Asian Institute of Technology
Water Engineering and Management

"QUANTIFYING THE IMPACT OF HUMAN ACTIVITIES AND CLIMATE CHANGE ON WATER RESOURCES IN SREPOK RIVER BASIN, VIETNAM"

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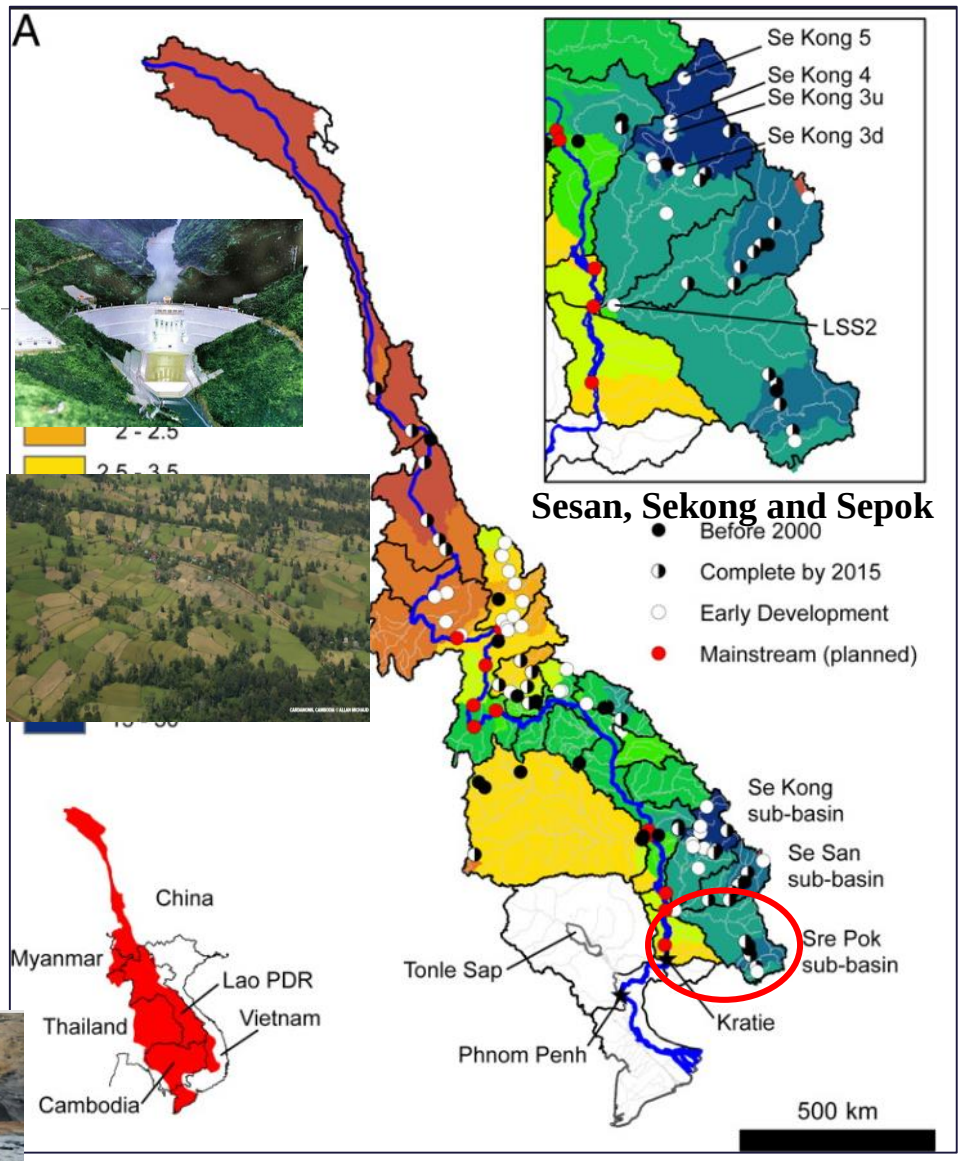
I. Introduction

Background

Srepok River basin:

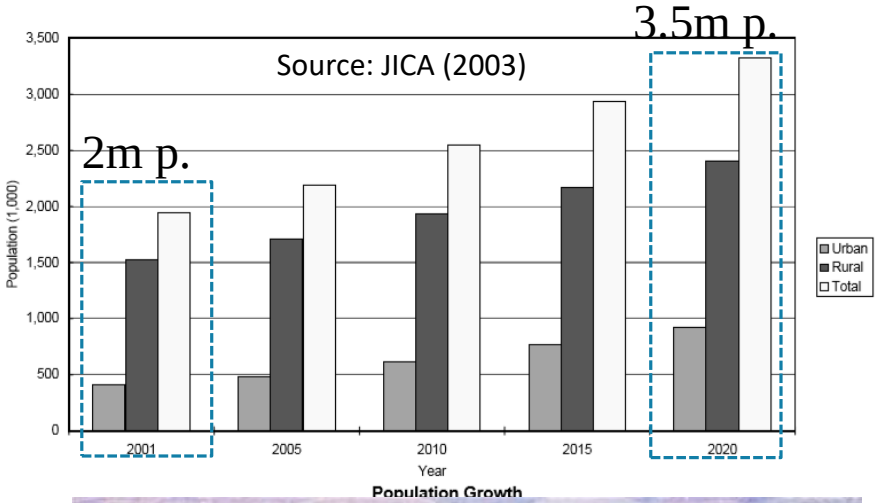
- Main tributary of the Mekong River
- Biological importance and key routes for fish migration
- Home of over 2 million people
- Hydropower and agriculture potential
- Provide the livelihoods of fishers, farmers and non-timber forest products

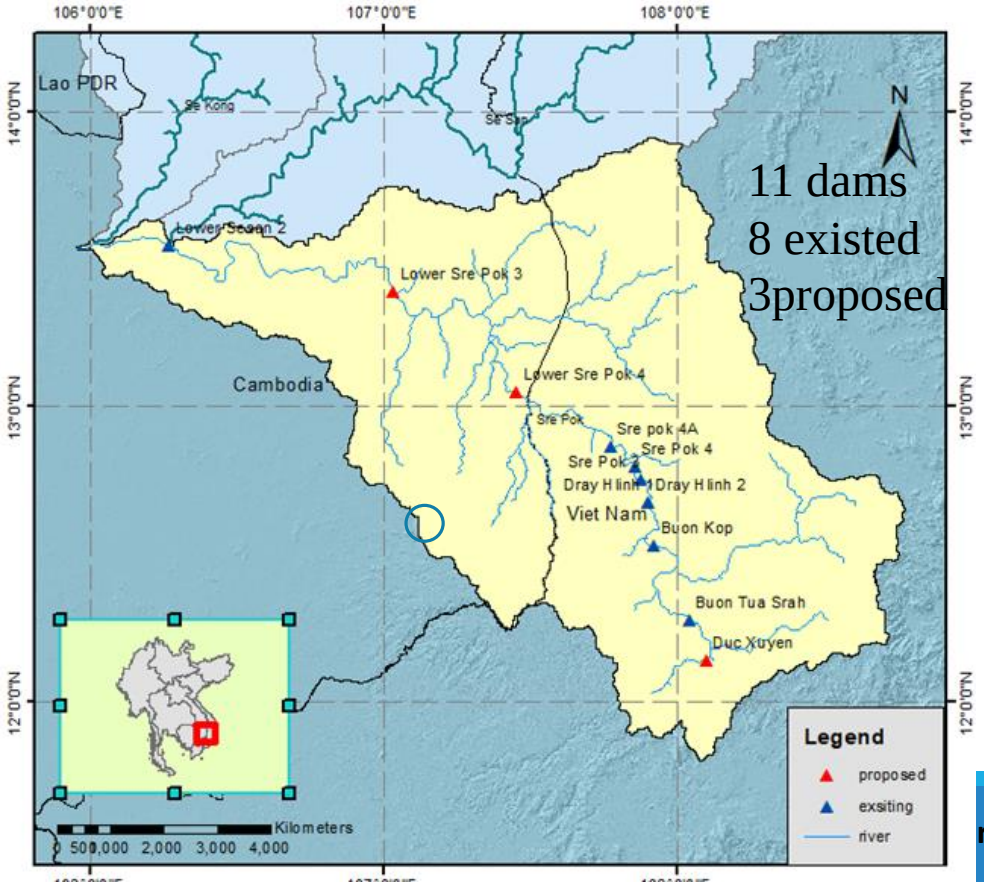


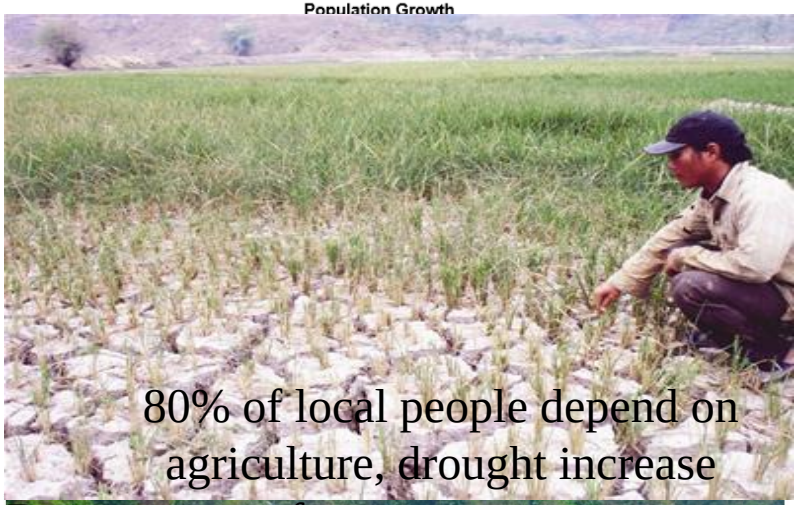
Source: Ziv Guy, et al. (2012)

Statement of the Problems

- Rapid population growth in the Srepok river basin
- Increasing agricultural areas
- Development hydropower plants → alter the flow regime, the livelihoods, the rich of fish biodiversity…







Objective

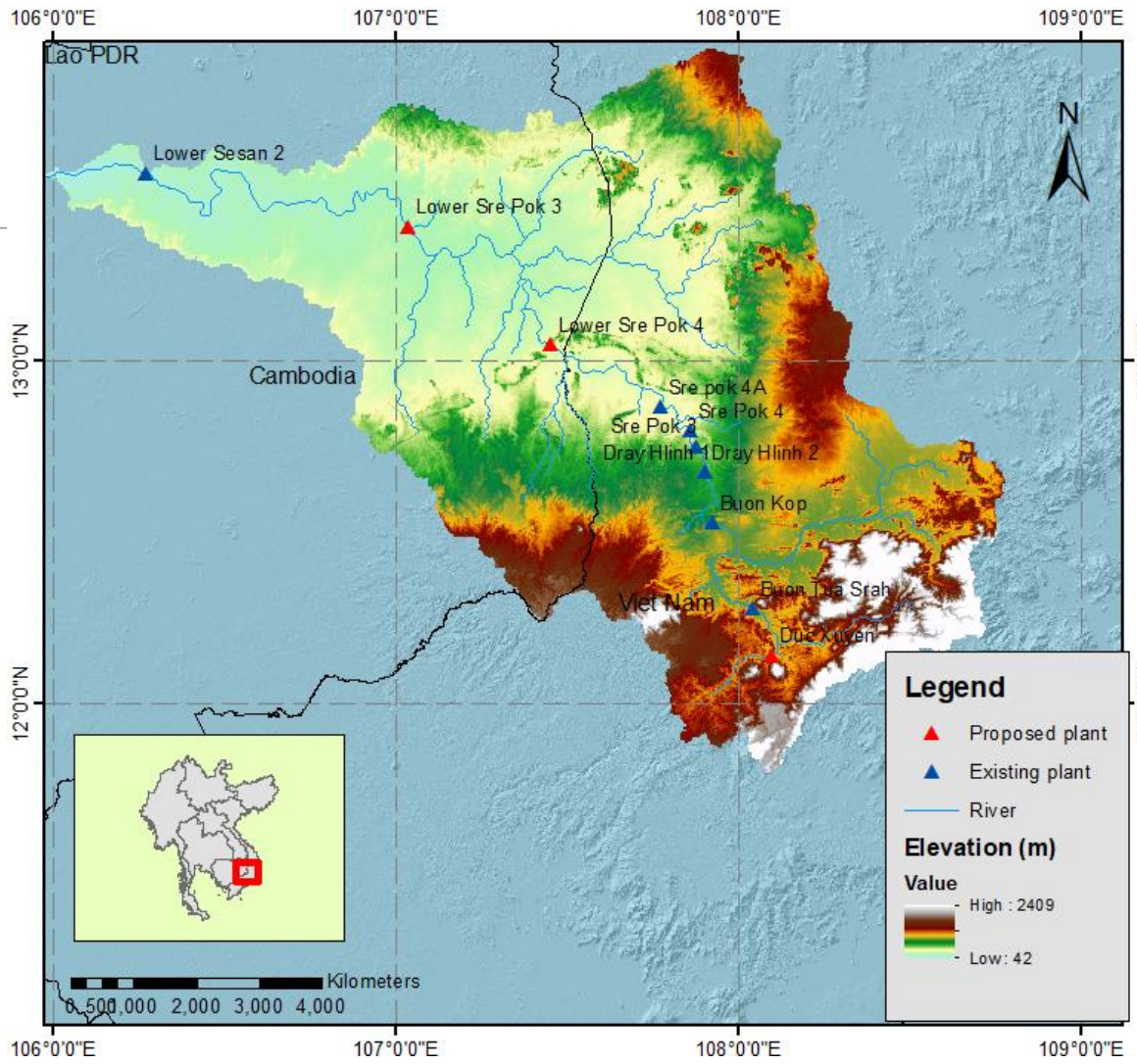
- To quantify the flow regime under the baseline scenario and future climate change scenarios for RCP 4.5 and RCP 8.5 in the Srepok River Basin
- To investigate the water demand for irrigation area (rice crop) in the downstream location of the Srepok river basin under current and future scenario.
- To analyze the hydropower production if consider water use for irrigation under baseline scenarios and to estimate the cumulative hydrological impacts of hydropower development, irrigation expansion

