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C2R-CD
Coastal Community Resilience to Climate and Diarrhoea

UNIVERSITY OF GHANA
INSTITUTE FOR ENVIRONMENT AND SANITATION STUDIES (IESS)

The Coastal Communities Resilience to Climate and Diarrhoea Project (C2R - CD) *https://www.c2rcdproject.com/*

ASSESSING THE IMPACT OF SEA LEVEL RISE, PRECIPITATION AND SUBSIDENCE ON FLOODING TRENDS IN COASTAL COMMUNITIES IN GHANA

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PRESENTATION OUTLINE

- Overview
- Results
- Conclusion and Recommendation

Introduction

- ❑ Coastal zones are highly vulnerable to changes due to the effects of climate change and SLR (Shepard *et al.*, 2012). [SLR NOAA 3.6mm/yr]

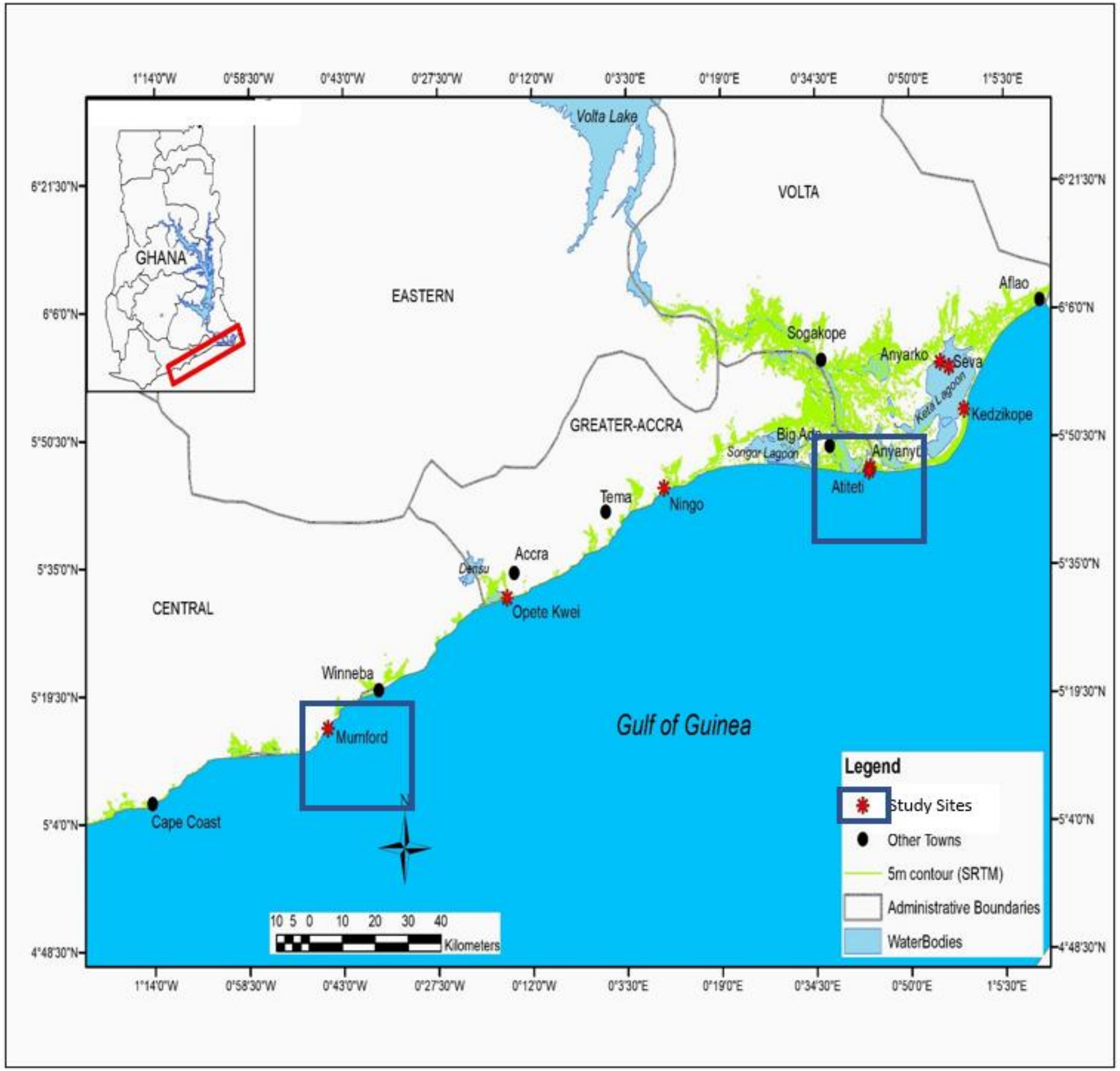
- ❑ Notable threats include flooding and erosion due to e.g. sea level rise (Shepard *et al.*, 2012), modified sediment budget flows

Fig 1: Coastal zone

Introduction

- This research aims to use numerical model and climatic data sets to assess the role of the biophysical environment, including impacts of climate change and SLR on the incidence of flooding and coastal erosion.

- Objectives
  - ✓ To estimate short and mid-term shoreline evolution dynamics
  - ✓ To estimate the effect of SLR and RSLR on the study sites
  - ✓ Predict future flooding scenarios under different precipitation conditions.



The study sites are:

- Mumford (in the Gomoa West District)

(05°15.653’ N and 000°45.373’ W)

- Fuvemeh and Atiteti (in the Anloga District)

(5°46'23.72"N and 0°42'4.73"E)

Study Area

Plate 3: A video showing site A (Mumford)

Plate 4: A video showing site B (Atiteti)

