INTEGRATING LAND-USE SCENARIO MODELING AND MACHINE LEARNING TO MITIGATE DROUGHT RISKS IN DEGRADED LANDSCAPES

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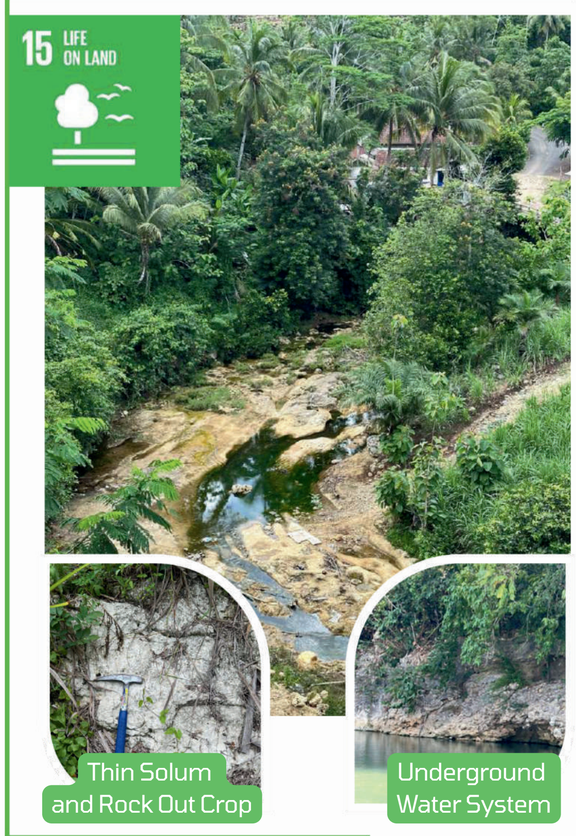
Research Background



Problem:

- Since 2000, drought frequency and duration have increased by 29% globally.
- More than 1.4 billion people have been affected by droughts.
- By 2050, around 75% of the global population will live in areas highly vulnerable to drought.
- In Indonesia, BMKG predicts that over 45% of regions will face peak drought in August 2024, especially in southern areas.
- One of the most drought-prone regions is the karst landscape of South Malang Plateau, where limited water storage and high degradation make communities more vulnerable

Gap:

Existing methods lack high-resolution, spatially explicit data to support effective mitigation.

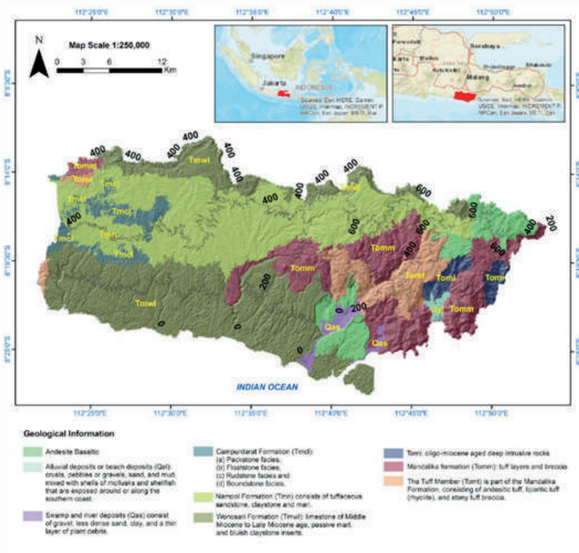
Highlight:

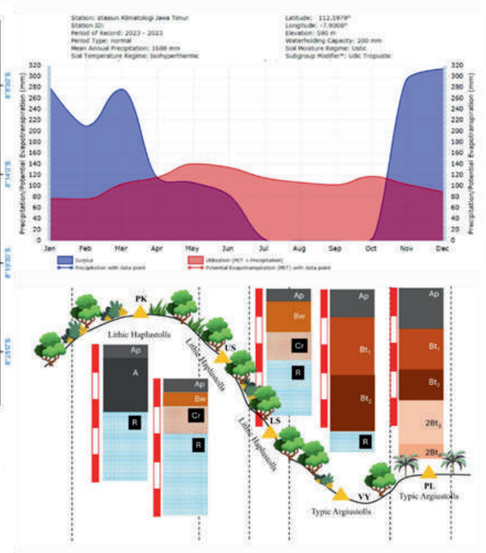
- A paradigm shift is needed, using remote sensing and machine learning to better capture land-use dynamics and predict drought impact.
- Land-use change (LUC) is a key driver of environmental drought.
- In 2023, vegetative cover dropped by 45%, leaving around 8.8 million hectares barren.
- The South Malang Plateau, already degraded, is increasingly threatened by drought due to these changes.

Objective:

To develop an innovative framework combining remote sensing with CA-ANN and Random Forest for improved LULC - drought risk assessment.

