Assessing TanDEM-X for Improved Flood Estimates in Small Island Developing States

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1) Motivation

- Small Island Developing States (SIDS) have some of the highest risks to hydro-meteorological hazards worldwide, as well as impacts of future climate change[1].
- However, little research has quantified this risk for current or future scenarios due to a lack of available data at an appropriate resolution.
- The newly-released ~12m TanDEM-X global Digital Elevation Model (DEM) provides a renewed opportunity to assess the capacity to improve flood estimates at a finer resolution using remotely-sensed data.

Aim

Determine the capacity of TanDEM-X to improve flood risk estimates in Fiji in comparison with LiDAR and MERIT-SRTM DEMs.

2) Study area

Ba and Nadi catchments in Fiji

LiDAR data available for 'ground truth' comparison for the towns in both catchments.

Recent flood events

- January 2009 = 50-yr return period (RP)
- January 2012 = 50-yr RP
- March 2012 = 25-yr RP
- February 2016 (Cyclone Winston) = 200-yr RP
- April 2018 (Cyclone Josie)

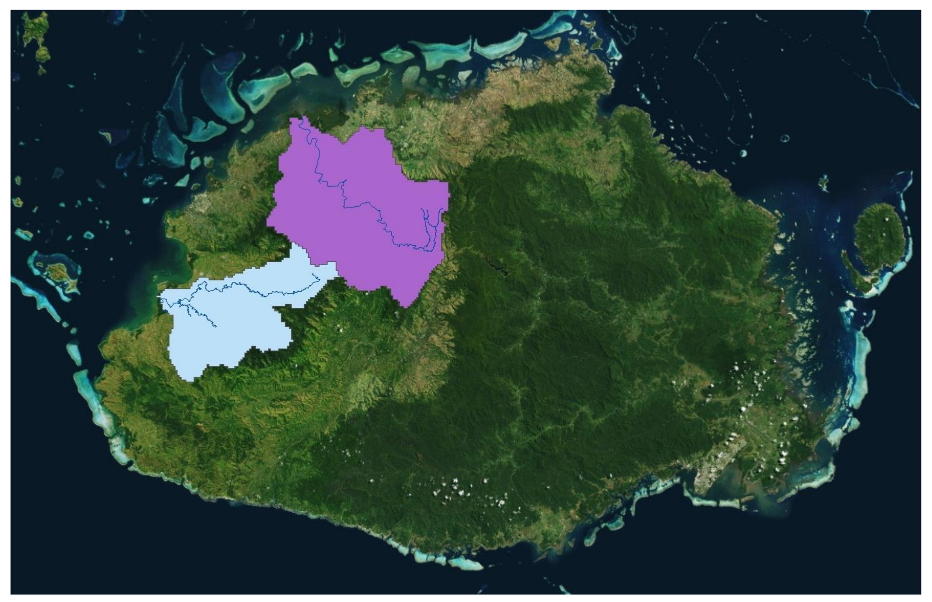
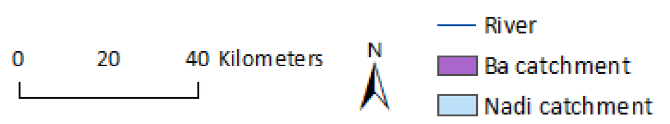


Figure 1 – Map showing the island of Viti Levu in Fiji, and the two catchments Ba and Nadi included as study sites in this project.



	Ba	Nadi
Catchment area (km²)	946.4	540.1
Population	16200	52800
Land used for agriculture (%)	63.85	69