OBJECTIVE 1- Short & midterm shoreline evolution dynamics

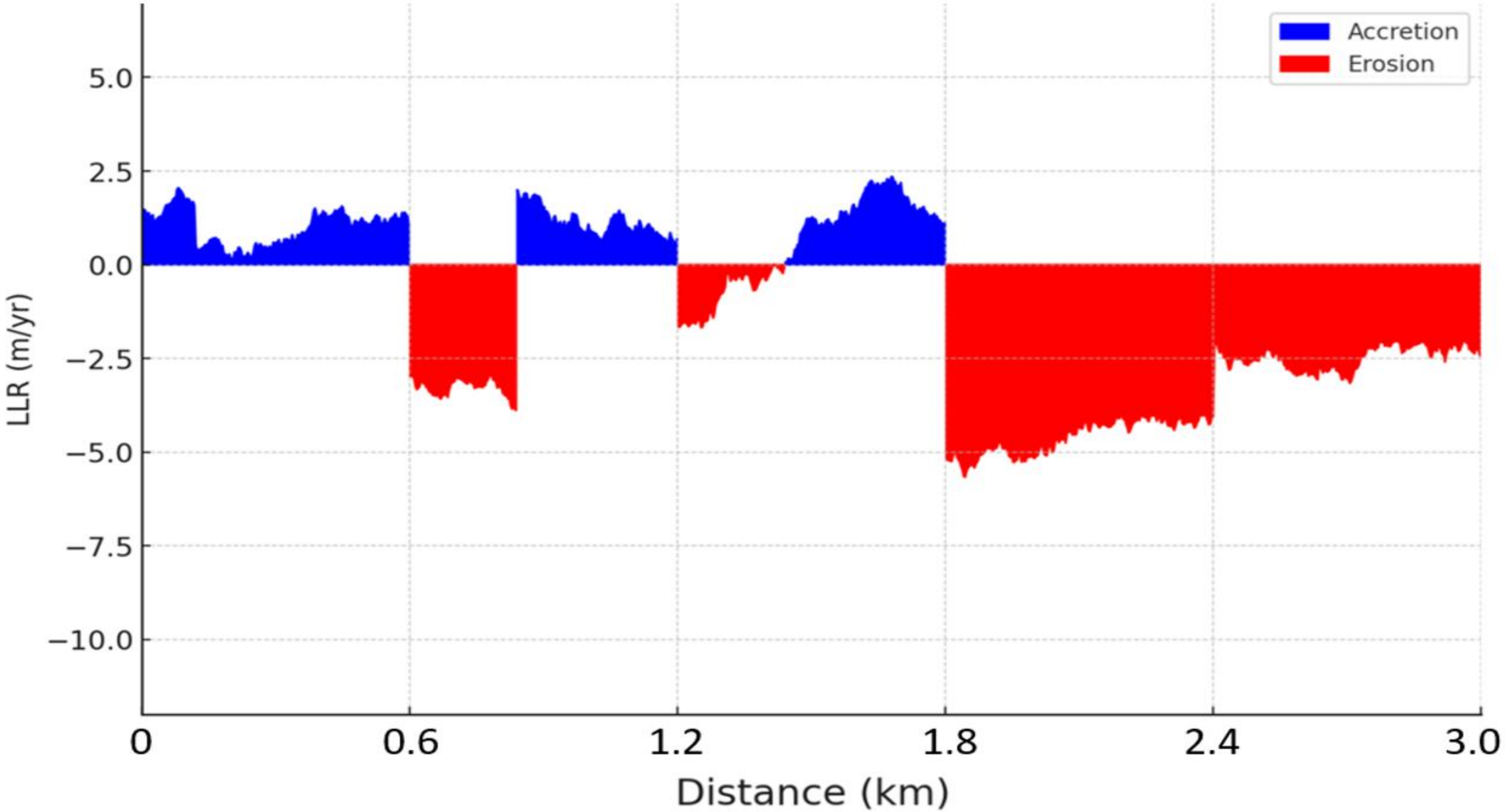


Figure 1- Shoreline LRR calculations for Mumford for 2021 to 2023

rocks

erosion

Plate 5:An image showing part of the Mumford coastline with the new landing site

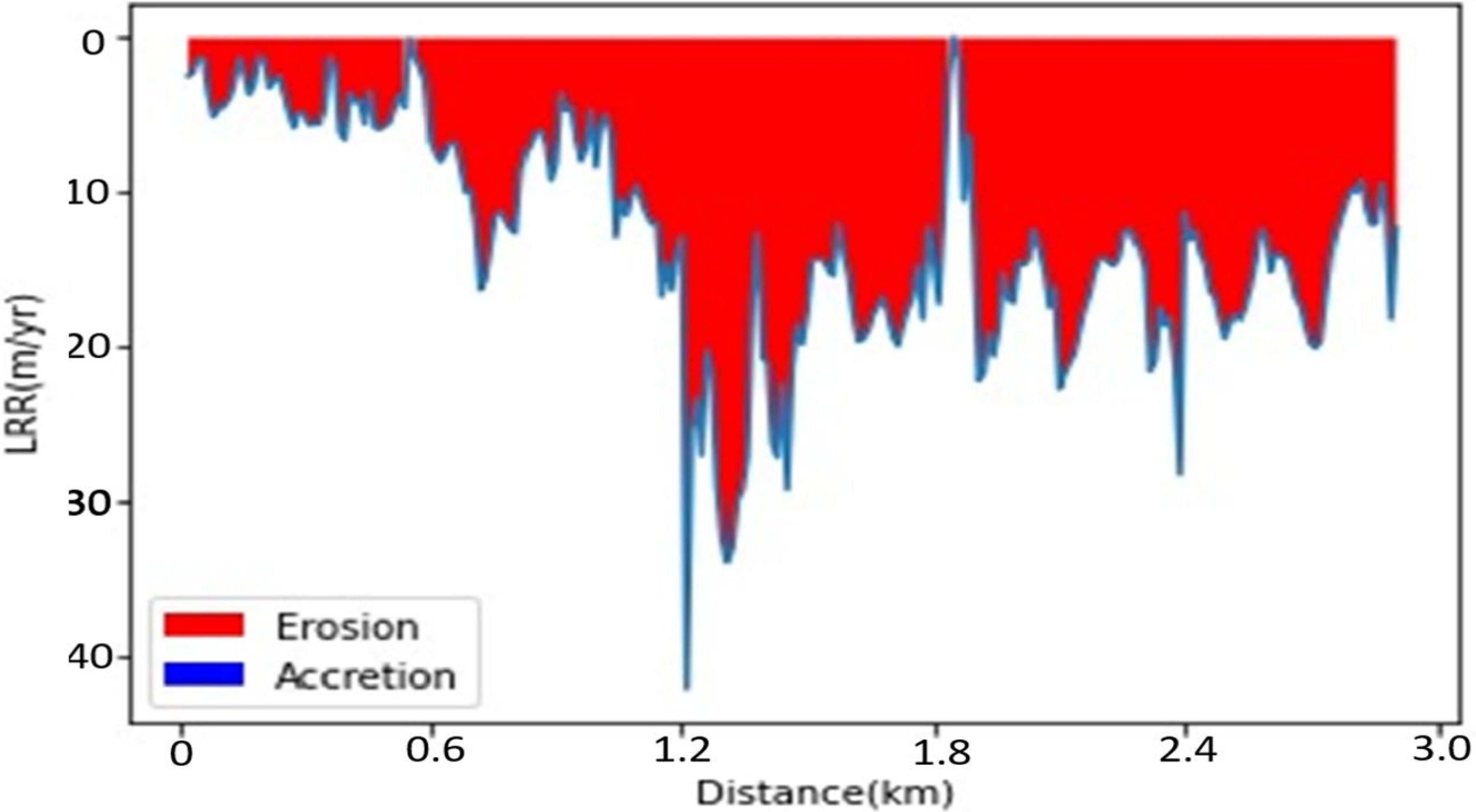


Figure 2- Shoreline LRR calculations for Atiteti for 2021 to 2023

Short & midterm shoreline evolution dynamics

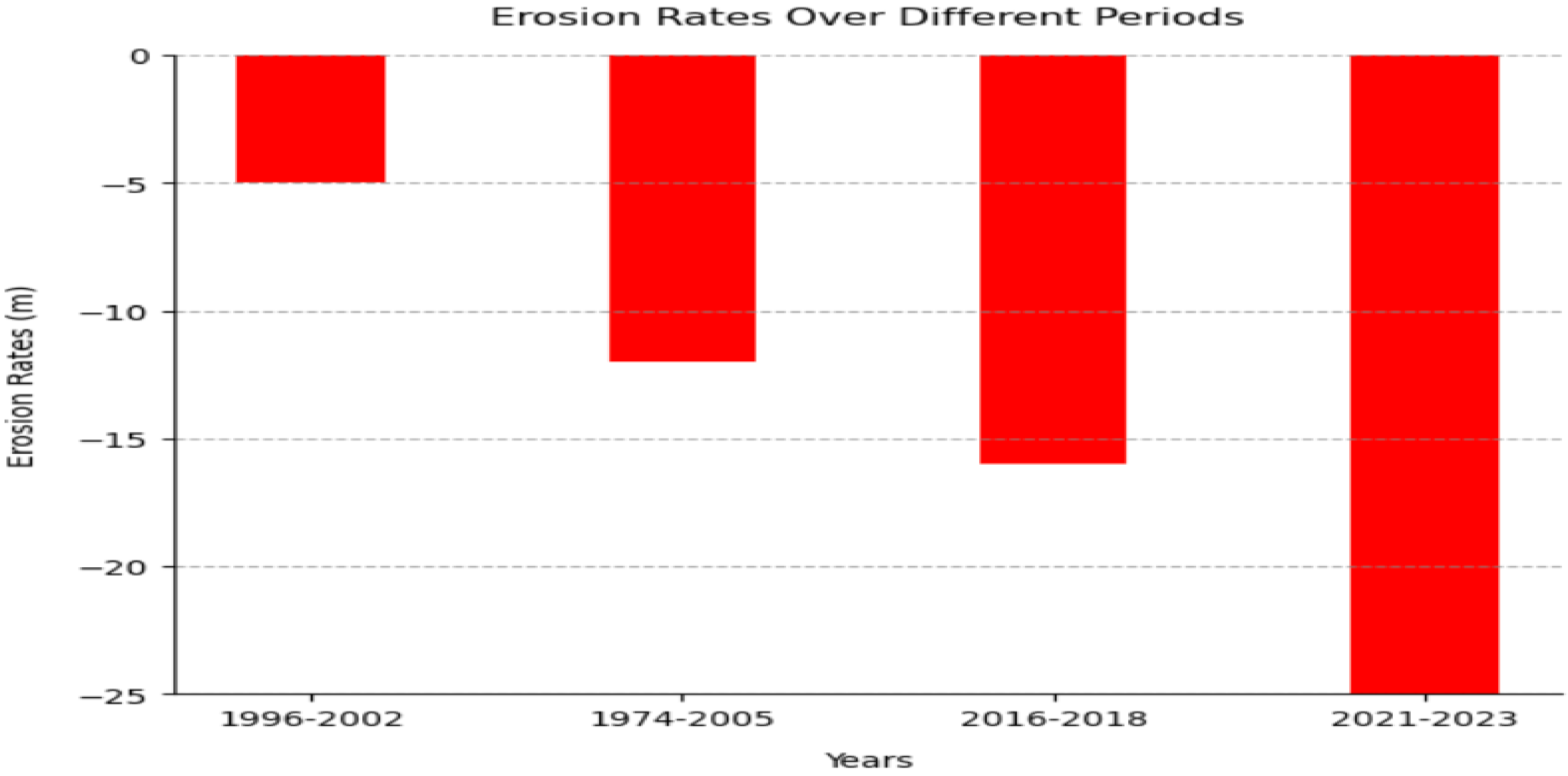


Figure 3: Shows the erosion trends for Atiteti from 1974 to 2023

Plate 6: An image showing the Ghana water pipeline in August 2013

Plate 7: An image showing the Ghana water pipeline in March 2022

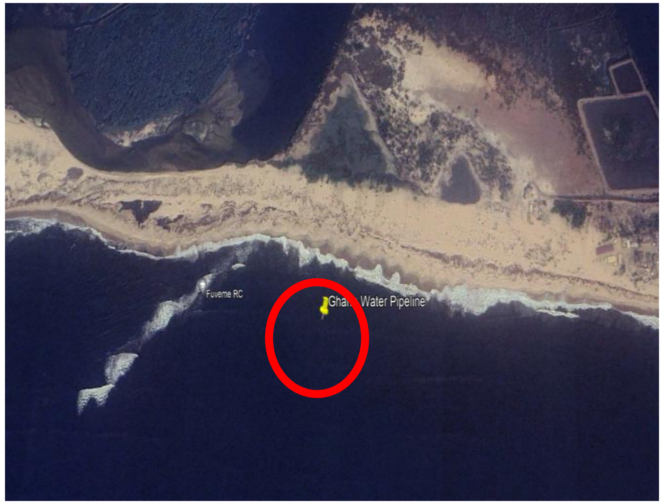


Plate 8: An image showing the Ghana water pipeline in July 2024

Plate 9: A gif showing the Ghana water pipeline in April 2022

Plate 10: An image showing coastal erosion in Fuvemeh

OBJECTIVE 2- Flooding Scenarios with SLR/rSLR

- ❑ Coastal zones are highly vulnerable to changes due to the effects of climate change and SLR (Shepard *et al.*, 2012). [SLR NOAA 3.6mm/yr]

- ❑ Notable threats include flooding and erosion due to e.g. sea level rise (Shepard *et al.*, 2012)

