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Automating a near real-time satellite rainfall pipeline for digital pastoralist decision support app

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Abstract

Timely and accessible climate information is critical for pastoralist communities operating in highly variable dryland environments. This study presents the design and implementation of an automated, near real-time rainfall data pipeline that integrates satellite-derived precipitation data into a decision support application tailored for pastoralists in selected areas in Kenya and Namibia. The system leverages dekadal rainfall estimates from the TAMSAT dataset, distributed in NetCDF format. A Python-based backend pipeline was developed to automatically retrieve newly released datasets upon availability (published every ten days) and store them on a dedicated server hosted at the University of Kassel. To optimise data transfer and usability within web and mobile environments, a Python script is used as a secondary processing step to convert the NetCDF files into GeoJSON format, significantly reducing data size while preserving spatial structure. The processed rainfall data are then made available through an API endpoint, enabling seamless integration with the frontend of the InfoRange application, a pastoralist decision support app. Within the user interface, rainfall patterns are visualised as blue-shaded rasterized polygons over a predefined bounding boxes encompassing the target areas in Kenya and Namibia. This approach ensures complete spatial coverage despite irregular administrative boundaries. The rainfall module represents one component of a broader pastoralist decision support system that integrates multiple data streams; however, this work focuses specifically on the backend architecture, data transformation workflow, and frontend integration of satellite-derived rainfall information. The proposed pipeline demonstrates how automated geospatial data processing and lightweight data formats can enhance the timeliness and accessibility of climate information services in data-scarce regions. The system is scalable and adaptable to other geographic contexts and environmental variables, offering a practical framework for strengthening climate resilience among pastoralist communities.

Keywords: API, digitalization, geospatial data processing, mobile app, near real-time pipeline, pastoralism, satellite-derived rainfall data

Introduction

Pastoralist communities in arid and semi-arid regions are highly vulnerable to rainfall variability and drought [1,2], making timely climate information essential for decision-making related to grazing mobility, water access, and livestock management. This is particularly evident across pastoral landscapes in East and Southern Africa, such as Marsabit County in northern Kenya and key pastoral zones in Namibia—including Omaheke and Kavango East regions—which face severe climatic unpredictability and pasture deficits [3,4,5,6]. While limited access to operational climate systems constrains how pastoralists adapt to environmental shifts, recent advances in satellite rainfall products and mobile technologies offer clear opportunities to improve data delivery in these data-scarce regions.

To address this gap, this study presents an automated, near real-time rainfall data pipeline integrated into the InfoRange mobile application—a digital decision support tool that merges environmental observatory data with localized, user-generated ecological insights to guide field-level livestock and resource management [7]. Within this framework, we detail the complete technical architecture, spanning automated data import, geospatial processing, and user-interface mapping, required to operationalize satellite-derived rainfall data for active deployment.

Table 1. Comparison of NetCDF and GeoJSON formats within the rainfall data processing pipeline.

Aspect	NetCDF	GeoJSON
Purpose	Scientific multidimensional data storage	Lightweight geospatial visualization
Structure	Raster/grid-based	JSON vector format
Use in this study	Raw TAMSAT rainfall storage	Mobile app rainfall display
File size	Large	Smaller
Processing	Requires scientific libraries	Web/mobile compatible
Frontend use	Limited direct rendering	Efficient frontend rendering
Data transfer	Higher bandwidth demand	Low-bandwidth friendly
Pipeline role	Backend processing	API and frontend delivery

Material and Methods

Dekadal rainfall estimates from the TAMSAT (Tropical Applications of Meteorology using SATellite data and ground-based observations) dataset were used as the primary rainfall source [8]. TAMSAT was selected because it provides spatially continuous, long-term climate data specifically optimized for African data-scarce dryland environments. While TAMSAT offers rainfall products at daily, pentadal (5-day), dekadal (10-day), and monthly temporal resolutions, this system specifically leverages the dekadal estimates. A 10-day interval was selected as the optimal temporal scale for pastoralist decision making, providing a meaningful balance between tracking short-term weather anomalies and long-term seasonal trends without overwhelming users with daily fluctuations. These datasets are released every ten days in NetCDF format—a multidimensional scientific data format designed for efficient storage and access of array-based data, commonly used for representing geospatial and climate variables structured along dimensions such as time, latitude, and longitude [9]. To manage the incoming data, a Python-based backend pipeline was developed to automatically retrieve newly released datasets upon availability and store them on a dedicated server hosted at the University of Kassel.

Because NetCDF files are relatively large and optimized for scientific analysis rather than lightweight mobile delivery, an additional Python processing script was implemented to convert the rainfall layers into GeoJSON format—a lightweight, JSON-based geospatial format for representing geographic features and their non-spatial attributes as key–value pairs [9]. The conversion reduced data size and improved compatibility with web and mobile visualization environments while preserving the spatial structure of rainfall information. Table 1 summarizes key differences between the two data formats.

Processed rainfall data were subsequently exposed via a backend service for integration into the InfoRange system architecture, allowing downstream components to manage and visualize the data. In the mobile application, rainfall conditions are displayed as blue-shaded polygons across predefined bounding boxes covering Kenya's Marsabit County and parts of Namibia's Omaheke, Kavango West and East, and Otjozondjupa regions. Fig. 1 illustrates the overall system architecture and data workflow from satellite acquisition to end-user visualization.