II. Materials and Method

Study area: Srepok river basin

Srepok River Basin covers parts of Dak Lak, Dak Nong, Gia Lai, Lam Dong provinces in Viet Nam and Mondulkiri, Ratanakiri, Stung Treng provinces in Cambodia

Variable	Cambodia	Viet Nam
Basin area (km2)	12,780	18,162
Basin length (km)	180	150
Basin width (km)	160	220
River length (km)	265	160 (Sre Pok only)
Elevation range (m)	45–1,081	140–2,409
Average elevation (m)	218	525
Major towns	Lumphat	Dak Min, Buon Ma Thuot
Population (2012)	128,074	2,139,470
Pop. density (pers./km2)	10	118
Average Pre. (mm)	1,569	1,575
Average temp. (°C)	23.2	21.2

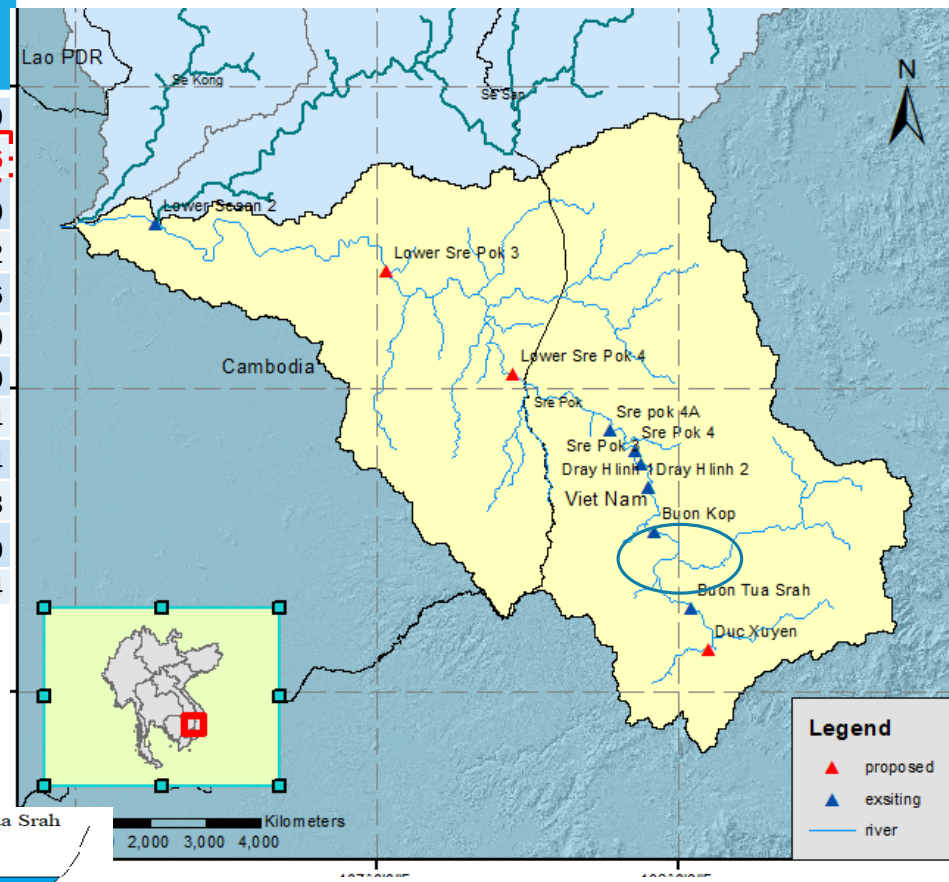


Hydropower development

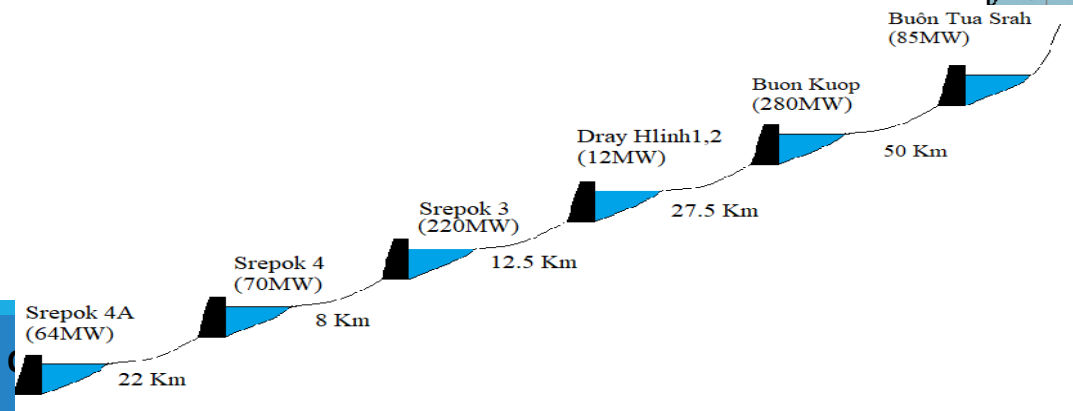
7 existing and 4 proposed plants with a total installed capacity of 1544 MW

No.	Name	Status	Live storage (mcm)	Designed discharge (m3/s)	Designed head (m)	Installed capacity (MW)
1	Duc Xuyen	PMT	413.4	81	71	49
2	Buon Tua Srah	E	**522.6**	204.9	46.5	**86**
3	Buon Kuop	E	**14.7**	316	98.5	**280**
4	Dray Hlinh 1	E	1.5	94.9	15	12
5	Dray Hlinh 2	E	1.5	101	18.5	16
6	Sre Pok 3	E	62.6	412.8	60	220
7	Sre Pok 4	E	10.1	468.9	17.1	70
8	Sre Pok 4A	E	10.1	468.9	17.1	64
9	Lower Sre Pok 3	PMT	5,310.0	775	31.5	204
10	Lower Sre Pok 4	PMT	2,700.0	327	52.2	143
11	Lower Se San2	UC	379.4	2,119.20	26.2	400
	Total					1544

E = existing; UC = under construction; PMT = proposed on main tributaries;



PROFILE OF 7 EXISTING HYDROPOWER PLANTS



Irrigation network

Downstream Buon Tua Shar plant:

Existing 700ha:

- Quang Phu : 80 hectares of rice.
- Nam Nia: 286 hectares of rice.
- Buon Choa: 281 hectares of rice.
- Ea Rbin: 53 hectares of rice

Propose:

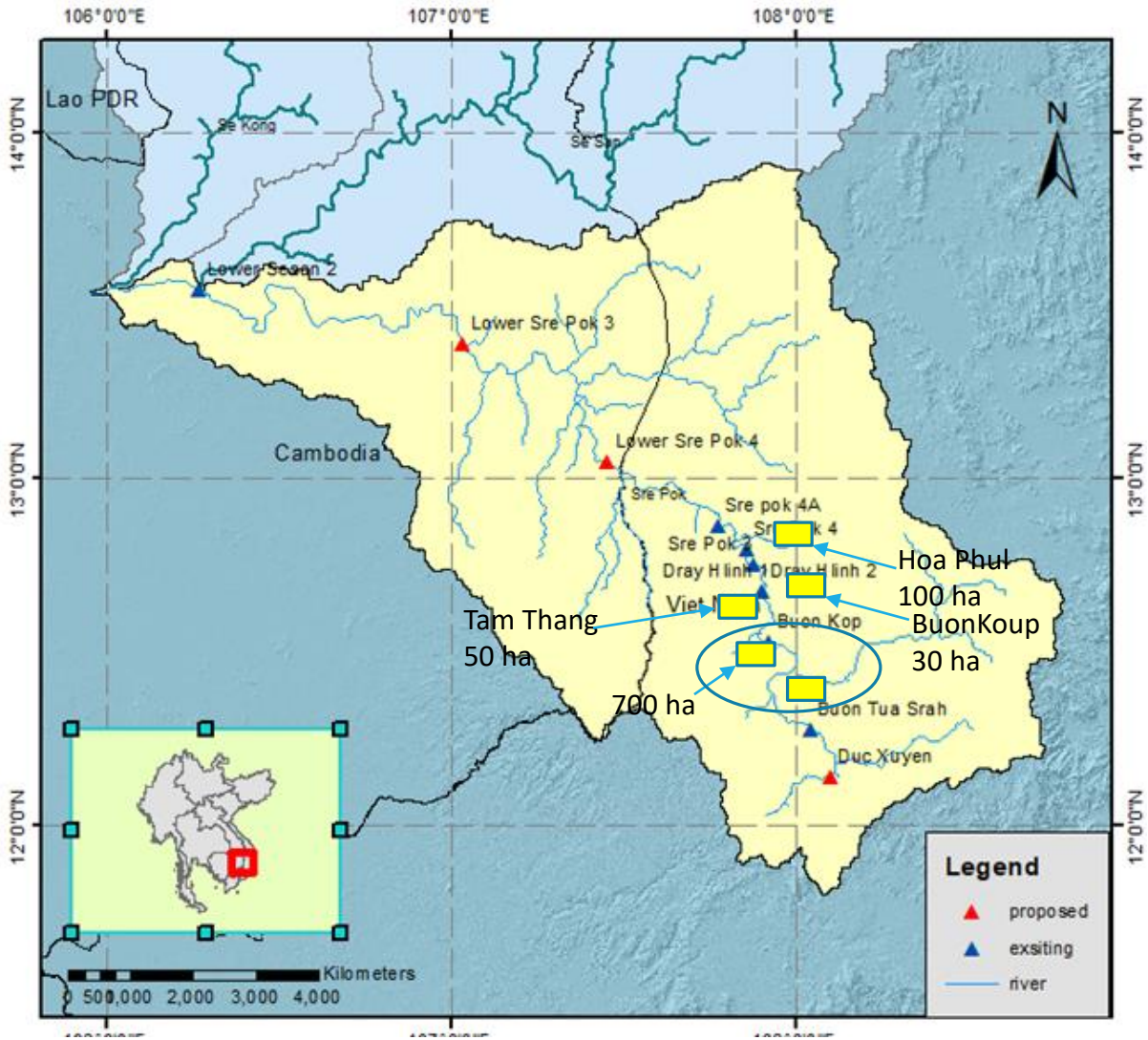
- Quang Hoa: 800 hectares of rice (under feasibility study)

Downstream Buon Koup plant:

- Buon Kuop: irrigated for 30 hectares of coffee.
- Tam Thang: irrigated for 50 hectares of coffee

Downstream Drayhlinh plant

- Hoa Phu: irrigated for 100 hectares of coffee



General layout of study area

- Buon Tuar Shar hydropower plants operate since 2011
- Existing 700ha of rice
- The livelihoods relied on a mixture of irrigated and rainfed agriculture
- Water pumping from the river for irrigation is important to ensure income for local communities
- Planning new irrigation pumping station for 800ha of rice