Study Area





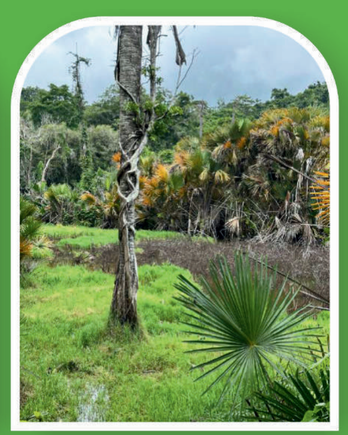
The South Malang Plateau spans 99,642 ha (112°17′–112°57′ E; 7°44′–8°26′ S) and features karst, volcanic, tectonic, and alluvial landscapes.

This area is highly vulnerable to degradation and desertification, especially in the karst region, due to poor water retention and fragile ecosystems.

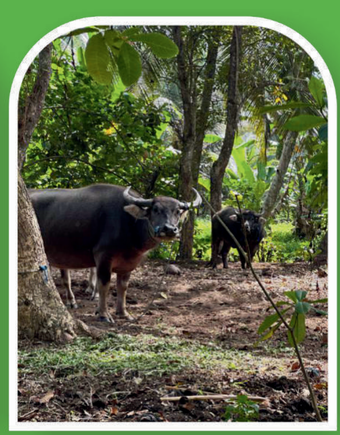
Without evidence-based interventions, environmental stress will worsen, causing ecological damage and serious socio- economic impacts on local communities that depend on natural resources.

