Impacts of climate change on groundwater recharge and agricultural water resources: A case study in Taiwan

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Introduction

Impact of Climate Change on Water Resources

- Climate change is causing more extreme weather events, making it harder to manage global water resources effectively.
- Taiwan faces water management challenges due to its steep terrain and seasonal monsoons. Although it gets about 2,500 millimeters of rain each year, the water quickly runs off because of the landscape, leaving limited storage.
- Climate change makes this problem worse, as future droughts and extreme weather are expected to further disrupt water supply and stability.

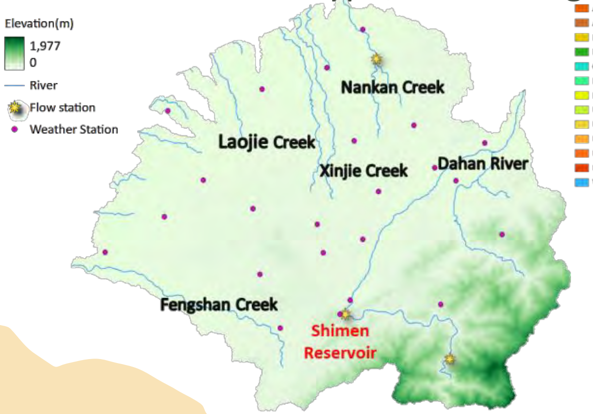
Review Application and Study of Numerical Models

- Gao et al. (2019) used the SWAT-MODFLOW model to estimate surface water resources in the agricultural basin of the Grand Sunflower River in the U.S. They also applied this model in central Alberta to explore how climate change and development influence the interaction between groundwater and surface water.
- Pisinaras et al. (2021) applied the SWAT model to study how agricultural water management affects aquifers along the Mediterranean coast. The study found that the interactions between aquifers and rivers change based on the location and season.

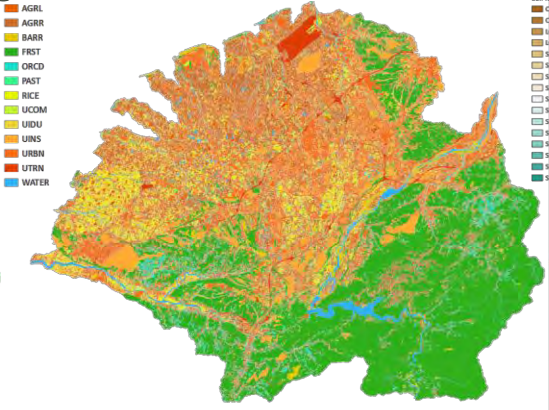
Materials & Method

Steady Area

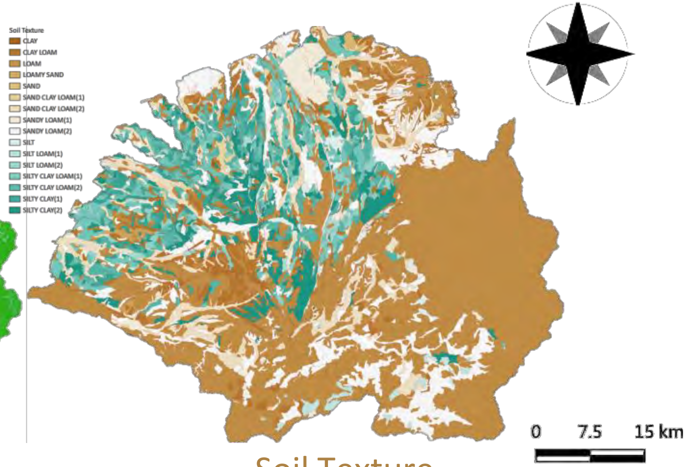
- In northwest Taiwan, the study area has terrain that rises toward the southeast, with the Dahan River supplying water for both agriculture and domestic .
- The region has an average yearly temperature of 23°C. July and August are the hottest months, while January and February are the coldest. Rainfall is higher in the summer and lower in the winter, with an annual average of 1,500 to 2,000 mm, typical of a subtropical monsoon climate.
- The area is mainly covered by forest land (37.45%) and row crops (16.36%), with loam being the dominant soil type, accounting for 46.49% of the area.