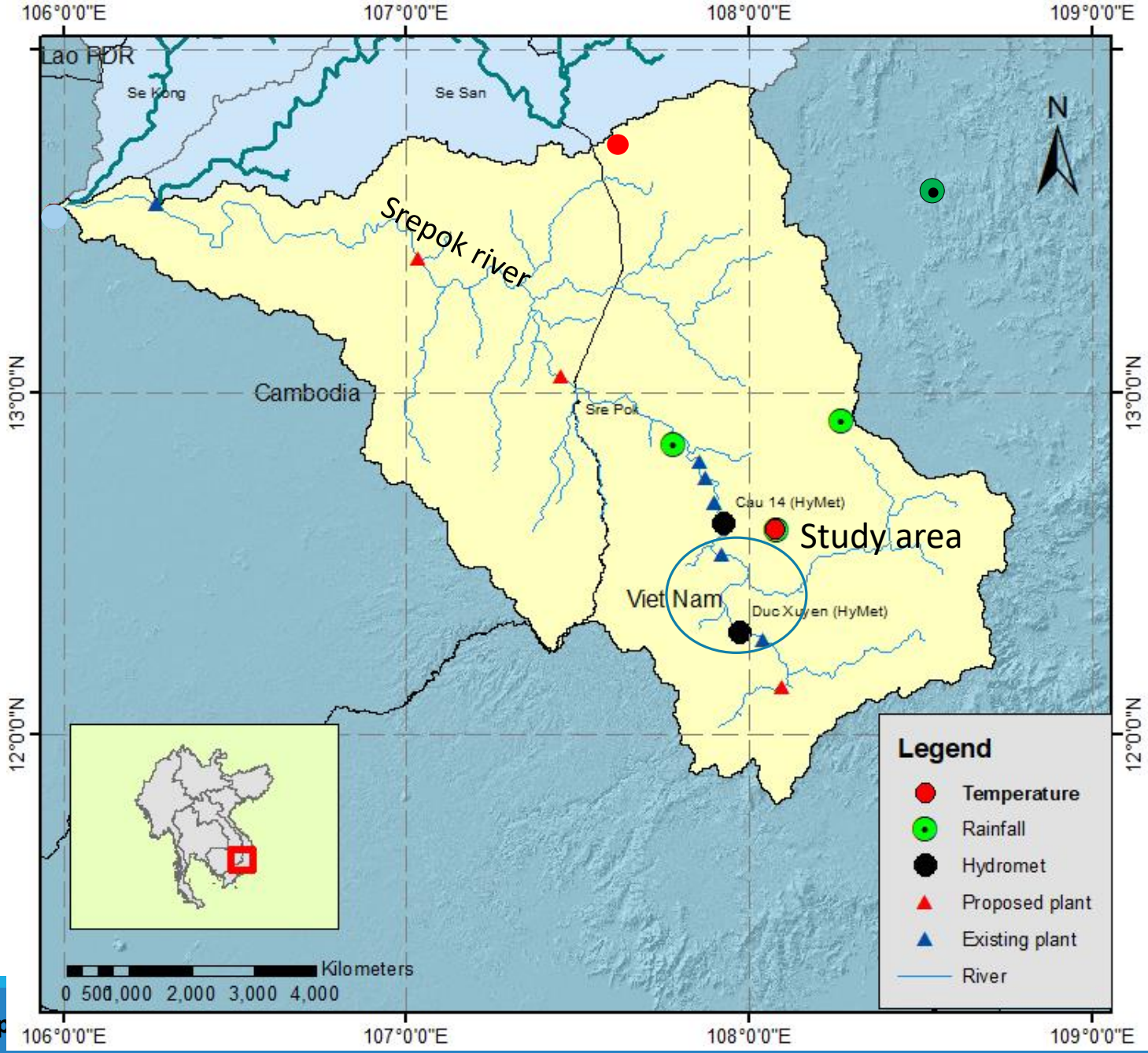
Data used

Nº	Data	Time period	Frequency	Sources
1	Climate data (Observed rainfall, temperature, relative humidity, wind speed, solar radiation)	1981-2005	Daily	National Hydro-Meteorological Service (4 rainfall stations, 2 temp.station)
2	Hydrological data (discharge)	1990-2005	Daily	National Hydro-Meteorological Service (2 station: Ducxuyen and Bandon)
3	RCM data (5 RCMs) (25kmX25km)	1981-2005 2005-2099	Daily	https://esgf-node.llnl.gov/search/esgf-llnl/
4	Topographic (DEM 30mx30m)	-	-	United States Geological Survey (USGS)
5	River network	-	-	http://Ref.data.fao.org/map?entryId=dc2a5121-0b32-482b-bd9b-64f7a414fa0d
6	Hydropower plants location	-	-	https://opendevelopmentmekong.net
7	Dam Characteristic (Dam height and length, Maximum, minimum, Normal water level, Reservoir capacity, dead storage)	-	-	Daklak DARD, Daknong DARD
8	Spillway Characteristic(Crest level, Discharge)	-	-	Daklak DARD, Daknong DARD
9	Hydropower information (guide curve, installed power generation capacity)			Daklak DARD, Daknong DARD
10	Soil type (1kmx1km)	2000	-	Mekong River Commission
11	Land use/cover (1kmx1km)	2000	-	Mekong River Commission
12	Irrigation data (current and future expansion)	2015, 2020	-	Daklak DARD, Daknong DARD
13	Crop calendar (rice crop)	2015	monthly	Daklak DARD, Daknong DARD

RCMs used

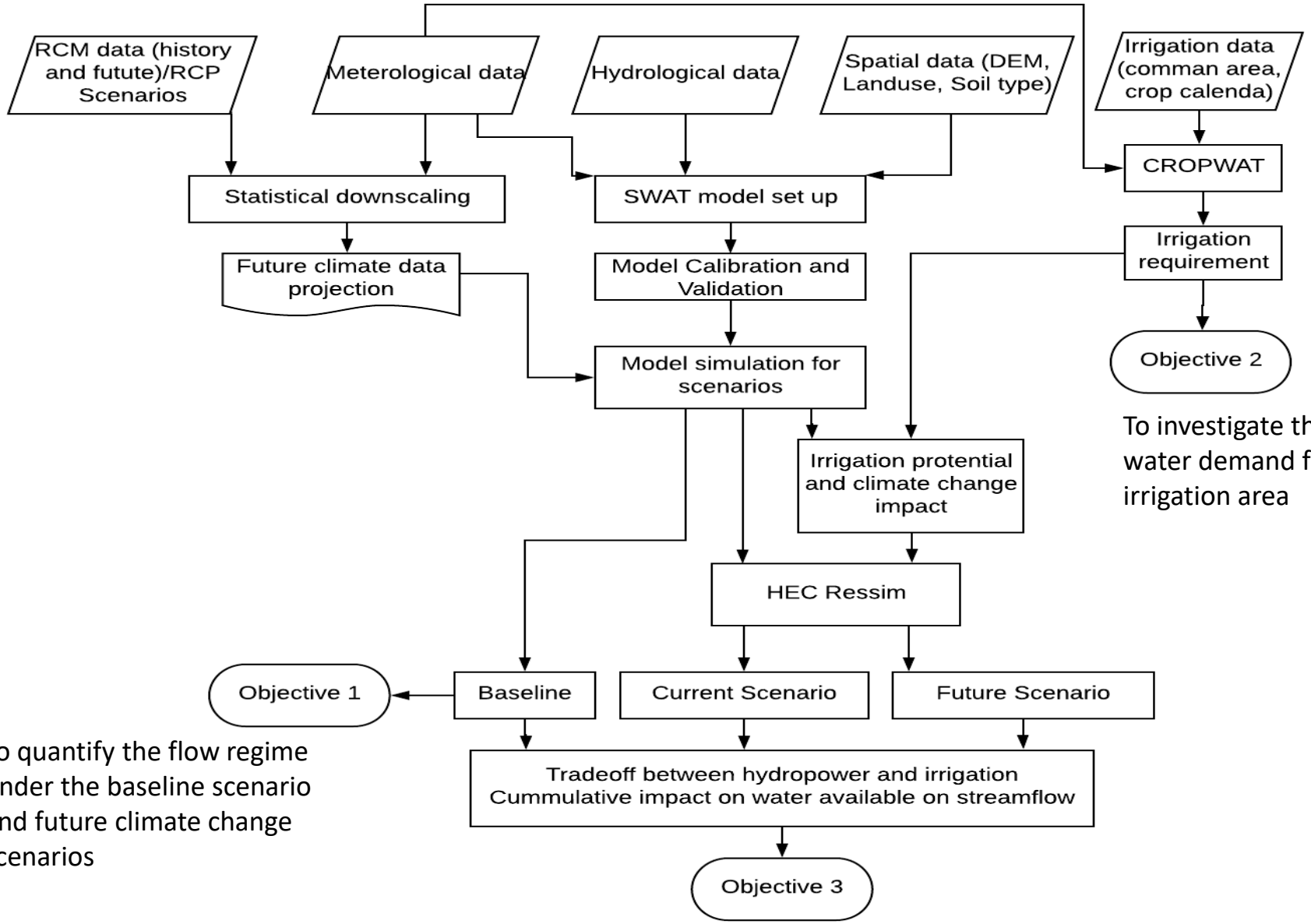
Feature	RCM "Project: CORDEX"				
	ACCESS	MPI	NorESM	CNRM	REMO2009
Research Institute	Commonwealth Scientific and Industrial Research Organisation, Australia	Commonwealth Scientific and Industrial Research Organisation, Australia	Commonwealth Scientific and Industrial Research Organisation, Australia	Commonwealth Scientific and Industrial Research Organisation, Australia	Helmholtz-Zentrum Geesthacht, Climate Service Center Germany
Resolution	25kmx25km	25kmx25km	25kmx25km	25kmx25km	25kmx25km
Driving model	CSIRO-BOM-ACCESS1-CCAM	MPI-CCAM	NorESM1-M-CCAM	CNRM-CM5-CSIRO-CCAM	MPI-M-MPI-ESM-ECHAM5
Output variables	Temperature, precipitation, etc.	Temperature, precipitation, etc.	Temperature, precipitation, etc.	Temperature, precipitation, etc.	Temperature, precipitation, etc.
Scenario	Historical RCP 4.5 RCP 8.5	Historical RCP 4.5 RCP 8.5	Historical RCP 4.5 RCP 8.5	Historical RCP 4.5 RCP 8.5	Historical RCP 4.5 RCP 8.5
Dat set coverage year	Historical: 1971-2007 RCP 4.5: 2006-2099 RCP 8.5: 2006-2099	Historical: 1971-2007 RCP 4.5: 2006-2099 RCP 8.5: 2006-2099	Historical: 1971-2007 RCP 4.5: 2006-2099 RCP 8.5: 2006-2099	Historical: 1971-2007 RCP 4.5: 2006-2099 RCP 8.5: 2006-2099	Historical: 1971-2007 RCP 4.5: 2006-2099 RCP 8.5: 2006-2099
Source	https://esgf-index1.ceda.ac.uk/search/esgf-ceda/				

Stations used to collect data



III. Overall framework

Overall framework



To investigate the water demand for irrigation area

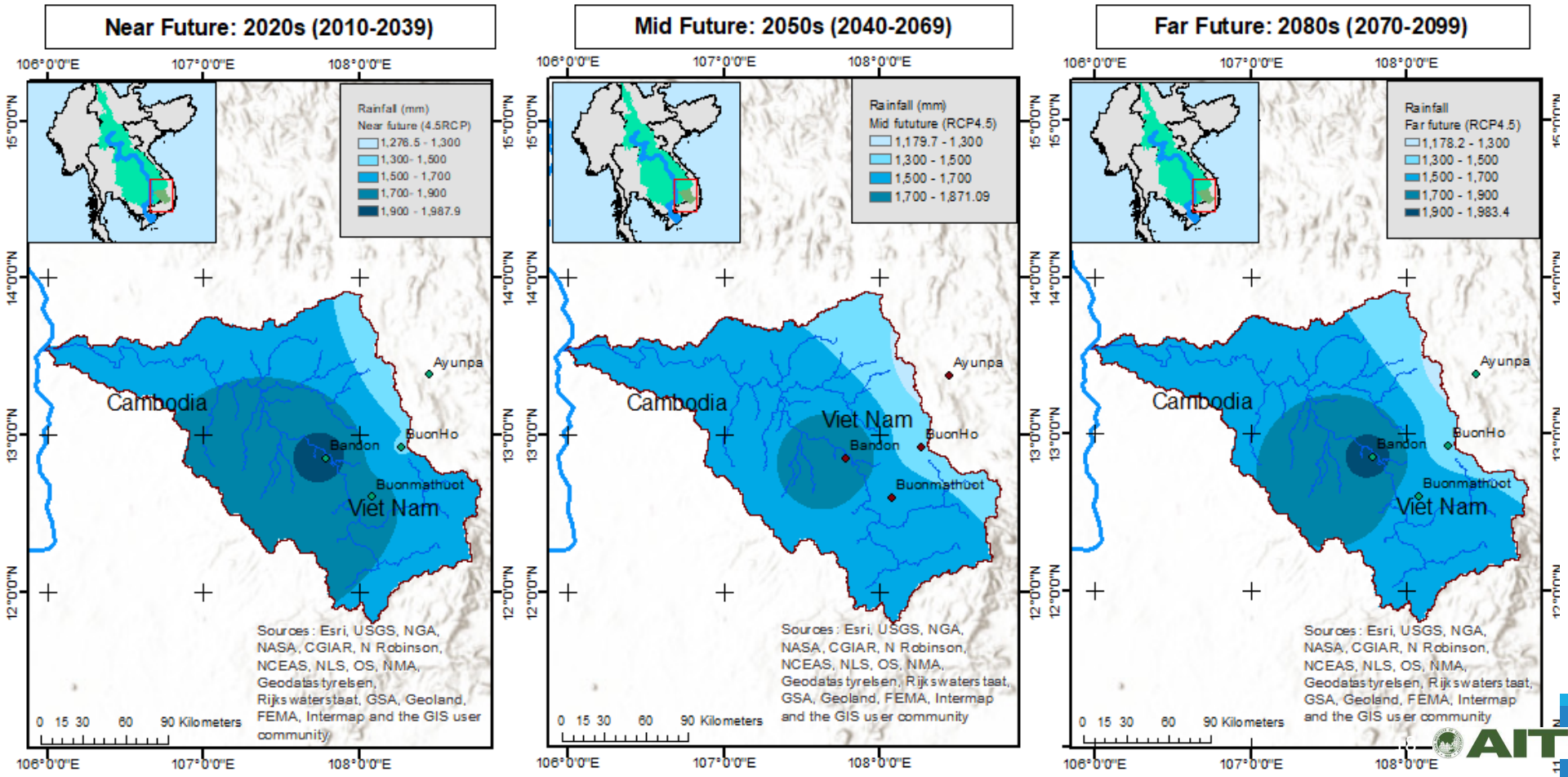
To quantify the flow regime under the baseline scenario and future climate change scenarios

