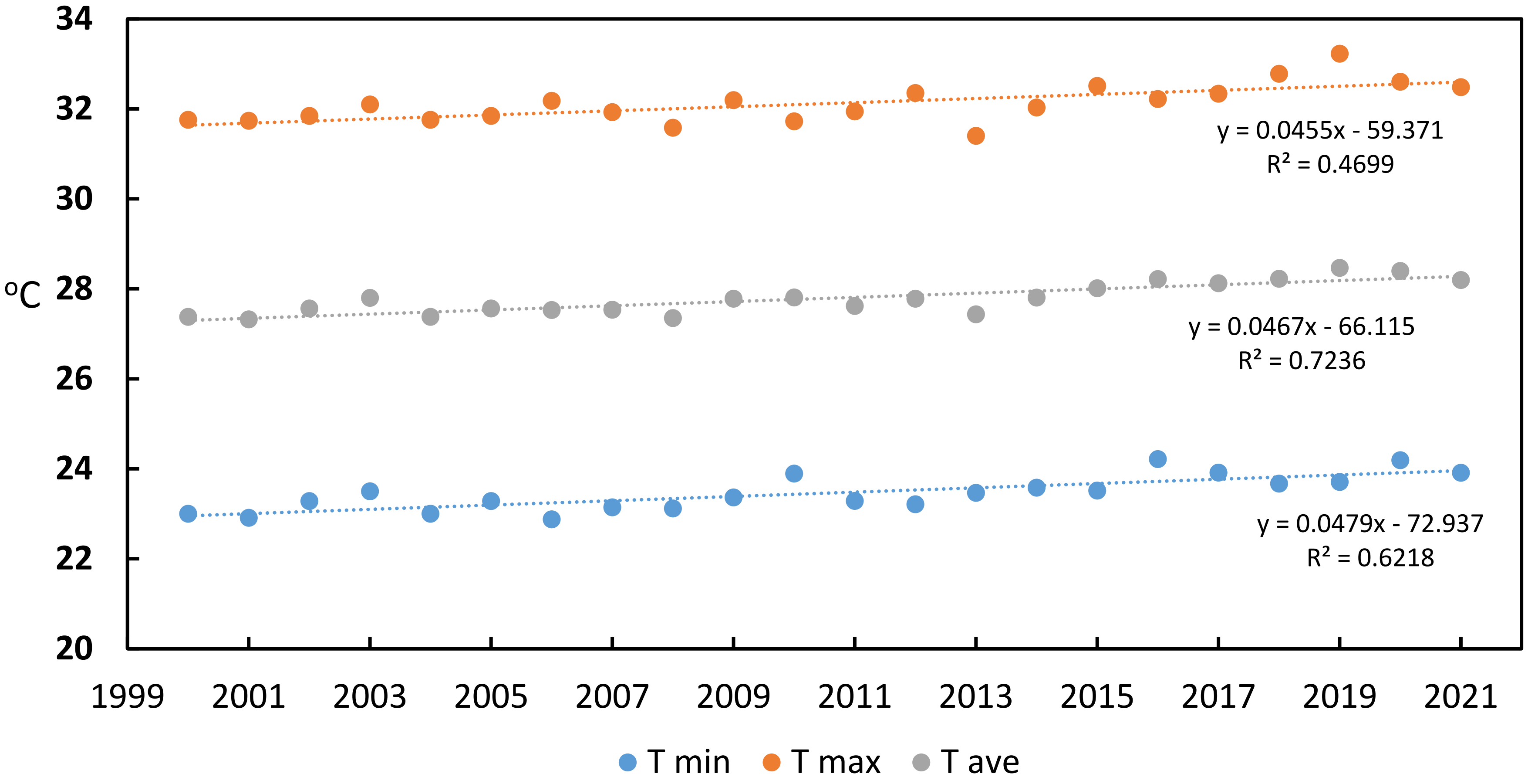




RESULTS AND DISCUSSIONS

CLIMATE CHANGE ANALYSIS

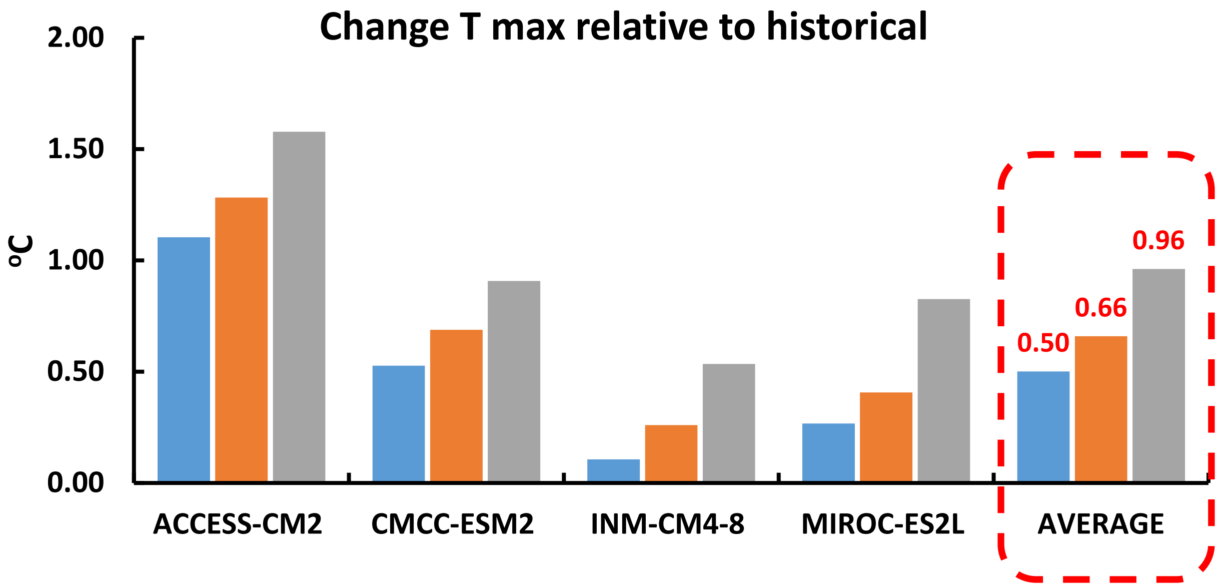
Trend of Historical Temperature (2000-2021)