Study Area



Land Use/Cover



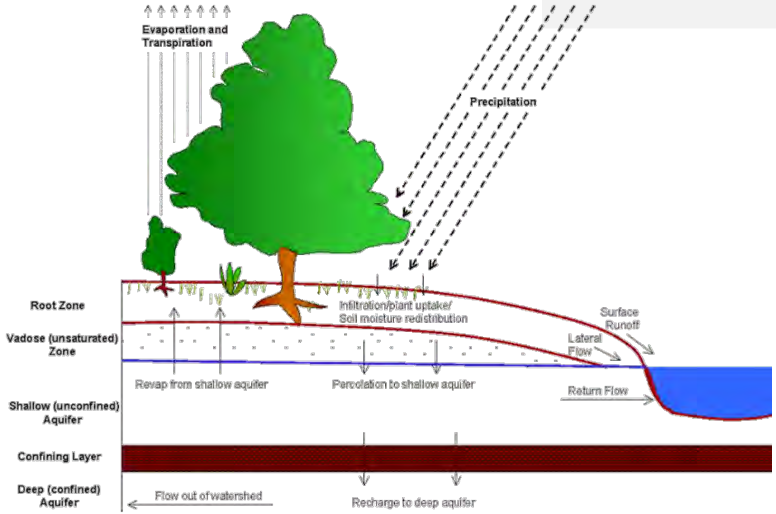
Soil Texture

Materials & Method

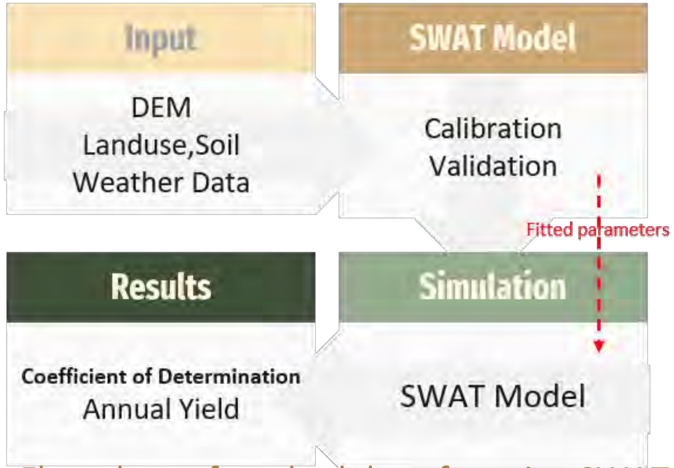
Soil and Water Assessment Tool (SWAT) Model

- The SWAT model is a semi-distributed physical model created by the United States Department of Agriculture (USDA) to assess soil and water resources.
- The model uses the water balance equation to analyze and predict hydrological changes within a watershed.

$$SW_t = SW_0 + \sum (R_{day} - Q_{surf} - ET_a - W_{seep} - Q_{gw})$$



Schematic representation of the hydrologic cycle



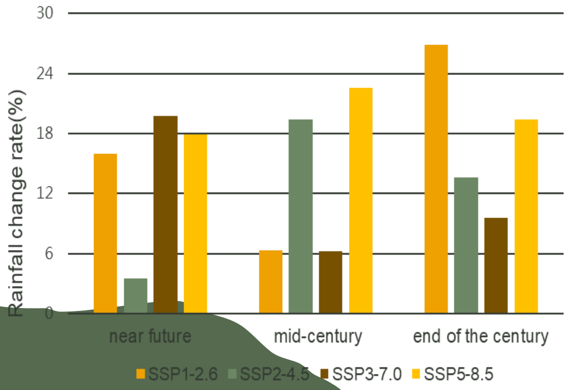
Flow chart of methodology for using SWAT