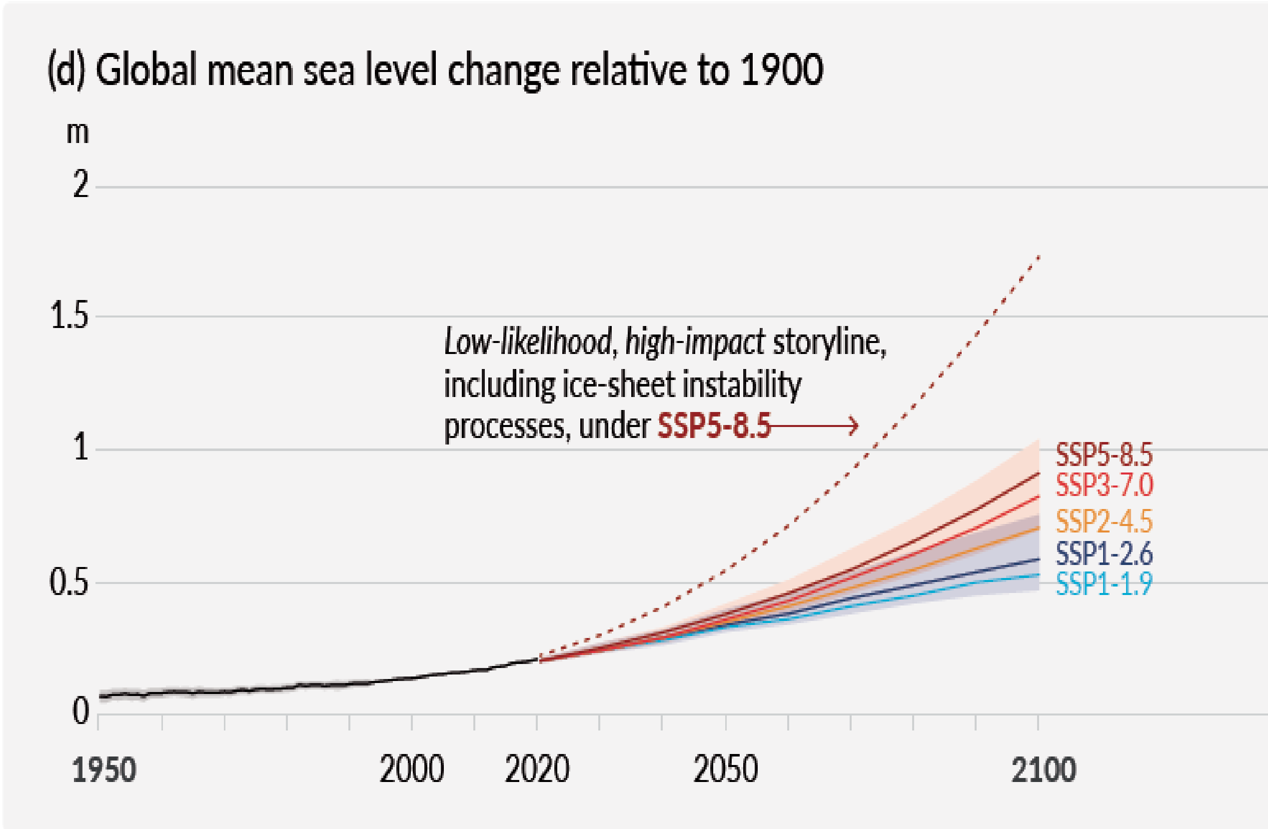
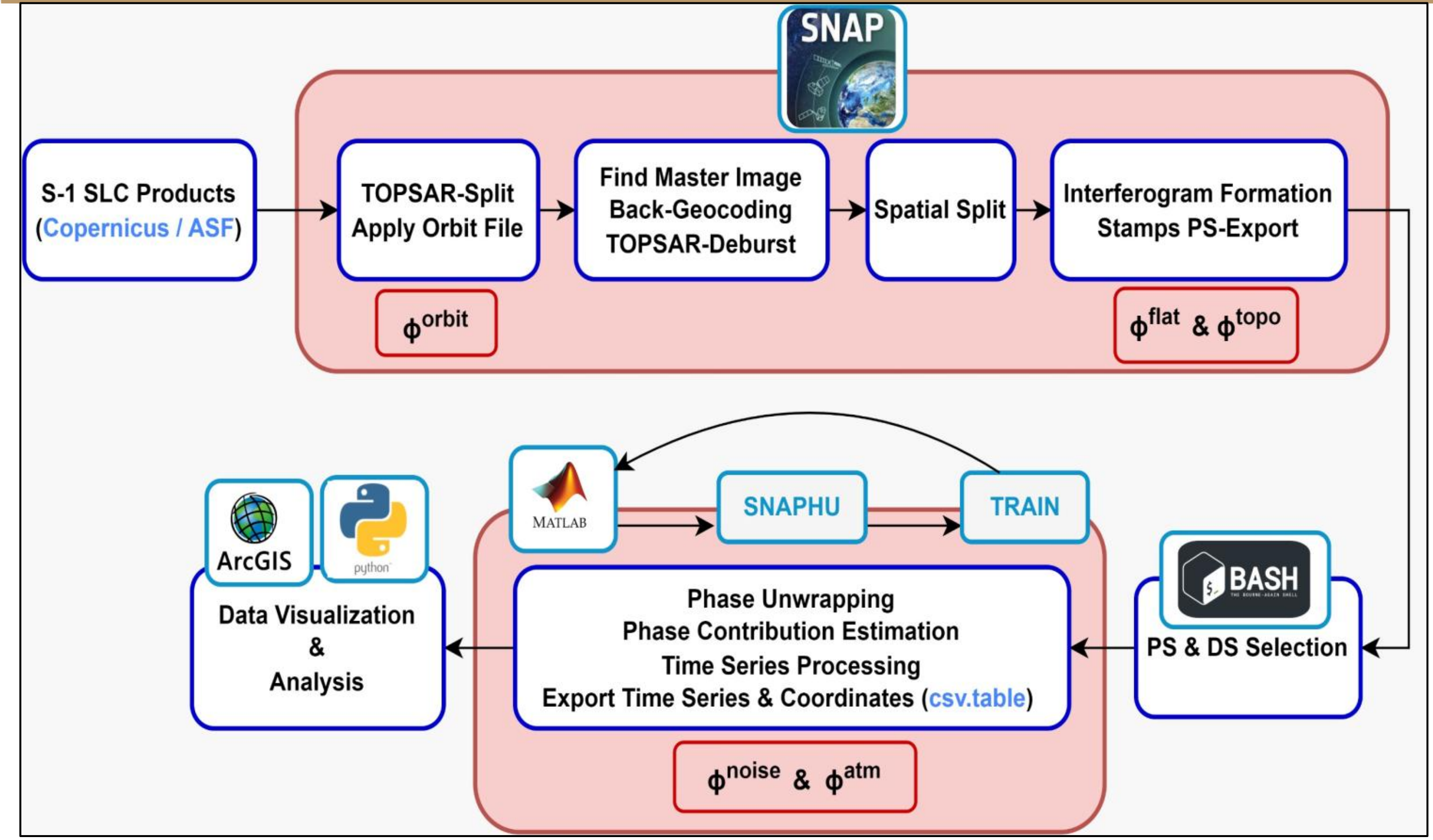


Plate 11: A drone image of an active storm in Fuvemeh in 2015 (video credit: M. Kwame- Biney

OBJECTIVE 2- Flooding Scenarios with SLR/rSLR



(Avornyo *et al*., 2024)

Workflow for PS-InSAR with corresponding software packages and the various phase contributions removed at each step

Assumptions for the extrapolation of values for the future InSar values (Ciro Aucelli *et al*, 2017)

- ❑ No horizontal movement
- ❑ Linearity of deformation values (VGD)

