GROUNDWATER MODELLING USING WETSPASS-M AND MODFLOW

by

AKANSHA V R

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ABSTRACT OF THESIS

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ABSTRACT

Groundwater is a major source of water for domestic, agricultural and industrial demands in Kerala despite the fact that the state is receiving a high average annual rainfall. Rapid growth in population, urbanization, and climate variability have put heavy pressure on groundwater. The Tavanur–Ponnani region along the banks of river Bharathapuzha where dense settlements, shallow aquifers, and rapid land-use changes occur, experiences groundwater stress which makes the area more vulnerable. Changes in land use such as loss of vegetation and expansion of built-up areas reduce natural infiltration capacity of the soil and increase the runoff, which in turn decreases groundwater recharge and contributes to declining groundwater water levels making it essential to understand these changes for sustainable groundwater management.

The study area covers an area of about 50 km² and receives an average rainfall of 2940 mm. Groundwater levels were monitored in 18 observation wells spread over the area. Landsat images were used to prepare NDVI, NDBI and LULC maps. Groundwater level trends were analysed using the Mann–Kendall test and Sen's slope estimator. Correlation analysis was used to study how NDVI and NDBI relate to groundwater levels. The results showed major land-use changes in the area for a period of 11 years from 2014 to 2025. Built-up land increased from 2.2 km² in 2014 to 6.91 km² in 2025. Vegetation cover decreased from 32.1 km² to 24.9 km². NDVI showed a decreasing trend, while NDBI showed increasing, indicating rapid urban growth. These changes reflect a shift from permeable land surfaces to built-up areas, leading to reduced infiltration and groundwater recharge.

Trend analysis of groundwater levels indicated a statistically significant increasing trend in depth to water table in most observation wells, implying a decline in groundwater levels over time. The Mann–Kendall test results showed significant trends at the 95% confidence level, while Sen's slope estimator indicated a maximum groundwater level decline of up to 3.38 m during the pre-monsoon season and about 2.5 m during the post-monsoon season over the study period. The decline was more serious in regions which are highly influenced by urbanization and intensive groundwater pumping.

The WetSpass-M model was used to get the recharge to groundwater in the region. The inputs such as land use, soil, slope, LAI, groundwater depth, and climate data were used as inputs to the model. WetSpass-M model results showed that the mean groundwater recharge dropped from 277 mm in 2014 to 220 mm in 2025, which is a reduction of about 20–21%.

Higher recharge values were observed in areas with more vegetation, while built-up areas showed very low recharge due to increased surface runoff and reduced infiltration. The reduction in recharge closely corresponded with the observed increase in built-up land and decrease in vegetation cover.

The recharge values obtained from WetSpass were then used in the MODFLOW model to simulate groundwater flow. The model was calibrated for a period of 2014 to 2021 and validated for a period of 2022 to 2025. MODFLOW simulations showed a steady fall in groundwater levels, especially in the highly urbanized parts of the study area. Groundwater flow was mainly from the northeast towards the Arabian Sea. Model calibration performed well, with an R^2 of 0.95 and NRMSE of 7.16% indicating satisfactory model performance. Simulation results showed that increased pumping rates caused an immediate and noticeable decline in groundwater heads across the model domain. Pumping scenarios with 5%, 10%, and 20% increase in pumping resulted in progressive decline of groundwater levels. After the initial drawdown, groundwater levels tended to stabilize at lower elevations, suggesting that the aquifer system is approaching a condition controlled by limited storage and presence of bedrock.

Overall, the study showed that land-use change is one of the main factors affecting groundwater recharge and groundwater levels. The combined WetSpass-M and MODFLOW approach clearly captured the effects of urban expansion, loss of vegetation, and reduced infiltration on groundwater decline. The results highlighted the need for sustainable land-use planning, protection of recharge zones, and controlled groundwater extraction to ensure long-term groundwater availability in the Tavanur–Ponnani region. Implementing rainwater harvesting measures at household and community levels, regulating unplanned urban expansion, encouraging water efficient practices etc are also suggested for the area.