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3) Methods

TanDEM-X Processing

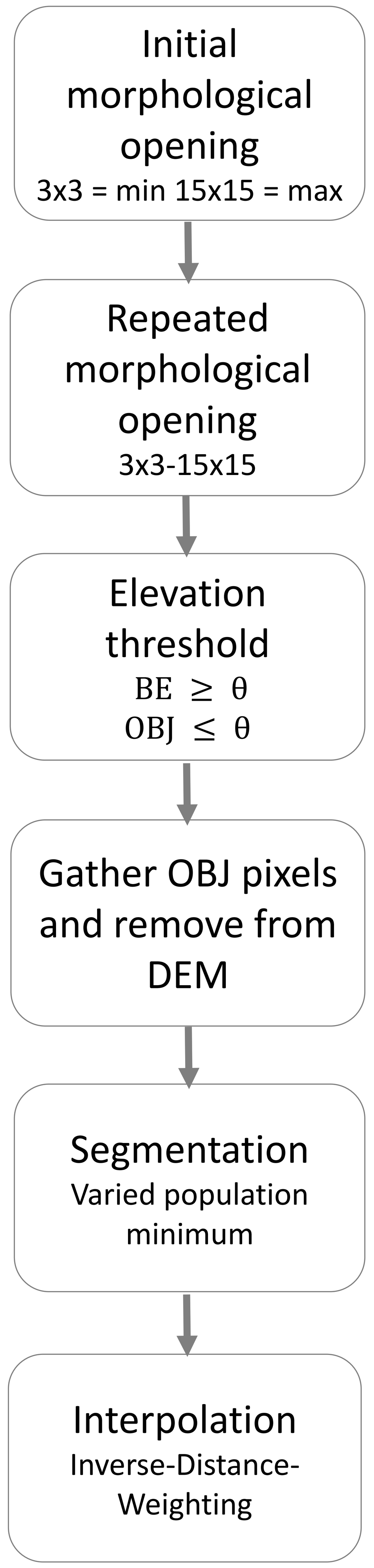


Figure 2 – Diagram showing the sequential steps implemented in the progressive morphological filtering vegetation-removal process

- TanDEM-X was acquired using an X-band Interferometric Synthetic Aperture Radar, measuring canopy and building tops as a Digital Surface Model (DSM). However, a Digital Terrain Model (DTM) is required for accurate flood simulation.
- A progressive morphological filtering method described in Figure 2 was created to remove artefacts from the original TanDEM-X DSM, producing TanDEM-X DTM[2]. Figure 3 and 4 demonstrate the artefact removal.
- In comparison to the LiDAR data, TanDEM-X DTM has the lowest error.

