Evaluating Water Resource Response to the Projected Climate Variability in a Coastal Tropical Environment: The Case Study of Mati City, Philippines

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ABSTRACT

Factors such as climate variability, rapid urbanization, and limited adaptive capacity affect the water resources of tropical coastal cities. This study evaluates the response of water resources to projected climate variability in Mati City, Davao Oriental, Philippines, using the Soil and Water Assessment Tool (SWAT). Surface runoff, Evapotranspiration (ET), and water yield were simulated by integrating historical climate records (2000–2024) and the downscaled Coupled Model Intercomparison Project Phase 6 (CMIP6)-based projections (2025–2050) from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (DOST-PAGASA) across seven sub-catchments. During simulations, three climate scenarios were considered: dry, median, and wet. The temperature trend analysis indicates a statistically significant positive trend (+0.004 °C/year) in contrast to non-statistically significant precipitation trends. Across all future scenarios, water yield is projected to decline due to increased ET and reduced recharge—despite a higher runoff under wetter conditions. The dry scenario results in the steepest reductions in water availability. The wet scenario fails to compensate for the present losses. Under the dry scenario, water availability per capita is expected to have decreased below the Falkenmark water stress threshold by the 2040s and to have reached scarcity by 2050, when considering the projected population growth. These findings underscore the necessity of climate-informed water governance, integrated planning, and resilient infrastructure investments to ensure future water security. The study supports Sustainable Development Goals 6 (Clean Water and Sanitation) and 13 (Climate Action) by providing a localized, evidence-based framework for water resource planning under climate change.

Keywords-water resource management; water availability; climate variability; sustainable water management

I. INTRODUCTION

Water is considered a fundamental resource and is essential to human well-being, economic development, and ecological integrity. However, climate change threatens the availability, reliability, and sustainability of water resources. The variability of temperature, rainfall patterns, and extreme weather events disrupts hydrological systems, negatively influencing impacts in developing and tropical regions, which present limited adaptive capacity [1, 2].

The western Pacific Ocean is subject to monsoonal systems and ocean-atmospheric interactions, such as the El Niño–Southern Oscillation (ENSO). Philippines, located in this region, is one of the most climate-vulnerable countries. Changes in rainfall directly influence water resource availability, influencing streamflow, ET, recharge rates, and reservoir storage. In particular, the tropical climate and coastal geography of the eastern seaboard of Mindanao—where Mati City is located—is exposed to both droughts and floods [3].

Water availability in Mindanao is dependent on seasonal rainfall and natural watershed function. Existing research focuses on the regional or national scale, lacking the spatial resolution and local calibration necessary for city-level adaptation. Agricultural or disaster vulnerability is prioritized, distracted from the long-term water balance and per capita water availability of urbanizing tropical coastal cities [4, 5].

Authors in [6] demonstrated SWAT's capability to evaluate catchment-scale responses to climate variability. Utilizing the model at the international level in tropical regions revealed that rising temperatures amplify ET and reduce effective yields, even with increasing precipitation [7]. However, there is a research gap in linking hydrological projections to per-capita availability metrics, such as the Falkenmark indicator. In addition, there is limited integration of locally downscaled CMIP6 climate projections into hydrological models at the city scale in the Philippines.

This study addresses the gaps in research detected by evaluating the hydrological response of water resources in Mati City of Davao Oriental under projected climate variability, using the SWAT model. Historical records (2000–2024) and localized CMIP6-based projections (2025–2050) from PAGASA are employed to simulate runoff, ET, recharge, and water yield across seven delineated sub-catchments. The novelty of this work lies in the combination of downscaled percentile-based climate scenarios with SWAT simulations. This is performed at fine spatial resolution and, in turn, translating outputs into per-capita water availability thresholds. Consequently, the study provides a city-level perspective that relates climate-hydrology modeling with policy-relevant water security indicators.

II. METHODOGY

A. Study Area

This study was conducted in Mati City, Davao Oriental, a coastal urban area in southeastern Mindanao that experiences a tropical Type IV climate. Rainfall is distributed year-round, strongly influenced by the Northeast Monsoon (Amihan), and the ENSO. Its geographic location along the eastern seaboard exposes the city to hydrometeorological hazards, including intense monsoonal rainfall, prolonged dry spells, and recurrent typhoons [2]. Although the Climate Change Commission (CCC) has identified Mati as a climate-priority area, hydrology-focused and simulation-based assessments at the local scale remain limited [8]. The area of Mati City is ideal for water resource modeling due to population growth, infrastructure expansion, and water demand. The geographic location of the city within the Philippines and its regional context in southeastern Mindanao are illustrated in Figure 1.