Meanwhile... The ecosystem function

Natural Forest ~ hydrology regulation



Biodiversity Function and Buffer Zone



Animal Habitat

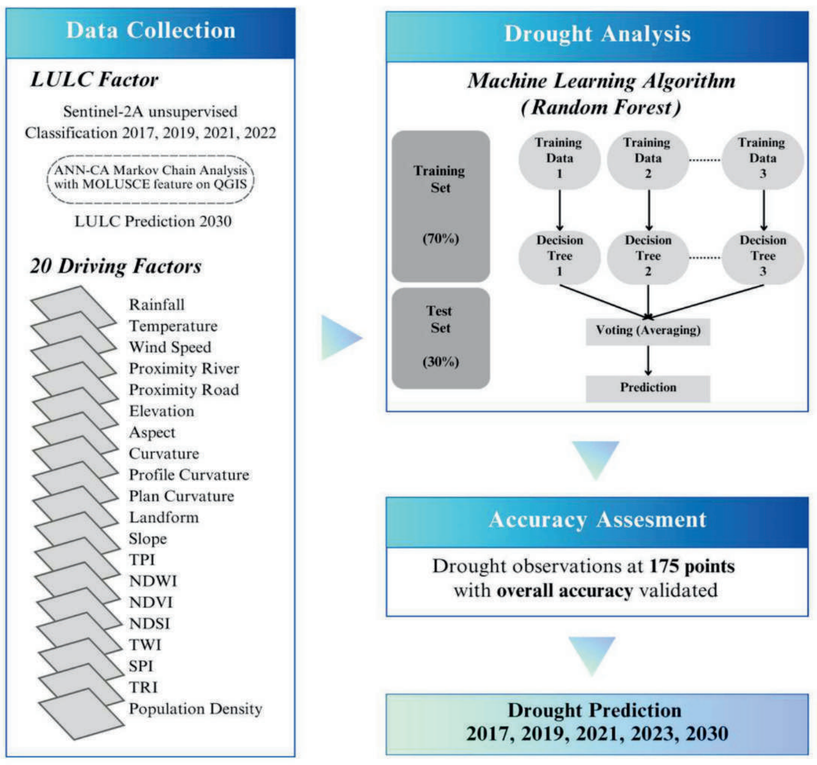
Agricultural Dry Lands

Springs Conservation

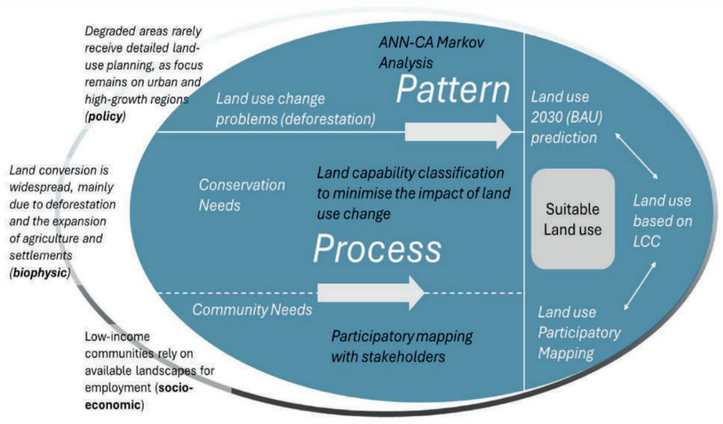
Water Usage

Agroforestry

Methodology



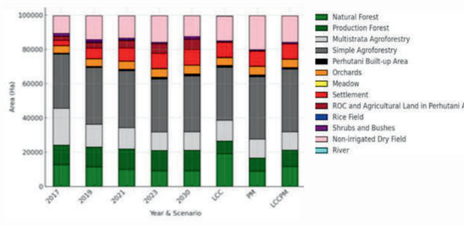
LULC Scenarios and Modelling



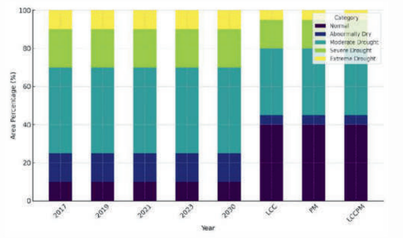
Accuracy Assessment

Accuracy: 92.57% (R^2 = 0.93; RMSE = 0.315)
Method: Random Forest with 25 variables Output: 5 drought classes (F1-score 0.97–1.00; Sensitivity ›0.95)
Validation: 45 field points confirmed high spatial match
Strengths: Robust in complex terrain, small data, multi-class
Limitations: Less reliable in different regions without local calibration

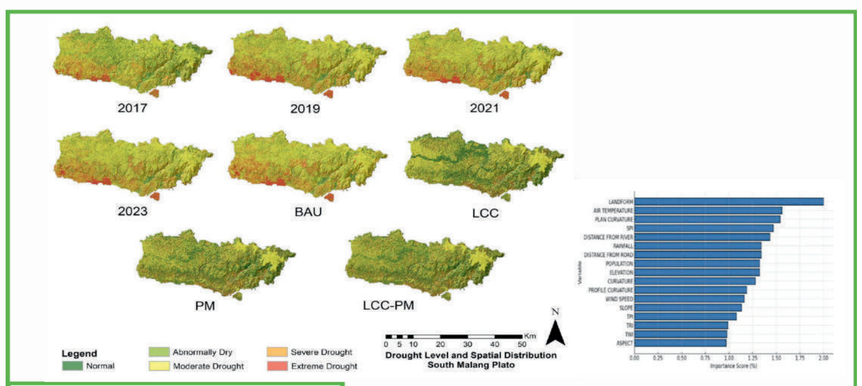
Main Findings



Natural Forest: Declined sharply (12.84% → 9.29%)
Multistrata Agroforestry: Significant decrease (21.57% → 10.79%)
Production Forest: Slight increase, relatively steady (11.40% → 11.84%)
Simple Agroforestry: Stable (≈30.95% → 30.96%)
Settlement: Rapid expansion (3.11% → 8.88%)
Perhutani Built-up Area: Gradual rise (0.51% → 1.14%) Orchards: Slight increase (4.26% → 4.84%)
ROC & Agricultural Land in Perhutani: Expanded (2.38% → 5.54%)
Rice Field: Minor growth (0.11% → 0.17%)
Non-irrigated Dry Field: Increased significantly (10.70% → 15.54%)



Severe Drought peaked at 18.1% in 2019, then dropped to 3.1% by 2030, possibly shifting to other drought types.
Extreme Drought increased steadily (6.2% in 2017 → 7.0% in 2030), indicating growing climate stress.
These trends reflect a shift toward harsher drought conditions, especially in deforested and degraded areas.
The projection aligns with land degradation theory, though it may underestimate feedback effects like soil degradation and adaptive land management.



Key Findings

- Multistrata agroforestry decreased from 21,493 Ha (2017) to 10,809 Ha (2023), and natural forest declined from 12,795 Ha to 9,255 Ha.
- Settlement areas increased significantly, from 3,096 Ha to 8,843 Ha during the same period.
- Drought severity intensified, with a noticeable reduction in “Normal” areas and expansion of “Moderate Drought” zones.
- The Business-As-Usual (BAU) 2030 scenario predicts further hydrological degradation and increased drought risk.
- The LCCPM classification method outperformed others by better capturing land-use dynamics and interactions.
- Random Forest modeling achieved 92.57% accuracy, identifying landform, air temperature, plan curvature, and SPI as key predictors.
- Effective mitigation requires integrated strategies involving forest conservation, sustainable farming, and regulated urban growth.

Conclusion

Land-use changes (2017–2023) in South Malang Plateau reduced forest cover and increased settlements/agriculture, worsening drought risk.
Drought severity shifted from “Normal” to more “Moderate Drought” zones; 2030 projection shows further decline.
LCCPM method improves land classification accuracy.
Random Forest (92.57% accuracy) identified key drought drivers: landform, temperature, curvature, SPI.
Mitigation requires forest protection, sustainable farming, and urban control. Calls for integrated land-use policy balancing ecology and development.

Aknowledgement

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