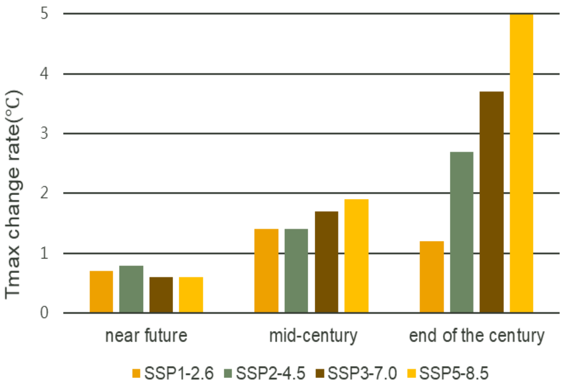
Source: swat user manual(2009)

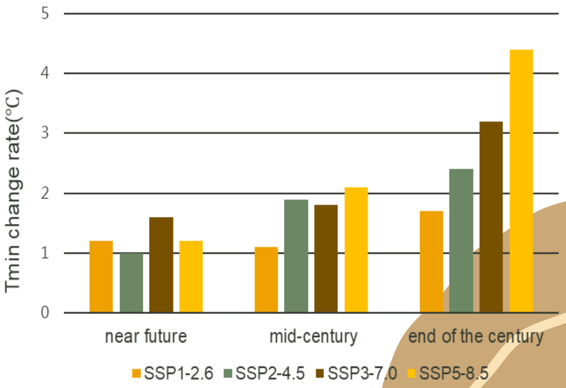
Materials & Method

Global Climate Model

- This study uses the TaiESM1 climate model to account for Taiwan's distinct environmental conditions.
- Projections indicate a rise in total annual rainfall for the study area. Under the fossil fuel-driven scenario (SSP5-8.5), annual rainfall is projected to increase by around 23% by the end of the century, while in the sustainable development scenario (SSP1-2.6), rainfall could increase by about 27%.
- In the fossil fuel-driven scenario (SSP5-8.5), the average annual temperature is expected to rise by more than 3.4°C by the end of the century.







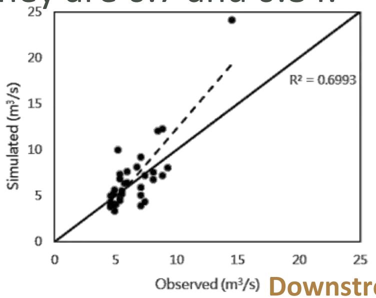
Results & Discussion

Calibration & Validation

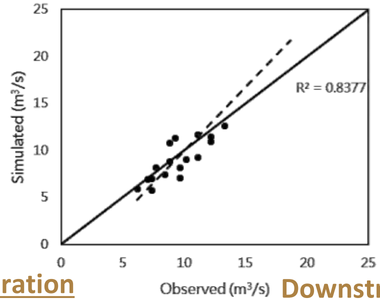
- The SWAT-CUP SUFI2 method was used to select 11 hydrological parameters that influence the watershed for calibration and sensitivity analysis.
- The R^2 values for calibration and validation at the upstream station are 0.65 and 0.54, respectively, while at the downstream flow station, they are 0.7 and 0.84.

Parameters	Method	Min	Max	Fitted
CN2	Relative	0.2	0.5	0.201
SOL_AWC		0	0.4	0.072
OV_N		-0.3	0.1	0.049
GW_REVAP	Replace	0.06	0.12	0.088
GWQMN		1	2600	2082.8
REVAPM		90	450	268.92
GW_DELAY		300	500	398.6
ALPHA_BF		0.88	0.2	0.743
CH_K2		0	180	57.42
CH_K1		20	140	136.76
RCHRG_DP		0.6	1	0.97
CH_N2		0	0.05	0.019

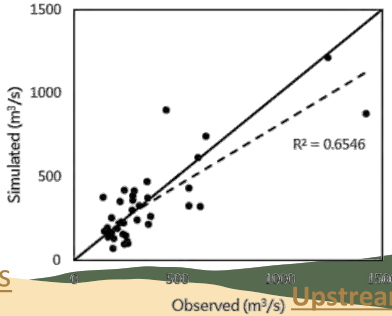
Calibration of hydrological parameters and fitted values



