IT4010 Research Project – 2025 July Topic Assessment Form

Project ID: 25-26J-520

1. Topic (12 words max)

Integrated Smart Irrigation System with Predictive Capabilities Using IoT and Machine Learning

2. Research group the project belongs to

SST - Software Systems & Technologies

3. Specialization of the project belongs to

Software Engineering (SE)

4. If a continuation of a previous project:

Project ID	
Year	

5. Brief description of the research problem including references (200 – 500 words max) – references not included in word count.

Sri Lanka's agricultural economy - anchored in centuries-old hydraulic civilization -continues to rely heavily on a vast network of tank cascades, canal systems, and large multipurpose reservoirs. Over 70% of cultivated land depends on irrigation sourced from these systems, particularly in the Dry Zone, where rainfall is highly seasonal and increasingly erratic [1]. Despite their historical effectiveness, the current irrigation systems are plagued by inefficiencies. Manual dam gate operations and rigid scheduling based on outdated heuristics frequently lead to over- or under-irrigation. This adversely affects both water conservation and agricultural yields. Most farmers lack access to real-time field data such as soil moisture, reservoir levels, or localized rainfall forecasts. As a result, irrigation decisions are often based on intuition rather than empirical insights, resulting in significant water waste and plant stress [2].

Sediment accumulation in reservoirs adds another critical dimension to the problem. Deforestation and watershed erosion, especially in basins such as Uma Oya, have increased soil loss rates to 3–130 times above sustainable limits [3]. This accelerates sediment deposition in reservoirs, reducing their effective storage capacity and potentially compromising structural safety. Globally, sedimentation has already reduced dam capacities by an average of 39%, and studies warn that losses could reach up to 50% by 2050 if no preventive measures are adopted [4]. In Sri Lanka, bathymetric surveys are infrequent and typically performed manually, making it nearly impossible for dam authorities to plan timely dredging operations. As a result, silted reservoirs not only store less water but also pose risks during heavy rainfall or flood events.

These hydrological vulnerabilities are further compounded by climate change, which has rendered rainfall patterns in Sri Lanka highly volatile. Sudden cloudbursts followed by extended dry spells are increasingly common. While the country maintains national-level hydrological and meteorological data systems, these are not sufficiently integrated into dam operations or local irrigation decision-making. Traditional rule-of-thumb approaches to flood and drought management lack the predictive capabilities needed to ensure proactive responses [5].

Recent advancements in Sri Lankan research indicate that integrating data-driven technologies - particularly those based on Internet of Things (IoT) sensors and machine learning (ML) - could offer practical solutions. For instance, Herath et al. proposed a deep machine learning–based water level prediction model using data from Colombo's detention areas. Their system, built on deep neural networks, achieved a coefficient of determination R^2 of 0.88, demonstrating the feasibility of applying ML to urban water forecasting [6]. Jayathilake et al. used artificial neural networks (ANNs) to forecast wetland water levels in the Muthurajawela marsh, achieving correlation coefficients exceeding 0.99 between observed and predicted values [7]. These studies provide strong evidence of the applicability of ML techniques in Sri Lankan hydrological contexts.

Rainfall forecasting is another area where predictive analytics can provide critical support. A study by Saubhagya et al. introduced a hybrid model combining Granger Causality analysis with a Bi-directional Long Short-Term Memory (Bi-LSTM) neural network. The model delivered high accuracy in predicting rainfall over the Ratnapura region, with a 3-day forecast RMSE under 5 mm [8]. This was further enhanced by a hybrid missing-value imputation method using Multi-Layer Perceptron (MLP) and spatial kriging, which addressed the frequent data gaps in Sri Lankan rainfall datasets [9].

In the domain of smart irrigation, Mallikarathne et al. developed a wireless sensor network (WSN)-based system integrating soil moisture, humidity, and temperature sensors. This IoT-based system automatically triggers irrigation based on real-time environmental inputs and has demonstrated significant water savings in pilot implementations [10]. Despite these isolated successes, there is currently no unified system in Sri Lanka that integrates predictive sediment mapping, real-time irrigation control, and time-series hydrological forecasting into a single platform.