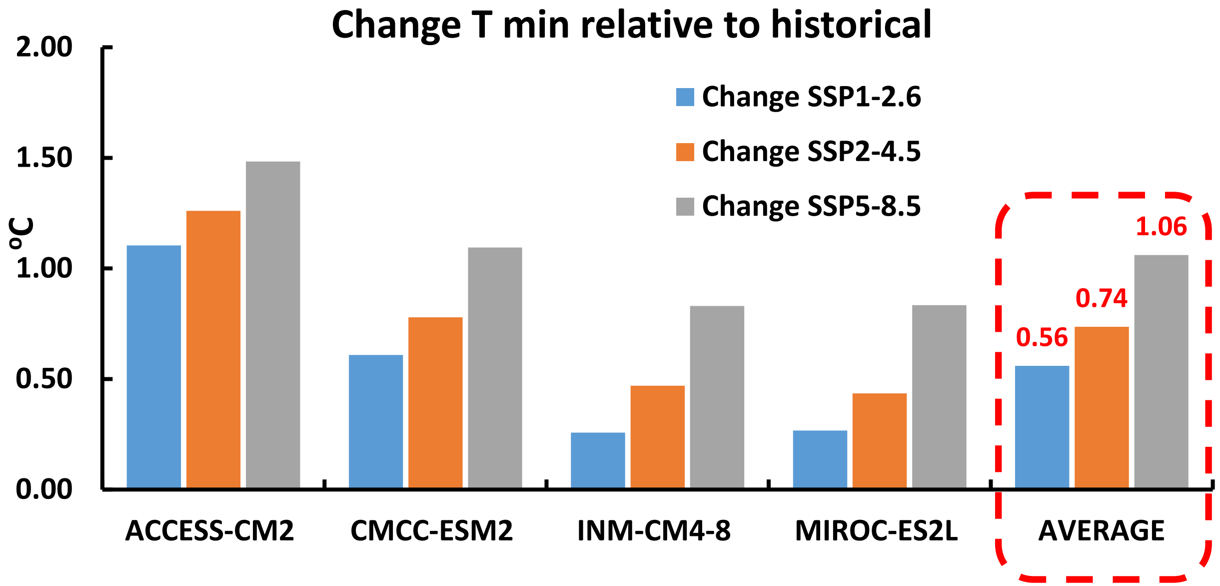


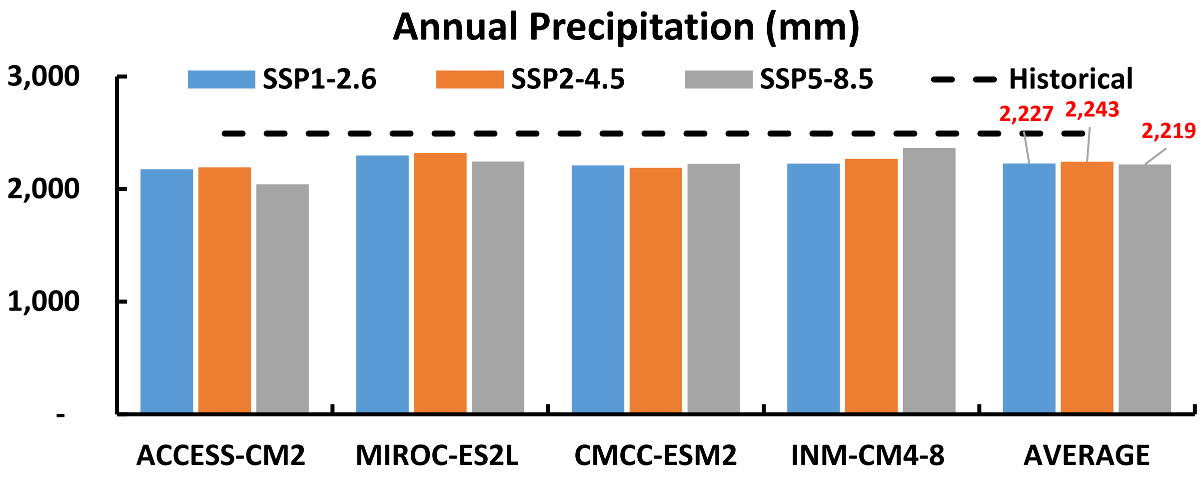
Weather Component	Linier Equation		
	Slope	**R2**	**Change (oC)**
T min (oC)	0.0479	0.62	0.9
T max (oC)	0.0455	0.46	0.8
T ave (oC)	0.0467	0.72	0.6

