Challenges faced in Determining the Most appropriate Digital Elevation Model (DEM) Resolution for orthorectifying 0.25m Aerial Imagery

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SUMMARY

The Chief Directorate: National Geospatial Information, the National Mapping authority of South Africa is responsible for systematic national aerial imagery acquisition and orthorectification. Determining the most appropriate Digital Elevation Model (DEM) for orthorectifying the acquired 0.25 m ground sample distance (GSD) digital aerial imagery is essential for achieving accurate and geometrically consistent orthoimages. However, this determination presents several technical challenges linked to terrain complexity, vegetation, and variations in DEM resolution and vertical accuracy.

This study examines these challenges through a detailed comparison between the externally sourced DEM (derived primarily from stereo aerial imagery) and a Light Detection and Ranging (LiDAR) derived DEM, used as the reference surface. The purpose was to identify which DEM resolution, namely 2 m, 5 m, or 10 m is most suitable for supporting the orthorectification of 0.25 m imagery over test grids in the Western Cape, South Africa.

Significant differences were observed in areas affected by steep slopes, dense vegetation, and drainage features such as dongas. These differences could largely be caused by variations in interpolation methods between photogrammetrically generated and LiDAR based surfaces. To ensure meaningful comparison, raster masking was applied to remove elevation differences exceeding +/-1 m, consistent with the stated vertical accuracy of the Externally sourced DEM (externally sourced DEM, 2024). The data were then statistically analysed using Mean Error, Standard Deviation, and Root Mean Square Error to evaluate the level of agreement and variability between the two datasets (Congalton and Green, 2019).

The study aimed to verify the externally sourced DEM using LiDAR as a benchmark, quantify

vertical differences across multiple resolutions, determine the most suitable DEM resolution for orthorectification of 0.25 m imagery for operational use within the Chief Directorate: National Geo-Spatial Information (CD: NGI).

Results show strong overall correlation/agreement between the LiDAR and externally sourced DEMs, with a consistent negative bias where LiDAR elevations were slightly lower. The bias (mean error) increased from −0.128 m for 2 m to −0.340 m for 10 m resolutions respectively, while variability remained relatively low (σ (standard deviation) 0.42–0.44 m). The 2 m DEM captured fine-scale terrain detail but exhibited greater local variation, the 5 m DEM achieved a balanced outcome between accuracy and smoothness; and the 10 m DEM offered a stable but generalised representation more suitable for regional analyses.

In conclusion, the externally sourced DEM demonstrates a strong agreement with LiDAR data within a +/-1 m tolerance, confirming its reliability for orthorectification of 0.25 m imagery when the correct resolution and masking are applied. The 5 m DEM provides the best balance between terrain detail, accuracy, and computational efficiency. Remaining challenges such as vegetation effects, slope distortions, and temporal differences highlight the need for continued refinement of DEM standards to support national mapping and land-reform initiatives (Mesa-Mingorance and Ariza-Lopez, 2020).