This research project seeks to close that gap by developing a modular, scalable smart irrigation and water management system tailored specifically for Sri Lanka's agricultural and dam-based ecosystems. The proposed solution incorporates field-deployable IoT sensors, unmanned surface vehicles (USVs) for bathymetric mapping, and ML-based forecasting models to automate and optimize water allocation. Additionally, it includes real-time alerts, scenario simulations (e.g., "what if we release X m^3?"), and adaptive control logic to support both farmers and reservoir operators. The system aims to not only improve efficiency but also enhance disaster resilience, ensure sustainable reservoir operations, and provide long-term food and water security in the face of a changing climate.

References

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[8] S. Saubhagya, "Granger Causality-Based Forecasting Model for Rainfall Prediction in Sri Lanka, Forecasting, vol. 6, no. 4," 2024. [Online]. Available: https://www.mdpi.com/2571-9394/6/4/56.

[9] S. Saubhagya, "A Novel Hybrid Spatiotemporal Missing Value Imputation Model for Rainfall Forecasting in Ratnapura, Sri Lanka, Applied Sciences, vol. 14, no. 3," 2024. [Online]. Available: https://www.mdpi.com/2076-3417/14/3/1476.

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6. Brief description of the nature of the solution including a conceptual diagram (250 words max)

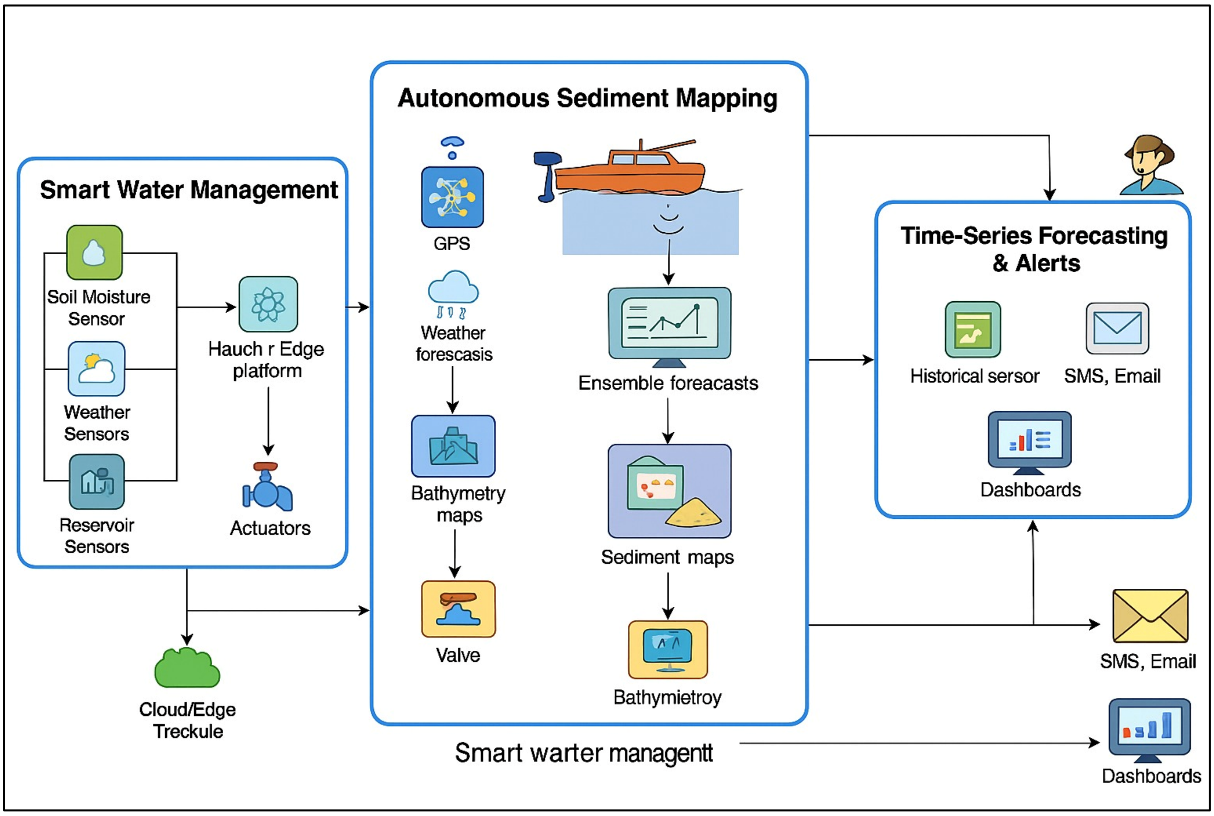
Nature of the Solution

Our solution is a modular, integrated platform that combines IoT sensing, autonomous mapping, and machine learning to optimize water management in Sri Lankan agriculture.

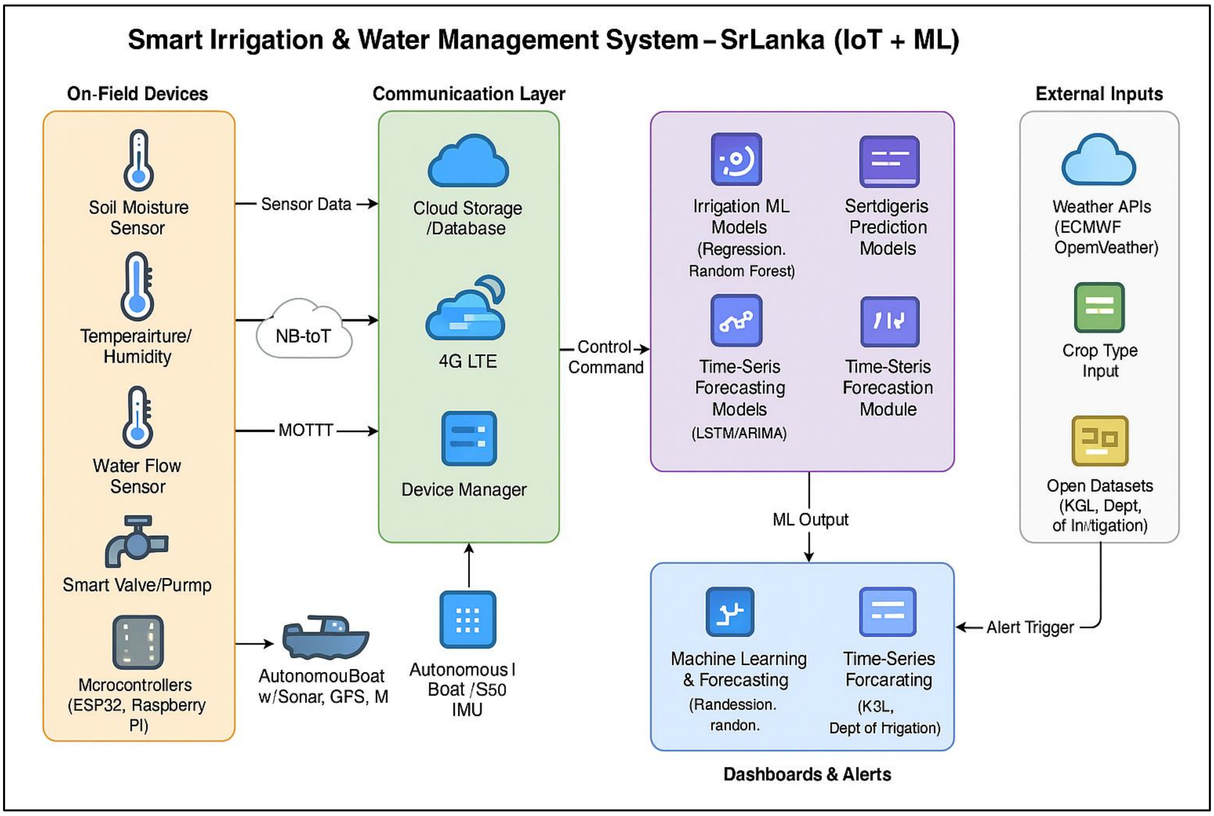
Core Concept

The system bridges three interconnected components built around real-world field data and pilot deployments:

- **Smart Water Management**: Soil moisture, weather, and reservoir sensors feed live data into control logic hosted on edge/cloud platforms. ML models (e.g., online regression or decision trees) dynamically calculate irrigation needs. Actuators - valves or pumps are triggered automatically, adjusting water flow to match crop requirements. This reduces waste and frees farmers from manual scheduling.
- **Autonomous Sediment Mapping & Prediction**: A small, unmanned surface vehicle (USV) equipped with GPS, IMU, and sonar autonomously surveys the reservoir. Paired ML algorithms generate accurate bathymetry maps, detect sediment hotspots, and forecast future siltation. This informs maintenance planning and prevents reservoir capacity loss.
- **Time-Series Forecasting & Alerts**: The cloud-based platform ingests historical sensor data, weather forecasts, and reservoir information. It applies ensemble forecasts (LSTM, ARIMA, Bi-LSTM) to predict inflows, droughts, flooding, and power generation needs. Scenario simulation tools (e.g., "release X m^3 today") help dam operators and farmers make data-driven decisions. Alerts are issued via SMS, email, and dashboards.



This diagram presents a high-level system architecture of the integrated smart irrigation and water management platform, showcasing how on-field IoT devices - such as soil moisture sensors, humidity sensors, water flow meters, and autonomous mapping boats - interface with a communication layer using NB-IoT, MQTT, and 4G LTE protocols. Sensor data is transmitted to cloud storage and device managers, which in turn feed into advanced machine learning modules for irrigation prediction, sediment forecasting, and time-series analysis (using algorithms like Random Forest, LSTM, and ARIMA). External data sources such as weather APIs, crop types, and open government datasets further enhance model accuracy. ML outputs are visualized through dashboards and trigger alerts (SMS, email) for actionable decision-making. This end-to-end system enables data-driven irrigation scheduling, reservoir sediment analysis, and proactive flood/drought risk mitigation.



This diagram breaks down the smart water management system into its three main functional components - Smart Water Management, Autonomous Sediment Mapping, and Time-Series Forecasting & Alerts - each with its internal workflow. The Smart Water Management module collects real-time data from soil moisture, reservoir, and weather sensors, processed via edge computing to control irrigation actuators. The Autonomous Sediment Mapping module uses a GPS and sonar-equipped unmanned surface vessel to generate bathymetry and sediment maps, feeding this data into forecasting models. The Time-Series Forecasting component integrates sensor history and weather forecasts to generate proactive alerts through SMS or dashboards. This modular breakdown emphasizes the independence yet interconnectivity of each system, allowing the platform to optimize irrigation, plan sediment removal, and anticipate climatic risks holistically.

7. Brief description of specialized domain expertise, knowledge, and data requirements (300 words max)

Effective development of the Smart Irrigation System requires collaboration with domain experts and access to high-quality data across multiple sectors. Here's a breakdown of necessary expertise and data:

1. **Domain Expertise & Knowledge Sources**

- **Irrigation Engineering**: The **Irrigation Department** and **Water Resources Board** offer critical support for understanding dam operations, water-release schedules, and field-level irrigation networks. We collaborate with them through one-on-one meetings, joint field visits, and supervised data access to optimize sensor placement and water flow modeling.

- **Agricultural Science & Soil Expertise**: The **Department of Agriculture (Agro-Climatology Division)** provides soil-type maps, agro-ecological zoning data, and crop-specific water advisories. This information is vital for calibrating soil moisture sensors and training models to match real-world irrigation needs. Sensor calibration is conducted under expert supervision during field experiments.

- **Climate and Hydrological Data Sources**: Daily inflow/outflow data from 73 major reservoirs is obtained via the **Irrigation Department**, while real-time and historical weather data is sourced from the **Department of Meteorology**. These datasets are used in time-series forecasting for rainfall, reservoir levels, and water demand prediction.