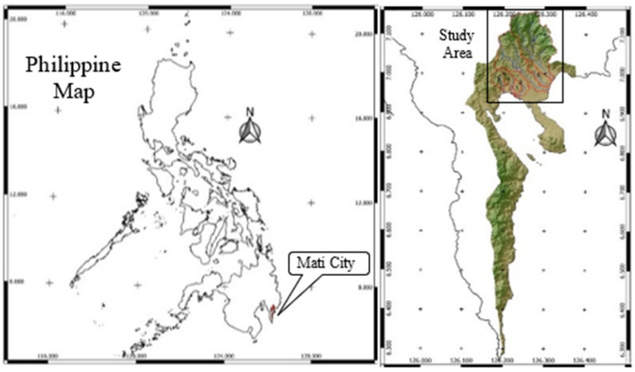

Fig. 1. Map of Mati City, Davao Oriental.

Watershed delineation is performed at a 30 m resolution Digital Elevation Model (DEM), obtained from the USGS Earth Explorer [9]. It is processed utilizing QGIS and the QSWAT plugin, which integrates GIS-based topography with hydrological modeling tools.

A total of seven distinct catchments are selected through flow direction and flow accumulation analysis, covering a combined area of approximately 289.33 km² within the urbanized area of Mati City. These include both major drainage basins, such as Mayo River and Bitanagan, and smaller but equally hydrologically significant catchments, like Matiao-Echavia, Matiao Lopez, Sudlon, and Mati Creeks. The catchments and their respective areas are summarized in Table I.

TABLE I. DELINEATED CATCHMENTS AND THEIR CORRESPONDING AREAS

Catchment no.	Catchment name	Area (km²)
1	Mayo River	133.29
2	Tagaumum Creek	18.93
3	Bitanagan River	86.86
4	Matiao Lopez Creek	16.05
5	Matiao Echavia Creek	6.89
6	Mati Creek	12.88
7	Sudlon Creek	14.43
Total		289.32

A composite map displaying the DEM overlaid with delineated catchment boundaries and stream networks is presented in Figure 2.

Fig. 2. DEM of the urban area of Mati City with the selected watersheds (red polygon) and stream network (blue lines).

B. Data Collection and Sources

The study used rainfall and temperature historical monthly climate data for the period from 2000 to 2024. The data are acquired from PAGASA, the national agency responsible for weather forecasting, climate monitoring, and atmospheric research in the Philippines [2]. The 2020 land cover map from the National Mapping and Resource Information Authority (NAMRIA) and soil data from the Bureau of Soils and Water Management (BSWM) are acquired via the Geoportal

Philippines' platform [3, 10]. These datasets are reclassified into SWAT-compatible categories.

Future climate projections from 2025 to 2050 are generated from a multi-model ensemble of Global Climate Models (GCMs), derived from CMIP6 datasets. They are statistically downscaled and bias-corrected to reflect localized conditions in the Philippines. DOST-PAGASA presents future climate projections using percentile-based scenarios, which correspond to low-end, mid-range, and high-end climate futures, respectively [11].

C. The SWAT Model Framework

The SWAT is a semi-distributed, process-based model developed by the USDA Agricultural Research Service to predict the impact of land use, soil, and climate changes on water resources in large, complex watersheds over time. The model divides the watershed into sub-basins, which are further partitioned into Hydrologic Response Units (HRUs)—unique combinations of land use, soil type, and slope class—allowing spatial variability in hydrological response. This model is selected for its capability to simulate long-term hydrological processes at the watershed level under varying climate conditions. The model setup involved the delineation of the watershed, reclassification of land use and soil maps, and the preparation of weather and hydrological input datasets. Key parameters are calibrated based on the available observed data to enhance model reliability [12].

Surface runoff is estimated employing the SCS Curve Number method, including rainfall, land cover, soil type, and antecedent moisture conditions. ET is calculated using the Penman-Monteith equation, forming part of the model's overall water balance computations [13]. Monthly simulations are conducted to estimate water availability under both historical (considered the baseline) and projected climate scenarios. Model calibration and validation are conducted using the observed streamflow and meteorological data to ensure the accuracy of simulations [14].

