**Paper 1**

**Literature Review on Groundwater Storage Changes in the Amazon River Basin**

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**Introduction**

Groundwater storage (GWS) is a critical component of the hydrological cycle, influencing water availability, ecosystem health, and climate dynamics. In the Amazon River Basin (ARB), a region of global hydrological significance, monitoring GWS variations is essential for understanding environmental changes and developing sustainable water management practices. However, the lack of ground-based observational networks and the complex spatial-temporal variability of GWS present significant challenges. Satellite missions, such as GRACE and GRACE-FO, offer a promising solution by providing large-scale terrestrial water storage (TWS) data. Yet, the coarse spatial resolution of these datasets necessitates downscaling approaches for localized analysis.

**Methodology**

This study employed machine learning (ML) models to downscale GRACE and GRACE-FO data, focusing on hydrometeorological and morphological variables specific to the ARB. The methodology included:

1. **Data Sources**: GRACE/GRACE-FO data, GLDAS, CHIRPS, GLEAM, and MERIT Hydro DEM were used for TWS and GWS modeling.
2. **Modeling Techniques**: Two ML models, based on Adaptive Boosting (AB) and Random Forest (RF), were developed to enhance spatial resolution from 1° to 0.25°.
3. **Validation**: Statistical correlation and validation with independent hydrological variables ensured the reliability of the downscaled data.

**Key Findings**

1. **Downscaling Efficiency**: Both AB and RF models successfully improved the spatial resolution of GWS data, with the AB model slightly outperforming RF in accuracy.
2. **Spatio-Temporal Analysis**: The study highlighted significant GWS variations in the ARB between 2002 and 2021, driven by climatic and anthropogenic factors.
3. **Error Minimization**: The ML models achieved low prediction errors, demonstrating their robustness in capturing localized hydrological patterns.

**Discussion**

The integration of ML techniques with GRACE/GRACE-FO data represents a significant advancement in hydrological research. By leveraging region-specific variables, the models provided high-resolution insights into GWS dynamics, addressing the limitations of coarse satellite data. The findings underscore the potential of ML-driven approaches for environmental monitoring in data-scarce regions like the ARB.

**Conclusion and Future Directions**

The study demonstrated the feasibility and effectiveness of using ML models for downscaling TWS data to assess GWS changes in the ARB. Future research should explore the integration of additional remote sensing datasets and advanced ML techniques, such as deep learning, to further enhance predictive capabilities. Additionally, efforts should focus on understanding the implications of GWS variability on regional water resources and ecosystems under changing climatic conditions.

**Paper 2**

**Literature Review on Drought Modeling Using Machine Learning Approaches**

**Authors:** Karpagam Sundararajan, Lalit Garg Kathiravan Srinivasan, Ali Kashif Bashir, Jayakumar Kaliappan, Ganapathy Pattukandan Ganapathy, Senthil Kumaran Selvaraj and T. Meena

**Published in:** Tech Science Press – Computer Modelling in Engineering & Sciences

**Introduction**

Drought is a complex natural disaster characterized by persistent precipitation deficits over an extended period. It significantly impacts ecosystems, agriculture, water resources, and socio-economic conditions. Unlike other natural disasters, drought develops slowly, propagates through the hydrological cycle, and is challenging to predict. With advancements in computational intelligence, machine learning (ML) approaches have gained prominence in drought prediction, offering data-driven and efficient solutions.

**Drought Indices and Metrics**

Drought indices are essential tools for quantifying and forecasting drought conditions. Over 100 indices have been developed, each tailored to specific types of drought (meteorological, agricultural, or hydrological). Common indices include:

* **Standardized Precipitation Index (SPI)**: Based on precipitation deficits.
* **Palmer Drought Severity Index (PDSI)**: Incorporates precipitation, temperature, and soil moisture data.
* **Standardized Precipitation Evapotranspiration Index (SPEI)**: Accounts for evapotranspiration to evaluate drought severity.
* **Normalized Difference Vegetation Index (NDVI)**: Monitors vegetation health using satellite data.

Performance metrics for ML-based drought prediction models include Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Nash-Sutcliffe Efficiency (NSE), which measure the accuracy of predictions compared to observed data.