IV. Result and discussion

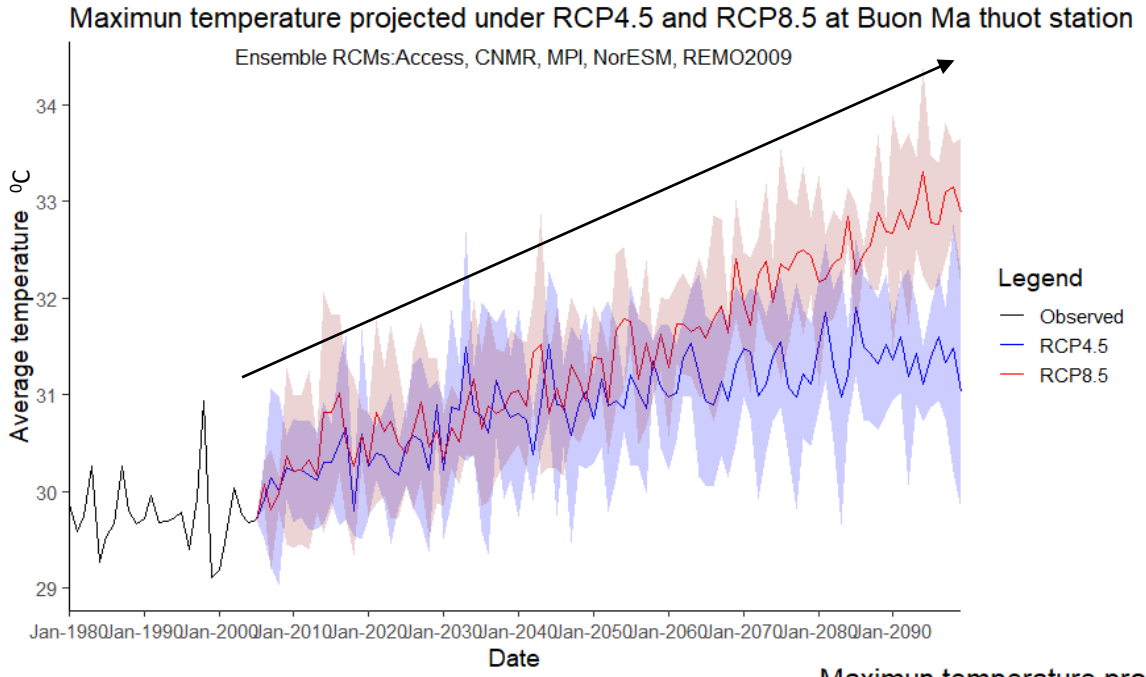
Future spatial distribution for rainfall under RCP4.5

The average annual rainfall in the central of Srepok river basin (middle part of the rivers) is higher than the other part of the basin

Period	Baseline	Near future	Mid future	Far future
Min	1337	1276	1197	1172
Max	2073	1967	1871	1983

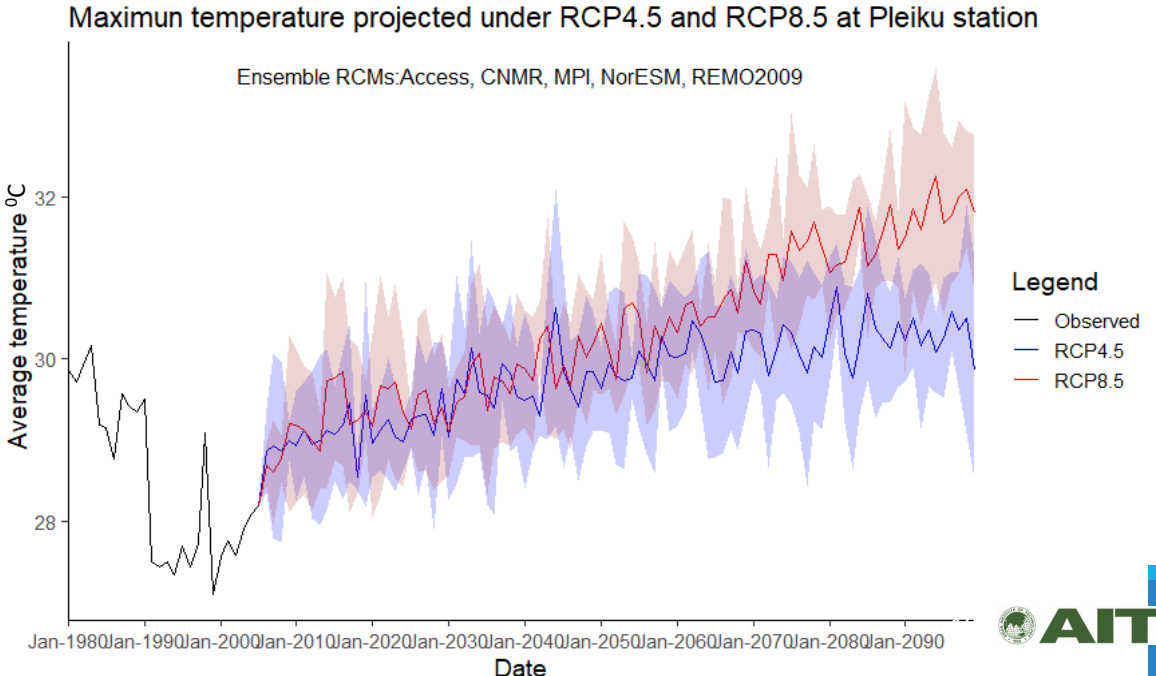


Future temperature projection for 2 stations



- ✓An increasing trend in temperature.
- ✓RCP 8.5 scenario increases in temperature more significant than the RCP 4.5 scenario.

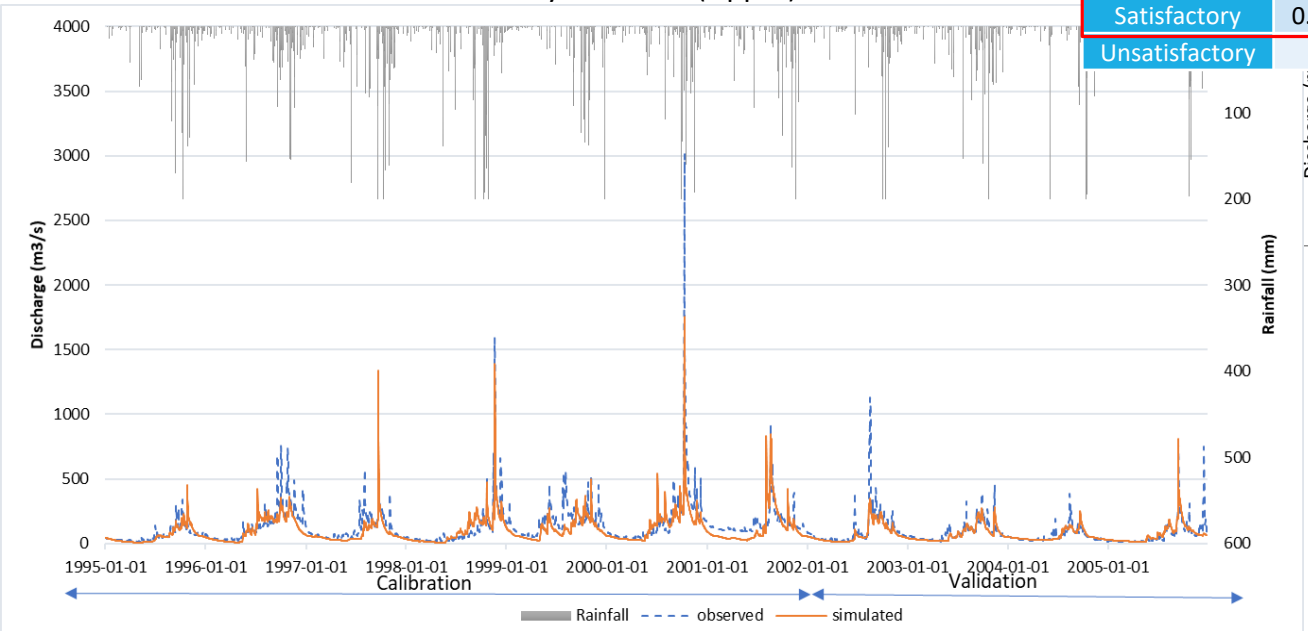
- ✓ Rising by nearly 2^0C in Buotmathuot station and 4^0C in Pleiku station under RCP 8.5.

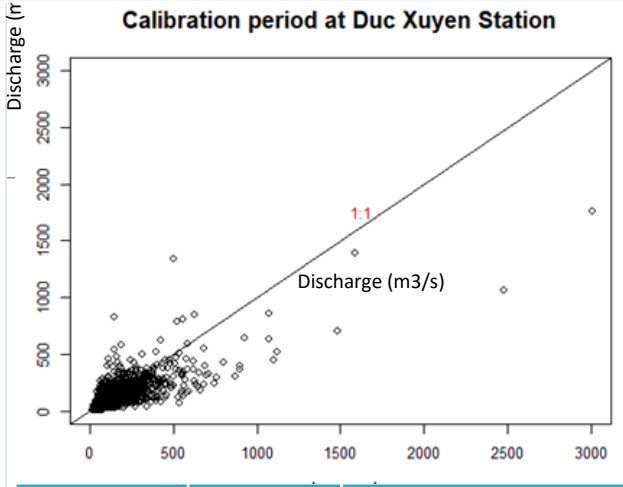


Hydrological model (SWAT)

Performance	R^2	NSE	PBIAS (%)
Very good	$R^2 > 0.85$	$0.75 < NSE \leq 1.00$	$PBIAS \leq \pm 1.00$
Good	$0.75 < R^2 \leq 0.85$	$0.65 < NSE \leq 0.75$	$\pm 10 \leq PBIAS < \pm 15$
Satisfactory	$0.60 < R^2 \leq 0.75$	$0.50 \leq NSE \leq 0.65$	$\pm 15 \leq PBIAS < \pm 25$
Unsatisfactory	$R^2 \leq 0.60$	$NSE < 0.50$	$PBIAS \geq \pm 2$

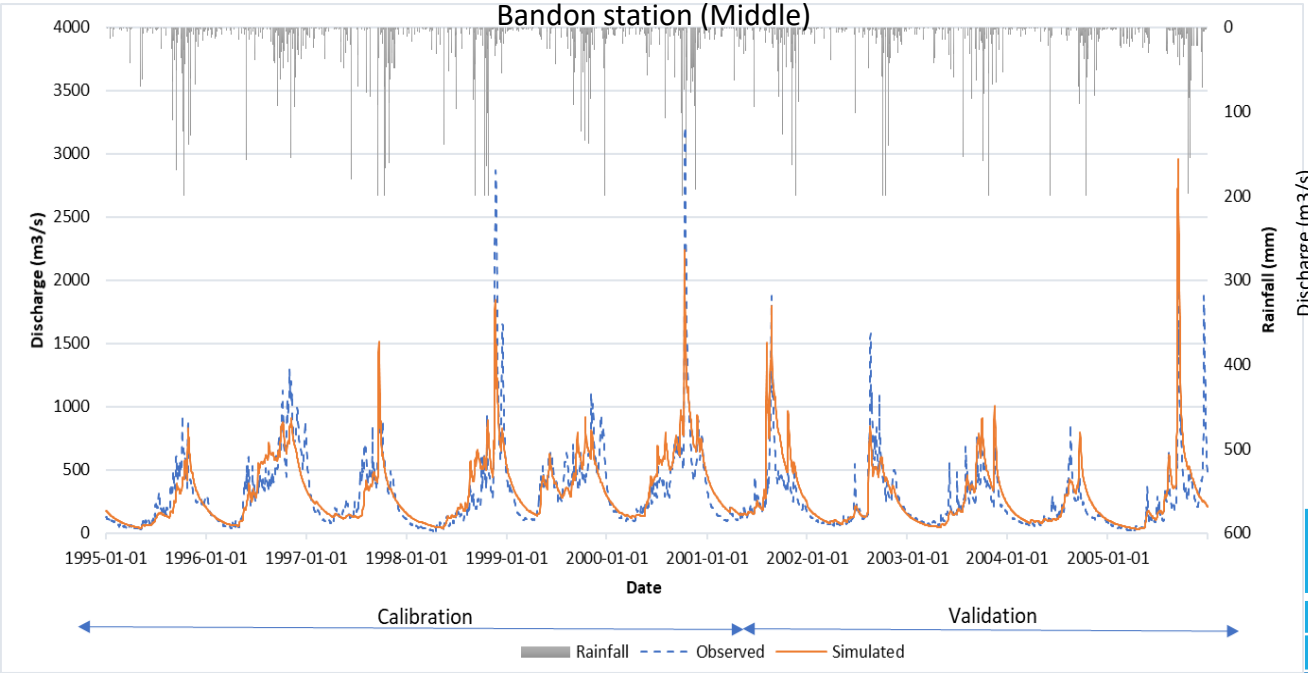
Duc Xuyen station (Upper)

