UNCERTAINTY AND EFFECTS OF RESOLUTION OF DIGITAL ELEVATION MODEL AND ITS DERIVED FEATURES:
CASE STUDY OF SUMBERJAYA, SUMATRA, INDONESIA

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Hydrological and erosion studies rely heavily on the information of slopes and other topographic features commonly derived from DEM. How reliable is the information while assessing using true values of geospatial information is quite problematic? Attempts to assess the uncertainty, as an estimate of error, using statistical approach and to find optimum spatial resolutions for the DEM in different types of terrains are presented in this work.

BACKGROUND

Why uncertainty?

- In the production of spatial data, e.g. Digital Elevation Model (DEM) true values are often unknown or difficult to obtain;
- When true values are unknown, uncertainty substitutes for the estimation of error;
- Uncertainty: lack of knowledge about reliability of a measurement in its representation of true values (Wechsler, 2000)** or simply lack of knowledge of the true values (Hunter & Goodchild, 1997)**.

Why slope?

- Because elevation error in a DEM propagates to the derived products, DEM uncertainty also causes uncertainty in derived products
- For Hydrological studies uncertainty assessment of the relevant derived products, e.g. slope, is more important than the elevation itself

### Why considering spatial dependence?

- In reality, elevation error is not purely random because of the spatial autocorrelation nature of elevation and so is the error (Hunter and Goodchild, 1997; Holmes, 2000; Wechsler, 2000)**
- The hypothesis is that pure random approach is considered as "worst case uncertainty assessment".

OBJECTIVE OF THE STUDY

The objectives of this study were to assess:
- Effects of DEM uncertainty on the uncertainty of the derived slope,
- Effects of the DEM cell resolution on the uncertainty of slope,
- Uncertainty of the derived slope when elevation error is considered spatially-dependent compared to that when error is considered spatially-independent (random).
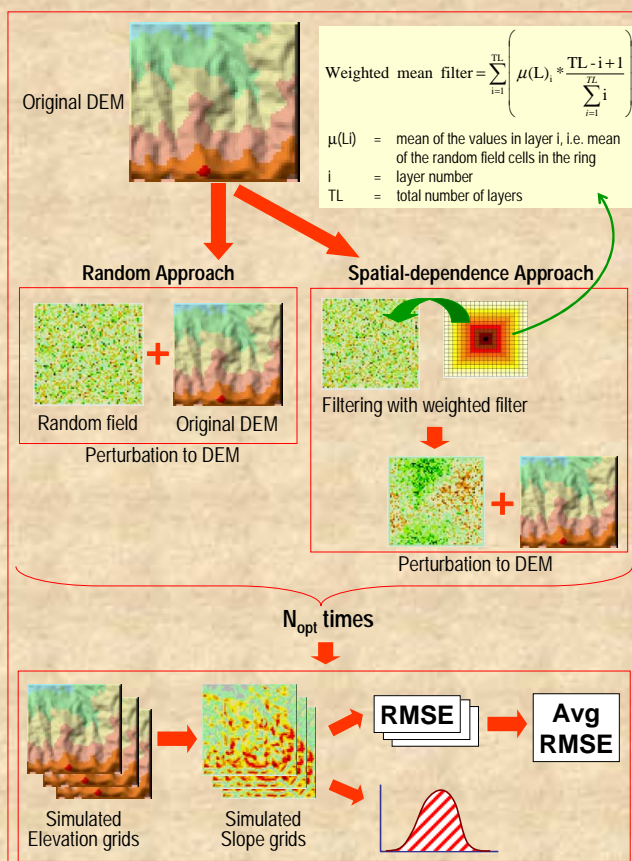
DATA AND STUDY SITE
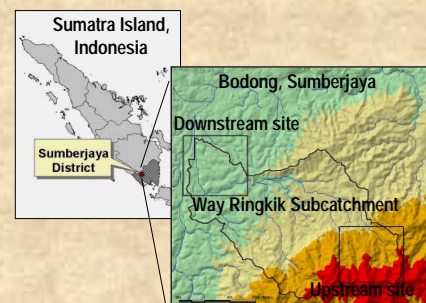
Part of DEM generated from aerial photo 1:24,000; two study sites, i.e: Upstream site and Dowsntream site
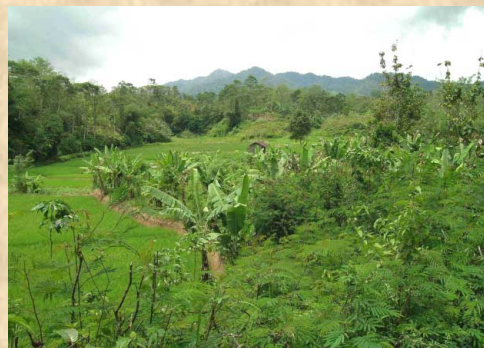
Landscape of midslope of Way Ringkik subcatchment, facing upstream (southward)

METHODS

$$\text{Weighted mean filter} = \sum_{i=1}^{TL}\left(\mu(L)_i * \frac{TL - i + 1}{\sum_{i=1}^{TL} i}\right)$$

$\mu(Li)$ = mean of the values in layer i, i.e. mean of the random field cells in the ring
i = layer number
TL = total number of layers

Original DEM

Random Approach   Spatial-dependence Approach

Random field   Original DEM
Perturbation to DEM

Filtering with weighted filter

Perturbation to DEM

N_{opt} times

RMSE → Avg RMSE

Simulated Elevation grids   Simulated Slope grids

Initial elevation RMSEs for the perturbation layers are: 5, 10, 15 and 20 m

Random field for perturbing the DEM are generated with $\mu = 0$, $\sigma = $ RMSE