**Machine Learning Models for Drought Prediction**

ML models have been extensively utilized to improve the accuracy of drought forecasts. Key methodologies include:

1. **Artificial Neural Networks (ANNs)**
   * Adaptive Neuro-Fuzzy Inference Systems (ANFIS) have shown high accuracy in predicting SPI and precipitation.
   * Wavelet-ANN hybrids improve prediction accuracy by denoising input data.
2. **Support Vector Machines (SVMs)**
   * SVMs effectively handle non-linear relationships between input variables and drought indices.
   * Enhanced SVMs, combined with wavelet analysis or evolutionary algorithms, demonstrate superior performance.
3. **Random Forests (RFs)**
   * RFs excel in feature selection and ensemble learning, making them suitable for drought index prediction using diverse datasets.
4. **Deep Learning**
   * Long Short-Term Memory (LSTM) networks capture temporal dependencies in drought data.
   * Hybrid models combining LSTM with Gaussian Process Regression (GPR) enhance prediction reliability.
5. **Markov Models and Bayesian Networks**
   * Hidden Markov Models (HMMs) are employed for short-term drought predictions.
   * Bayesian networks model probabilistic relationships and drought propagation dynamics.

**Findings and Challenges**

1. **Findings**:
   * Hybrid models combining ML techniques with wavelet or fuzzy logic frameworks outperform standalone methods.
   * Incorporating climatic indicators (e.g., ENSO, NAO, and PDO) enhances the accuracy of drought forecasts.
   * Data-driven models are effective for short-term predictions but may struggle with long-term accuracy.
2. **Challenges**:
   * The availability and quality of historical climate data remain critical constraints.
   * High computational costs associated with deep learning models.
   * Limited interpretability of complex ML models hampers practical implementation.

**Future Directions**

To advance ML-based drought modeling, researchers should:

* Integrate multi-source datasets, including remote sensing and ground observations.
* Explore advanced ML techniques, such as reinforcement learning and ensemble deep learning.
* Focus on explainable AI to improve model interpretability and stakeholder trust.

**Conclusion**

ML approaches offer robust tools for drought modeling and prediction, addressing the limitations of traditional statistical methods. Continued innovation and integration of diverse data sources will further enhance the reliability and applicability of these models in managing drought impacts globally.

**Paper 3**

**Literature Review on Urban Groundwater Vulnerability Under Climate Change and Management Scenarios**

**Authors:** M Shekhar, M Shindekar, Sat K Tomer, P Goswami

**Published in:** Earth Interactions – Volume 17

**Introduction**

Groundwater serves as a critical resource for urban and rural areas, especially in regions like southern India, where it meets 85% of rural domestic and 50% of urban water demands. Urbanization and climate variability exacerbate groundwater vulnerability, leading to challenges such as reduced recharge, declining water levels, and deteriorated water quality. Despite advancements in understanding groundwater dynamics, the combined impacts of climate change and urban management practices remain underexplored.

**Key Themes in Urban Groundwater Research**

1. **Groundwater-Urbanization Interactions**:
   * Urban expansion often modifies groundwater cycles, influencing recharge, well yields, and quality (Foster et al., 2010).
   * Wastewater leakage and improper drainage can lead to shallow groundwater levels, affecting both quality and recharge patterns.
2. **Climate Change Impacts**:
   * Temperature increases and erratic rainfall patterns significantly affect recharge rates and groundwater availability.
   * Climate models, such as GCMs, project uncertain rainfall trends, requiring careful integration with hydrological assessments (Adger et al., 2007; Allen et al., 2004).
3. **Numerical Modeling Approaches**:
   * Lumped and distributed groundwater models are effective tools for simulating groundwater levels and evaluating scenarios.
   * Advances like the CRD method and software tools such as PORFLOW enable high-resolution, scenario-specific analyses.
4. **Management Practices and Policy Implications**:
   * Management practices, such as induced recharge through lakes and controlled pumping, can mitigate urban groundwater stress.
   * Policy frameworks must integrate long-term groundwater surveys, urban water use mapping, and sustainable infrastructure development.