D. Trend and Correlation Analysis

To evaluate long-term changes in climate and hydrology, the Mann-Kendall test is applied to detect monotonic trends in rainfall and temperature. Sen's slope estimator is utilized to quantify the trend magnitude. The non-parametric Mann-Kendall test is ideal for detecting trends in environmental time series without assuming normality [15]. Additionally, Pearson correlation analysis is conducted to explore the relationship between rainfall, temperature, and water availability indicators, including runoff, recharge, and ET [16].

E. Water Stress Assessment

The Falkenmark Indicator is applied to evaluate future water availability in relation to demand. This indicator classifies water stress based on per capita renewable water resources [17], as follows:

- Adequate: >1,700 m³/person/year
- Water Stress: 1,000 – 1,700 m³/person/year
- Water Scarcity: <1,000 m³/person/year

The projected water yield from SWAT is divided by estimated population figures, extrapolated using the Philippine Statistics Authority data and historical growth rates from 2024 to 2050. The full research framework is illustrated in Figure 3.

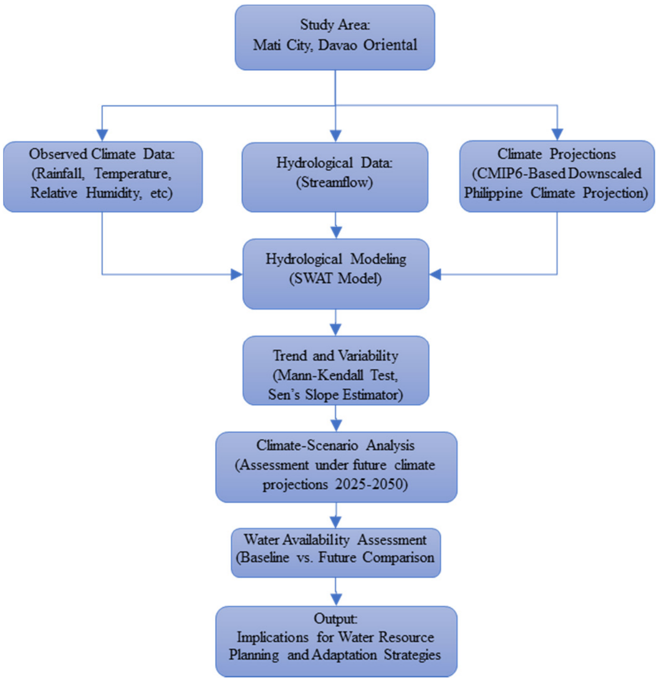

Fig. 3. Research methodology flowchart.

III. RESULTS AND DISCUSSION

A. Model Calibration and Validation

The hydrological model is calibrated using observed streamflow data from the Bitanagan Catchment for the period 2000-2004. It achieves a Nash-Sutcliffe Efficiency (NSE) of 0.74 and a coefficient of determination (R^2) of 0.79 during calibration [18]. The validation was performed for the 2018-2022 period, and yielded an NSE of 0.71 and R^2 of 0.76. The results indicate that the model has the required performance to simulate streamflow dynamics in Mati City's watershed.

B. Historical Climate and Hydrological Patterns

Based on observed climate data from 2000 to 2024, Mati City exhibits a Type IV climate, characterized by no pronounced wet or dry season and relatively even rainfall distribution throughout the year [19]. However, monthly data reveal moderate variability with increasing rainfall in November up to January and lower values in March and April. Mean monthly temperature ranges from 26.0 °C to 28.0 °C, with the highest temperatures typically recorded in April and May, and December, January being considered relatively cooler months. The temperature peak typically precedes the rainy season, potentially affecting ET and soil moisture conditions. These seasonal patterns, over the 2000–2024 baseline period, are presented in Figures 4 and 5.

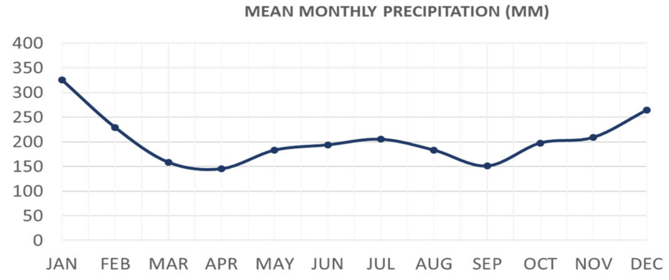

Fig. 4. Mean monthly precipitation.