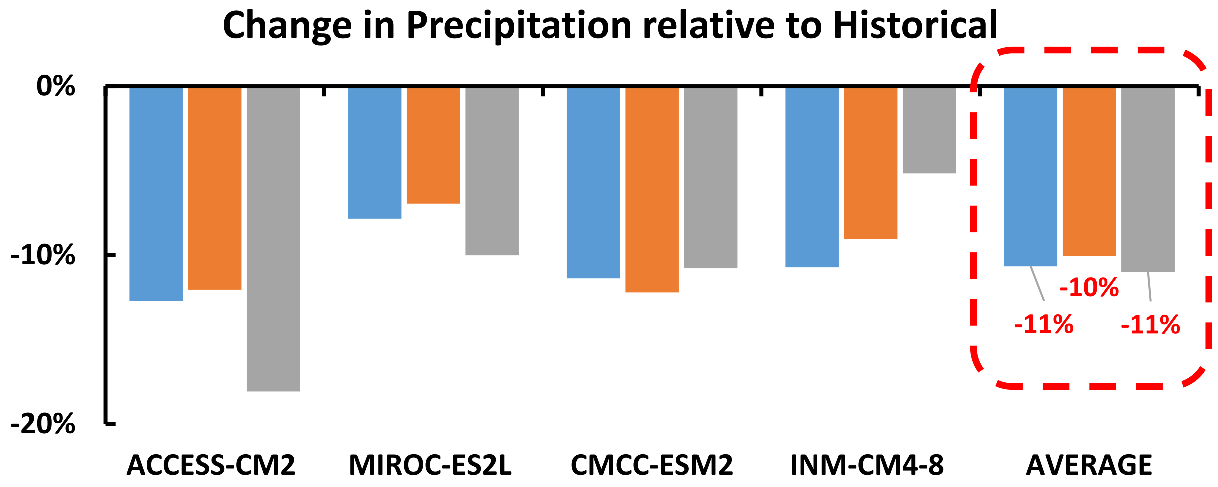
RESULTS AND DISCUSSIONS

CLIMATE CHANGE ANALYSIS (2040 – 2060)





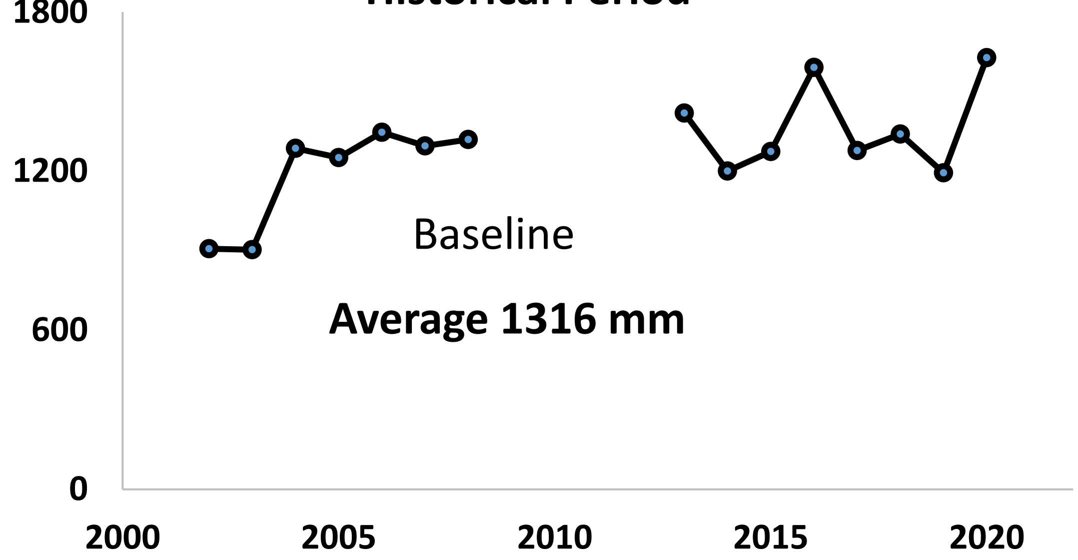




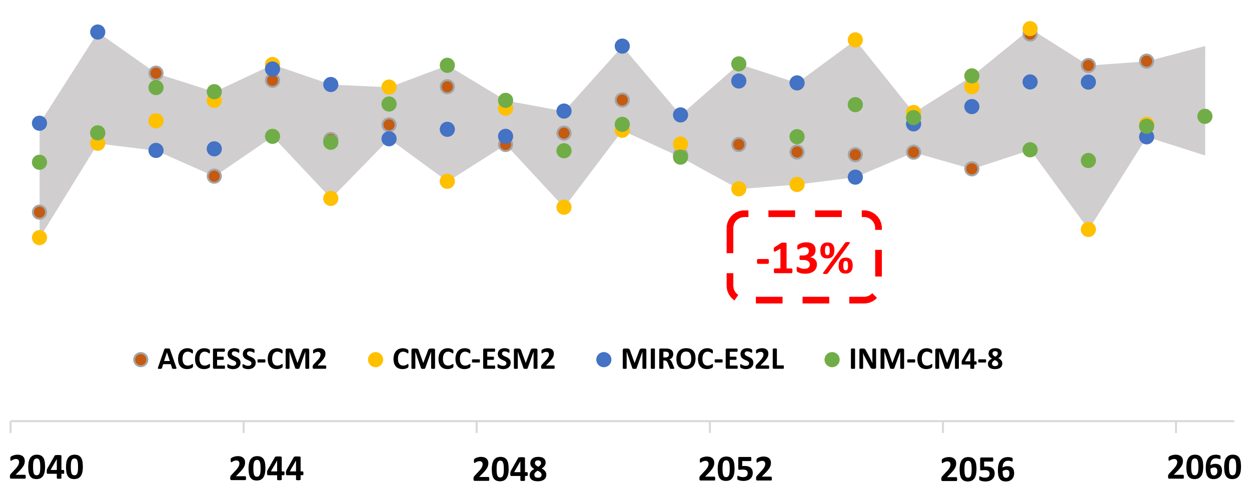
RESULTS AND DISCUSSIONS

ANNUAL WATER YIELD in mm (2040 – 2060)