ATTITETI

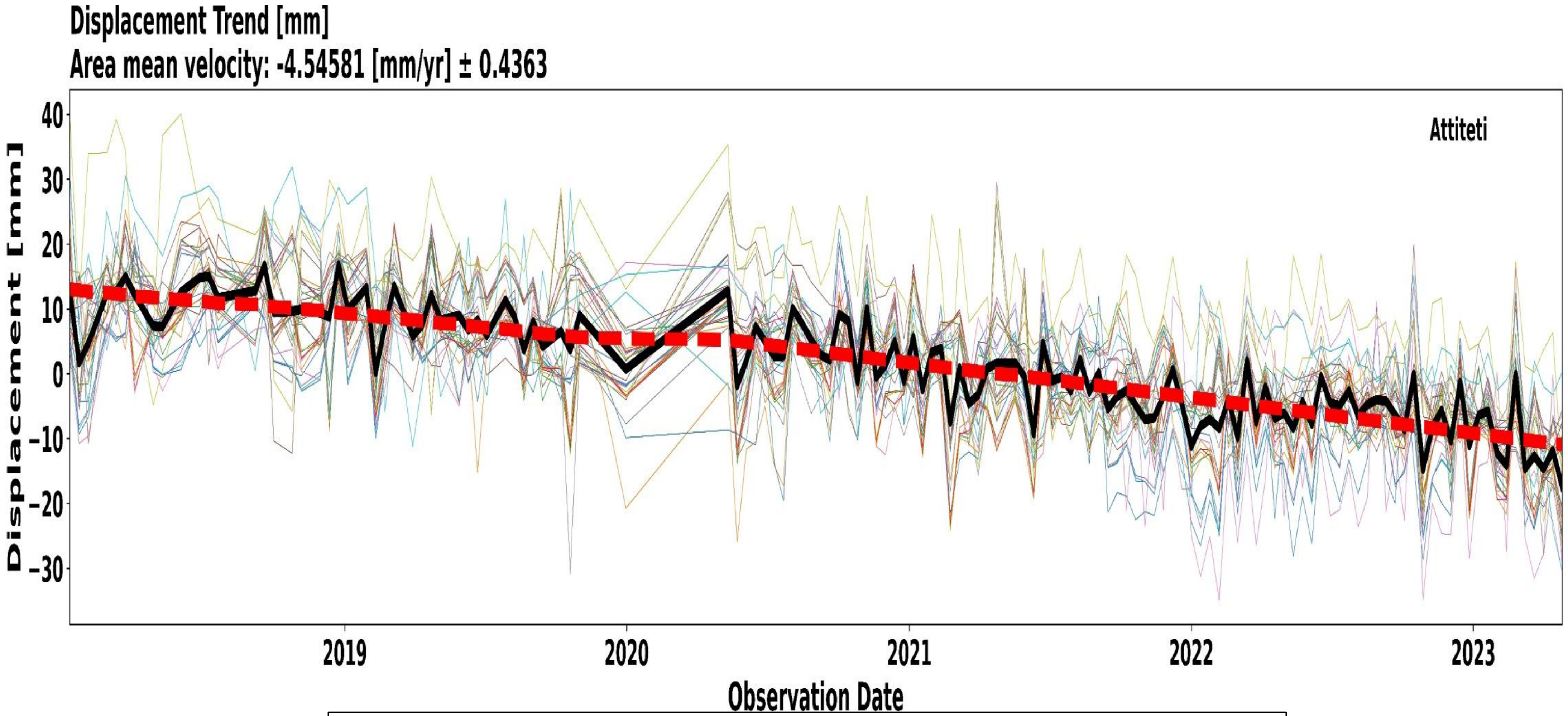


Figure 4: Shows VLM trend in Atiteti for a 6 year period

MUMFORD

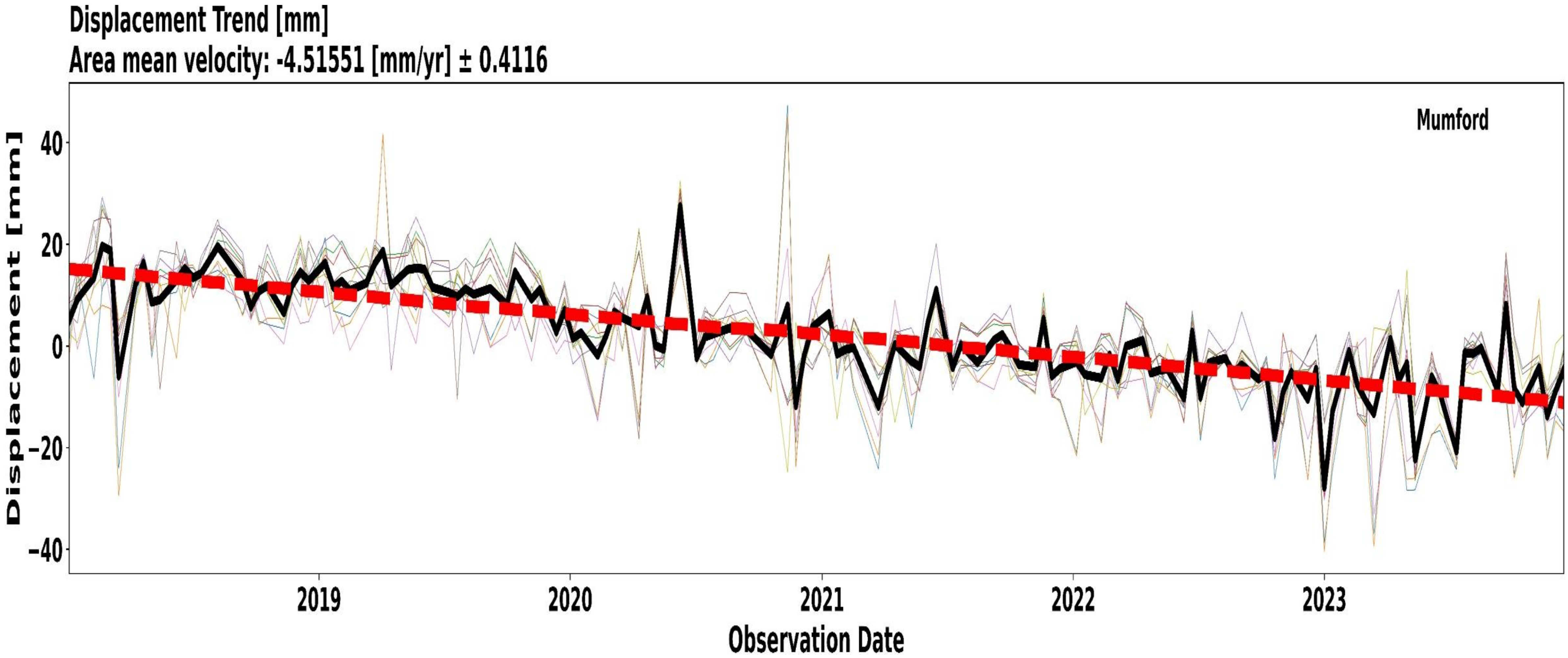
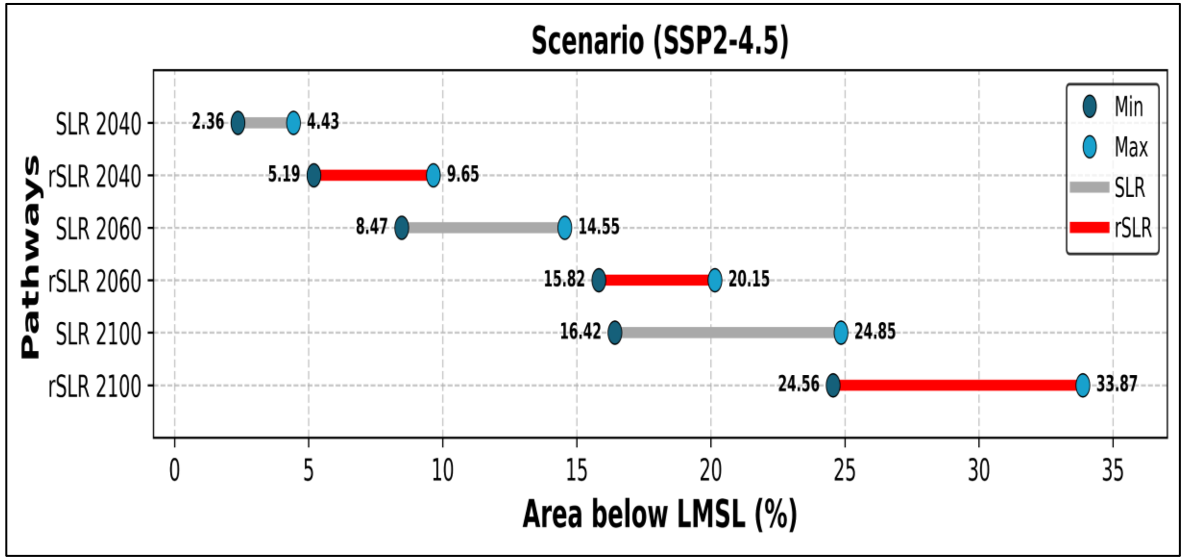


Figure 5: Shows VLM trend in Mumford for a 6 year period

Flooding Scenarios with SLR/rSLR (Mumford)



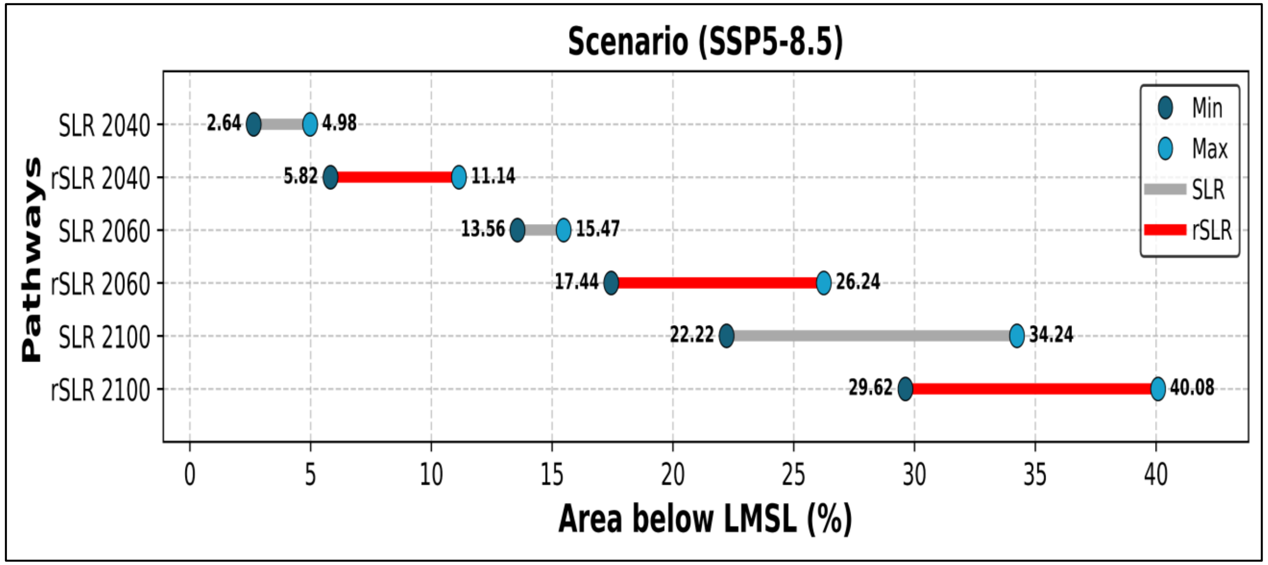
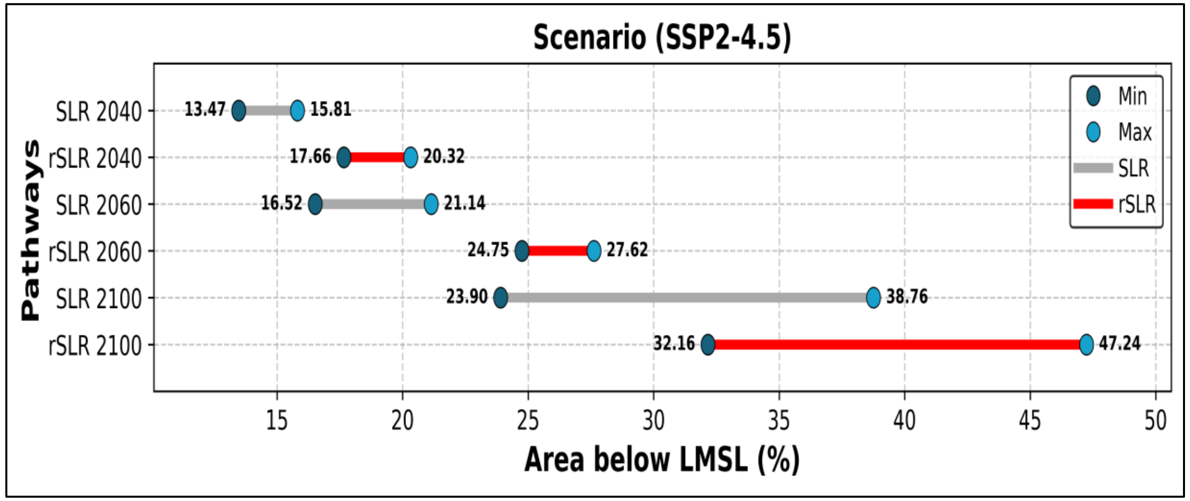


Figure 6: A graph showing projections of areas (%) below LMSL for projected SLR and RSLR pathways under the SSP2-4.5 and SSP5-8.5 scenarios.