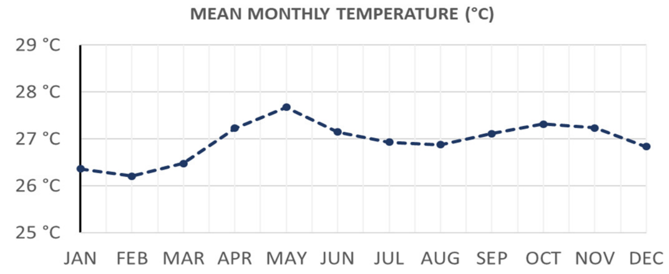

Fig. 5. Mean monthly temperature.

To evaluate long-term climate variability in Mati City, trend analysis is conducted for both annual precipitation and mean monthly temperature over the period 1995-2024, using the Mann-Kendall test and Sen's slope estimator [20]. The Mann-Kendall test for annual precipitation revealed a statistically significant Kendall's tau statistic of 0.056 and a p-value of 0.150. This indicates that there is no statistically significant trend in annual rainfall during the baseline period.

The Sen's slope is calculated at +0.084 mm/year, with a 95% confidence interval ranging from –0.029 to +0.199 mm/year. These findings are presented in Figure 6, revealing pronounced interannual variability and a gradual increase in overall rainfall.

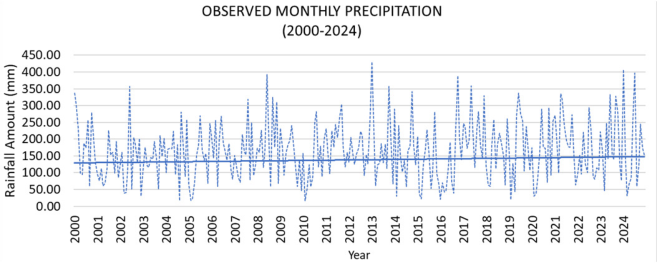

Fig. 6. Monthly precipitation time series.

In 2011, 2017, and 2023, particularly high wet-season peaks were observed, especially from November to January. Conversely, during 2016 and 2005, lower precipitation values were recorded. Some years displayed an even monthly distribution of rainfall, typical of a Type IV climate, where no pronounced dry or wet season is observed.

A statistically significant upward trend in mean temperature is observed in Mati City based on monthly temperature records, as illustrated in Figure 7.

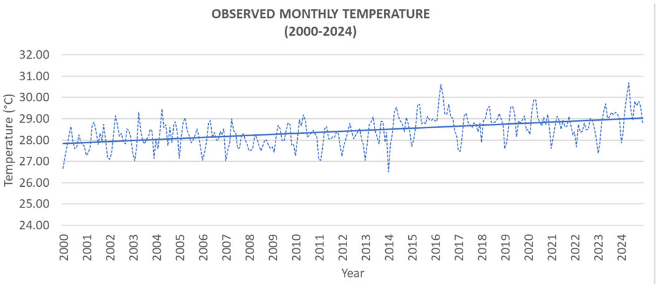

Fig. 7. Monthly temperature time series.

The Mann-Kendall test produced a Kendall's tau statistic of 0.354 and a p-value of 0.0001. The Sen's slope estimator was approximately +0.004 °C per year, with a 95% confidence interval ranging from +0.003 °C to +0.005 °C per year. This indicates a clear and consistent warming pattern, despite minor variability due to seasonal or interannual fluctuations. The intercept of the trend line is approximately 27.870 °C, aligning closely with the observed mean temperature of 28.44 °C across the 300 monthly records. Temperatures ranged from a minimum of 26.51 °C to a maximum of 30.70 °C. From 2020 onward, temperatures above 29.5 °C are frequently recorded, particularly in peak months such as April and May.

This warming trend has important hydrological implications. Even in the absence of significant precipitation changes, increased temperatures are likely to drive higher ET rates, reduce soil moisture, and alter runoff behavior, especially during the dry season. These changes can contribute to reduced effective water availability and increased pressure on local water resources.

C. Projected Climate Variability

To assess future hydroclimatic changes in Mati City, this study used the CMIP6-based Philippine Climate Projections developed and released by the DOST-PAGASA. These projections are derived from a multi-model ensemble of GCMs under the CMIP6 framework. The datasets were statistically downscaled and bias-corrected to capture localized climatic features in the Philippine setting, including Mindanao's eastern seaboard. Instead of relying on specific SSPs, DOST-PAGASA presents climate futures using a percentile-based approach [21]:

- The 25th percentile represents a dry, low-end climate scenario.
- The 50th percentile, or median, represents a moderate, mid-range climate future.
- The 75th percentile reflects a wet, high-end scenario with greater warming and precipitation.