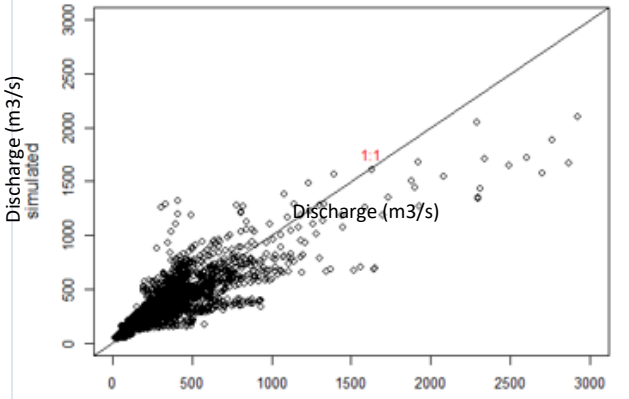




Period	Time	Duc Xuyen		
		R2	NSE	PBIAS
Calibration	1995-2001	0.63	0.58	23.3
Validation	2002-2005	0.60	0.58	-3.7

Bandon station (Middle)

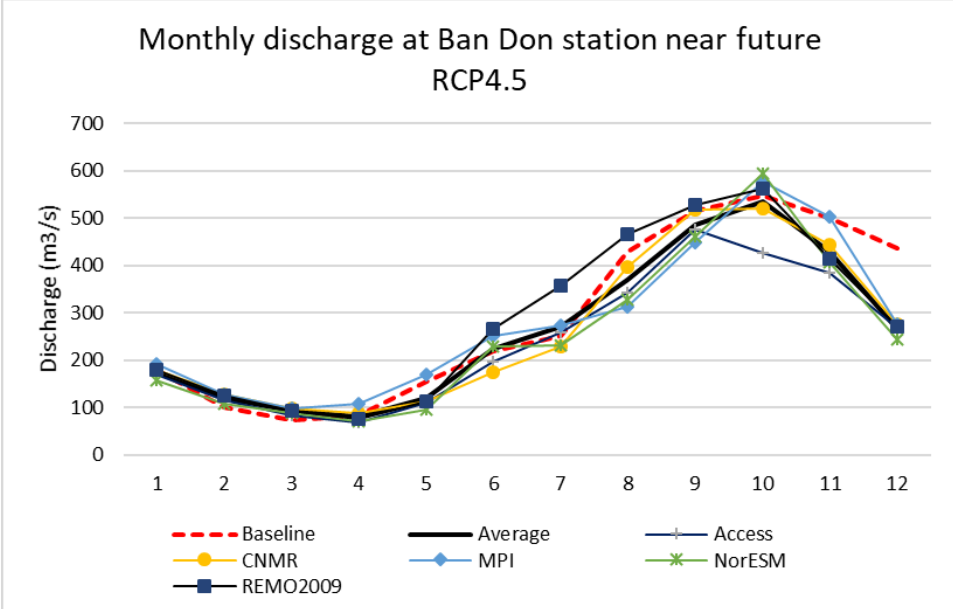


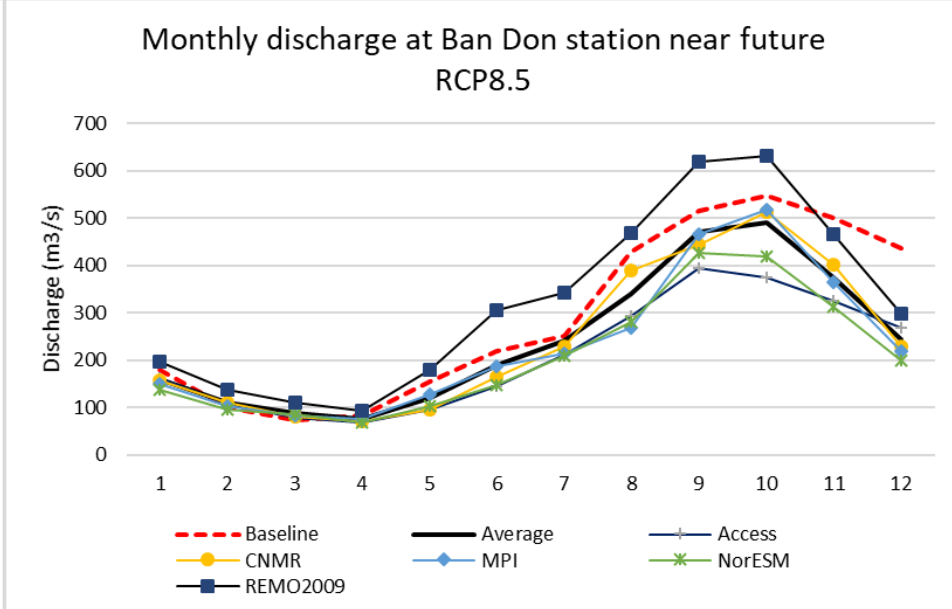


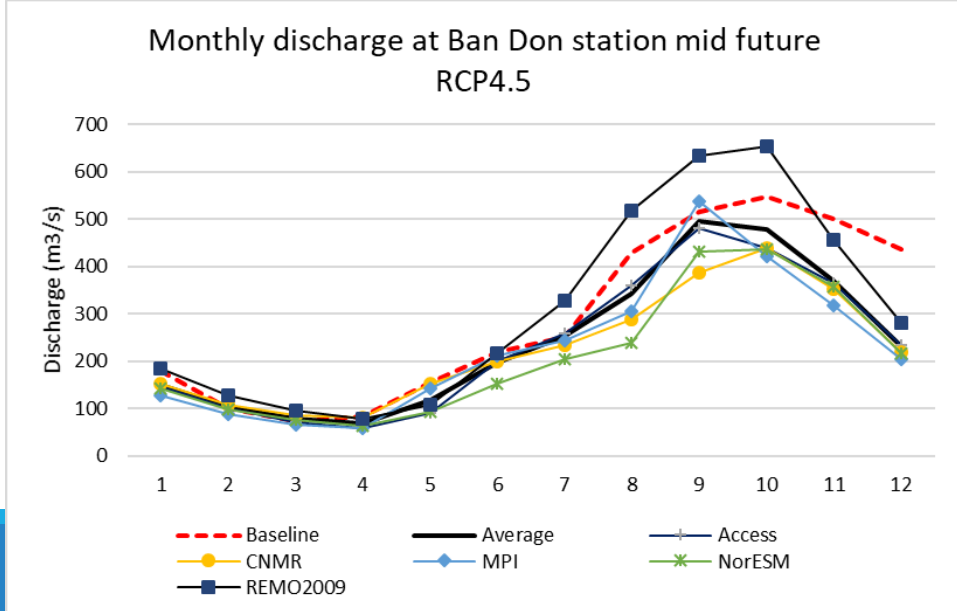
Period	Time	Ban Don		
		R2	NSE	PBIAS
Calibration	1995-2001	0.72	0.72	-4
Validation	2002-2005	0.62	0.56	-13.4

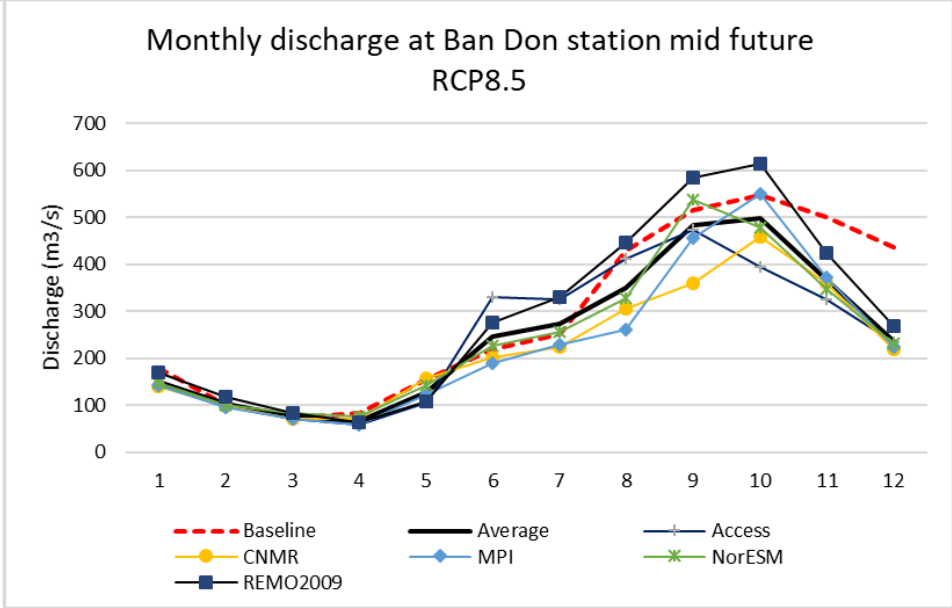
Future monthly discharge at Ban Don (middle station)

- Ensemble average RCMs shows the decreasing in monthly discharge during wet season
- Uncertain in RCMs, Remo2009 is the highest projection



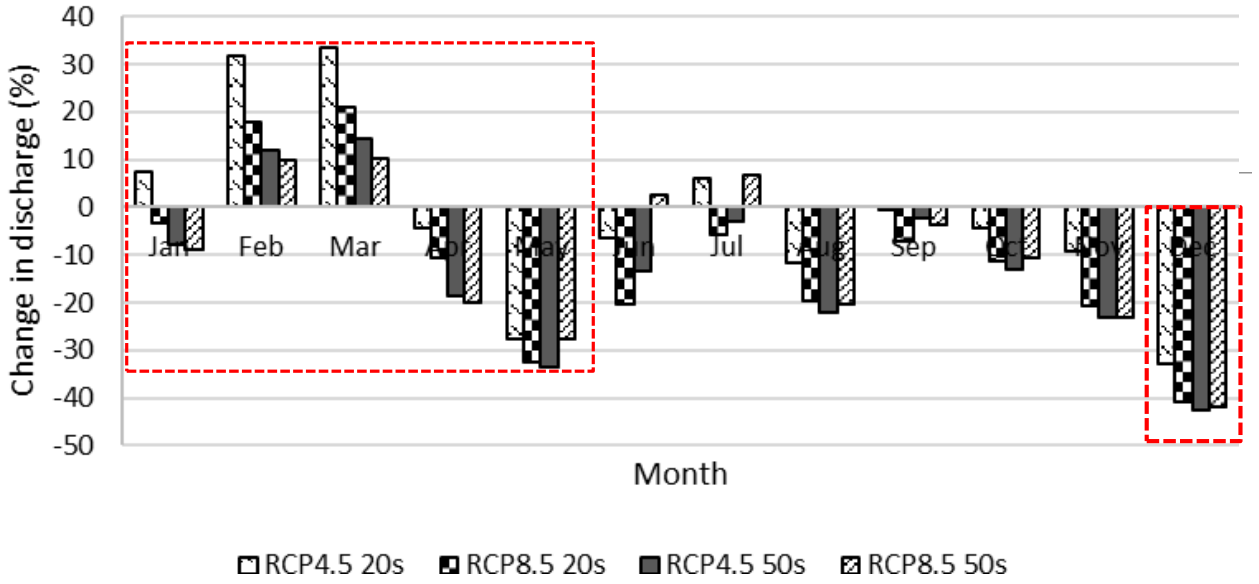




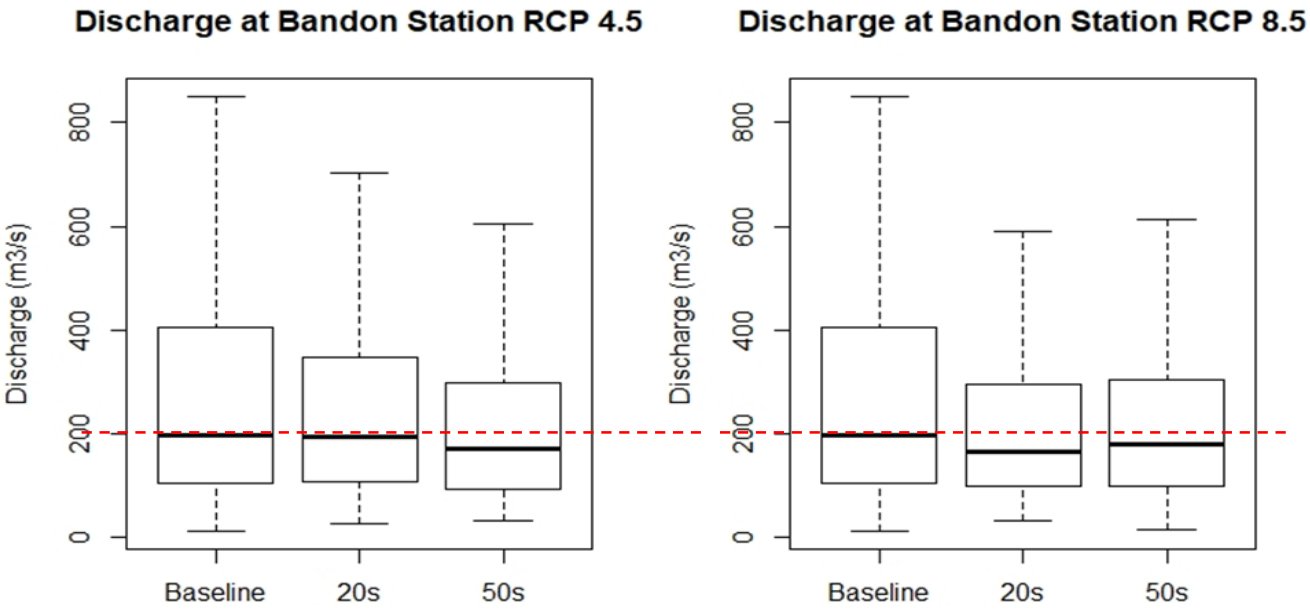


Climate change impact on river discharge at Ban Don station

Relative change in monthly discharge at Ban Don station



- Decrease up to 40% in the month of December under RCP 8.5
- There is a slight increase in the dry season streamflow from Feb to Mar
- Median value of streamflow discharge future lower than baseline.
- The range of daily streamflow discharge is narrower than the historical reference.