- **Smart Farming and Digital Platforms**: We integrate datasets from **AIMS** and **GeoGoviya**, which provide access to farmer records, field profiles, irrigation histories, and crop types. With secure API access (in progress), we ensure data is used responsibly, with anonymization protocols in place to maintain privacy.

- **External Supervision and Energy Integration**: Our **external supervisor**, an electronics and energy systems expert, supports sensor hardware validation, especially for **solar-powered setups**, and facilitates data acquisition across departments. They ensure technical reliability and compliance with data ethics and traceability standards throughout the project.

2. **Data Requirements**

- **Soil & Field Sensor Data:** Calibrated soil moisture and temperature readings across different soil types and plantation depths - obtained via field deployments supported by agrarian offices.
- **Reservoir Hydrological Records:** Real-time and historical reservoir levels, discharge flows, and catchment inflow data sourced from Irrigation Department archives.
- **Bathymetry & Sediment Data:** Initial manual depth surveys create ground truth; augmented by autonomous boat missions collecting GPS/sonar maps.

- **Climatic & Agro-Meteorological Data**: Historical rainfall and temperature datasets (10+ years), plus 7–14-day forecasts from departmental sources to feed into predictive models.
- **Crop & Irrigation Metadata**: GIS-based crop type maps, growth stage information, Kc coefficients, and irrigation schedules maintained by AIMS and agrarian officers.

Data Integration Strategy:

Access to OISA experts and coordination with national agencies - especially the Department of Irrigation, Department of Agriculture, and local agrarian services - ensures data authenticity and domain alignment. Together, expertise from these sources enables accurate sensor configuration, ML model training, and system calibration tailored to Sri Lanka's diverse agro-irrigation landscapes.

Data Plan for Smart Irrigation System

1. Data Sources & Ownership

Data Type	Source Agency/Platform	Ownership/Access Method
Soil Moisture & Temperature	IoT Sensors in pilot fields	Collected by research team; calibrated with DoA data
Reservoir Water Levels & Flow	Irrigation Department (73 major reservoirs)	Official reports, on-site logs, and data requests
Bathymetry & Sediment Profiles	Autonomous USV + Ground-Truth Surveys	Collected by team; verified by Irrigation Dept
Weather & Climate Data	Department of Meteorology, Agro-Climatology Division	Public reports, forecast APIs, and internal archives
Crop & Irrigation Metadata	AIMS, GeoGoviya, Agrarian Services	API access (in progress), direct field-level records
Energy System & Solar Inputs	Energy Department, Sensor Hardware Logs	Supervisor-supported access via energy institutions

2. Data Collection & Frequency

Data Type	Collection Frequency	Notes
Soil & Field Sensor Data	Real-time (every 10–30 min)	Pushed via LoRaWAN to edge nodes
Reservoir Data	Daily	Downloaded or scraped from official portals
Bathymetric Data	Weekly/Monthly	From autonomous USV missions
Climate Forecasts	Hourly to Daily	7- and 14-day forecasts used for ML prediction
Crop Metadata	Seasonal Updates	Changes per cultivation cycle; collected via field officers

8. Objectives and Novelty

Main Objective

To design and develop an integrated smart irrigation and water management system using IoT, machine learning, and autonomous sensing technologies to optimize water usage, predict sediment accumulation, and provide real-time forecasting for Sri Lankan agriculture and dam operations.

Member Name with Registration No	Sub Objective	Tasks	Novelty
Dilruksha A.G.C.D. IT22561770	Autonomous Sediment Mapping & ML-Enhanced Prediction with 3D Visualization	• Design and assemble an autonomous surface vessel (ASV) with sonar, GPS, and IMU sensors • Develop navigation logic (grid path planning) and remote control or autonomous movement capabilities • Collect bathymetric data from selected reservoirs or lakes using the ASV • Process and visualize depth data to generate 2D and 3D maps of the lakebed • Collect environmental data (rainfall, inflow, soil type, surrounding vegetation)	By integrating machine learning directly into the USV's data pipeline and fusing ultrasonic sensor feeds, this component transcends static bathymetry surveys. A real-time ML model ingests both sonar and ultrasonic depth measurements to detect anomalous sediment plumes and forecast future deposition hotspots. Simultaneously, an augmented-reality (AR) interface renders a live 3D overlay of water levels and sediment (sand) layers—allowing operators to "see" the current reservoir cross-section and predicted buildup in situ. Proactive maintenance alerts are triggered whenever forecasted deposition