This percentile-based framework supports a more robust evaluation of climate variability impacts, capturing uncertainty and potential extremes in both rainfall and temperature trends [22].

Table II summarizes the projected changes in annual rainfall and mean temperature for the Province of Davao Oriental under each percentile scenario, relative to the historical baseline period of 2000–2024.

TABLE II. SUMMARY OF PROJECTED CHANGES IN RAINFALL AND TEMPERATURE (2025–2050 VERSUS 2000-2024)

Percentile	**Rainfall change**	**Mean temperature increase**
25th	10% to 15% decrease	0.5 °C to 1.0 °C
50th	Up to 5% increase	1.0 °C to 1.5 °C
75th	Up to 15% increase	1.5 °C to 2.0 °C

These projections indicate a significant change in rainfall under the lower-bound scenario. On the contrary, they reveal increased rainfall intensity and frequency in the higher percentiles. In addition, temperature increases across all scenarios, consistent with global and regional warming trends. Monthly patterns reveal intensified rainfall during the wet season (November–January) and minimal increases during the dry season (March–May). Warmer temperatures, particularly during April and May, may lead to elevated ET rates, placing further stress on soil moisture and surface water systems.

The percentile-based climate projections are used as primary meteorological inputs in the SWAT model to evaluate hydrological responses under future climate variability. Daily rainfall and temperature data corresponding to the three scenarios are formatted and entered as inputs to the model for the simulation period 2025–2050, replacing historical climate drivers. Each scenario is modeled independently to enable comparative analysis of watershed-scale hydrological processes, including surface runoff, ET, groundwater recharge, streamflow, and water yield. All other watershed parameters are held constant across scenarios to isolate the effects of climate variability. By running three distinct climate scenarios, the study captures the range of plausible hydrological outcomes and allows for the evaluation of:

- Sensitivity of water resources to changing climatic inputs.
- Seasonal shifts in water availability.
- Scenario-specific risks, including drought and flood implications.

The hydrological simulations using SWAT reveal distinct changes in water balance components across Mati City's seven delineated catchments. The analysis focuses on surface runoff, ET, groundwater recharge, and water yield compared to the historical baseline period (2000–2024).

Despite varying rainfall trajectories, the results consistently indicate a decline in water yield across all climate futures. This is attributed to increased ET and limited subsurface retention, which reduces the effective availability of water even under wetter conditions. These changes imply a shift toward more intense but less sustainable hydrological cycles, with elevated flood potential during wet months and increasing water scarcity in dry seasons [23].

Regarding the dry scenario (25th percentile), runoff decreases by 11.7%-15.7%, and while ET slightly increases by 0.3% -1.1%. Consequently, water yield decreases from 21.7% to 24.3%. Similar reductions are observed in streamflow and groundwater recharge. Furthermore, for the median scenario (50th percentile), runoff increases moderately by 12.2%-19.0%, with ET rising by 0.8%-1.4%. Water yield still decreases by 8.5%-10.9%. This suggests that while rainfall increases, much of it is lost to ET and rapid surface flow, limiting long-term water availability. The wet scenario (75th percentile) runoff increases significantly by 32.2%-53.4% and recharges also increase by up to 12.4%. ET increases by 1.5%-2.1% and water yield highlights only a minor change (–1.9% to +0.7%). This indicates that while the system experiences higher rainfall and surface flow, contributing to runoff rather than sustained water storage, and thus increases both flood and dry-season vulnerability.

These simulation results underscore the critical role of ET and recharge dynamics in determining effective water availability. The catchments exhibit climate sensitivity, but also hydrological inefficiency under warming conditions.

Figure 8 presents the SWAT-simulated hydrological components aggregated across all catchments. It highlights the relative differences in runoff, ET, recharge, and water yield under the baseline and projected scenarios, showing the trade-offs between rainfall input, ET losses, and effective yield.

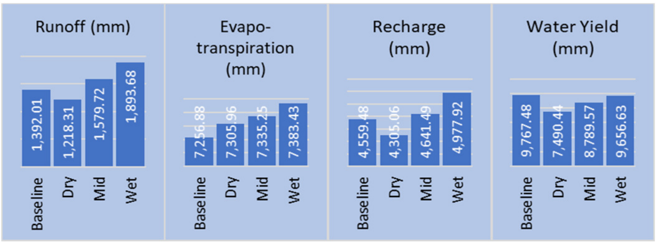

Fig. 8. SWAT-simulated hydrological components under baseline (2000–2024) and projected climate scenarios (2025–2050).