**Study Insights and Methodologies**

1. **Study Area**: The study focuses on Mulbagal, a small urban town in Karnataka, India, relying predominantly on groundwater for water supply. The town’s semiarid conditions and growing population intensify water stress.
2. **Data Collection**:
   * Groundwater and rainfall data were collected between 2008 and 2011.
   * A monitoring network of 272 wells facilitated spatiotemporal analysis.
3. **Modeling and Simulation**:
   * Lumped models estimated recharge rates, revealing a mean annual recharge of 68mm from rainfall.
   * PORFLOW simulations assessed future groundwater levels under scenarios such as reduced lake recharge and increased pumping.
4. **Climate and Management Scenarios**:
   * Six GCMs with high correlation to historical rainfall data were used for future projections.
   * Combined scenarios (e.g., reduced lake recharge, enhanced pumping) indicated significant groundwater declines, particularly near pumping stations.

**Findings and Implications**

1. **Groundwater Vulnerability**:
   * Recharge from lakes plays a critical role in mitigating depletion. Simulations revealed that reductions in lake recharge significantly affect groundwater levels.
   * Increased pumping and operational drainage systems exacerbate declines.
2. **Scenario Outcomes**:
   * Under a combined scenario, groundwater levels near pumping stations could decline by 20 meters over 20 years.
   * Wastewater leakage contributes substantially to shallow urban groundwater levels but poses quality risks.
3. **Policy Recommendations**:
   * Sustain lake recharge and develop managed aquifer recharge projects.
   * Conduct comprehensive groundwater-level mapping and integrate findings into urban planning frameworks.
   * Adopt policies that balance water extraction with long-term aquifer sustainability.

**Conclusion**

The study underscores the importance of integrating climate projections and management scenarios into urban groundwater planning. By addressing both anthropogenic and climatic factors, sustainable water management strategies can mitigate future groundwater stress. These methodologies are applicable beyond the case study, offering a framework for other urban settings globally.

**Paper 4**

**Mapping and Assessing Spatial Extent of Floods from Multitemporal Synthetic Aperture Radar Images: A Case Study over Chennai City, India**

**Authors:** Sreechanth Sundaram, Suresh Devaraj, Kiran Yarrakula

**Published in:** Research Square

The document titled " Mapping and Assessing Spatial Extent of Floods from Multitemporal Synthetic Aperture Radar Images: A Case Study over Chennai City, India " presents a comprehensive study on urban flooding in Chennai, focusing on the application of Synthetic Aperture Radar (SAR) data for flood mapping. Below is a literature survey derived from the key themes and findings presented in the document.

**Literature Survey**

**Urban Flooding and Its Impacts**

Urban flooding has emerged as a critical issue globally, particularly in densely populated areas. The literature indicates that urban floods not only lead to significant economic losses but also pose severe risks to human life. Chaudhary and Piracha (2021) highlight that urban floods are among the most devastating types of flooding, exacerbated by rapid urbanization and climate change (Sundaram et al., 2021; Dube et al., 2021). The increasing frequency of such events in Indian cities like Chennai is attributed to inadequate infrastructure and poor urban planning (Ilam Vazhuthi and Kumar, 2020; Surampudi and Yarrakula, 2020).

**Remote Sensing Applications**

Remote sensing technologies, particularly those utilizing SAR, have been identified as effective tools for monitoring flood extents. Studies by Ouled Sghaier et al. (2018) and Das et al. (2007) emphasize the utility of these technologies in disaster management and mitigation. SAR systems are favored for their ability to acquire data under all weather conditions, making them superior to optical sensors which are limited by cloud cover (Huang et al., 2015; Vickers et al., 2019).

**SAR Technology and Methodologies**

The document discusses various methodologies for extracting flooded areas using SAR datasets, including ISODATA techniques, multi-temporal analysis, and thresholding methods. Zhang et al. (2020) note that effective flood mapping requires advanced processing techniques to reduce noise and enhance accuracy. The study finds that methods such as the Grey Level Co-Occurrence Matrix yield promising results in delineating flooded regions.