		• Train a machine learning model to predict future sediment accumulation patterns • Integrate sediment prediction output with alert/notification system for early dredging decision support • Evaluate accuracy and practicality of automated vs manual sediment mapping methods	exceeds safety thresholds. This seamless coupling of autonomous navigation, multi-sensor ML inference, and AR-driven situational awareness dramatically reduces response latency and preserves reservoir capacity at minimal cost.
Hesara P.K.A.N. IT22561398	IoT-Enabled ML-Driven Smart Water Management System	• Identify crop types, water needs, and region-specific irrigation practices in Sri Lanka • Select and configure IoT sensors (soil moisture, temperature, humidity, water level) • Set up wireless communication (e.g., LoRaWAN, NB-IoT) between field sensors and base station • Build a microcontroller-based control system for valve or pump automation • Collect initial field data from pilot farms or dam-fed irrigation networks • Train and deploy a machine learning model for adaptive	This component leverages an IoT fabric of low-power soil-moisture sensors, weather stations, and valve/pump actuators to feed live telemetry into an online ML model. Unlike conventional threshold-based controllers, the system continuously ingests granular field data—soil moisture, ambient climate, and reservoir levels—via LoRaWAN/NB-IoT gateways. The ML engine then dynamically adjusts valve openings and pump schedules to match evolving crop water requirements, crop type, and seasonal patterns. Case-based learning refines irrigation strategies per field, while seamless field-to-dam integration

		irrigation control (e.g., online regression, random forest) • Implement web/mobile dashboard for real-time monitoring and manual overrides • Conduct controlled experiments comparing smart irrigation vs manual irrigation • Analyze water savings, crop health, and response latency of system	automatically synchronizes upstream reservoir releases with downstream sensor feedback. This tight IoT-ML loop eliminates manual intervention, optimizes water use efficiency, and adapts in real time to both microclimate variability and broader hydrological changes.
Trishni W.M.T. IT22076366	ML-Based Multi-Objective Time-Series Forecasting, Simulation & Alert System	• Gather historical data on rainfall, reservoir levels, discharge rates, and energy consumption • Set up real-time data ingestion pipeline from field sensors and weather APIs • Preprocess and normalize time-series data for model training • Develop and compare multiple forecasting models (e.g., LSTM, Prophet, ARIMA) • Implement scenario simulation tool for "what-if" analysis (e.g., “if 100,000 m³ released”) • Build an alerting system with custom thresholds for flood, drought, and power decisions	This component unifies flood-risk, drought-likelihood, and hydropower optimization into a single ML forecasting and simulation framework. An ensemble of LSTM and ARIMA models ingests historical reservoir, rainfall, and energy output data alongside global climate forecasts (e.g., ECMWF) to deliver high-accuracy predictions across multiple horizons (1–14 days). A built-in “what-if” simulation card lets operators tweak reservoir release volumes, timing, or inflow scenarios and instantly view ML-generated projections for water security, drought risk, and hydropower yield—directly within the dashboard.

		• Integrate forecasting dashboard with smart irrigation and sediment systems • Validate prediction accuracy using real field conditions and user feedback	Automated alerts are issued when any forecast metric crosses critical thresholds. By combining multi-model ML forecasting with interactive scenario simulation, this system provides an unprecedented decision-support tool for balancing flood control, drought mitigation, and energy production.