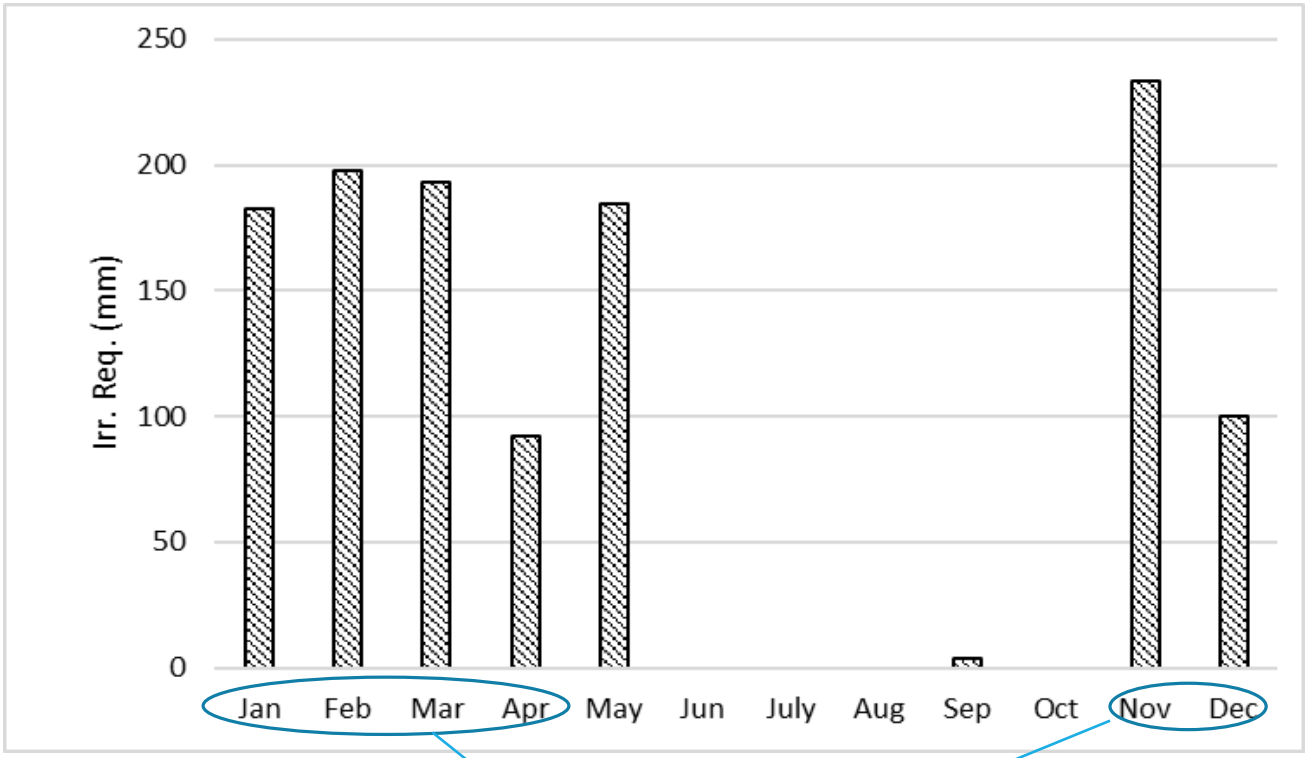


Water requirement for rice crop by Cropwat

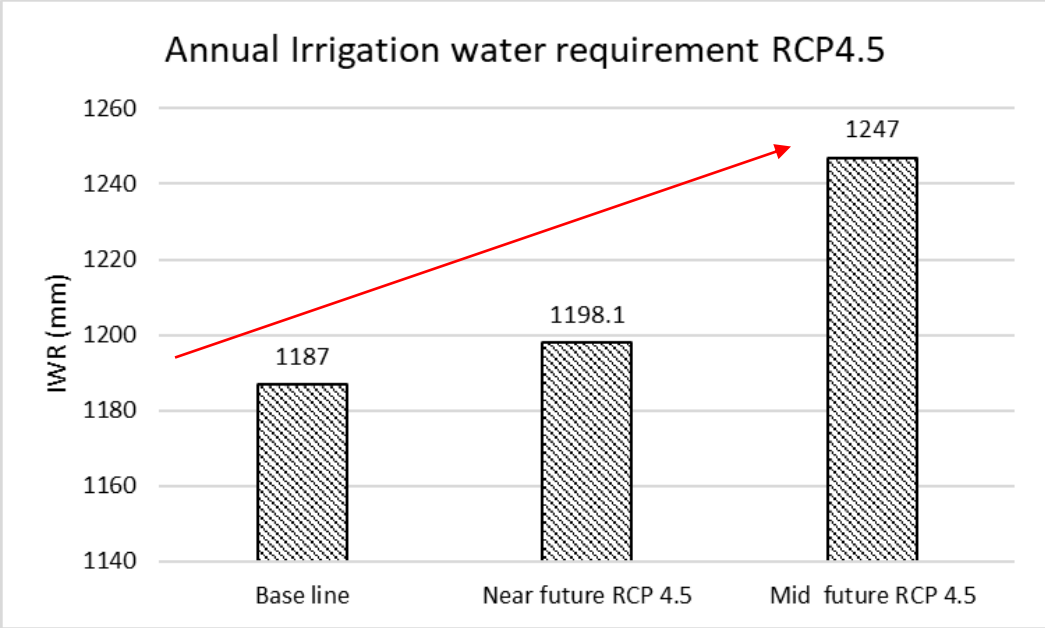
- ✓ **Baseline:** The annual water requirement for irrigation in the Upper Srepok River Basin averaged 1187 mm of which 270 mm were for wet season irrigation.

Study	Scenario	Wet season rice (mm)	Dry season rice (mm)
Thesis	Baseline	270	917
Feasible study of ADB's project at Buonmathuot	Baseline	270.2	928
Räsänen et.al (2013) at Sesan river	Baseline	218	1248

Monthly Water requirement for rice crop (baseline)

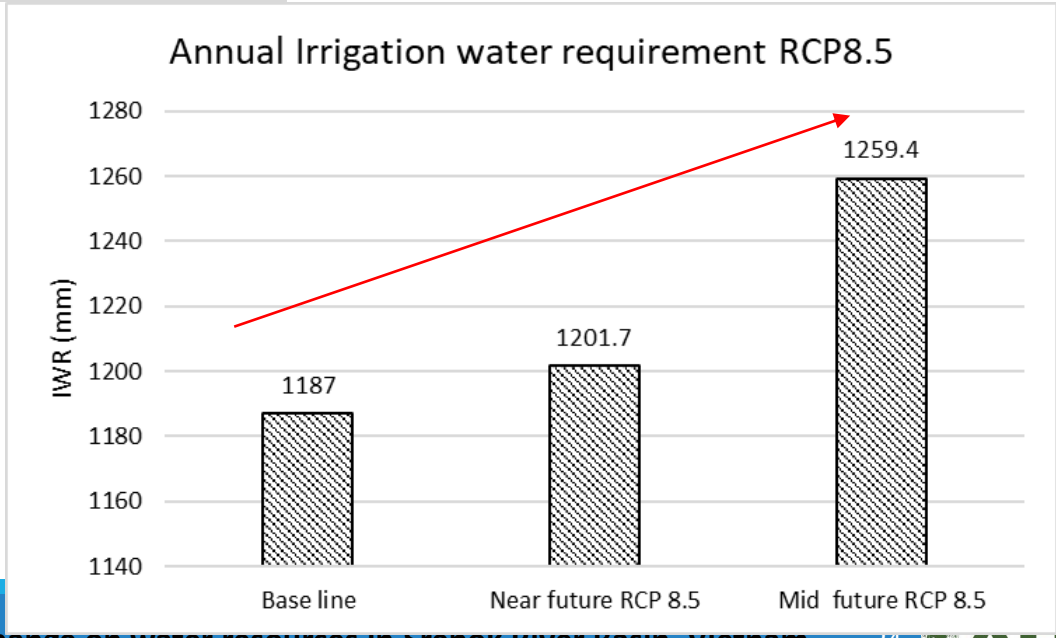


Climate change impact on irrigation water requirement



- The annual irrigation water requirement increases in the near and mid future.
- The scenario of RCP 4.5 results in lower value than the scenario of RCP 8.5.

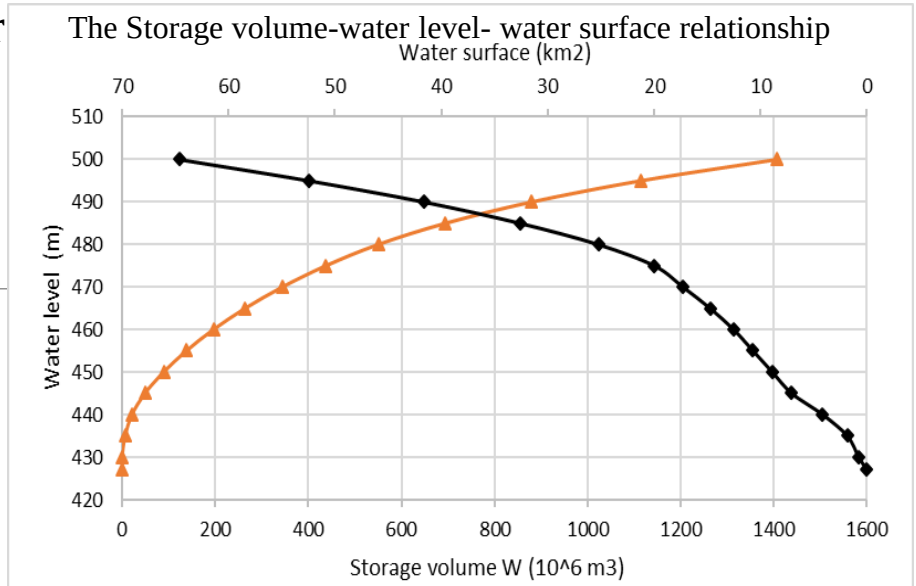
- The most increase is mid future under RCP 4.5 and RCP 8.5 Scenario.