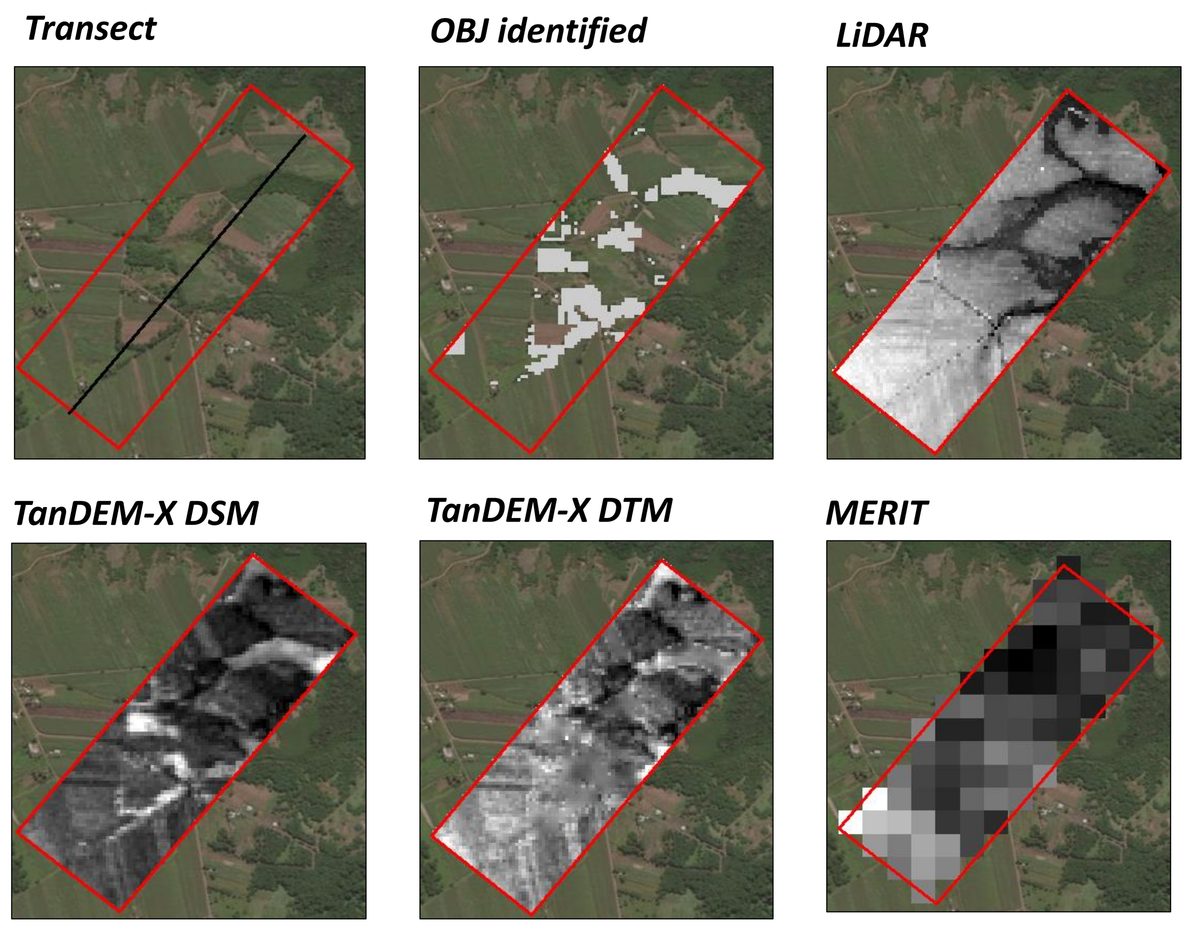


Figure 3 – Diagram showing the DEM difference in an area of floodplain in the Ba catchment, as well as the transect used in the DEM cross-section in Figure 4 and the objects identified by the progressive morphological filtering method.