**Historical Context of Flooding in Chennai**

Chennai's vulnerability to flooding has been documented extensively, with significant events recorded over the past decades. The catastrophic floods in 2015, driven by extreme rainfall linked to El Niño, serve as a case study underscoring the city's susceptibility (Rasti et al., 2018). The analysis of historical data reveals a correlation between urban development patterns and flood occurrences, suggesting that improper resource management has exacerbated these risks (Ehrlich et al., 2021; Kookana et al., 2020).

**Technological Advancements in Flood Monitoring**

The evolution of satellite technology since the launch of the first satellite in 1957 has revolutionized earth observation capabilities (Fu et al., 2020). The Sentinel missions by ESA are highlighted for their contribution to making SAR data widely accessible for scientific research and practical applications in flood monitoring (Nagler et al., 2015; Chatenoux et al., 2021). These advancements have facilitated improved temporal resolution and spatial accuracy in flood assessments.

**Conclusion**

The literature surrounding urban flooding emphasizes the need for integrated approaches combining remote sensing technologies with effective urban planning strategies. The case study of Chennai illustrates the potential of SAR data in enhancing flood risk assessment and management efforts. Continued research is essential to refine methodologies and improve predictive capabilities regarding urban flooding.

This survey synthesizes key insights from the provided document while situating them within broader academic discourse on urban flooding and remote sensing applications.

**Citations:**

[1] https://ppl-ai-file-upload.s3.amazonaws.com/web/direct-files/50294207/ed5817f6-1479-4726-b3f1-

99d3d3a0f343/fd9e0fde-7bb9-4f9a-b3e5-591774236a6b.pdf

**Paper 5**

**Flood susceptibility mapping of Northeast coastal districts of Tamil Nadu India using Multi-source Geospatial data and Machine Learning techniques**

**Authors:** Saravanan Subbarayan, Abhijith Devanatham

**Published in:** Research Gate

**Literature Review**

**Overview of Flooding as a Natural Disaster**

Flooding is one of the most significant natural disasters, exacerbated by climate change, which has led to increased frequency and intensity of extreme precipitation events. Historical data indicate that floods are responsible for substantial socioeconomic losses and property damage globally, with water-related disasters accounting for approximately 74% of all natural disasters [1]. The Indian subcontinent, characterized by its vulnerability to various hazards, has witnessed catastrophic flooding events, particularly in coastal regions like Tamil Nadu. Notably, the state experienced devastating floods in 2015 due to heavy rainfall linked to cyclonic activity and poor urban planning, which highlighted the urgent need for effective flood susceptibility mapping [1].

**Methodologies for Flood Susceptibility Mapping**

Several methodologies have been employed for flood susceptibility mapping, including multi-criteria decision analysis (MCDA), statistical methods, physically-based models, deep learning, and machine learning techniques. Traditional methods often rely on expert opinions or linear assumptions that may not adequately capture the complexities of flooding phenomena. In contrast, machine learning (ML) approaches have gained traction due to their ability to model non-linear relationships and extract significant patterns from historical data[1]. Techniques such as Gradient Boosting Machine (GBM), XGBoost, Support Vector Machine (SVM), and Naive Bayes (NB) are increasingly utilized for their predictive capabilities in flood risk assessment.

**Role of Remote Sensing and Geospatial Data**

Remote sensing technologies have revolutionized flood mapping by providing comprehensive spatial data over large areas. The use of platforms like Google Earth Engine (GEE) allows researchers to process satellite imagery efficiently, facilitating the identification of flood-prone areas[1]. Multi-source geospatial data, including Synthetic Aperture Radar (SAR) images from the European Space Agency's Sentinel-1 mission, are particularly effective in monitoring flood extents under varying meteorological conditions. This integration of remote sensing with machine learning enhances the accuracy and reliability of flood susceptibility maps.

**Importance of Feature Selection in Machine Learning Models**

Effective feature selection is critical in improving the performance of machine learning models used for flood susceptibility mapping. Recursive Feature Elimination (RFE) is a prominent technique that helps identify and eliminate weak predictors from the model, thereby refining the input variables to enhance predictive accuracy[1]. The choice of features significantly influences the model's ability to generalize across different scenarios and datasets.