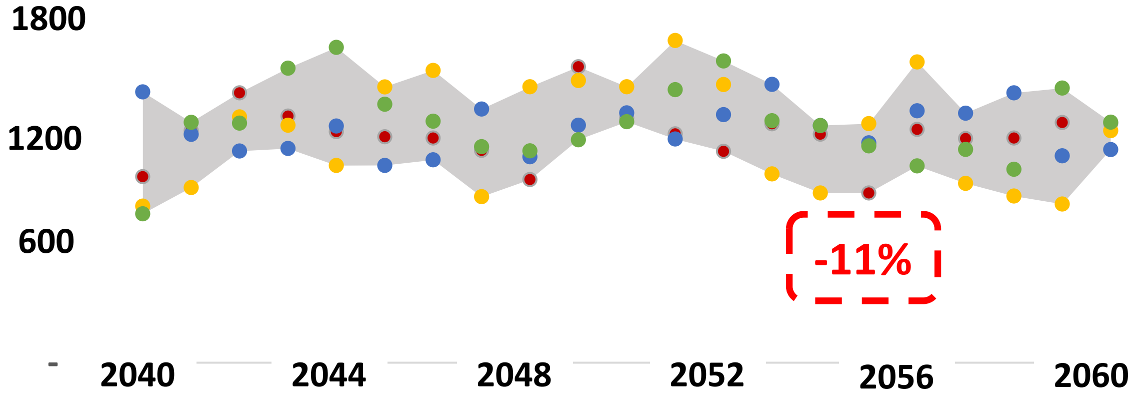
Historical Period



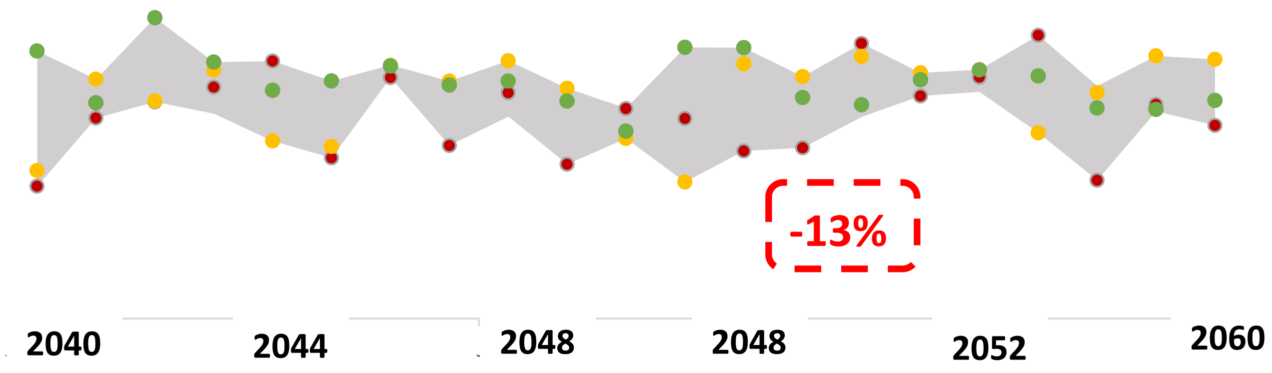
Future Climate Change Projection SSP1-2.6