DEM	RMSE	MAE	ME
TanDEM-X DSM	2.39	2.22	2.04
TanDEM-X DTM	2.02	1.89	1.38
MERIT	2.61	2.53	0.71

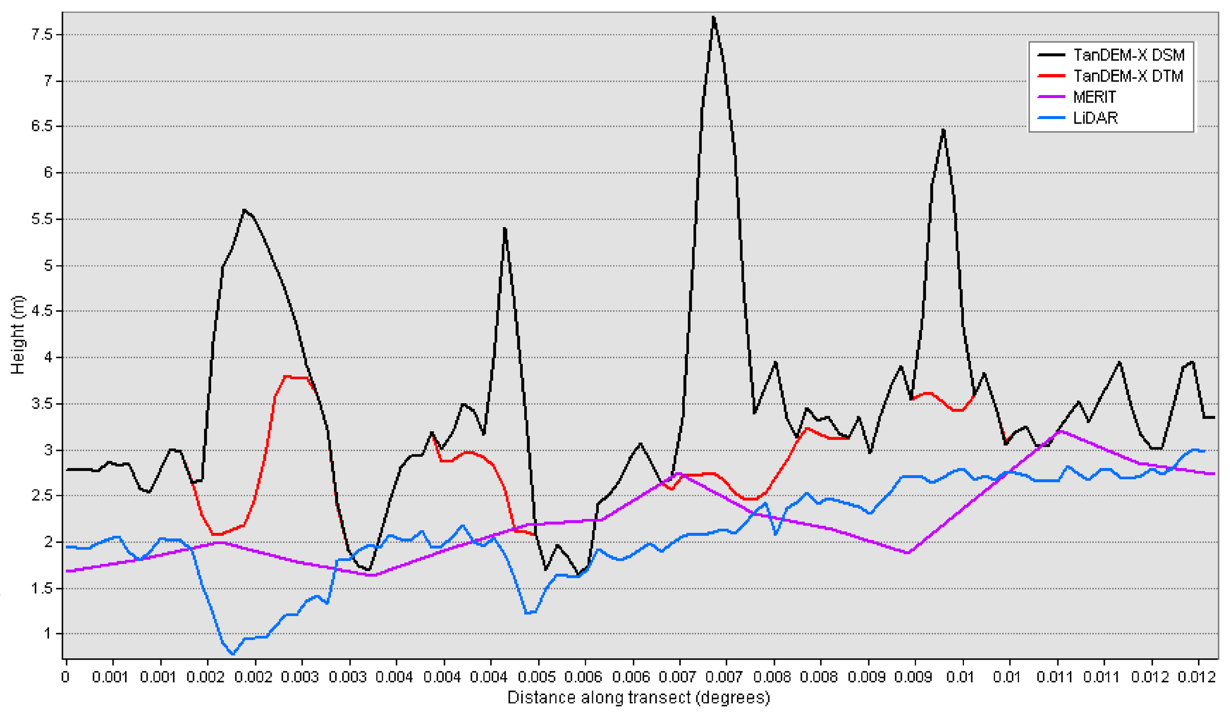


Figure 4 – Graph showing a cross-section of DEM heights along an area of floodplain, indicating where the TanDEM-X DTM has lower elevation values after vegetation removal.

Model set-up

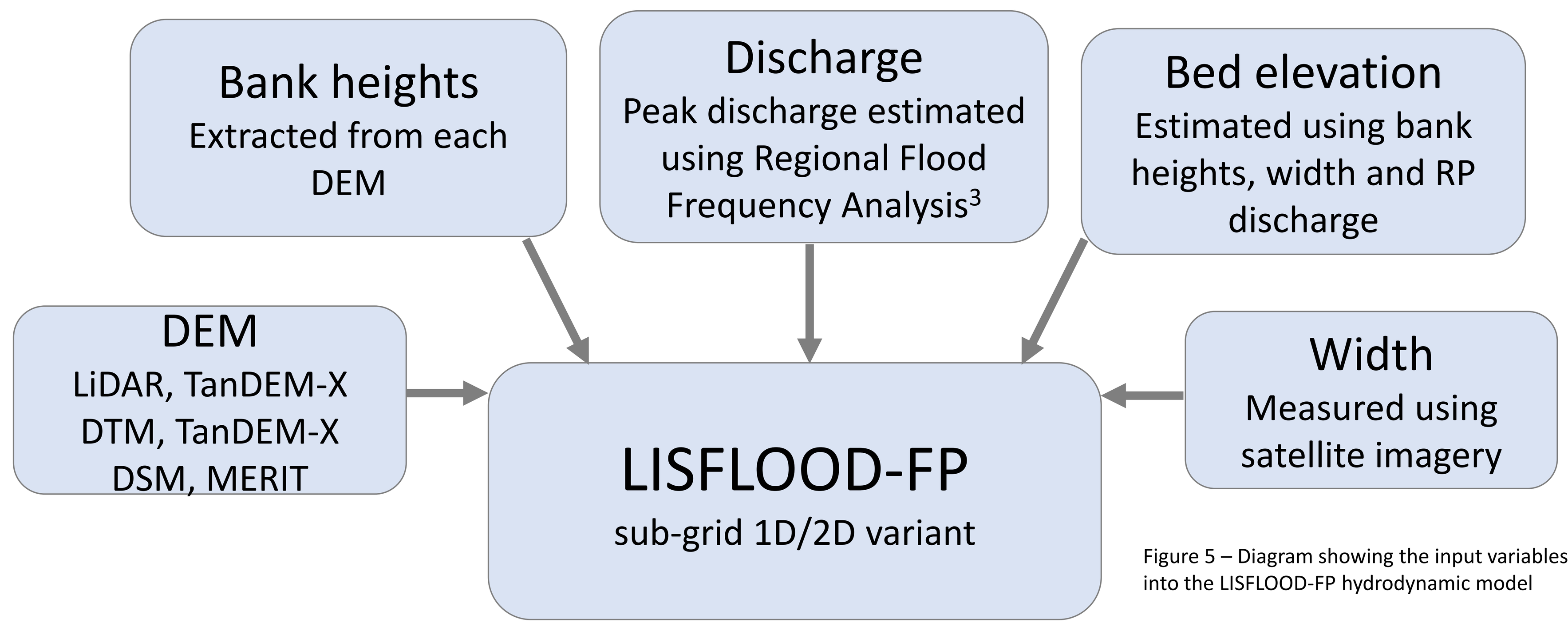


Figure 5 – Diagram showing the input variables into the LISFLOOD-FP hydrodynamic model

4) Results for Ba

F1-Score for inundation accuracy

- F1-score measures accuracy from 0 (no accuracy) to 1 (complete accuracy).

$$F1 = \frac{2(\text{Recall x Precision})}{(\text{Recall} + \text{Precision})}$$

- The TanDEM-X models do not simulate the mangroves at the downstream boundary well, meaning MERIT has the highest F1-score.
- Without mangroves, the F1-scores for the TanDEM-X DTM are highest, followed by MERIT then TanDEM-X DSM, highlighting the importance of vegetation removal.