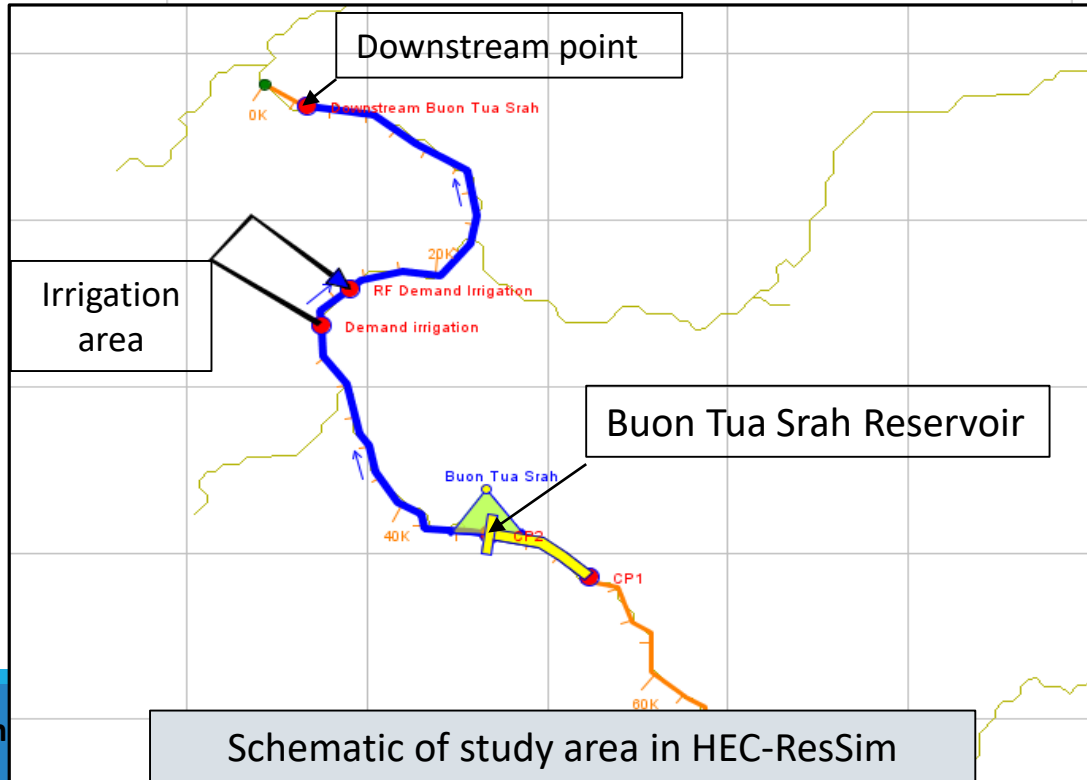


Reservoir operation used HEC-RESSIM

Physical Characteristic of Buon Tua Shar Reservoir

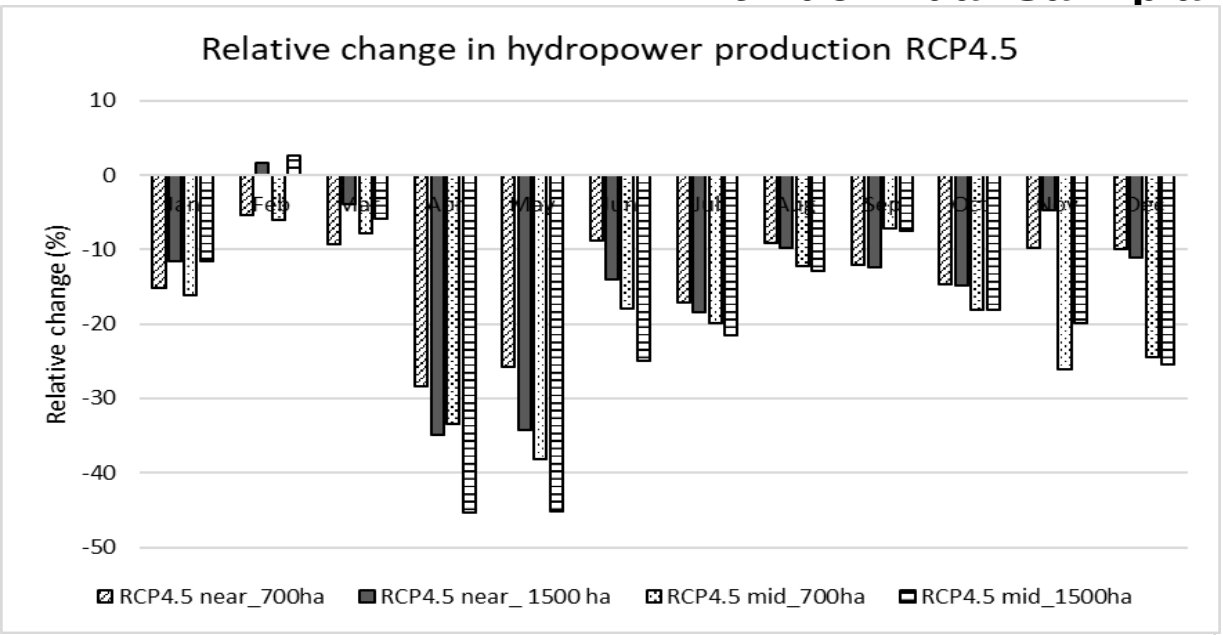
General Characteristics		
Catchment area	2930	km2
River length from its origin to headworks	380	km
Maximum water level	487.82	m MSL
Normal water level	487.5	m MSL
Minimum water level	465	m MSL
Reservoir capacity at maximum level	786.9	CM
Reservoir capacity at normal level	522.6	m MSL
Reservoir capacity at minimum level	264.3	m MSL
Dam		
Type	Earth Type Dam	
Crest level	492,3	m MSL
Dam height	83	m
Dam length	1041.14	m
Spillway (controlled, 3 gates)		
Crest level	473.5	
Discharge capacity at normal level	4124	
Discharge capacity at maximum level	4216	
Plant		
Designed Discharge (Q)	204.9	m^3/s
Designed water level (H)	46.5	m
Installed capacity (N_{lm})	86	MW
Number of operators	2	

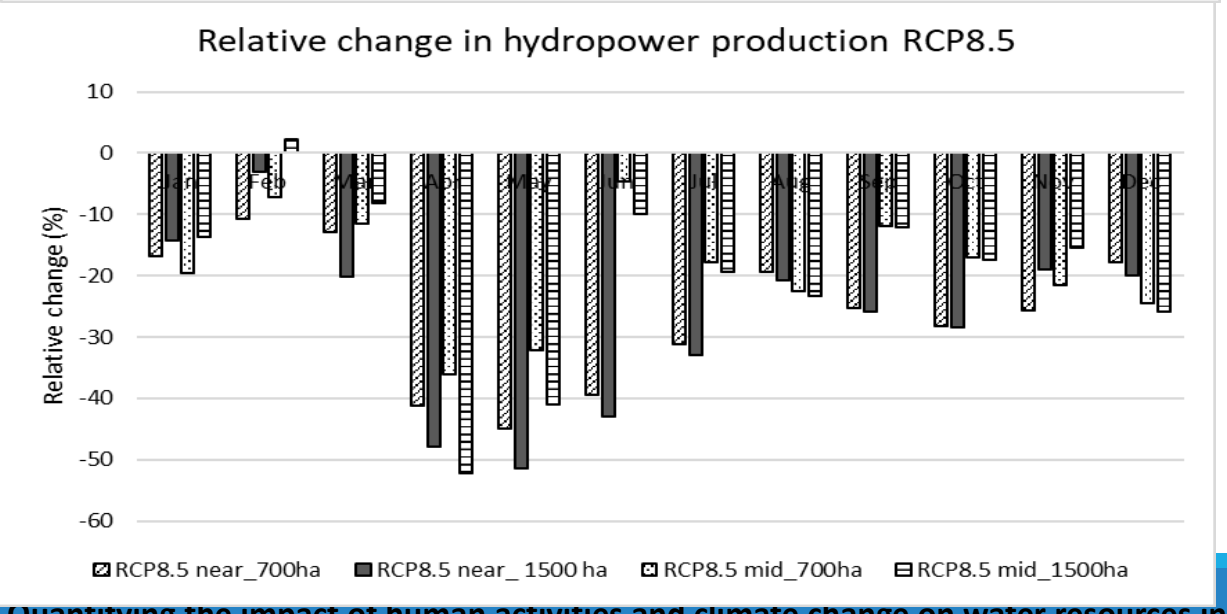




Schematic of study area in HEC-ResSim

Climate change and Irrigation area increase impact to hydropower production At Buon Tuar Sarh plant

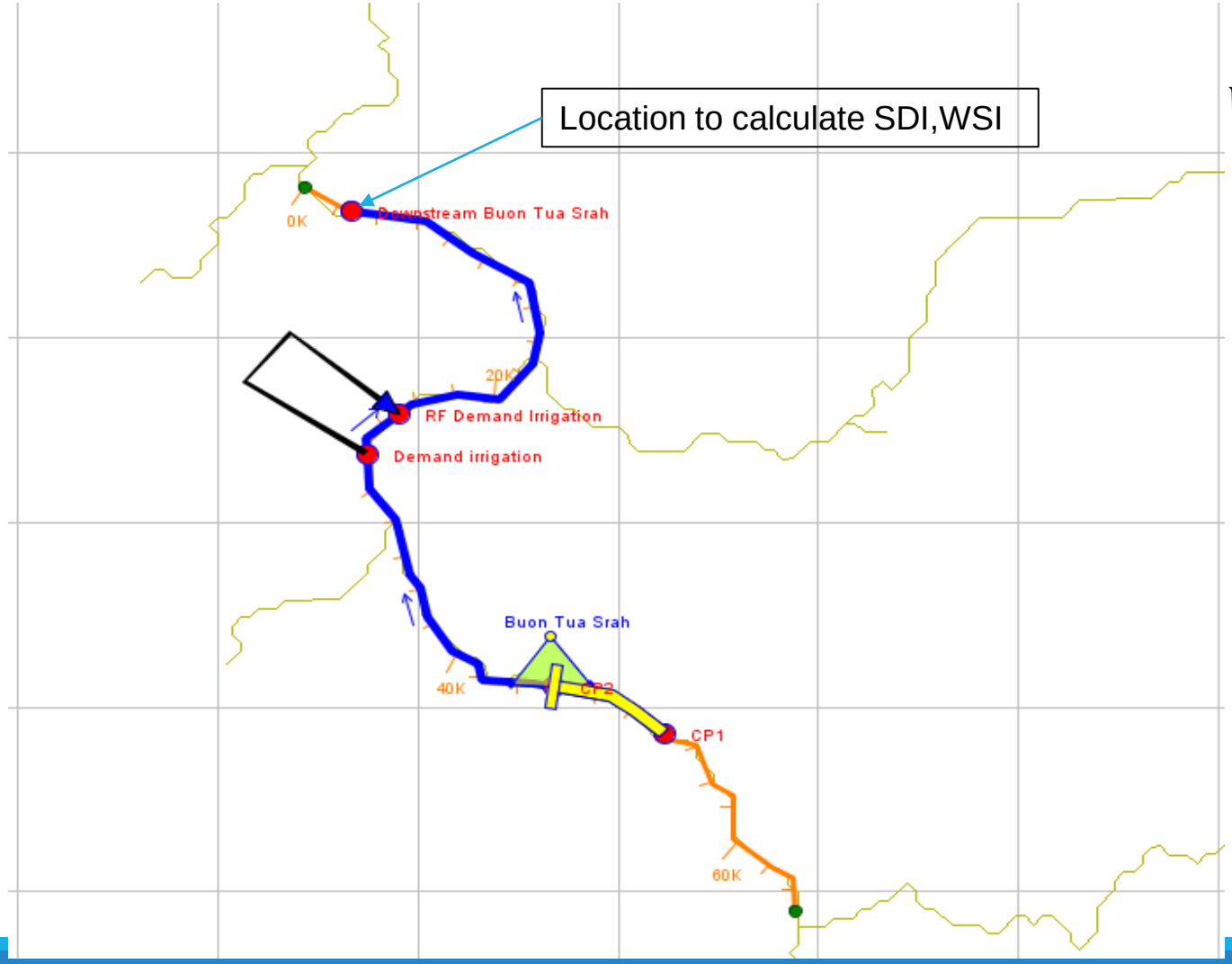




- The hydropower production decreased under future scenarios.
- Increasing irrigated area → hydropower production decrease slightly
- The hydroelectricity generation change under RCP 8.5 significant decrease than RCP 4.5.

Human activities and climate change impact on water available

- Access drought at downstream using Streamflow drought index (SDI). DrinC (Drought Indices Calculator) software was used to estimate the SDI
- Investigate water stress level using water stress indicator (WSI)



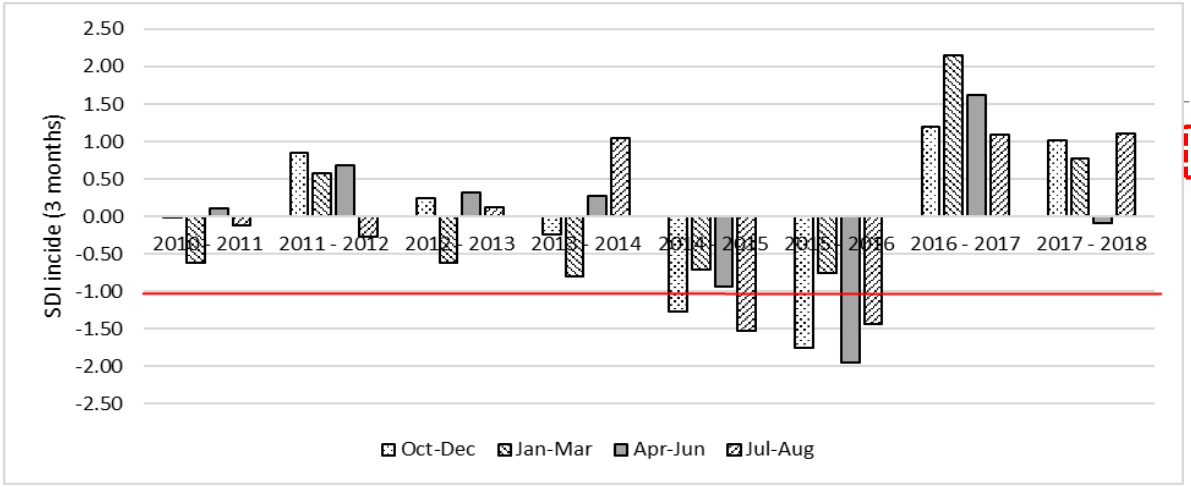
$$WSI = \frac{Withdrawals}{MAR - EWR}$$

MAR mean annual runoff
EWR Environmental water requirement

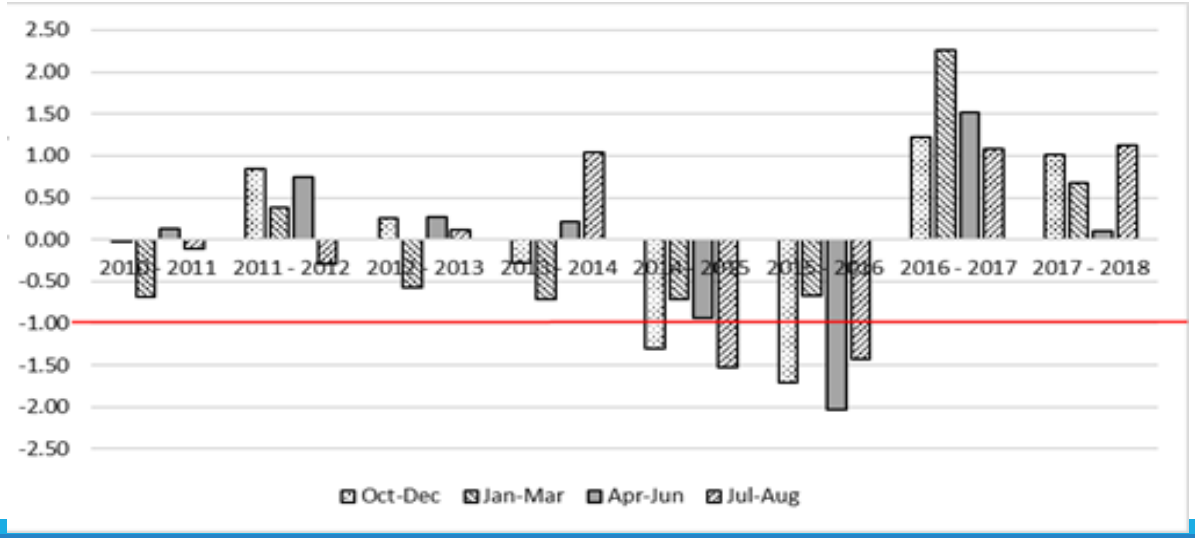
Access drought at downstream using Streamflow drought index (SDI)