A more detailed breakdown of these hydrological changes across the seven sub-basins is displayed in Tables III and IV, capturing the spatial variability of responses across Mati City's watershed.

TABLE III. SIMULATED HYDROLOGICAL IMPACTS UNDER THE BASELINE SCENARIO (2000-2024)

Catchment no.	**Runoff (mm)**	**ET (mm)**	**Recharge (mm)**	**Streamflow (cms)**	**Water yield (mm)**
1	243.955	1002.776	488.459	69.967	1409.785
2	298.102	1032.982	786.426	10.167	1393.473
3	69.458	1043.936	650.298	45.987	1395.329
4	45.613	1065.954	723.859	8.553	1383.517
5	327.810	1022.904	717.339	3.664	1399.192
6	347.840	1032.603	633.049	6.835	1394.104
7	59.236	1055.725	560.053	7.653	1392.083
Total	1392.014	7256.88	4559.483	152.826	9767.483

TABLE IV. SIMULATED HYDROLOGICAL IMPACTS UNDER THE BASELINE SCENARIO (2000-2024)

Scenario	Catchment no.	Runoff (mm)	ET (mm)	Recharge (mm)	Streamflow (cms)	Water yield (mm)
25th Percentile (2025-2050) – dry scenario	1	212.167 (-13.0%)	1011.418 (+0.9%)	448.460 (-8.2%)	54.661 (-21.9%)	1084.097 (-23.1%)
	2	262.663 (-11.9%)	1044.113 (+1.1%)	752.880 (-4.3%)	7.816 (-23.1%)	1061.657 (-23.8%)
	3	58.529 (-15.7%)	1047.453 (+0.3%)	624.780 (-3.9%)	35.107 (-23.7%)	1070.041 (-23.3%)
	4	38.965 (-14.6%)	1070.632 (+0.4%)	688.860 (-4.8%)	6.501 (-24.0%)	1083.674 (-21.7%)
	5	288.597 (-12.0%)	1031.205 (+0.8%)	681.640 (-5.0%)	2.774 (-24.3%)	1064.242 (-23.9%)
	6	307.247 (-11.7%)	1039.33 (+0.7%)	601.670 (-5.0%)	5.206 (-23.8%)	1055.214 (-24.3%)
	7	50.139 (-15.4%)	1061.813 (+0.6%)	506.770 (-9.5%)	5.893 (-23.0%)	1071.513 (-23.0%)
	Total	1218.307 (-12.48%)	7305.964 (+0.68%)	4305.06(-5.58%)	117.958 (-22.82%)	7490.438 (-23.31%)
50th Percentile (2025-2050) – median scenario	1	277.742 (+13.8%)	1013.745 (+1.1%)	490.154 (+0.3%)	63.919 (+16.9%)	1270.469 (-9.9%)
	2	335.54 (+12.6%)	1046.959 (+1.4%)	805.626 (+2.4%)	9.164 (+17.2%)	1249.628 (-10.3%)
	3	82.386 (+18.6%)	1052.468 (0.8%)	677.734 (+4.2%)	41.154 (+17.2%)	1252.305 (-10.3%)
	4	54.26 (+19.0%)	1080.86 (+1.4%)	737.029 (+1.8%)	7.652 (+17.7%)	1265.245 (-8.5%)
	5	369.023 (+12.6%)	1033.896 (+1.1%)	729.615 (+1.7%)	3.268 (+17.8%)	1251.808 (-10.5%)
	6	390.433 (+12.2%)	1042.183 (+0.9%)	646.891 (+2.2%)	6.132 (+17.8%)	1242.764 (-10.9%)
	7	70.333 (+18.7%)	1065.142 (+0.9%)	554.441 (-1.0%)	6.919 (+17.4%)	1257.347 (-9.7%)
	Total	1579.717 (+13.48%)	7335.253 (+1.08%)	4641.49 (+1.80%)	138.208(-9.57%)	8789.566(-10.01%)
75th Percentile (2025-2050) – wet scenario	1	334.583 (+37.1%)	1020.497 (+1.8%)	531.849 (+8.9%)	70.44 (+10.2%)	1393.809 (-1.1%)
	2	397.02 (+33.2%)	1054.522 (+2.1%)	858.372 (+9.1%)	10.062 (+9.8%)	1373.961 (-1.4%)
	3	105.867 (+52.4%)	1059.297 (+1.5%)	730.688 (+12.4%)	45.194 (+9.8%)	1373.693 (-1.6%)
	4	69.166 (+51.6%)	1085.122 (+1.8%)	785.198 (+8.5%)	8.418 (+10.0%)	1392.85 (+0.7%)
	5	436.425 (+33.1%)	1041.284 (+1.8%)	777.591 (+8.4%)	3.597 (+10.1%)	1376.094 (-1.7%)
	6	459.724 (+32.2%)	1049.724 (+1.7%)	692.112 (+9.3%)	6.746 (+10.0%)	1367.039 (-1.9%)
	7	90.891 (+53.4%)	1072.981 (+1.6%)	602.112 (+7.5%)	7.594 (+9.8%)	1379.181 (-0.9%)
	Total	1893.676 (+36.04%)	7383.427 (+1.74%)	4977.922 (+9.18%)	152.051 (-0.51%)	9656.627 (-1.13%)