DEM	F1-score			
	50-yr RP		*25-yr RP*	*10-yr RP*
	Incl.	*Excl.*		
TanDEM-X DSM	0.762	0.864	0.825	0.730
TanDEM-X DTM	0.871	0.914	0.954	0.786
MERIT	0.900	0.887	0.860	0.773

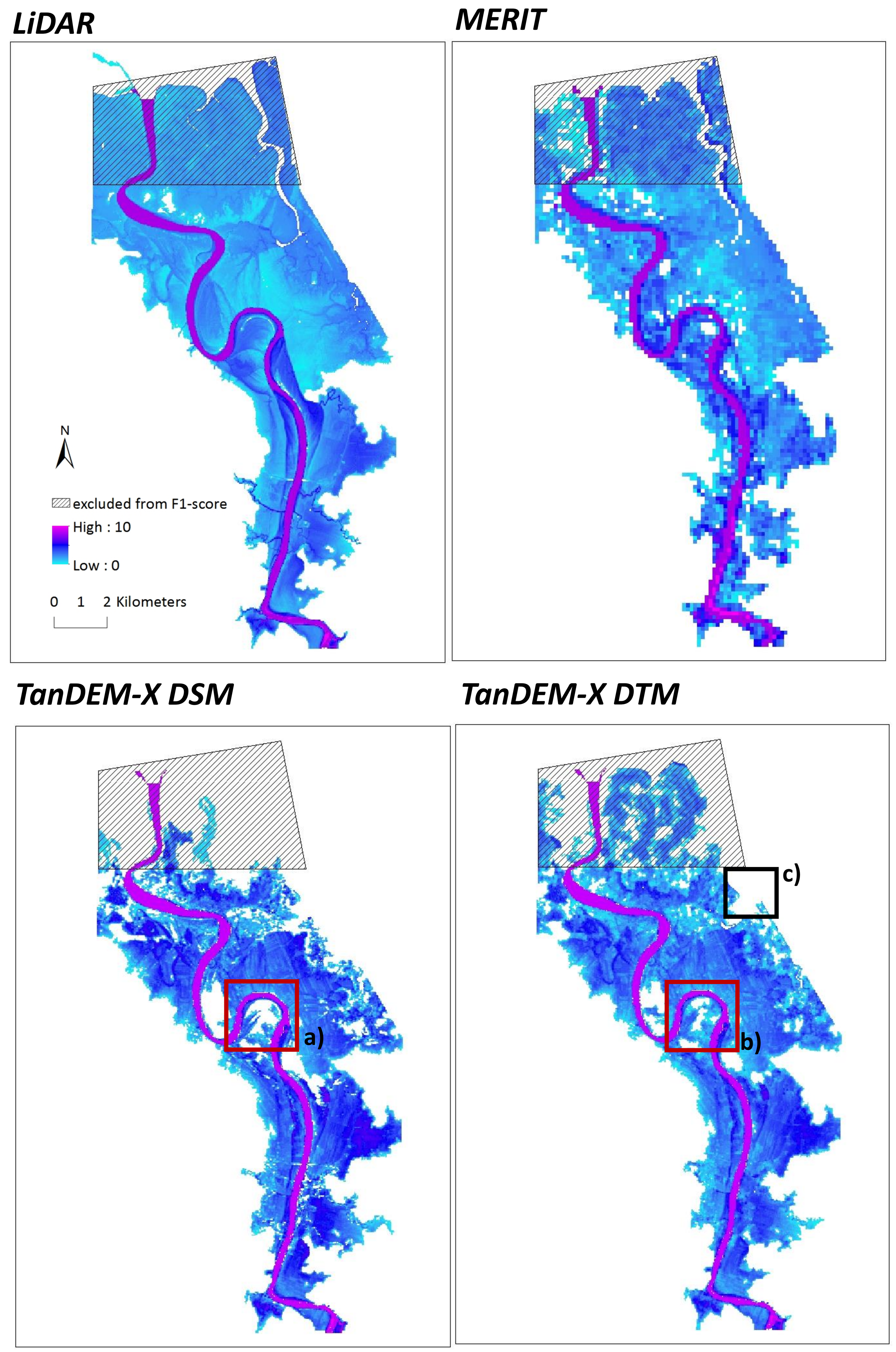
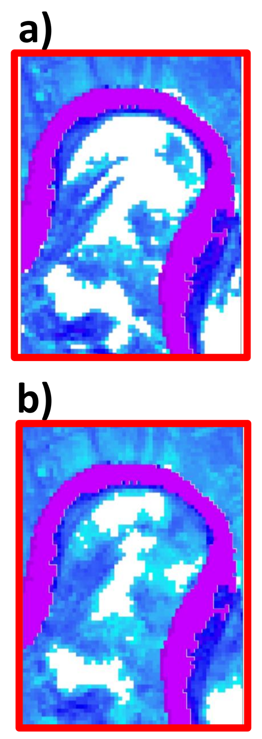
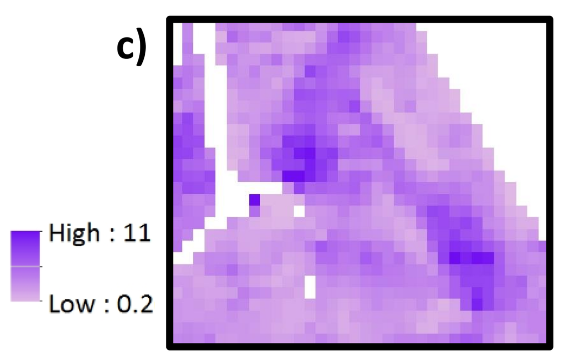