Baseline period (2011-2018)

SDI indices for 700ha of irrigated area



SDI indices for 1500ha of irrigated area

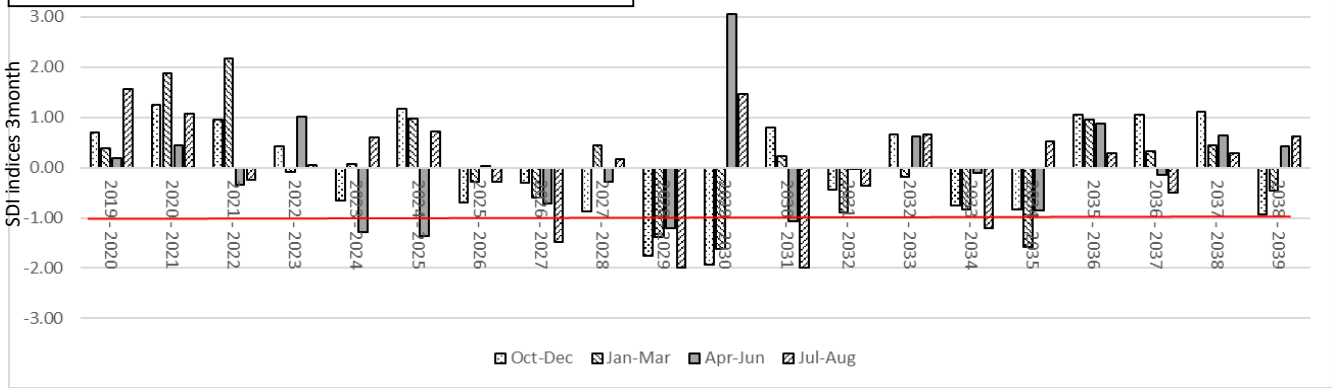


State	Description	values
0	Non-Drought	SDI≥0.0
1	Mild drought	-1.0≥SDI<0.0
2	Moderate drought	-1.5≥SDI<-1.0
3	Severe drought	-2.0≥SDI<-1.5
4	Extreme drought	SDI<-2.0

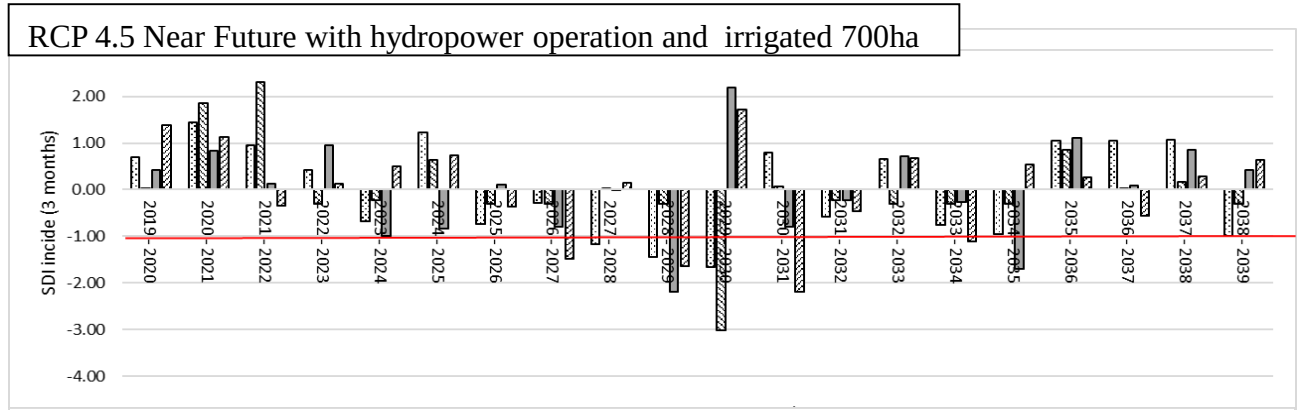
- Current irrigation demand: no extreme drought. A severe drought in two years of 2014-2015 and 2015-2016.
- If increasing irrigation to 1500ha, the basin occurred extreme drought during the period of 2015-2016.

Access drought at downstream for future period

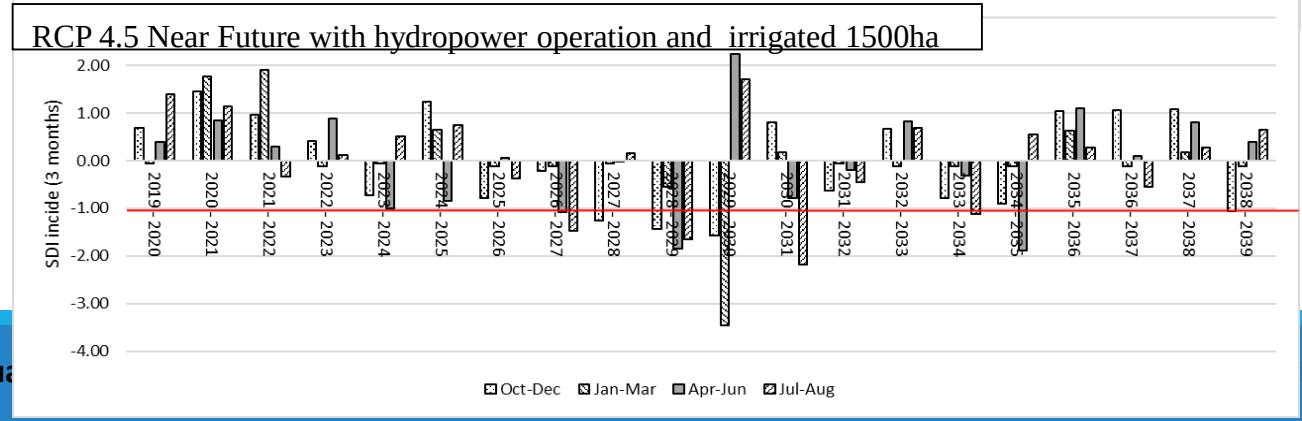
RCP 4.5 Near Future with natural flow



RCP 4.5 Near Future with hydropower operation and irrigated 700ha



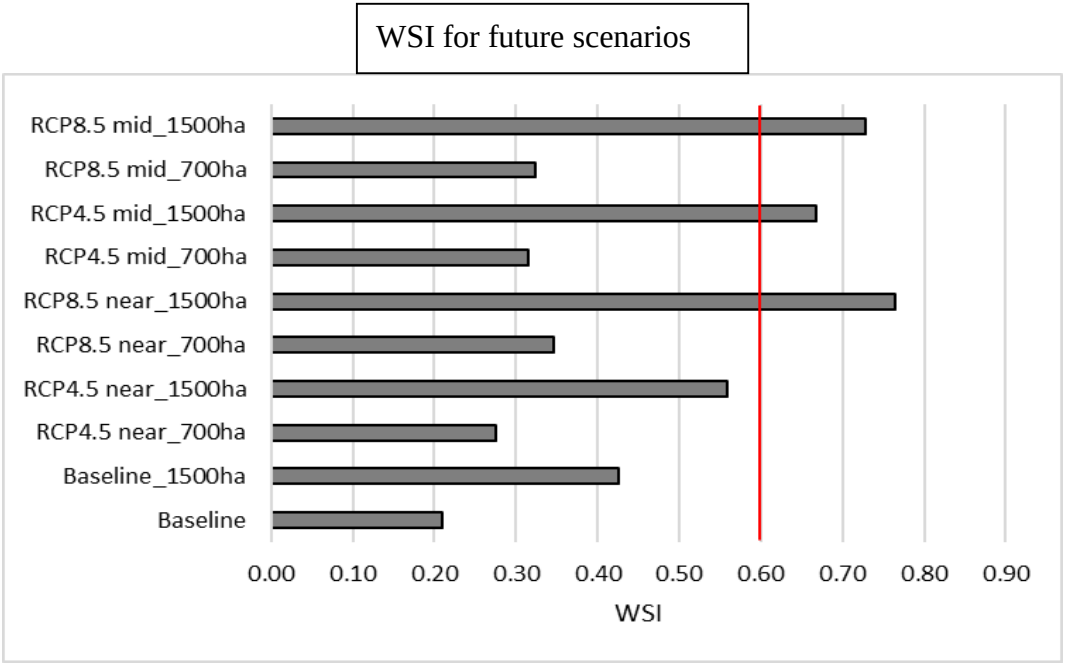
RCP 4.5 Near Future with hydropower operation and irrigated 1500ha



- Under natural flow, severe drought in 8 years.
- Under hydropower operation and irrigation development (700 ha and 1500 ha), facing with drought in 6 years and 7 year but extreme drought

→The increasing of irrigation water demand, increase the extreme drought.

Access the water stress level at downstream using WSI



WSI	Stress Level
WSI > 1	Overexploited
0.6 ≤ WSI < 1	Heavily Exploited
0.3 ≤ WSI < 0.6	Moderately Exploited
WSI < 0.3	Slightly Exploited

- Projected to be heavily exploitation under RCP 8.5 scenario if increase irrigated area.
- No heavily stress when irrigated for 700ha

→The increasing of irrigated area is the main reason in terms of increasing water stress level.

WSI (water stress indicator) under baseline, RCP 4.5 and RCP 8.5 scenarios

Scenario	WSI	Stress level
Baseline_700ha	0.21	Slightly exploitation
Baseline_1500ha	0.43	Moderately exploitation
RCP4.5 near_700ha	0.27	Slightly exploitation
RCP4.5 near_1500ha	0.56	Moderately exploitation
RCP8.5 near_700ha	0.35	Moderately exploitation
RCP8.5 near_1500ha	0.76	**Heavily exploitation**
RCP4.5 mid_700ha	0.32	Moderately exploitation
RCP4.5 mid_1500ha	0.67	**Heavily exploitation**
RCP8.5 mid_700ha	0.32	Moderately exploitation
RCP8.5 mid_1500ha	0.73	**Heavily exploitation**

V. Conclusion and Recommendation

Conclusion

1. The future temperature projected to increase for both near, mid and far future period.

2. The future rainfall will decrease for both near, mid and far future period.

3. The monthly changes in discharge projected to decline at Duc Xuyen station. At Ban Don station, an increase in discharge during the dry season and decrease during the rainy season.

4. Future irrigation water requirement projected to increase in both near future and mid future.

5. If increasing water demand for irrigation to 1500ha, hydroelectricity generation will slightly decrease under baseline period.

6. Change in climate conditions in the future result in the reduction of hydropower production for both the near and mid future.

7. Under future climate and an increase in water demand for irrigation results that there will be slightly reduced in hydroelectricity generation.

8. Human activities impact to water availability: The result of SDI has showed that hydropower and water demand for irrigation cause the drought becomes more serious under both scenarios.

The WSI values also show the same result. Increase water demand may be the main reason of increasing the water stress level.

Recommendation

I. Recommendation for the basin:

- Water budget allocation should be developed under the climate change impact.
- Change rice crop to others high value crop use less amount of water such as coffee, maize, pepper.
- Change irrigation practice by water used efficiency irrigation system (drip irrigation system). Upgrade irrigation system to reduce water loss such as using pipeline instead of channel.
- Develop the water pricing for irrigation to Operation & Maintenance the irrigation system.
- Management of energy demand base on the changes in energy supply due to climate change

II. Recommendation for next study:

- The future climate model causes lots of uncertainties. The ensemble of RCMs based on weighting method should consider for the next study.
- Land-use change also affects the results. Therefore, next study should include the impact of land-use change.
- In the future study, the existing and planned hydropower dams are should be considered in the reservoir simulation model.
- The study only focused on SWAT model. Therefore, in the next study should use another hydrological model to compare the result.

THANK YOU FOR YOUR ATTENTION