D. Climate-Hydrology Correlation

To quantify the relationships between the climate drivers and watershed behavior, Pearson correlation analysis was conducted using historical simulation outputs. This analysis examined how variations in rainfall and temperature influenced key hydrological components, such as surface runoff, ET, groundwater recharge, and overall water yield [24]. The results are presented in Table IV.

TABLE V. PEARSON CORRELATION COEFFICIENTS BETWEEN CLIMATE AND HYDROLOGICAL VARIABLES

Variable pair	Pearson's R	p-value	Interpretation
Rainfall - runoff	+0.968	< 0.0001	Very strong positive correlation; highly significant
Rainfall – water yield	+0.932	< 0.0001	Very strong positive correlation; precipitation drives water yield
Runoff – water yield	+0.949	< 0.0001	Very strong positive; runoff is a major component of water yield
Temperature - ET	+0.401	< 0.0001	Moderate positive; significant – temperature increases ET
Temperature - recharge	-0.284	< 0.0001	Moderate negative; significant – higher temperature tends to reduce recharge
Temperature – water yield	–0.245	< 0.0001	Weak to moderate negative correlation; statistically significant

Strong associations between rainfall and surface water responses are highlighted. Temperature exhibits a moderate positive correlation with ET, and a moderate negative correlation with recharge and runoff. This suggests that warming may reduce effective water availability by increasing atmospheric water loss and limiting infiltration [25]. However, while Pearson's R reflects linear association, some climate-hydrology relationships may be nonlinear in nature. These statistical relationships reinforce the modeling results and underscore the dual impact of precipitation and temperature on watershed-scale hydrology in tropical coastal environments.

E. Implications on Demand Growth and Water Availability

To assess the long-term sustainability of water resources in Mati City under projected climate variability, this study compares SWAT-simulated water yields with projected population growth [26]. Future per capita water availability is estimated using the Falkenmark indicator. The analysis reveals a consistent decline in water availability across all climate scenarios, driven by the dual pressures of the rising demand and declining or stagnant water yields.

Specifically, under the dry scenario, by 2043, per capita renewable water availability will have decreased to 1,630 m^3/year, exceeding the water stress range. By 2050, availability will have further declined to 962 m^3/year, signifying the transition to water scarcity. This scenario illustrates the compounded effects of reduced rainfall, elevated ET, and high population growth, resulting in critical water insecurity during the dry months.

Moreover, in the median scenario, water availability is projected at 1,609 m^3/year by 2045, remaining within the stress range. Despite a moderate increase in rainfall, the benefits are mitigated by ET losses and rapid urban growth, therefore suggesting that the current yield levels are insufficient to meet the future demand.

Furthermore, under the wet scenario, per capita availability is projected to have reached only 1,632 m^3/year by 2046, remaining within the stress level. This emphasizes that increased rainfall does not directly lead to improved water security, especially in the context of warming temperatures and inefficient hydrological retention. The detailed projections are summarized in Table V.