Figure 6 – Maps showing the four flood extent outputs simulated by LISFLOOD-FP using the four different DEMs. **a)** TanDEM-X DSM vegetation patches inhibit flooding in model output. **b)** TanDEM-X DTM has reduced vegetation artefact, leading to more flooding than TanDEM-X DSM. **c)** The TanDEM-X DTM has remaining high pixel values, blocking flow paths in the model.

Vegetation pixel removal



- The TanDEM-X vegetation processing method does not completely remove large patches of dense vegetation, meaning these areas do not flood.
- Smaller artefacts are removed well.



- High pixel areas still present in the TanDEM-X DTM block key flow paths, reducing the F1-score.

5) Conclusions

- The TanDEM-X DTM and DSM shows better agreement with the LiDAR DEM in RMSE and MAE calculations than MERIT.
- However, when incorporated into LISFLOOD-FP, areas of vegetation in the TanDEM-X DSM and DTM limit floodplain flow. As a result, vegetation removal is a key step required for using TanDEM-X in hydrodynamic models, and the method shown in this poster is useful for removing isolated vegetation.
- To remove the larger areas of vegetation, the TanDEM-X 50m Global Forest/Non-Forest Map[4], could be used in conjunction with this method and may further improve the capacity of TanDEM-X in improving flood estimates.
- Further work will conduct an identical study in the Nadi catchment to identify whether these conclusions are concurrent in another study area.

References

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[2]Schreyer, J., Geiß, C., Lakes, T., 2016, 'TanDEM-X for large-area modeling of urban vegetation height: Evidence from Berlin, Germany', *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 9, no. 5, 1876-1887

[3]Smith, A., Sampson, C., Bates, P., 2015, 'Regional flood frequency analysis at the global scale', *Water Resources Research*, vol. 51, no. 1, 539-553

[4]Martone, M., Rizzoli, P., Wecklich, C., *et al.,* 2018, 'The global forest/non-forest map from TanDEM-X interferometric SAR data', *Remote Sensing of Environment*, vol. 205, 352-373