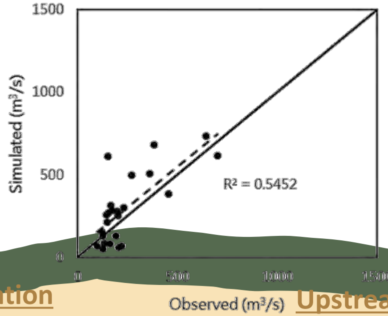
Downstream calibration



Downstream validation



Upstream calibration

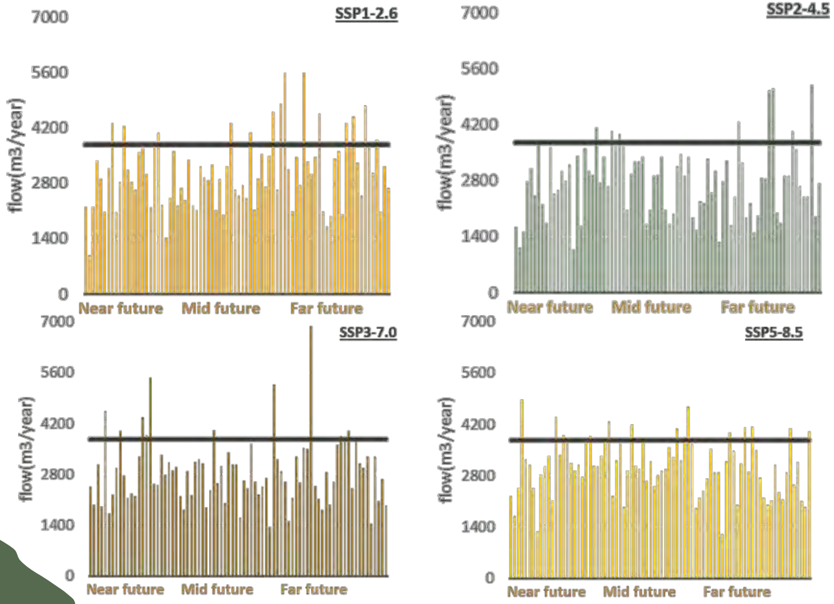


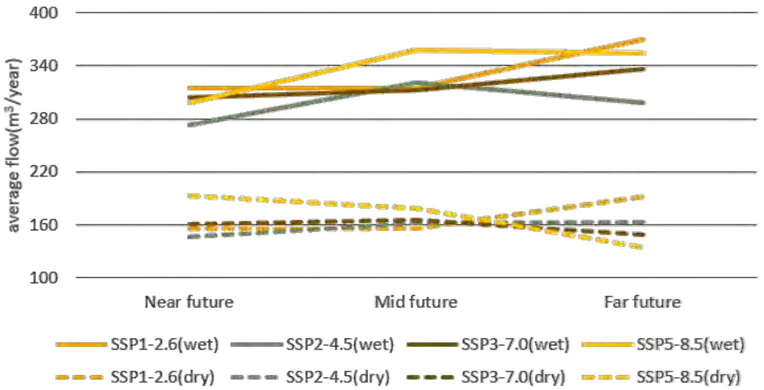
Upstream validation

Results & Discussion

Flow changes in Shimen Reservoir during climate change

- In the SSP5-8.5 scenario, the wet season flow rate rises sharply, highlighting the severe effects of intense warming.
- Across all scenarios, the gap between wet and dry season flows widens over time, with the largest difference seen in the SSP3-7.0 and SSP5-8.5 scenarios, peaking in the mid to far future.





Results & Discussion

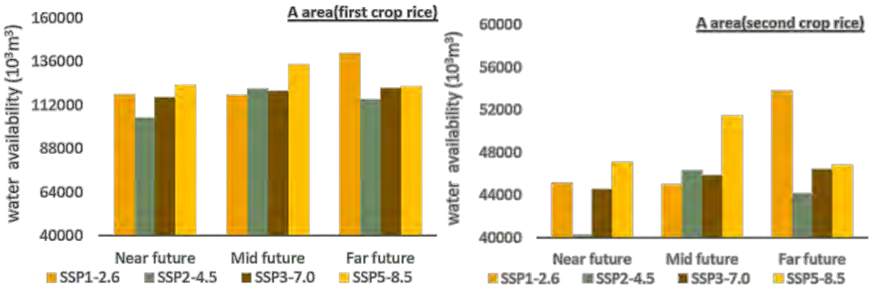
Water availability changes in irrigation areas during climate change