Future Climate Change Projection SSP2-4.5

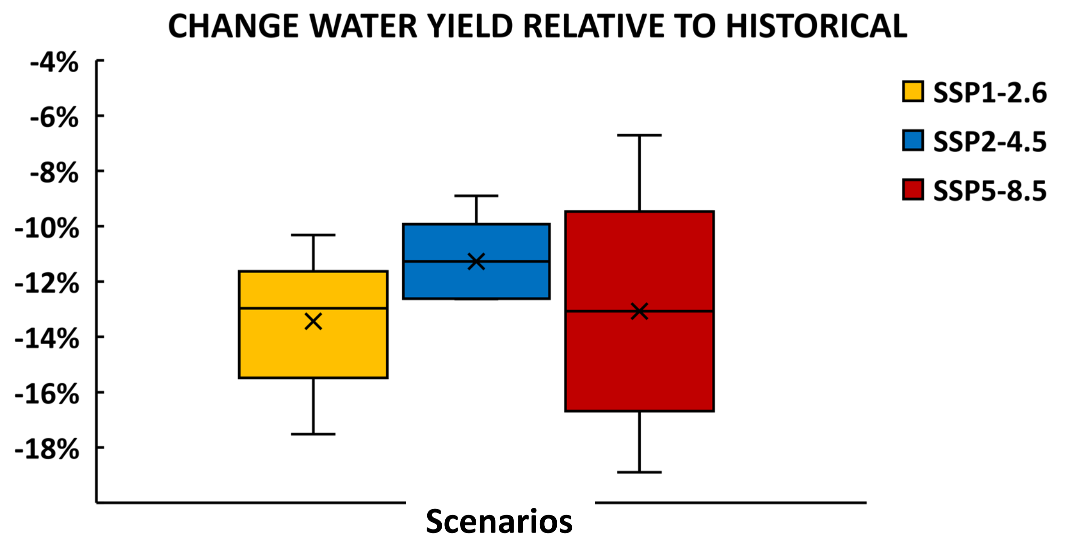


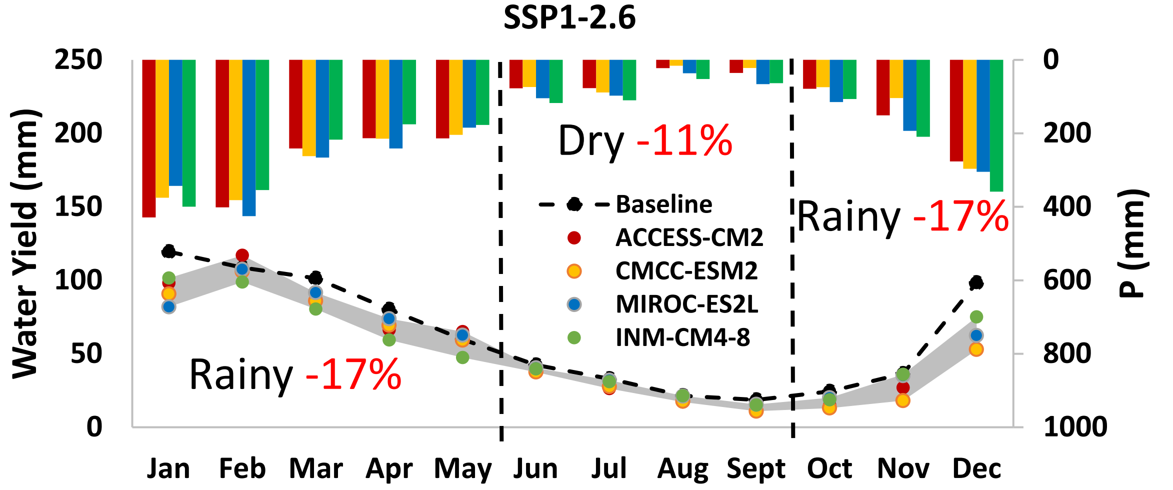
Future Climate Change Projection SSP5-8.5

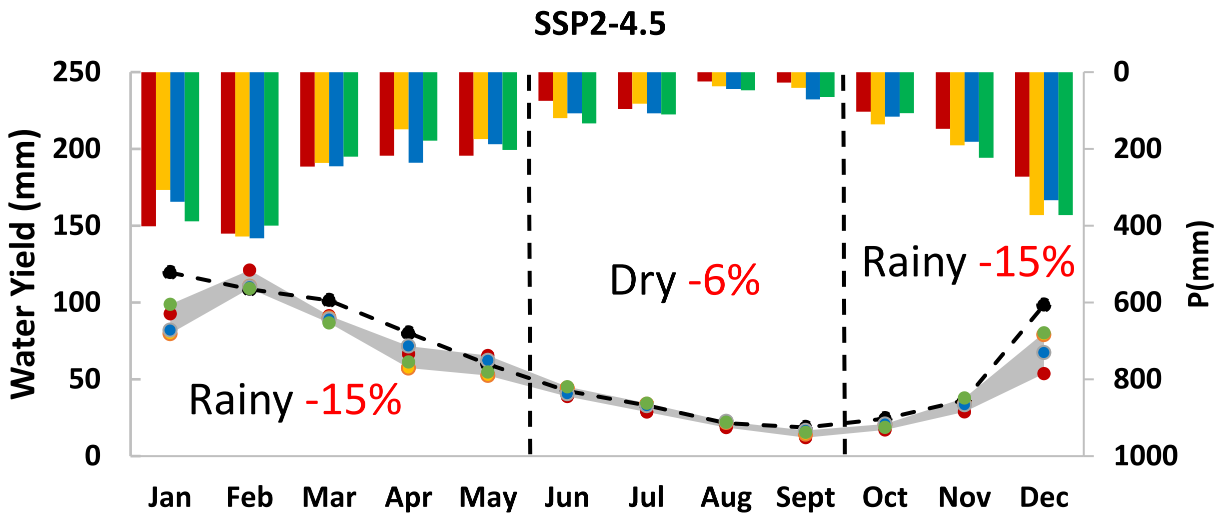


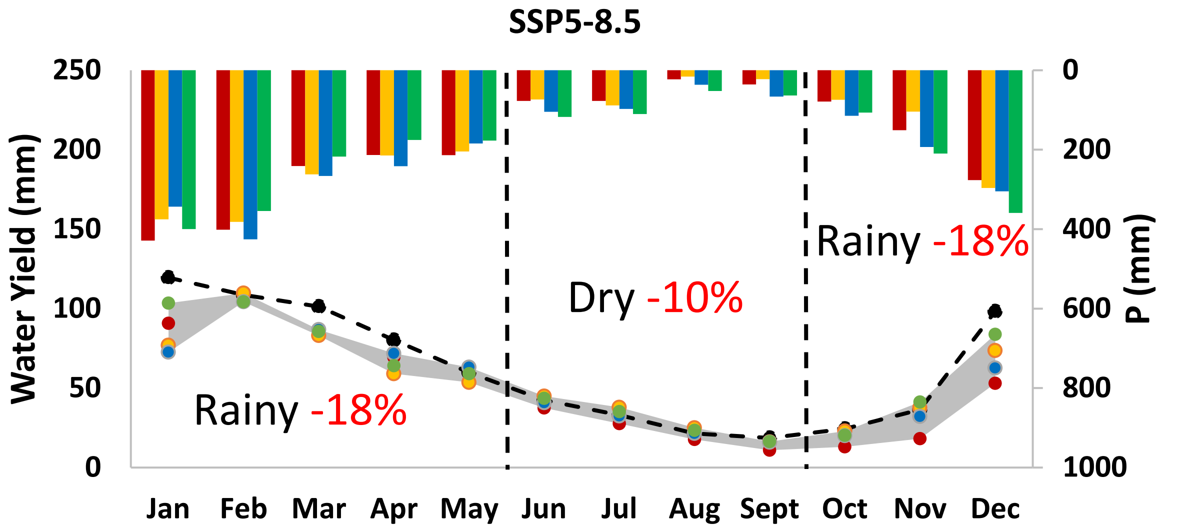
RESULTS AND DISCUSSIONS

CHANGE ON WATER YIELD (2040 – 2060)



