NDVI Forecasting and Afforestation Monitoring in Ethiopia

Using Baseline, CNN-LSTM, and Hybrid Multi-Input ConvLSTM Models

(we can use only the last one too , Hybrid Multi-Input ConvLSTM Models)

Description:

This project develops a progressive deep learning framework for **monitoring and predicting afforestation trends** in Ethiopia.
It starts with a **Baseline MLPRegressor model**, advances to a **CNN-LSTM model** for spatiotemporal NDVI prediction, and culminates in a **Hybrid Multi-Input ConvLSTM architecture** that integrates NDVI imagery with external environmental data (rainfall, temperature, soil moisture, and policy factors).
The system provides a complete end-to-end solution for vegetation forecasting, environmental analysis, and strategic afforestation planning — deployed via a **Streamlit app** linked to **Google Earth Engine (GEE)**.

NDVI Forecasting Project Work Plan (Professional Standard)

Phase 1: Project Definition & Planning

Step	Description	Deliverables / Outputs
1.1 Objective Definition	Clearly define the goal: *"To predict NDVI for future years based on past NDVI and environmental factors for Areas of Interest (AOIs) in Ethiopia."*	Problem statement document.
1.2 Scope & AOI Selection	Define study areas (AOIs) based on afforestation or vegetation change zones in Ethiopia. Include location details, coordinates, and data availability.	AOI selection map and metadata.
1.3 Data Source Identification	Identify NDVI and environmental datasets (MODIS, Sentinel-2, CHIRPS rainfall, ERA5 temperature, SRTM elevation).	Data inventory table with links and access notes.
1.4 Tools & Framework Setup	Set up required tools: Google Earth Engine, Python (TensorFlow/PyTorch), Jupyter Notebook, and version control (Git).	Configured environment and project repository.
1.5 Timeline & Resource Planning	Define project timeline, deliverables, and computational resources required for model training and visualization.	Project timeline (Gantt chart) and resource plan.

Phase 2: Data Acquisition & Model Development

Step	Description	Deliverables / Outputs
2.1 Data Collection	Acquire **multisource datasets** including NDVI (e.g., MODIS, Sentinel-2), climate data (rainfall, temperature), and terrain features (elevation, slope).	Raw imagery and tabular datasets (GeoTIFF, CSV, NetCDF).
2.2 Data Preprocessing	Perform **cloud masking, atmospheric correction,** and **resampling** to achieve spatial and temporal consistency. Generate annual or seasonal composites.	Cleaned and preprocessed data layers ready for analysis.
2.3 Feature Engineering	Derive additional features such as vegetation anomalies, rainfall index, and temperature deviations. Normalize or rescale all features for uniform input range.	Feature-enhanced dataset for model training.
2.4 Baseline Model Development	Build an initial **LSTM or DNN model** to predict NDVI using past NDVI values only. Evaluate baseline accuracy.	Baseline performance metrics and plots (RMSE, MAE, R^2).
2.5 CNN–LSTM Model	Develop a **CNN–LSTM** model to capture both **spatial and temporal patterns** in NDVI image sequences.	Spatiotemporal model and validation results.
2.6 Hybrid ConvLSTM Model	Integrate **multisource variables** (NDVI + climate + terrain) using **ConvLSTM architecture** for advanced forecasting. Tune hyperparameters and optimize training.	Final hybrid model with superior predictive accuracy and generalization capability.
2.7 Model Evaluation &	Compare all models (Baseline → CNN–LSTM →	Model comparison report, confusion matrices, and

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Comparison	Hybrid ConvLSTM) using statistical and visual metrics. Select the best-performing model.	performance dashboard.

Phase 3: Model Deployment & Visualization

Step	Description	Deliverables / Outputs
3.1 Model Export & Integration	Save the trained hybrid ConvLSTM model and integrate it into a Python-based or cloud-hosted application (e.g., Flask, Streamlit, or Google Earth Engine API).	Deployed prediction model ready for execution.
3.2 Prediction Generation	Use the deployed model to forecast NDVI for future years (e.g., 2025–2030). Generate spatial NDVI maps and time-series outputs.	Forecasted NDVI raster layers and CSV files.
3.3 Spatial Visualization	Visualize NDVI predictions through interactive maps, overlays, or dashboards (e.g., Folium, Kepler.gl, or Mapbox). Include AOI boundaries and vegetation classes.	Interactive NDVI forecast map and visualization dashboard.
3.4 Temporal Trend Analysis	Analyze NDVI trends across years and regions to identify greening or degradation patterns. Highlight potential afforestation zones.	NDVI trend graphs, zonal statistics, and comparative analysis reports.
3.5 Validation & Ground Truth Comparison	Compare forecasted NDVI values with observed satellite data or field measurements to assess accuracy.	Validation report with error analysis (RMSE, correlation).
3.6 Reporting & Documentation	Compile the full workflow, results, and interpretations into a final report and	Final technical report, documentation, and

Step	Description	Deliverables / Outputs
	presentation (including visuals and methodology).	presentation slides.

Phase 4: Results Interpretation & Policy Implications

Step	Description	Deliverables / Outputs
4.1 Interpretation of Model Results	Analyze the spatial and temporal patterns from NDVI forecasts to identify regions showing significant greening or degradation. Interpret results in the context of local land use and climate factors.	Analytical summary highlighting NDVI change patterns and their drivers.
4.2 Afforestation Assessment	Evaluate the effectiveness of afforestation initiatives within the Areas of Interest (AOIs). Identify newly established vegetation zones and quantify NDVI improvements.	Afforestation impact assessment maps and quantitative metrics.
4.3 Environmental Insights	Relate NDVI dynamics to environmental variables such as rainfall and temperature trends. Discuss implications for ecosystem health and carbon sequestration.	Correlation analysis and ecological insight report.
4.4 Policy and Planning Recommendations	Translate model findings into actionable insights for decision-makers, NGOs, and environmental planners. Suggest data-driven strategies for reforestation and land management.	Policy recommendation brief and strategic guidelines.
4.5 Stakeholder Communication	Prepare communication materials (visuals, maps, dashboards, reports) to share with government	Stakeholder-ready infographics, summary

Step	Description	Deliverables / Outputs
	agencies, local communities, and research institutions.	briefs, and outreach content.
4.6 Future Work and Model Extension	Recommend future improvements such as higher temporal resolution data, inclusion of soil or socio-economic factors, and integration with real-time monitoring systems.	Future roadmap document and research extension plan.

✅ **Summary:**
This four-phase plan ensures a complete professional workflow — from **data acquisition** and **modeling** to **policy-relevant insights** — supporting Ethiopia's afforestation and environmental monitoring goals through advanced NDVI forecasting.