Flooding Scenarios with SLR/rSLR (Atiteti)



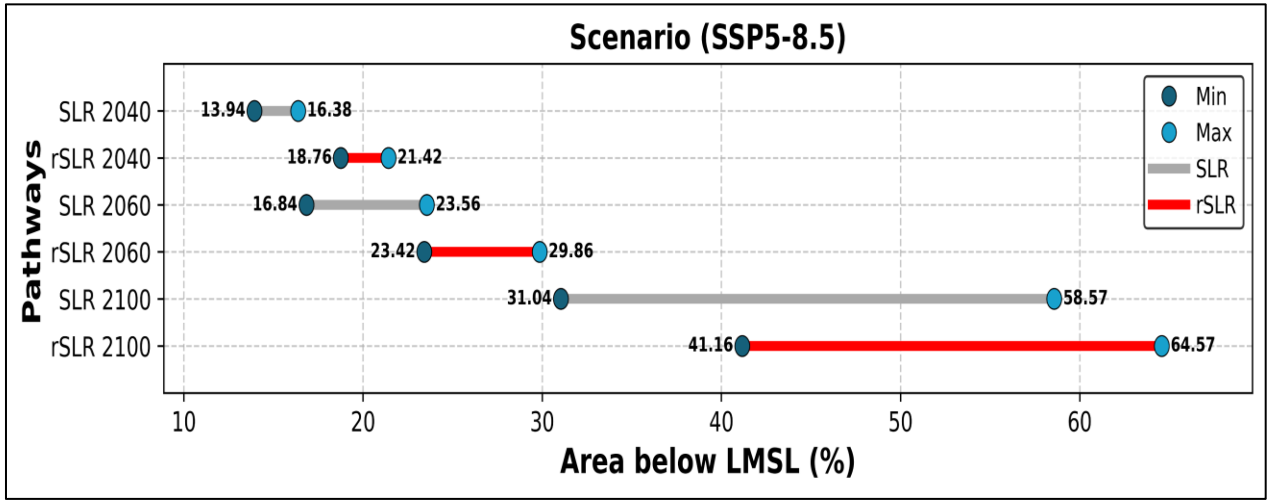


Figure 7: A graph showing projections of areas (%) below LMSL for projected SLR and RSLR pathways under the SSP2-4.5 and SSP5-8.5 scenarios

OBJECTIVE 3- Flooding Scenarios from Precipitation

- ❑ The Malstrøm model, developed by T. Balstrøm and D. Crawford, is a 1D hydrologic model designed for flooding scenarios.

- ❑ This model uses high-resolution digital surface models (DSMs) to analyze water flow and identify potential flood areas, also known as "bluespots."

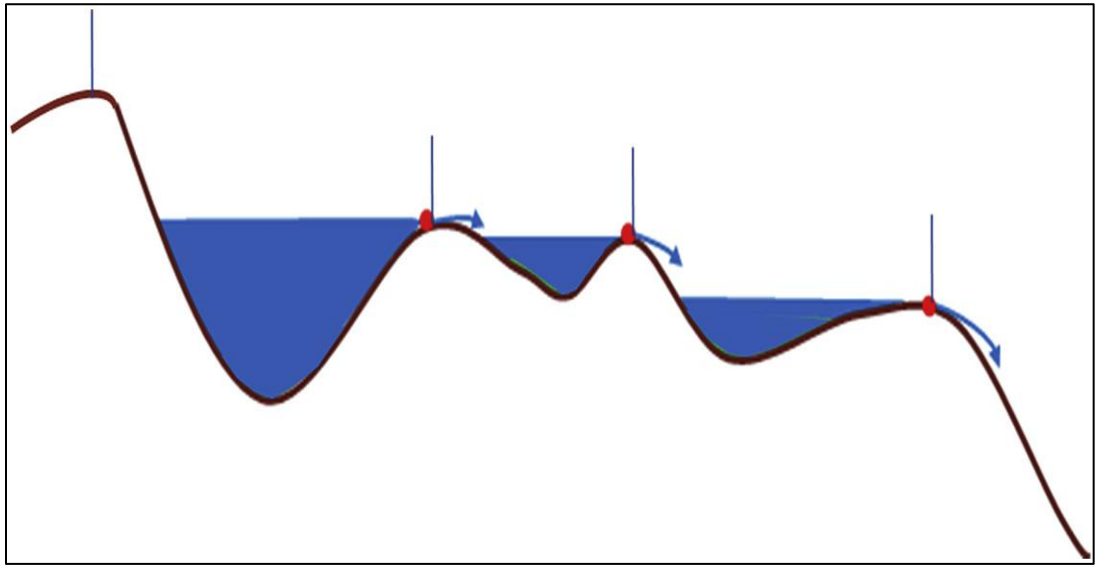


Figure 18: An illustration of the flow pattern from malstroem model

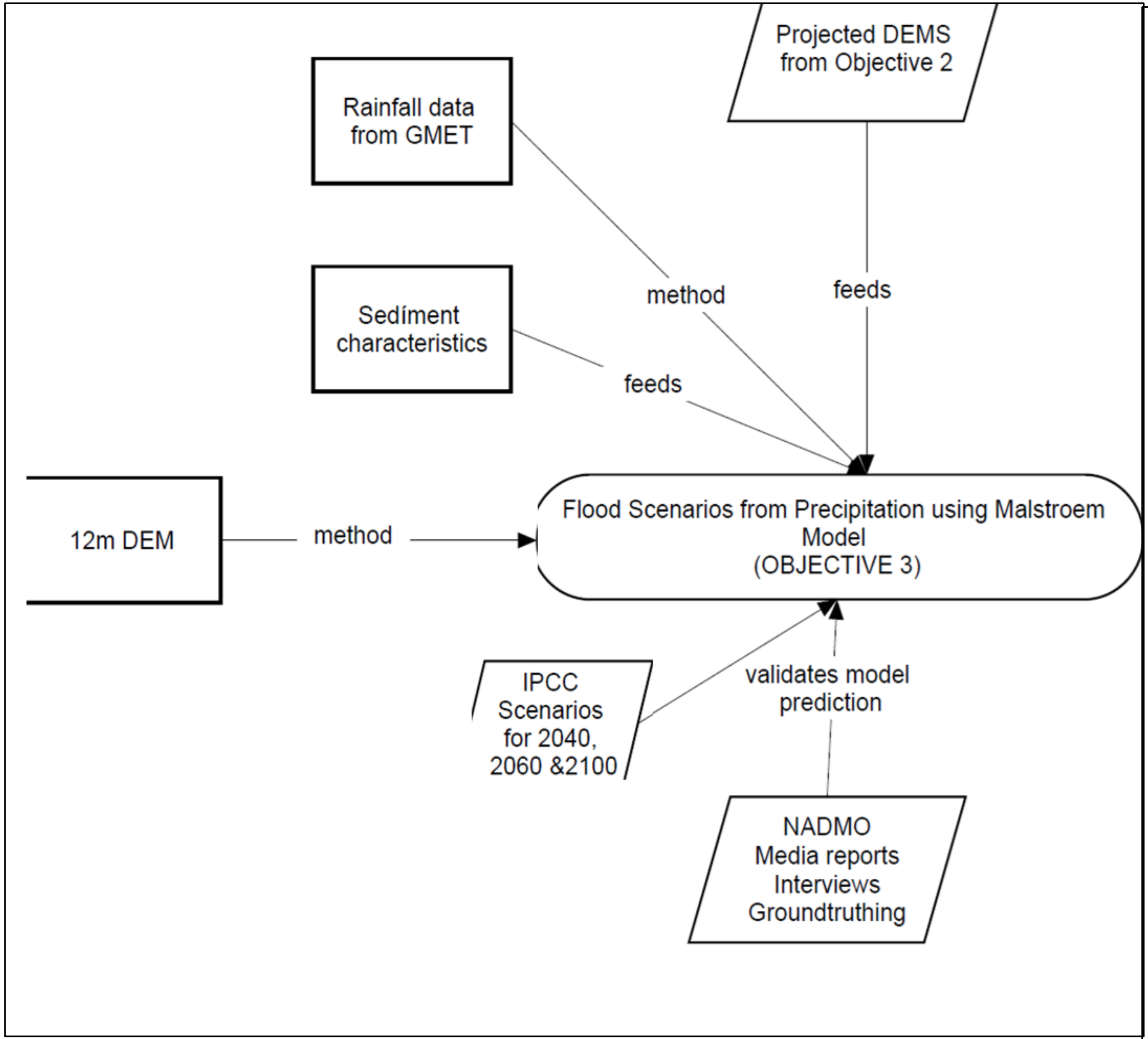


Figure 8: Concept for malstroem model

1. Water Accumulation (W_accum):

$$\text{Waccum} = \sum(R - I - E) \ldots\ldots\ldots (1)$$

Where;

- R is the rainfall input
- I is the infiltration (assumed to be zero for impermeable surfaces)
- E is the evaporation (often negligible in short-term events)