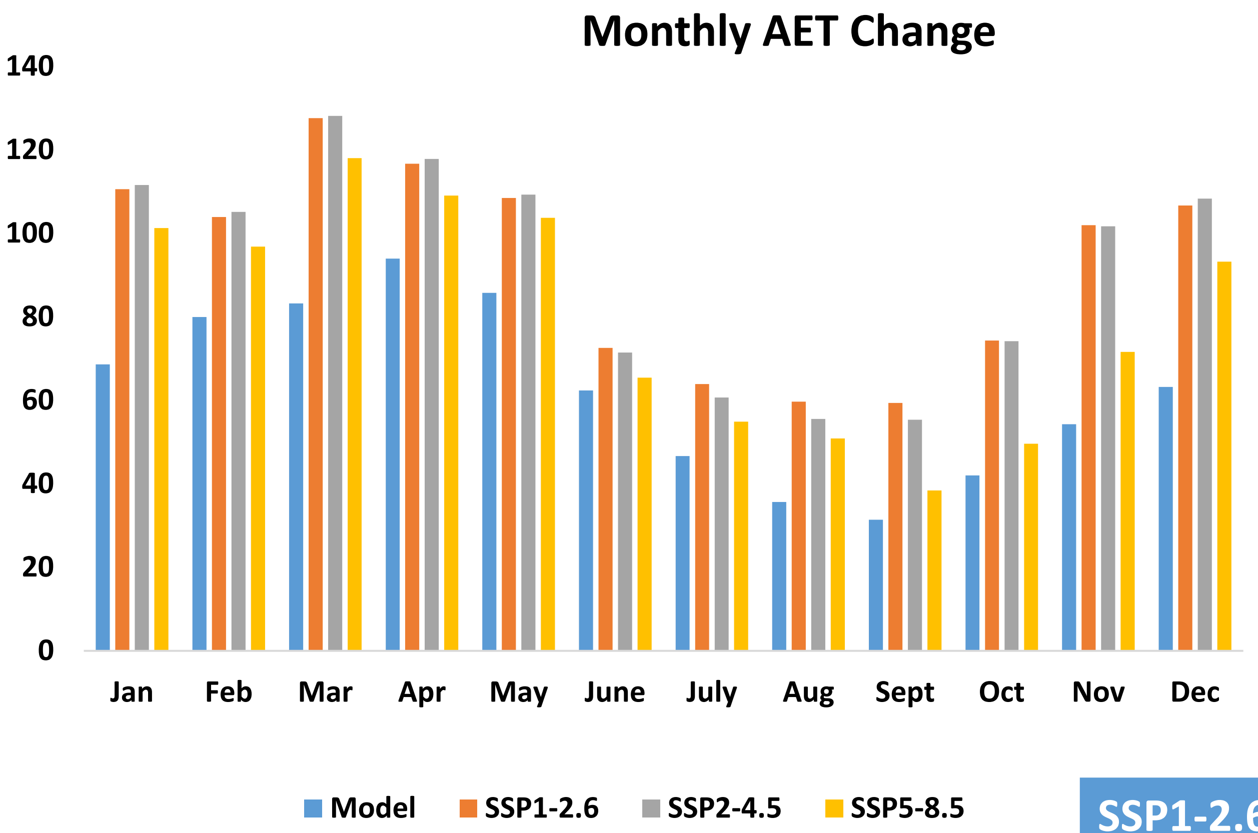


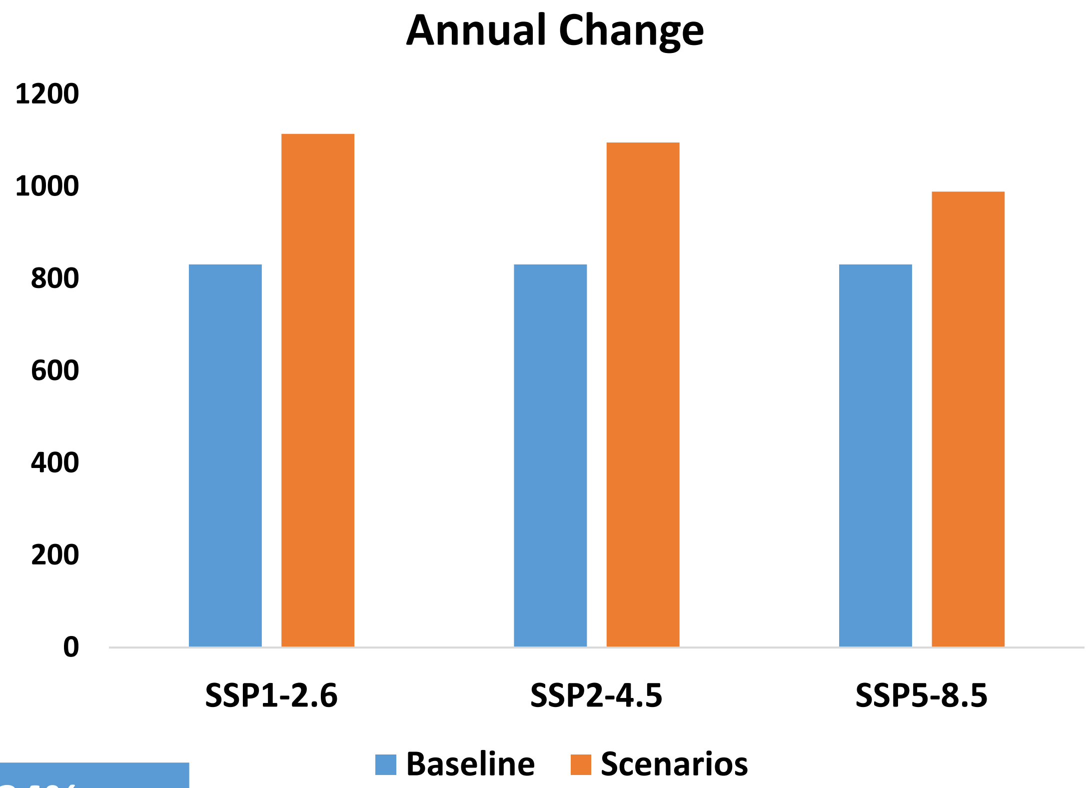




RESULTS AND DISCUSSIONS

CHANGE ON ETP (2040 – 2060)