Filter size is obtained from Spatial Dependence Distance (SDD) from Semivariogram analyses; i.e: 375 m for downstream site and 130 m for Upstream site

N optimum for simulation is: 150 times

To observe the effects of resolution, the DEMs are resampled into 5 m (original), 10 m and 20 m pixel sizes

The spatial-dependence approach is only conducted on DEM of 20 m pixel size

RESULTS AND DISCUSSION

### Sensitivity analysis – effects of initial RMSE on slope RMSE

Increase of initial DEM RMSE affects the increase of slope RMSE following linear trend, while for the higher resolution (5 m), the trend tend to be curvilinear

For each initial DEM RMSE and each cell size, the slope RMSE is higher in the Downstream site than in the Upstream site.
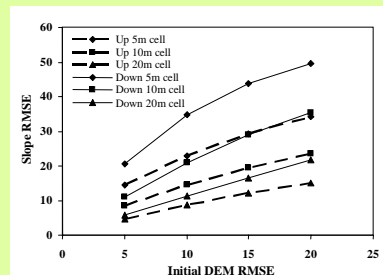

Effects of resolution on slope RMSE

Slope RMSE decreases with increase of cell size following a negative power trend →The negative relationship shows that more slope variability occurs for the surface with smaller cell size than that with bigger cell size.
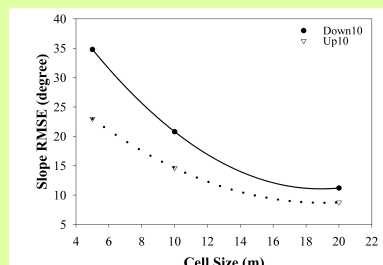
Effects of incorporating spatial-dependence

Upstream Site

original
unfiltered   filtered

Downstream Site

original
unfiltered   filtered
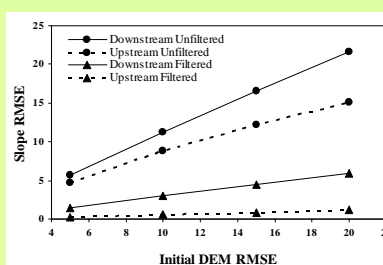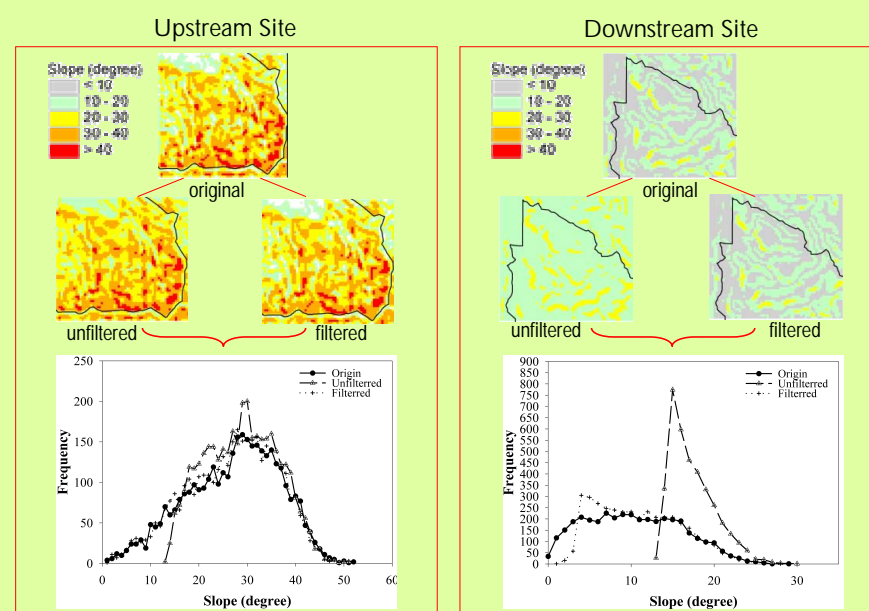
The incorporation of spatial dependence, i.e. by applying weighted-mean filter, decreases slope RMSE into 12% of the unfiltered one in the Upstream site, and into 27% in the Downstream site → Incorporation of spatial dependence of elevation error reduces the estimated error of slope.

CONCLUSION

1. The increase of initial DEM uncertainty affects the increase of derived-slope uncertainty. Slope uncertainty is larger in flat area than in undulating area

2. Slope RMSE increases by the increase of resolution (smaller cell size).

   This shows the importance of choosing the optimum resolution to minimize big slope uncertainty. Because higher slope uncertainty occurs in the flat area than in the undulating area, the choice of resolution is more crucial for flat terrain than for undulating one.

3. Assuming that error is spatially-dependent, error propagation from DEM to the slope error occurs in a lower magnitude compared to the propagation when error is considered random. And the magnitude of the reduction is bigger in the undulating terrain than in the flat terrain.

4. Points for further improvement:

   - With the spatial dependence assumption, the relationship between the spatial dependence of elevation and that of the error is yet to be studied further. The question is: Is spatial dependence of elevation error linearly correlated with that of the elevation?.

   - Comparison of slope RMSE obtained as the DEM-derived feature with that obtained from field observation may result in a different magnitude of uncertainty.

   - For overall outcomes of erosion and river flow, the frequency distribution of slopes, and thus of the error, is important to assess. However for spatially-explicit intervention, the demand is on the location aspects of the error/uncertainty.