2. Flow Path (F_path):

$$\text{Fpath} = f(DTM, B, R, S) \ldots\ldots\ldots (2)$$

Where;

- DTM is the digital terrain model data
- B represents building and other structures
- R is the road network data
- S are the streams and channels
-

3. Bluespot Identification (B_spot):

$$Bspot = Identify(Waccum, Fpath) \ldots\ldots\ldots (3)$$

4. Spillover Calculation (S_spill):

$$\text{Sspill} = \sum(Bspot, overflow\ paths) \ldots\ldots\ldots (4)$$

Flooding Scenarios from Precipitation (Mumford)

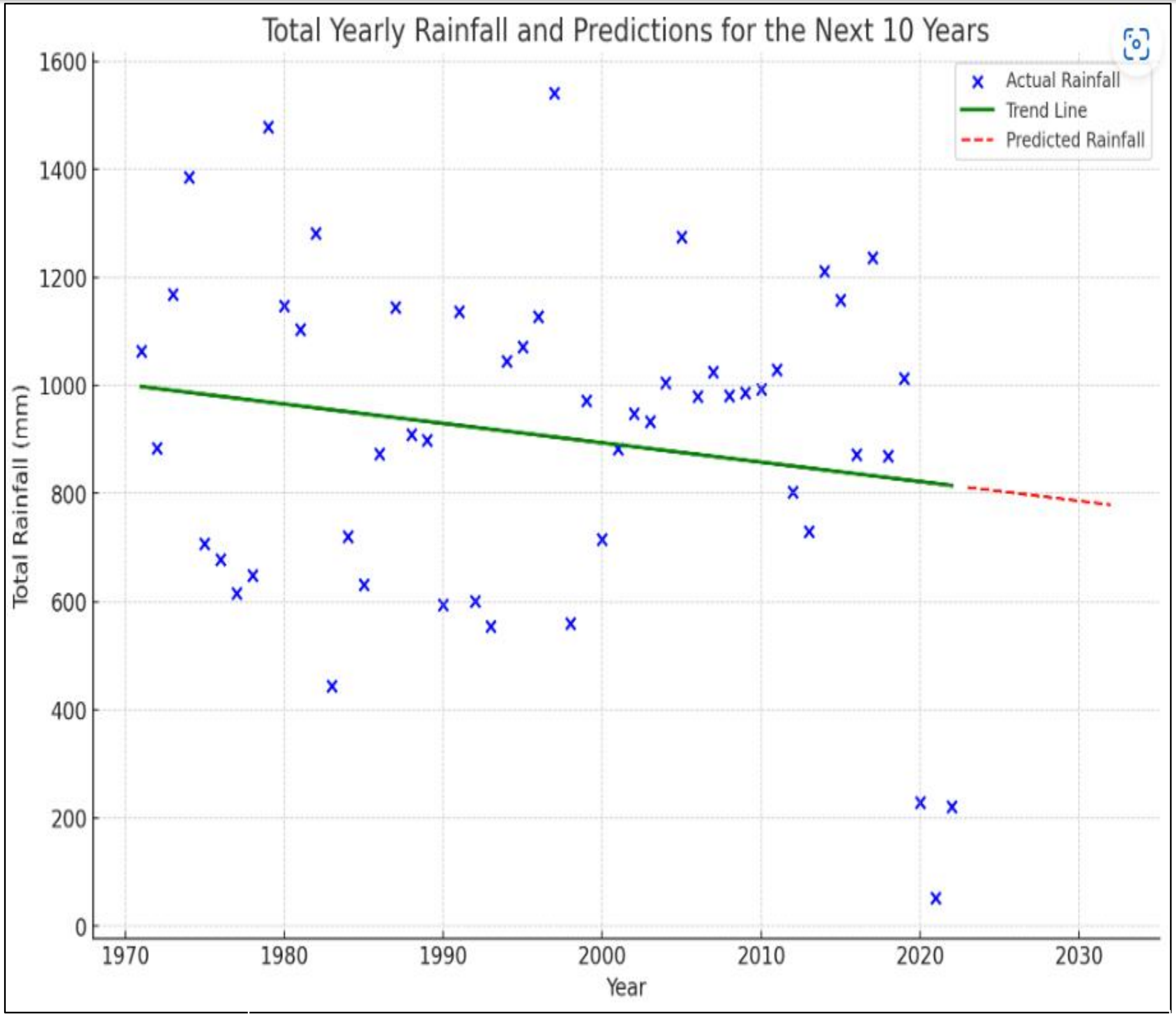


Figure 9: Rainfall trend from 1971 to 2021

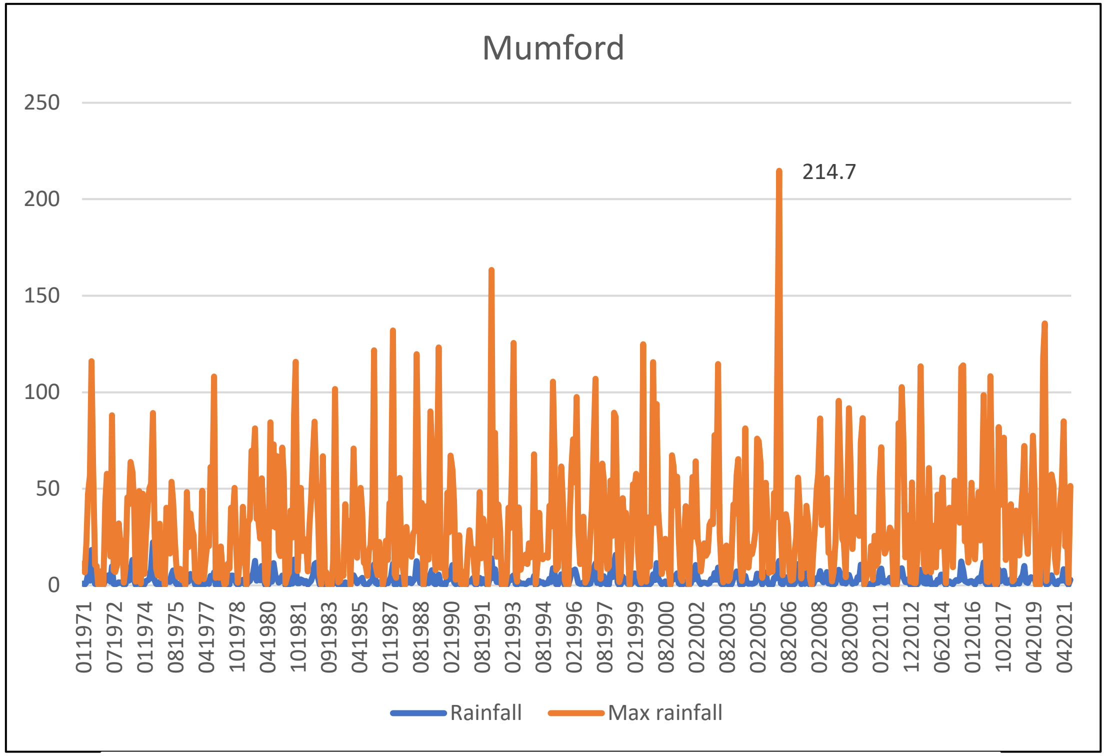


Figure 10: Max daily rainfall in mm

Flooding Scenarios from Precipitation (Atiteti)