SSP1-2.6	34%
SSP2-4.5	32%
SSP5-8.5	19%

Conclusion

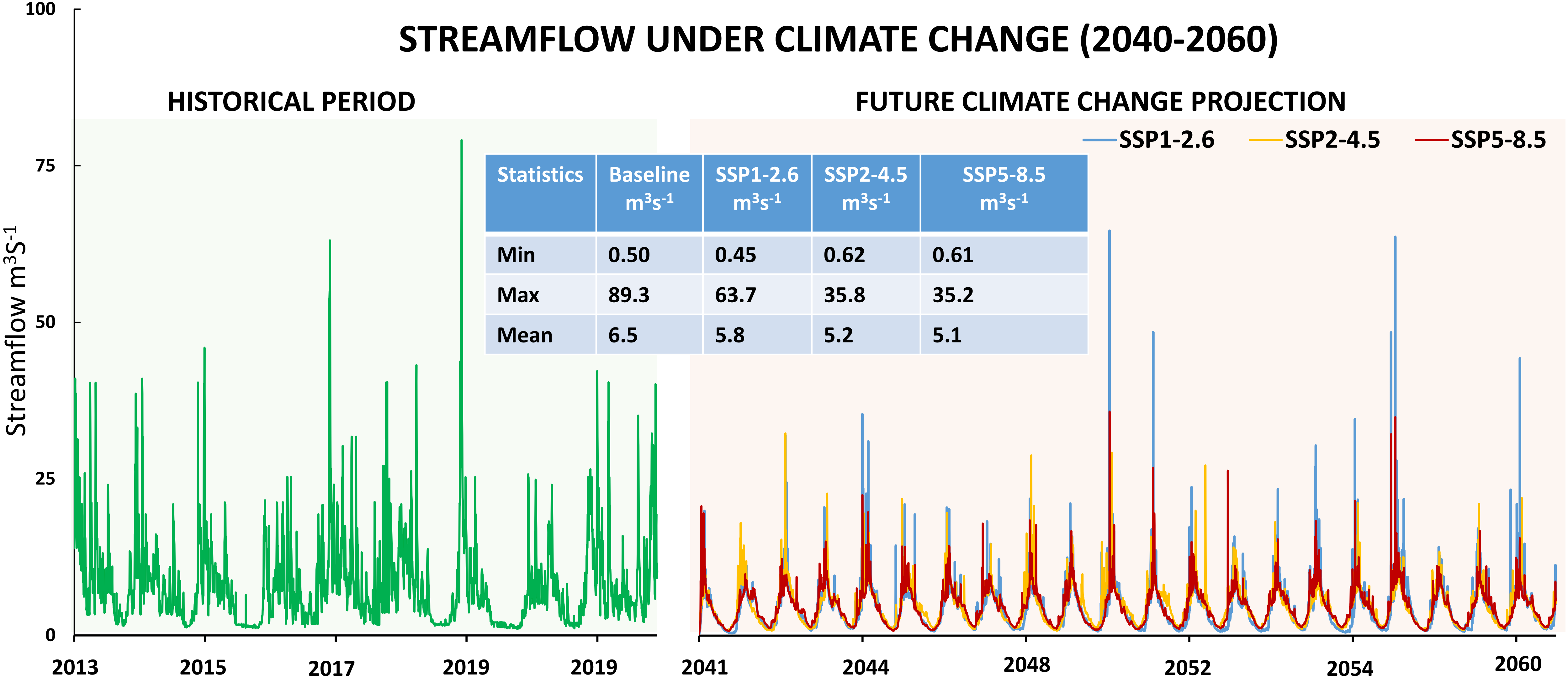
- The SWAT model **successfully simulated** hydrological processes in the study area with **satisfactory statistical model performance**
- **Projected temperatures** (Tmax,Tmin) were expected to **increase** while **annual rainfall** was expected to **decrease** in the future under climate change scenarios SSP1-2.6, SSP2-4.5, and SSP5-8.5.
- There was a general **decline in the future water yield** under all **climate change scenarios**.
- The **water yield decline** was highest in **the rainy season.**
- **Increasing temperature** is the main driver of climate change hence increased **evapotranspiration**