TABLE VI. PROJECTED PER-CAPITA RENEWABLE WATER AVAILABILITY IN MATI CITY

Scenario	Year	Projected population	Water yield (MCM/year)	Falkenmark indicator (m^3/year/person)	Status
Baseline	2024	109,790	402.41	3,665.28	Adequate
Dry	2043	195,528	335.91	1629.80	Stress
	2050	323,585	311.41	962.38	Scarcity
Midean	2045	230,987	371.69	1,609.15	Stress
Wet	2046	245,615	400.78	1,631.72	Stress

To further illustrate these trends, Figure 9 presents the projected per capita water availability from 2024 to 2050 across the three scenarios. In addition, the Falkenmark thresholds are represented by the shaded zones: Adequate (>1,700 m^3/person/year), Water Stress (1,000–1,700 m^3/person/year), Water Scarcity (<1,000 m^3/person/year), and Absolute Scarcity (<500 m^3/person/year). The trajectory of water availability presents a negative trend across all scenarios. Stress conditions are projected to have increased in the mid-2040s under both the median and wet scenarios, while scarcity is expected by 2050 under the dry scenario.

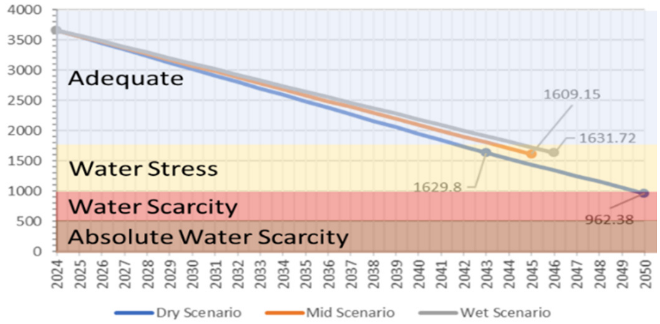

Fig. 9. Projected per capita renewable water availability in Mati City (2024–2050) under dry, median, and wet scenarios.

These projections highlight the risk of water stress or scarcity across all climate scenarios due to population growth and decline in per capita water yield, emphasizing the urgency of integrated water resource management [27].

IV. CONCLUSION AND RECOMMENDATIONS

This study evaluated the water resource behavior under three scenarios: wet, median, and dry, corresponding to the 25th, 50th, and 75th percentiles, respectively. The analysis focuses on Mati City, Davao Oriental, utilizing the Soil and Water Assessment Tool (SWAT) and Coupled Model Intercomparison Project Phase 6 (CMIP6)-based climate projections.

Trend analysis of the historical period (2000-2024) revealed statistically significant temperature increases during the last three decades. Similarly, the analysis for precipitation resulted in not statistically significant results. Furthermore, simulations indicated increasing temperatures, adding to the increase in Evapotranspiration (ET), therefore decreasing the effective availability of water. Future climate projections (2025-2050) in the SWAT model outputs forecast reduced water yield in all catchments, even under the wet scenario. This can be attributed to enhanced ET rates and limited groundwater recharge. The projections show that rainfall increments may not be sufficient to overcome the increased atmospheric water loss, especially during the dry season (March-May). Additionally, the research forecasts a steep drop in per capita water supply attributed to the cumulative impact of declining yield and increasing population. In the wet case, per capita availability is within water stress categories by the mid-2040s. In the dry scenario, by 2050, Mati City will have been considered water scarce.

This research employs a localized and multi-scenario hydrologic modeling framework to study city-scale climate adaptation planning. It demands climate-resilient investment in infrastructure, protection of strategic watershed areas, and policy systems aligned with future climate and population conditions. Ultimately, the findings highlight the necessity to align local water management planning with Sustainable Development Goal 6 (Clean Water and Sanitation) and Goal 13 (Climate Action).

Demand-side support includes water conservation and efficiency of water use in residential, commercial, and agricultural sectors along with the installation of water-saving devices. In addition, watershed protection and restoration can be achieved through reforestation, soil conservation, and riparian buffer management. Another measure, regarding infrastructure planning, includes multipurpose reservoirs, rainwater harvesting facilities, and flood-control structures to manage both surplus and scarcity situations. In addition, relevant policies of equitable allocation of water, land-use planning are required for long-term adaptation.

The research also identifies gaps to be filled by future studies. Higher resolution climate data and longer hydrological records will enhance calibration and accuracy. Future models must include land-use change scenarios, like urban development and agriculture expansion, to capture relevant effects on water resources. Coupling SWAT outputs with socio-economic models and governance models would provide a more integrated perspective on water management under climate variability. Moreover, advances in remote sensing and field monitoring can improve the representation of ET, recharge, and streamflow processes in tropical coastal ecosystems.

In summary, the results of this study confirm that climate variability will have greatly contributed to water scarcity or stress in Mati City by mid-century. With pragmatic solutions, strong governance, and ongoing scientific inquiry, resilience and the future of water resources can be secured for this exposed tropical coastal city.

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