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Fusion of Copernicus and ALOS World 3D DEMs for watershed and stream network delineation

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Abstract:
Digital elevation models (DEMs) have wide applications in cartography and are the most common basis for digital relief maps. The 30m resolution Copernicus GLO-30 and ALOS World 3D (AW3D) DEMs have been released to users worldwide for applications that include cartographic modelling, topographic mapping and hydrological analysis. The terrain representation and hydrological correctness of DEMs can be improved through fusion (Okolie and Smit, 2022), but very few researchers have demonstrated this. In this study, we compare watersheds and drainage networks delineated from Copernicus GLO-30 and AW3D DEMs, a fused version of both DEMs, and a 10m aerial LIDAR DEM. The DEMs were co-registered, and the LIDAR DEM was resampled to 30m. The fusion of Copernicus and AW3D was achieved through weighted averaging within ArcGIS software, in which the weights (w) were calculated as the inverse proportional of the squared height errors, e (i.e., $w_i = 1/e_i^2$) (Bagheri et al., 2018). The accuracies of the DEMs were calculated by comparison with a more accurate 2m aerial LIDAR DEM (Table 1). The watersheds and streams were generated across different terrain contexts in the Table Mountain, Cape Town Peninsula and cultivated fields in the Western Cape Province of South Africa. Basic watershed properties such as stream length and watershed area were calculated and compared.

DEM	Mean (m)	SD (m)	RMSE (m)
Copernicus DEM 30m	0.15	3.63	3.63
AW3D DEM 30m	2.39	3.29	4.07
Fused DEM 30m	0.51	2.70	2.75

Table 1. Summary of height differences of Copernicus, AW3D and the Fused DEM with the reference LIDAR DEM

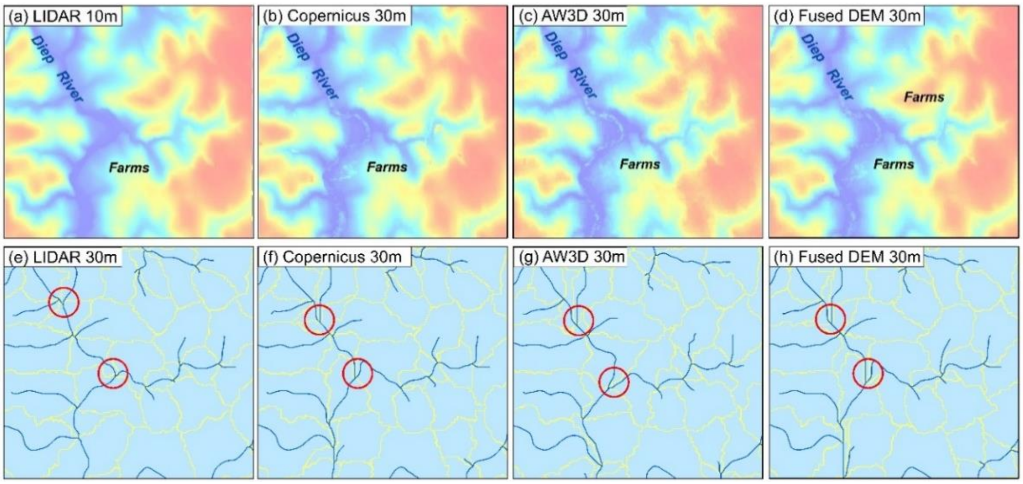

Figure 1: Visualisation of cultivated fields in the Diep River floodplain showing the DEMs (a – d), delineated streams and watershed boundaries (e – h). Elevation range: 20 – 110m. Stream intersections are compared in the red circles

The fused DEM achieved higher vertical accuracy than the source DEMs (Table 1). The cultivated fields and the Table Mountain are visualised in Figures 1 and 2. The Diep River channel with its tributaries, the Table Mountain, and the adjoining Camps Bay are finely depicted by the LIDAR DEM. The terrain visualisation shows that the fused DEMs are more consistent with the LIDAR DEM. The narrow drainage stems in the Diep River floodplain are not precisely depicted by Copernicus and AW3D due to their coarse resolution. The streams exhibit a dendritic drainage pattern in which there are no inner (endorheic) basins, and the floodplain is drained through the main drainage stem of the Diep River.