Thank You For Listening

ありがとうございます

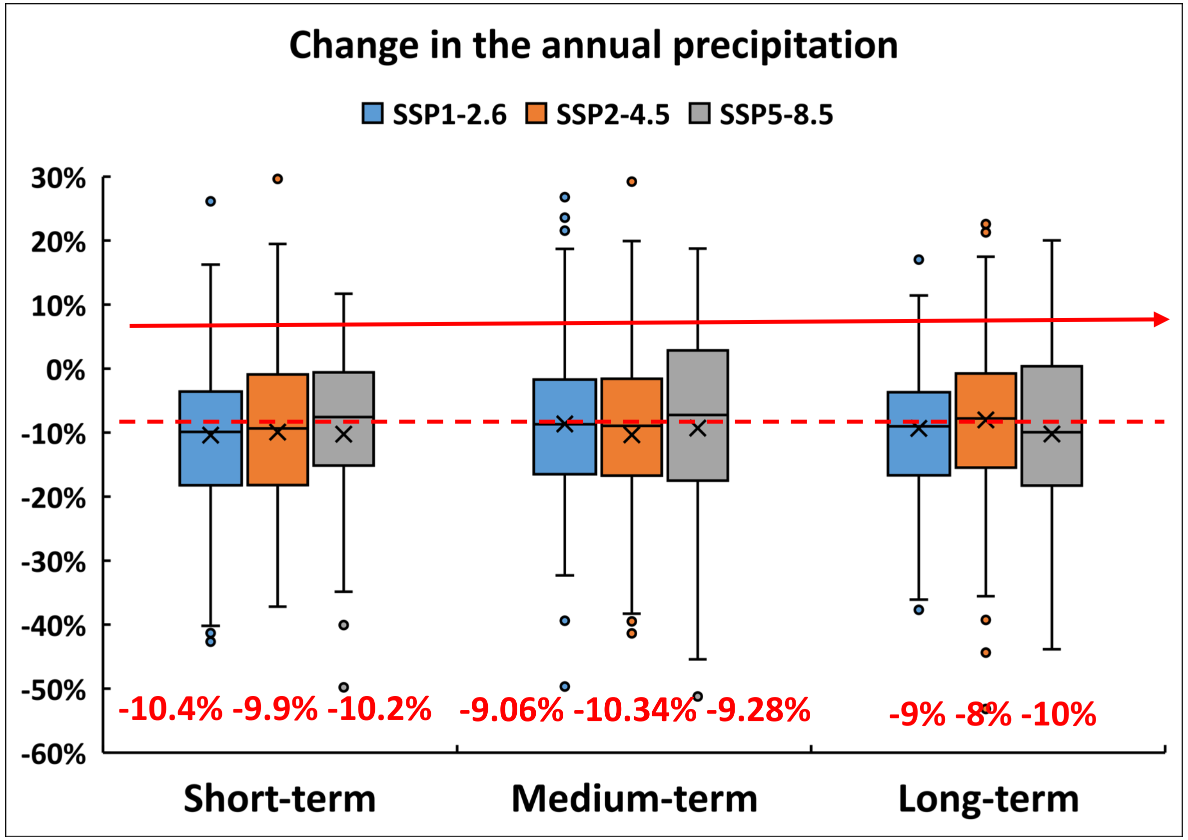
RESULTS AND DISCUSSIONS

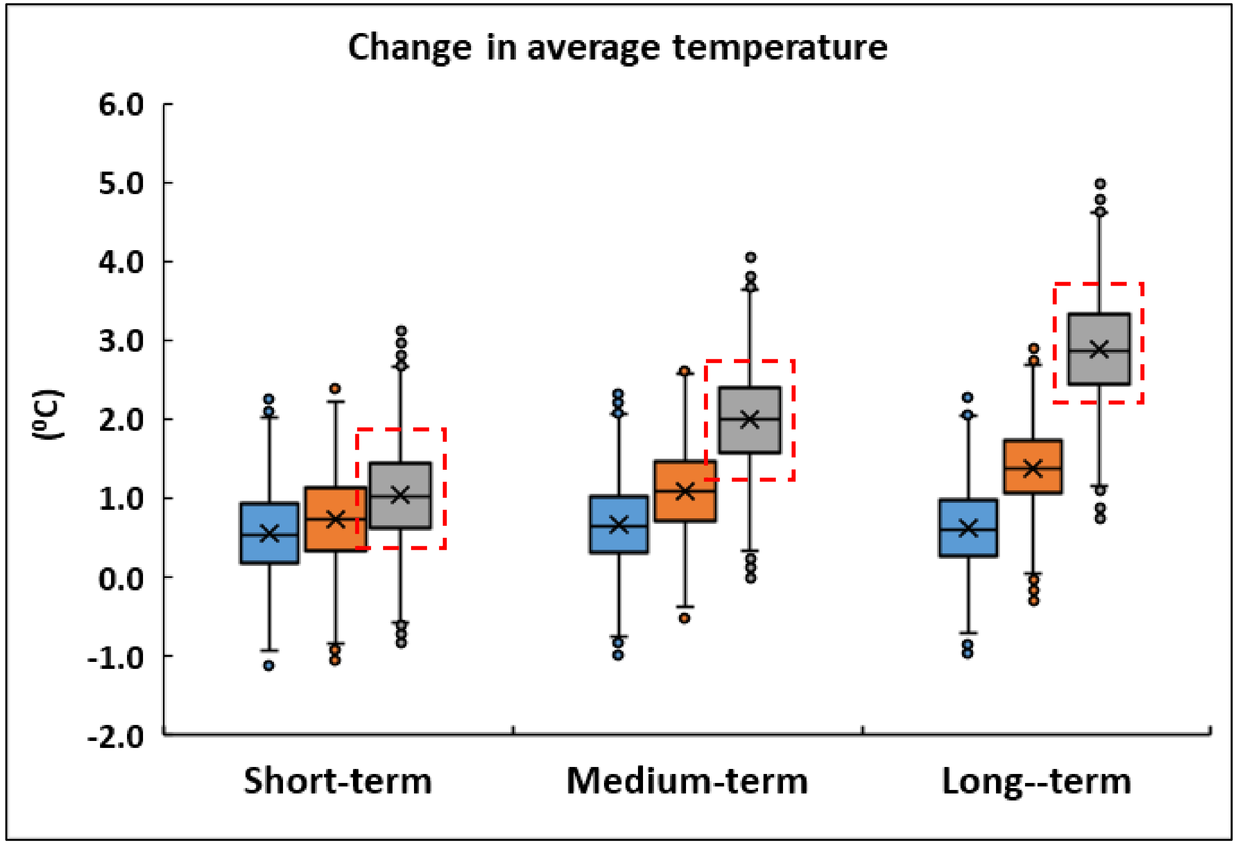
STREAMFLOW UNDER CLIMATE CHANGE (2040-2060)



Statistics	Baseline m^3s^{-1}	SSP1-2.6 m^3s^{-1}	SSP2-4.5 m^3s^{-1}	SSP5-8.5 m^3s^{-1}
Min	0.50	0.45	0.62	0.61
Max	89.3	63.7	35.8	35.2
Mean	6.5	5.8	5.2	5.1

RESULTS AND DISCUSSIONS





RESULTS AND DISCUSSIONS