**Previous Studies and Findings**

Research has demonstrated that ML models outperform traditional statistical methods in flood susceptibility assessments. For instance, studies have shown that ML techniques can effectively identify flood-prone regions based on historical occurrences without necessitating a deep understanding of underlying physical processes[1]. Furthermore, various studies have highlighted the effectiveness of ensemble approaches in optimizing predictions while minimizing computational costs.

**Conclusion**

The literature indicates a growing recognition of machine learning as a powerful tool for flood susceptibility mapping. By leveraging multi-source geospatial data and advanced algorithms, researchers can develop more accurate models that aid in disaster preparedness and response. The integration of remote sensing data with ML methodologies presents a promising avenue for enhancing flood risk management strategies in vulnerable regions like Tamil Nadu. Future research should continue to explore innovative approaches to improve model accuracy and applicability across diverse geographical contexts.

**Citations:**

[1] <https://ppl-ai-file-upload.s3.amazonaws.com/web/direct-files/50294207/a9509f11-f29c-4e7c-84e5-95949d1c82d5/Flood-susceptibility-mapping-of-Northeast-coastal-districts-of-Tamil-Nadu-India-using-Multi-source-Geospatial-data-and-Machine-Learning-techniques.pdf>

**Paper 6**

**The Impact of Climate Change on Groundwater and Crop Yield in Asia: A Comprehensive Literature Review**

**Authors:** Anandhi Santhosh, Sujatha Prabhakaran, Davamani Veeraswamy, Asadi Srinivasulu, Alvin Lal, Ravi Naidu

**Published in:** Pre-Prints

**Introduction to Climate Change in Asia**

The literature review begins by highlighting the critical environmental challenges facing Asia, the world's largest and most populous continent. Climate change is dramatically transforming the region's ecological landscape, with far-reaching consequences for water resources, agriculture, and human settlements. The review emphasizes that Asia is warming faster than the global average, with mean temperatures in 2022 rising significantly compared to historical baselines. This accelerated warming presents multiple threats, including potential sea-level rises that could displace over 180 million people, primarily in low-lying coastal areas of countries like Bangladesh and Indonesia.

**Groundwater Dynamics Under Climate Stress**

The review reveals a complex picture of groundwater resources in Asia. Climate change is fundamentally altering groundwater recharge, availability, and quality across the continent. Regions like South Asia are experiencing alarming groundwater depletion, with an annual loss of 60 Billion Cubic Meters and increasing air temperatures driving higher evapotranspiration rates. The research highlights that groundwater availability is increasingly insufficient to meet growing demands, leading to overexploitation of water resources. This trend is particularly pronounced in agricultural regions, where irrigation needs are constantly expanding.

**Crop Yield Vulnerabilities and Adaptive Challenges**

Agricultural productivity emerges as a critical concern in the review. Climate change is projected to significantly impact crop yields through multiple mechanisms, including temperature increases, altered precipitation patterns, and more frequent extreme weather events. The research indicates varying effects across different crops and regions. For instance, wheat yields in some areas might increase slightly, while maize yields could decline by up to 16.3%. The temperate climate zones are shifting, dramatically affecting the geographical suitability for major crops like rice, cotton, wheat, and maize.

**Machine Learning: A Promising Predictive Approach**

A key innovative aspect of this review is the exploration of machine learning techniques as powerful tools for predicting and understanding climate change impacts. The researchers found that machine learning models, particularly ensemble and hybrid approaches, can more accurately forecast groundwater levels and crop yields compared to traditional statistical methods. Models like Random Forest, Support Vector Regression, and Extreme Gradient Boosting demonstrated superior performance in capturing complex, non-linear relationships between climate variables and agricultural outcomes.

**Adaptation and Mitigation Strategies**

The literature review underscores the urgent need for comprehensive adaptation strategies. Recommended approaches include judicious groundwater management technologies such as water recharge options, need-based irrigation, and strategic crop selection. The research emphasizes that sustainable water management practices must consider soil properties, climate variability, and emerging technological solutions to build resilience in agricultural systems.

**Conclusion: Complexity and Uncertainty**

The review concludes by acknowledging the inherent complexity of predicting climate change impacts. While machine learning offers promising predictive capabilities, the researchers caution against universal solutions. Each region, crop, and water system presents unique challenges that require nuanced, context-specific approaches. The study calls for continued research, particularly in exploring climate-resilient crop enhancement techniques and understanding the spatiotemporal variability of groundwater quality.