Results and Discussion

The developed workflow enabled the automated integration of newly released TAMSAT rainfall datasets into the mobile application with minimal manual intervention. The pipeline successfully automated data acquisition, storage, processing, and API delivery, thereby improving the timeliness of rainfall information availability within the application.

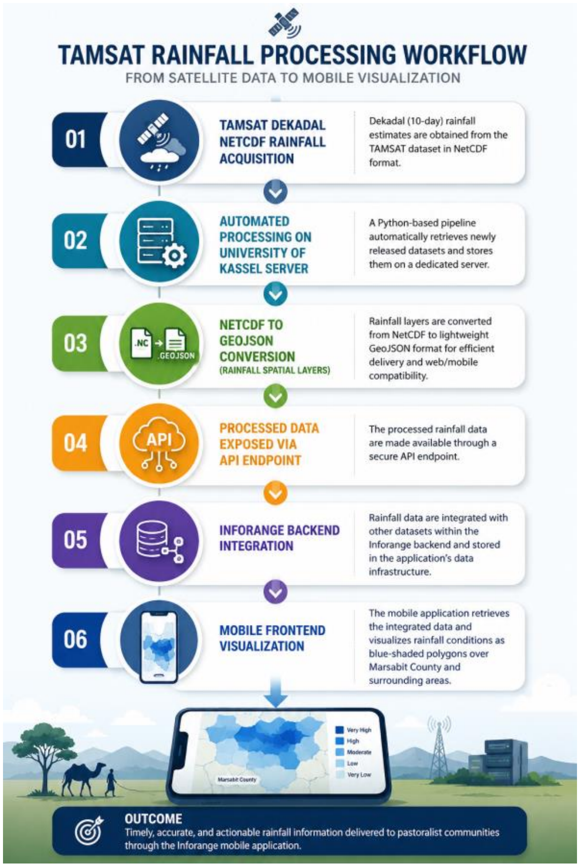

Fig. 1. Automated rainfall data pipeline from satellite acquisition to mobile application visualization.

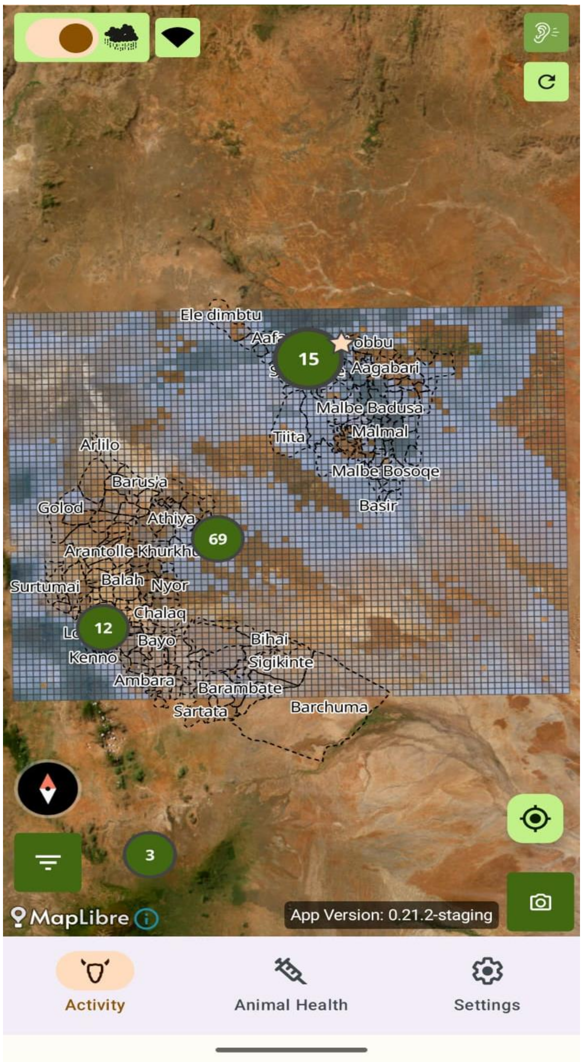

Fig. 2. Rainfall visualization interface in the Inforange mobile application for Marsabit County and surrounding areas.

The conversion from NetCDF to GeoJSON substantially improved frontend usability and reduced data transfer requirements, which is particularly important in regions with limited internet connectivity and mobile bandwidth constraints. The GeoJSON outputs were efficiently rendered in the application as spatial rainfall overlays, allowing users to visualize rainfall distribution patterns across regions of interest. Fig. 2 illustrates the rainfall visualization interface within the InfoRange mobile application, displaying blue-shaded spatial overlays covering Marsabit County and surrounding areas (Namibian regions are not displayed for conciseness).

Integrating satellite-derived rainfall information into a mobile platform highlights the value of digital tools for pastoral climate services. While evaluated on rainfall, this extensible framework can easily adapt to other environmental datasets and regions.

Conclusion

This study demonstrated the feasibility of automating a near real-time satellite rainfall data pipeline for a digital pastoralist decision support mobile application. The workflow combined automated retrieval of TAMSAT rainfall products, geospatial data transformation, API-based delivery, and mobile visualization within an operational system. The approach contributes to improving the accessibility and timeliness of climate information services for pastoral communities and provides a scalable framework for future digital climate service applications in dryland regions.

Declaration of AI use

AI tools were used only for language editing and structuring. The authors reviewed all content and accept full responsibility for the final manuscript.

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