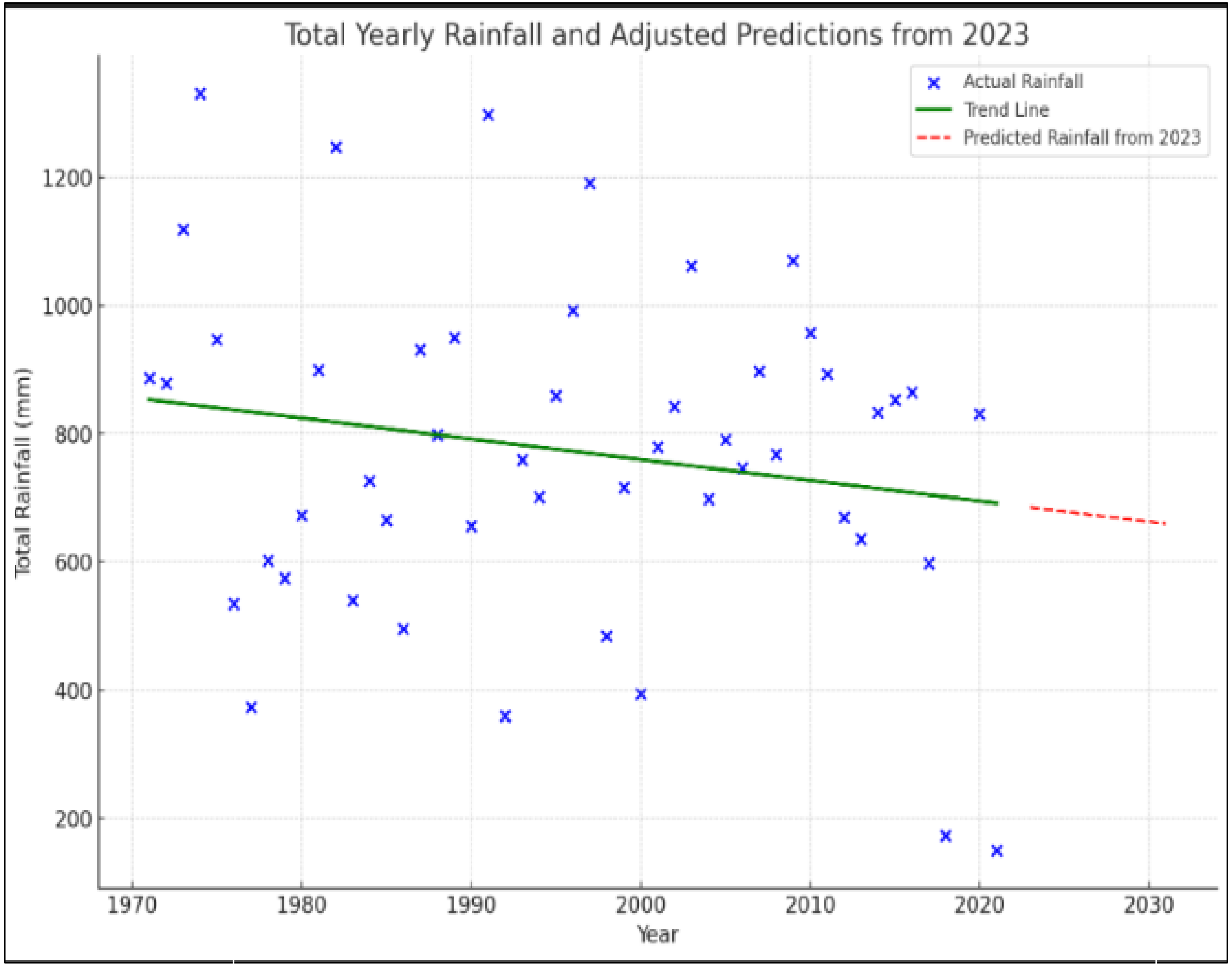


Figure 11: Rainfall trend from 1971 to 2021

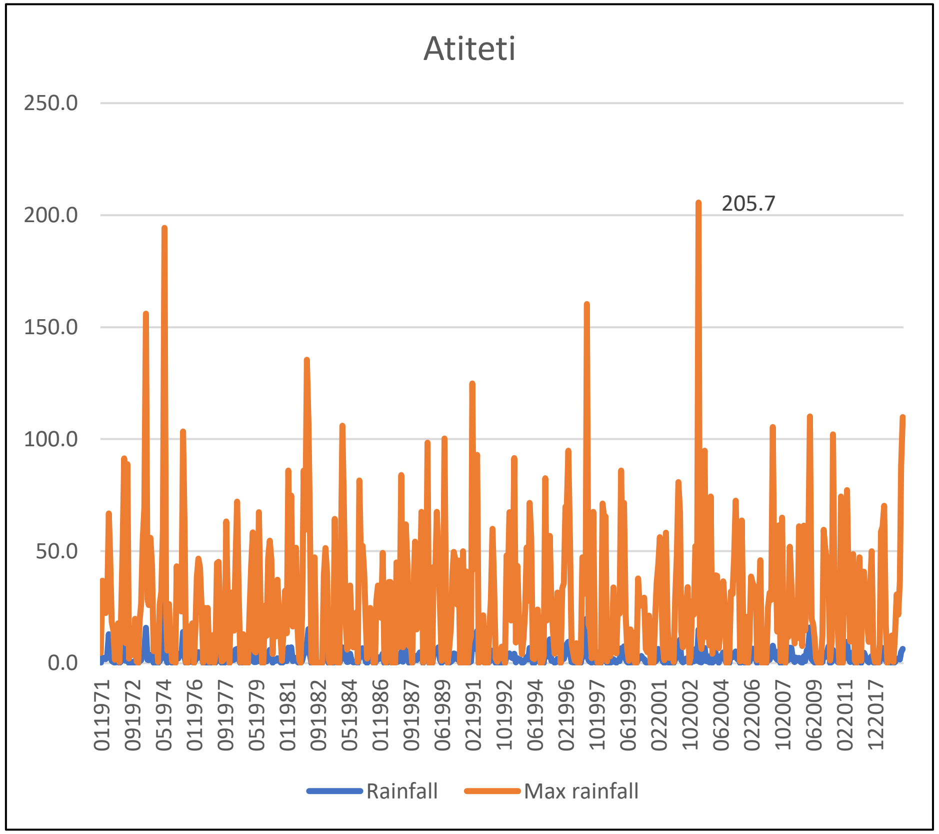
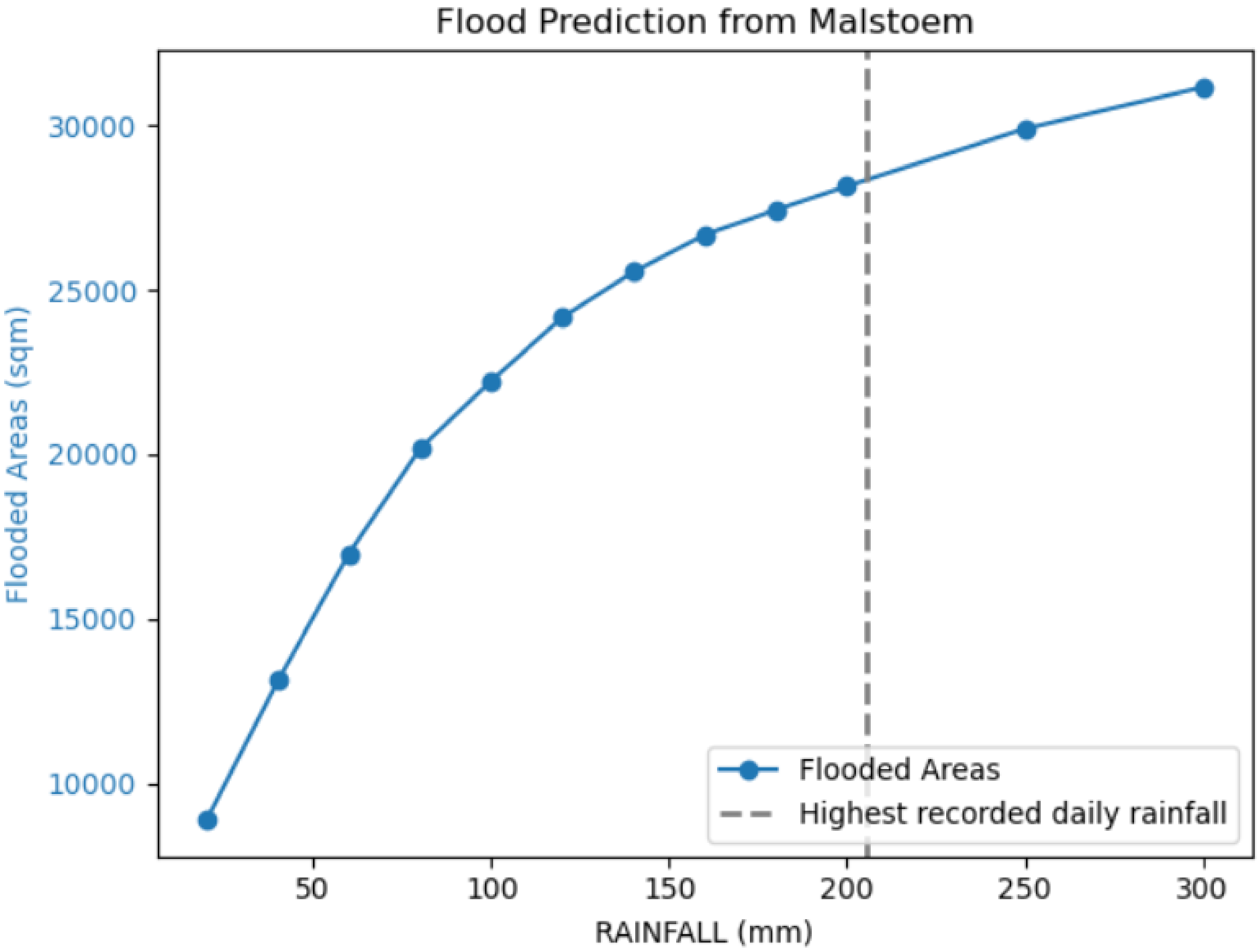


Figure 12: Max daily rainfall in mm

Flooding Scenarios from Precipitation (Atiteti)