This comprehensive literature review provides a critical overview of the intricate relationships between climate change, groundwater resources, and agricultural productivity in Asia, highlighting both the challenges and potential technological innovations for addressing these complex environmental transformations.

**Paper 7**

**Comparative Analysis of Deep Learning and Swarm-Optimized RandomForest for Groundwater Spring Potential Identification in Tropical Regions**

**Authors:** Viet-Ha Nhu, Pham Viet Hoa, Laura Melgar-García and Dieu Tien Bui

**Published in:** Remote Sensing MDPI

The study compares the effectiveness of deep neural networks (DeepNNs) and swarm-optimized random forests (SwarmRFs) in predicting groundwater spring potential in Gia Lai province, Vietnam. Let's break down the details:

1. Data and Study Area:

* Study Area: Gia Lai province, Central Highlands of Vietnam. This area is characterized by a tropical monsoon climate with distinct wet and dry seasons, varying elevations (80m to 1740m), and slopes (0.0 to 79.9 degrees). The region also experiences significant economic development (coffee and pepper cultivation) and population growth, leading to unsustainable groundwater use.
* Groundwater Data: The study used a comprehensive database of 938 groundwater spring locations with measured water flow (0.01 to 118.35 L/s) and mineralization (0.01 to 0.980 g/L).
* Influencing Factors: Twelve variables were considered:
  + Land Use/Land Cover (LULC): Derived from JAXA's 2020 dataset.
  + Geology: Obtained from a 1:200,000 scale Geological and Mineral Resources Map. The Tuc Trung formation was found to be dominant and highly correlated with spring locations.
  + Distance to Fault: Calculated by buffering fault networks.
  + Distance to River: Calculated using a buffer analysis of the OpenStreetMap river network.
  + Rainfall: Data from NASA's POWER project (1981-2020).
  + Remote Sensing Indices: NDVI, NDMI, and NDWI, calculated from Landsat 8 OLI imagery.
  + Topographic Factors: Slope, aspect, elevation, and curvature derived from ALOS DEM data.

1. Methodology:

* Feature Selection: A wrapper method using random forest and mean absolute error (MAE) was used to identify the most important variables. Geology was identified as the most important factor.
* Deep Neural Network (DeepNN): A model with 12 input neurons, 3 hidden layers (32 neurons each), and 2 output neurons was used. The ADAM optimizer was employed for parameter optimization, and mean squared error (MSE) was used as the objective function.
* Swarm-Optimized Random Forest (SwarmRF): A random forest model where the number of trees (nTree), maximum tree depth (dTree), and number of randomly chosen features (fTree) were optimized using the Harris Hawks Optimizer (HHO) algorithm. MSE served as the cost function.
* Model Evaluation: Performance was assessed using accuracy, AUC, kappa coefficient, F-score, PPV, NPV, sensitivity, and specificity. A Wilcoxon signed-rank test was used to compare the performance of the models statistically.

1. Results:

* Variable Importance: Geology was the most important factor, followed by elevation, NDVI, NDMI, LULC, rainfall, distance to fault, and NDWI.
* Model Performance: Both DeepNN and SwarmRF showed robust predictive capabilities. SwarmRF performed slightly better than DeepNN in the validation phase (80.2% accuracy vs. 77.9% accuracy). The Wilcoxon signed-rank test confirmed this difference was statistically significant (p-value = 0.011).
* Groundwater Spring Potential Maps: Maps were generated showing the spatial distribution of groundwater spring potential based on the DeepNN and SwarmRF models.

1. Conclusions:

* Both DeepNNs and SwarmRFs are effective for predicting groundwater spring potential.
* SwarmRF showed a statistically significant slight advantage over DeepNN.
* Geology was the most significant factor influencing groundwater spring potential.

The study provides valuable information for water resource management and sustainable development planning in the Gia Lai province. The use of SwarmRF offers an advantage due to its higher accuracy and the interpretability provided by the random forest model, allowing for a better understanding of the factors influencing groundwater spring potential.