9. Individual component description of how it is complied with the specialization.

Member Name with Registration No	Description
Dilruksha A.G.C.D. IT22561770	**Autonomous Sediment Mapping & Prediction** **Software Architecture & Modular Design:** Define ROS-based microservices for navigation, sensor fusion, ML inference, and communication. **Containerization & Deployment:** Package each microservice as a Docker image; deploy via Kubernetes or Docker Compose on USV edge nodes and cloud. **CI/CD Pipelines:** Automate builds, tests (rostest, pytest), and over-the-air updates using GitHub Actions or GitLab CI. **Testing & QA:** Write unit and integration tests in Gazebo simulations and hardware-in-the-loop benches; target ≥ 80% coverage. **Monitoring & Observability:** Instrument services with Prometheus metrics and structured logging; create Grafana dashboards for USV health and anomaly alerts. **API & HCI Concepts:** Expose RESTful endpoints (via Swagger) for control and data queries; design AR interface controls for 3D sediment visualization.
Hesara P.K.A.N. IT22561398	**Smart Water Management System** **Microservices Architecture:** Decompose into services for sensor ingestion, ML inference, actuation control, and dashboard UI. **Edge-to-Cloud Orchestration:** Run lightweight containers on Raspberry Pi gateways (K3s); manage cloud infra with Docker/Kubernetes and Terraform. **Networking & Security:** Secure sensor-to-cloud links over MQTT/TLS and LoRaWAN; implement Circuit Breaker patterns at actuator interfaces. **CI/CD & DevOps:** Use GitHub Actions to lint (PEP8, ESLint), test (pytest, unit tests), build Docker images, and publish Helm charts. **HCI & UX Design:** Apply user-centered design for a responsive React-based farmer dashboard, optimized for low bandwidth and accessibility. **Quality Assurance:** Automate end-to-end tests via Docker Compose simulations (sensor → cloud → actuator); enforce peer-reviewed code and coverage thresholds.
Trishni W.M.T. IT22076366	**Time-Series Forecasting & Alert System** **ETL & Data Pipelines:** Architect containerized ingestion workflows using Apache NiFi or AWS Glue for reservoir, rainfall, and energy data. **Model Serving & APIs:** Deploy batch training pipelines (e.g., SageMaker) and real-time inference services (TensorFlow Serving + FastAPI); version with MLflow.

	CI/CD for ML: Automate model validation, drift detection, and pipeline rebuilds via GitHub Actions; schedule retraining with Airflow DAGs. **Dashboard & HCI:** Implement interactive "what-if" simulation cards in React, following MVC patterns and HCI best practices for clarity. **Monitoring & Logging:** Expose Prometheus metrics for both batch jobs and online services; configure Grafana alerts on failures and performance regressions. **Testing & Governance:** Use pytest for data transformations, implement backtesting for forecast accuracy, and enforce data provenance via metadata tagging.

- Currently serves as a Renewable Energy Consultant, providing expertise to:
  - Metrix Pvt Ltd
  - Luminex PLC
  - Tantri Pvt Ltd
  - Manahara Lanka Pvt Ltd

- Registered member of the following professional bodies:
  - Engineering Council Sri Lanka
  - Sri Lanka Energy Managers Association (SLEMA)
  - Engineers' Guild of Sri Lanka
  - Institute of Incorporated Engineers, Sri Lanka (IIESL)

- Brings in-depth technical knowledge and practical experience in renewable energy, electrical systems, and project consultancy - making him well-qualified to serve as an external supervisor for academic or industry-based projects.

IT4010 Research Project – 2025 July
Topic Assessment Form

<u>This part is to be filled by the Topic Screening Staff members.</u>

a) Does the chosen research topic possess a comprehensive scope suitable for a final-year project?

Yes		No	

b) Does the proposed topic exhibit novelty?

Yes		No	

c) Do you believe they have the capability to successfully execute the proposed project?

Yes		No	

d) Do the proposed sub-objectives reflect the students' areas of specialization?

Yes		No	

e) Supervisor's Evaluation and Recommendation for the Research topic:

Acceptable: Mark/Select as necessary

Topic Assessment Accepted	
Topic Assessment Accepted with minor changes*	
Topic Assessment to be Resubmitted with major changes*	
Topic Assessment Rejected. Topic must be changed	

* Detailed comments given below

Comments

Staff Member's Name	**Signature**

*__Important__:

1. According to the comments given by the evaluator, make the necessary modifications and get the approval by the **Evaluator**.
2. If the project topic is rejected, identify a new topic, and request the RP Team for a new topic assessment.