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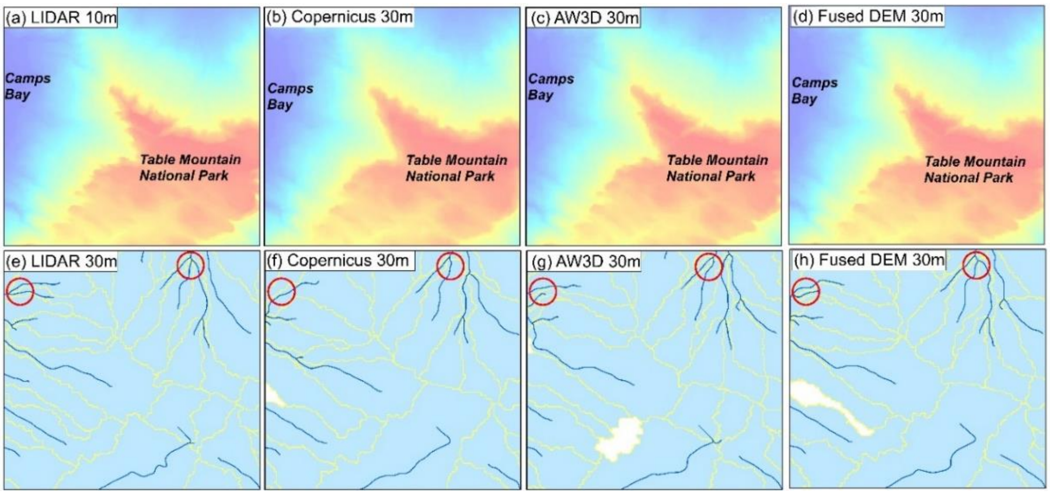

Figure 2: Visualisation of Table Mountain showing the DEMs (a – d), delineated streams and watershed boundaries (e – h). Elevation range: 0 – 1085m. Stream intersections are compared in the red circles

In the Cape Peninsula, the hydraulic lengths of the streams from the fused DEM are closest to the LIDAR DEM (Table 2), whereas in the cultivated fields, the streams delineated from Copernicus are closer to the LIDAR DEM, followed by the fused DEM. In the cultivated fields and Cape Peninsula, Copernicus and AW3D overestimate the actual stream lengths, whereas in the Table Mountain, both DEMs underestimate the lengths. There are no differences in the watershed areas from all DEMs in the cultivated field, and the stream lengths from the fused DEM are more closely aligned with the LIDAR DEM. This is possibly due to the low relief and gentle slopes in the floodplain which poses fewer challenges for space-borne SAR and LIDAR elevation sampling, unlike mountainous regions

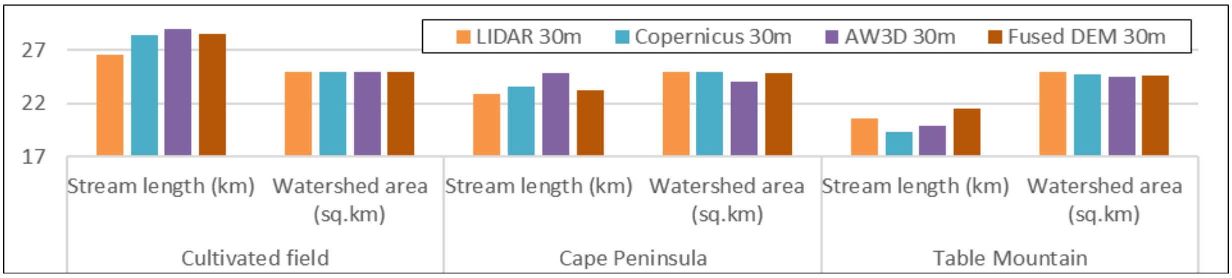

Figure 3: Comparison of stream length and watershed areas

	Cultivated field		**Cape Peninsula**		**Table Mountain**	
	ΔL (km)	**ΔA (km^2)**	**ΔL (km)**	**ΔA (km^2)**	**ΔL (km)**	**ΔA (km^2)**
Copernicus 30m	1.89	0.00	0.71	-0.03	-1.22	-0.20
AW3D 30m	2.39	0.00	2.00	-0.95	-0.69	-0.46
Fused DEM 30m	1.97	0.00	0.42	-0.05	0.90	-0.42

Table 2: Differences in stream length (ΔL) and watershed areas (ΔA), with LIDAR as reference

Summarily, through the fusion of Copernicus and AW3D, the terrain visualisation and characterisation were improved. This fusion has the potential to improve the cartographic quality of topographic maps, and with further applications in environmental and hydrological modelling.

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