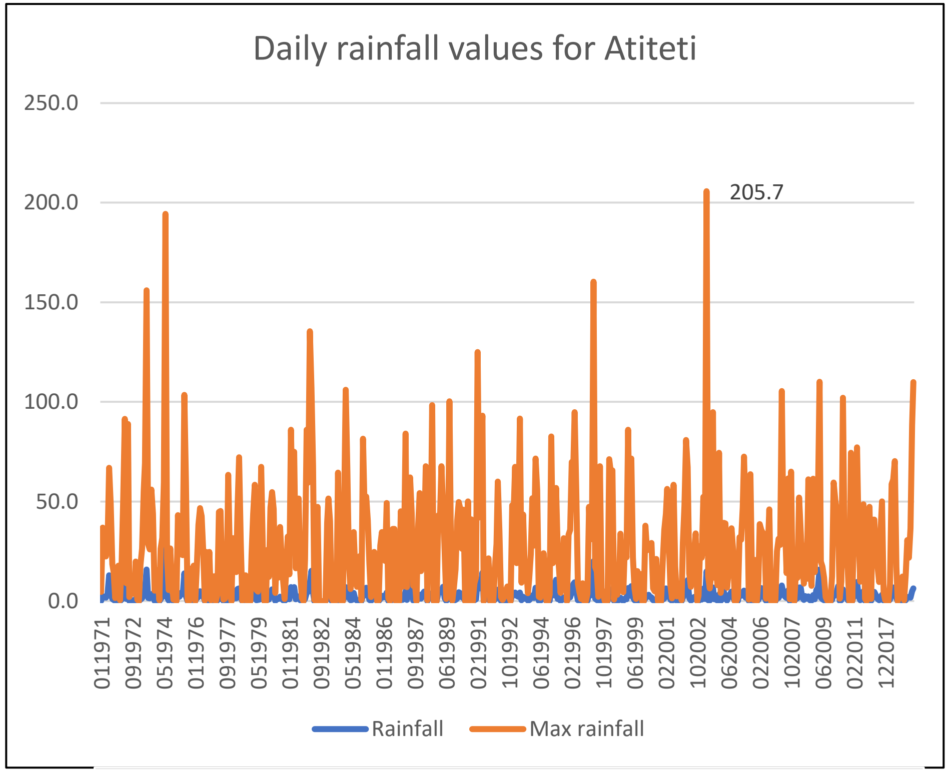
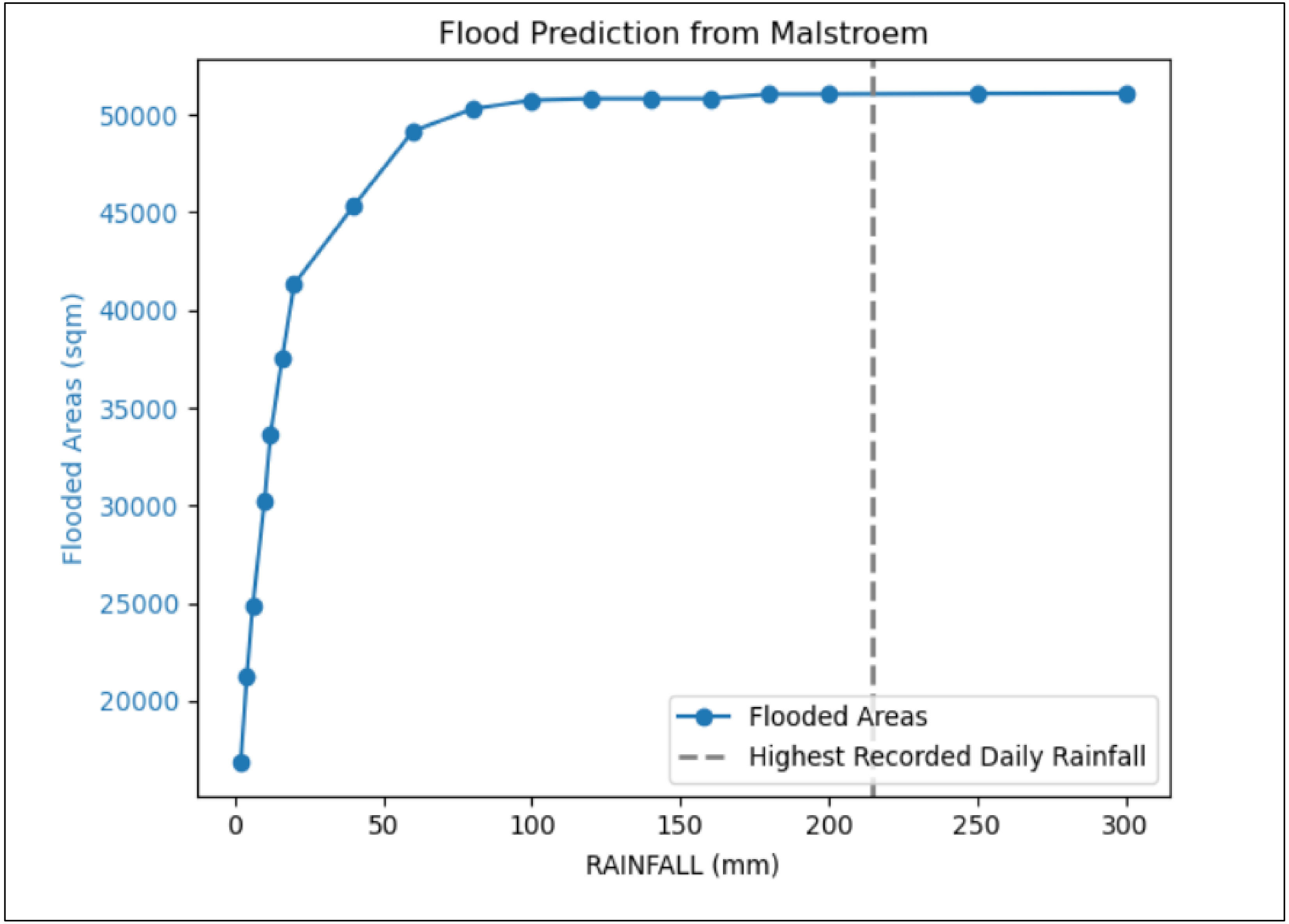


Figure 14: Max daily rainfall in mm

Figure 13: Model results showing flooded areas in Atiteti based on rainfall scenarios

Flooding Scenarios from Precipitation (Mumford)



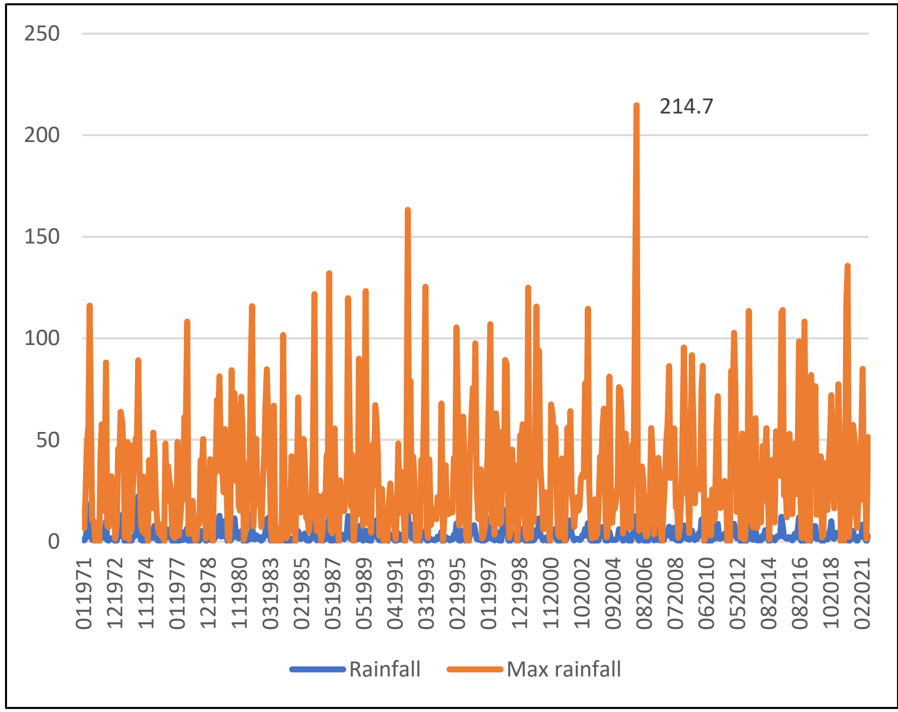


Figure 15: Model results showing flooded areas in Mumford based on rainfall scenarios

APPLICATIONS

- This study improves on typical static topography models by including subsidence, dynamically enhancing flood prediction accuracy, vital for effective long-term urban and climate adaptation planning.

- Applications:

  - ***Urban planning (flood defenses)***
  - ***Insurance and risk management (insurance companies can use this a more precise data to adjust premiums and risk assessments of flood-prone areas***

Recommendations

01 National Shoreline Monitoring Strategy: Invest in long-term, UAV, Bathy, tide gauge networks, especially in high-risk areas, while considering ICZM strategies

02 Enforce the Institutional Collaboration Framework (Gmet, NADMO, Hydro & Academic Institutions)

03 Early Warning System Policy: Mandate integration of Early Warning Systems and Decision Support tools into local planning schemes and advocate framework to install and maintain flood monitoring stations

04 Climate-Responsive Urban Planning Policy: Require the use of flood risk projections in zoning urban development decisions

References

- Adger W.N., Adams H., Kay S., Nicholls R. J., Hutton C. W., Hanson S. E., Rahman M. M., Salehin M. (2018) Ecosystem Services, Well-Being and Deltas: Current Knowledge and Understanding. Palgrave Macmillan, Cham
- Appeaning Addo K., Walkden M., Mills J. P. (2008). Detection, Measurement and Prediction of Shoreline recession in Accra, Ghana. ISPRS Journal of Photogrammetry and Remote Sensing 63: 543-558.
- Avornyo, S. Y., Appenning Addo, K., Teatini, P., Minderhoud, P. & Woillez M.-N. (2023). Vulnerability of Ghana's Coast to Relative Sea-level Rise: A Scoping Review. AFD research paper.
- Boateng, I. (2009). Development of Integrated Shoreline Management Planning: A Case Study of Keta, Ghana. Proceedings of the International Federation of Surveyors Working Week, May 3rd-8th, Eilat, Israel 1-19.
- Cian, F., Blasco, J. M. D., & Carrera, L. (2019). Sentinel-1 for monitoring land subsidence of coastal cities in Africa using PSInSAR: A methodology based on the integration of SNAP and staMPS. Geosciences (Switzerland), 9(3), 1–32. https://doi.org/10.3390/geosciences9030124
- Ericson J. P., Vorosmarty C. J., Dingman S. L., Ward L. G., Meybeck M. (2006). Effective sea-level rise and deltas: causes of change and human dimension implications. Global Planet. Change50, 63–82
- Nairn R.B., Macintosh K.J., Hayes M. O., Nai G., Anthonio S.L. and Valley W.S. (1998). Coastal Erosion at Keta Lagoon, Ghana – Large Scale Solution to a Large Scale Problem.
- Nicholls, R. J. et al. in IPCC Climate Change 2007: Impacts, Adaptation and Vulnerability (eds Parry, M. L., Canziani, O. F. , Palutikof, J. P., van der Linden, P. & Hanson, C. E.) 315–357 (Cambridge Univ. Press, 2007).
- Stouthamer, E., & Asselen, S. V. A. N. (2015). DRIVERS OF DELTA SUBSIDENCE. In IAHR World Congress (pp. 1–2). https://doi.org/10.1038/ngeo629.2
- Syvitski, J. P. M., Kettner, A. J., Overeem, I., Hutton, E. W. H., Hannon, M. T., Brakenridge, G. R., Day, J., Vörösmarty, C., Saito, Y., Giosan, L., Nicholls, R. J. (2009). Sinking deltas due to human activities. Nature Geoscience, 1-6, doi:10.1038/ngeo629.
- Vörösmarty, C., Syvitski, J. P. M., Day, J., Paola, C. & Serebin, A. (2009). Battling to save the world's river deltas. Bull. Atom. Sci. 65, 31–43.

We are open for collaboration- ***michaelkwamebiney@gmail.com***