A Irrigation Area:

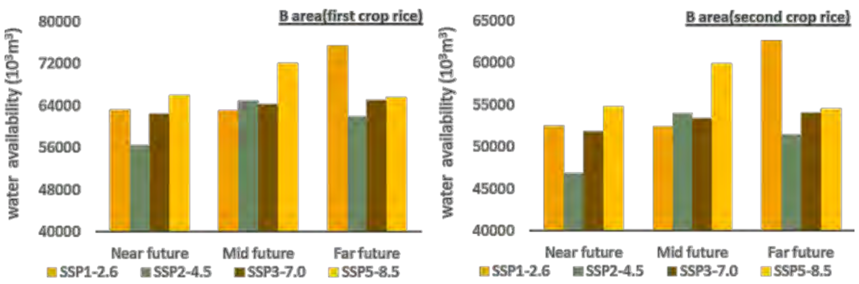
- Water availability for the first rice crop fluctuates over time, with significant reductions expected under the SSP5-8.5 scenario. For the second rice crop, although water availability varies, it remains relatively stable, especially in the SSP1-2.6 and SSP2-4.5 scenarios.

B Irrigation Area:

- The trend in water availability for the first rice crop is similar to that of Area A but with lower overall usage. Irrigation demand is expected to increase significantly in the next century, especially under the SSP3-7.0 and SSP5-8.5 scenarios.



A area irrigation water requirement



B area irrigation water requirement

Results & Discussion

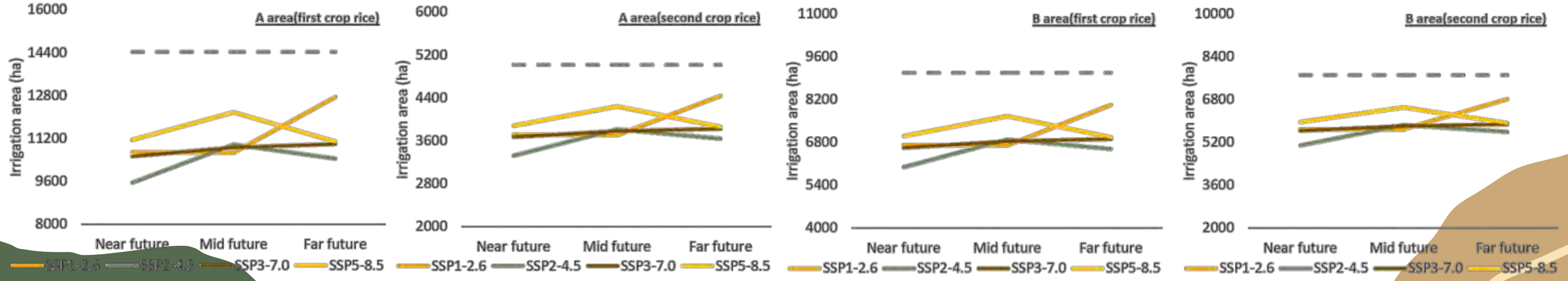
Trends in A and B irrigated area changes during climate change

Impact of Climate Change:

- In the fossil fuel-driven scenario (SSP5-8.5), irrigated areas in Zones A and B decline significantly due to reduced water availability caused by climate change.

Stable Irrigation:

- In the sustainable development scenario (SSP1-2.6), the reduction in irrigated areas is minimal, suggesting that agriculture can maintain current levels by implementing more efficient irrigation methods under a sustainable development approach.



Conclusion

Irrigation Water Availability

Encourage the combined use of surface water and groundwater by increasing groundwater use during droughts and recharging it during rainy periods.

Promote water-efficient irrigation methods to reduce waste, lessen reliance on groundwater, and enhance agricultural productivity.

Irrigation Area

Water shortages in agriculture are a significant threat to food security.

Effective policies, technologies, and management strategies are essential to sustaining food production amidst climate and water-related challenges.

Reservoir Management

Improve reservoir management to address future extreme flow variations and implement sustainable long-term water resource strategies.

Thank you for listening.