POTENTIAL SITE SELECTION FOR WATER HARVESTING IN A MICRO WATERSHED WITH FUTURE WATER BALANCE PERSPECTIVES

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CHAPTER V

SUMMARY AND CONCLUSION

The present study entitled "Potential site selection for water harvesting in a micro watershed with future water balance perspectives" was carried out for the Valanchery micro watershed of Malappuram district, Kerala. The study aimed to identify suitable sites for water harvesting based on the future water balance to ensure water security and to enhance groundwater recharge.

LULC classification analysis was carried out for the years 2015, 2020 and 2023 using Google Earth Engine platform. Accuracy assessment of LULC classification results gave higher overall accuracy (0.84-0.89) and kappa coefficient (0.79-0.87) representing ideal classification. LULC change studies showed that there is an increase in the growth of urban areas. Rapid urban expansion and reduction in paddy cultivation and plantation areas were observed in the central part of the study area during 2015-2023.

MOLUSCE plugin of QGIS plugin was used for predicting land use maps for the future using the driving variables such as DEM, urban disturbances, road networks, population density map and slope map prepared using the ArcMap software. Kappa coefficient obtained while comparing the actual and predicted LULC map of 2023 was 0.79, which states that the predicted image is 79% accurate and suggests good agreement between predicted and actual LULC changes. LULC for 2025 and 2030 was then predicted with a high accuracy of (79%) and it is expected that the urban areas will increase and there was a reduction in paddy cultivation and plantation areas in future based on the predicted LULC maps. It was found from the study that the MOLUSCE plugin predicted the future land use map reliably aligning with the natural changes and land use planning can be done to fulfill the future requirements of the increasing population and urbanization.

SWAT hydrological modelling was carried out for the present period and the model was calibrated and validated using the measured runoff at the outlet of the watershed. SWAT model showed an optimal performance during the calibration period with an NSE value of 0.90, R^2 value of 0.92, RMSE of 0.41, PBIAS of 0.48 and RSR of 0.0175. The performance indices during the validation period were NSE 0.98, R^2 0.98, RMSE 0.02, PBIAS 0.26 and RSR 0.011.

Compromise programming was used to identify the best suited climate model for future climate study based on the model performance parameters from twenty CMIP 6 models. Based on the CP results, the highest ranked best suited model for precipitation was CESM2-WACCM model with a CP Value of 0.05 and for maximum temperature and minimum temperature EARTH model was selected as a best suited model with a CP value of 0.06 and -0.0006. Linear scaling bias correction technique was applied for temperature and power transformation bias correction was applied for precipitation.

Calibrated SWAT model successfully simulated the water balance components of the study area for the present as well as for the future period (2025 and 2030). Bias-corrected CMIP6 GCM datasets (SSP126, SSP245 and SSP585) indicated increased rainfall extremes and rising temperatures, shifting hydrology from infiltration-driven to runoff-dominated by 2030. Streamflow ratios revealed increasing surface runoff dominance under high-emission scenarios (SSP585). LULC change and prediction studies revealed the urbanization effect and the future climate data confirms an enhanced effect in the water balance for near future.

Machine Learning models were applied based on IMSD guidelines to identify potential sites for water harvesting based on the future water balance of 2025 and 2030. XG Boost outperformed other methods with an Area Under Curve (AUC) value of 0.92, followed by Random Forest (AUC=0.75), Gradient Boosting, and KNN. The Potential sites for check dams, percolation ponds, and farm ponds were scientifically located to tackle the effects of climate change and urbanization. The results indicate that while the SSP126 scenario maintains a higher number of suitable sites, particularly for check dams and percolation ponds, the SSP245 and SSP585 scenarios exhibit a noticeable reduction.

Under the SSP585 scenario, check dams were predominantly suggested along the 1st order streams, while percolation ponds were found to be more suitable in the upstream and midland regions. In contrast, other climate scenarios showed a more distributed pattern of suitable locations for both check dams and percolation ponds across the watershed. The analysis highlights that with increasing chances of extreme rainfall events under future climate conditions, large volumes of runoff tend to get concentrated in the downstream areas, making it challenging to store or manage water effectively in these places. Therefore, the study emphasizes the importance of storing excess runoff in the upstream and midland zones through decentralized structures such as check dams and percolation ponds. This strategy not only enhances groundwater recharge and soil moisture availability but also reduces the risk of downstream flooding and erosion.

The analysis revealed that the watershed possesses significant potential for implementing water harvesting structures such as check dams, percolation ponds, and contour bunds. Areas with higher runoff generation, moderate slopes, and suitable land cover were found most suitable for these interventions. The prioritization of sites was carried out to optimize water storage and enhance groundwater recharge while minimizing possible negative impacts such as soil erosion or land degradation.

Implementation of the identified structures is expected to improve the overall water availability in the watershed, particularly during dry periods. It will contribute to sustainable agricultural productivity, groundwater recharge, and improve the resilience of the local community to climate variability. Moreover, these measures align with the principles of integrated watershed management and promoting conservation of soil and water resources by ensuring long-term ecological balance.

Conclusions

The study aimed to identify potential sites for water harvesting based on the future water balance from calibrated SWAT model for the near future of 2025 and 2030. The key findings of the research revealed that, there will be an increase in the urban settlements and a decrease in vegetative class in both present and future scenarios. SWAT hydrological modeling for the future scenarios revealed an increase in surface runoff and a decrease in groundwater recharge. **T**he combined effect of urbanization and climate change intensify hydrological stress, leading to higher surface runoff and reduced groundwater recharge.

Scenario-based water harvesting structure under different SSPs revealed that strategic placement of small-scale structures could significantly stabilize lean flow and enhance groundwater recharge. The results highlight that IMSD-guided and data-driven site-specific recommendations for watershed interventions (check dams, percolation ponds, farm ponds, etc.,) can improve resilience against water scarcity and flooding risks. The integration of LULC prediction, climate models, SWAT model, and ML-based site selection provides a robust framework for water management under watershed scale. Using a combination of remote sensing (RS), hydrological modeling (SWAT), bias-corrected GCM climate projections, and machine learning (ML) techniques, the research identified sustainable strategies for water resource management. Continued monitoring, community participation, and adaptive management techniques will be essential to ensure the long-term success and sustainability of these initiatives.

Implementation of the recommended potential sites would reduce the effects of flooding in the low-lying areas and would enhance the water availability in upstream area, to ensure the availability of water throughout the year. In overall, this research establishes a scientifically credible and operationally feasible framework for climate-resilient watershed planning, offering valuable guidance for sustainable water resource management in humid tropical climate.

Future scope of research work

- Linking SWAT model with groundwater flow models to quantify and study the recharge potential can give a more accurate prediction.
- The design and capacity of structures for flood reduction need to be optimized to ensure water availability throughout the year.
- Establishment of real time monitoring systems for runoff and groundwater to validate and refine model predictions in more places - for accurate results.
- Development of Decision support system to assist governing authorities to implement watershed intervention activities under different SSP scenarios.