Effects of DEM resolution and source on hydrological modeling

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Abstract: Digital Elevation Model (DEM) has been widely used in hydrological model. The accuracy of hydrological model depends on the source and resolution of DEM data. This study investigated the effects of DEMs on deriving topographic and hydrological attributes. Two DEMs at four resolutions including 5m, 10m, 20m, and 30m were prepared and tested for generating stream network and watershed area in Phuket Province, Thailand. Contour line interval 5 m and GDEM resolution 30 m were used in this study. Using higher resolution DEMs can derive more accurate stream network, but highest resolution data may not necessarily offer the best results, depending on the resolutions selected to compare the extracted networks. DEM resolution may have minor different impacts but the significantly different is DEM data source.

INTRODUCTION

Resampling is widely used by GIS-based environmental model users to make all raster data layers have the same cell size to facilitate the spatial analysis. The resolution of GIS data is closely associated to the computation speed in spatial analysis. Recent developments in computational models to monitor and predict hydrology, erosion, and landscape evolution by Earth and water scientists rely heavily on the integrity of the Digital Elevation Models (DEMs) available (Moore and Grayson, 1991; Moore et al., 1991; Lane et al., 1994). Topography is an importance role in hydrological modeling which is for water management and flood protecting. It can be derived from Digital Elevation Model (DEM) which is one of the most commonly used and widely available basic spatial information. The DEM could be acquired through techniques such as photogrammetry, LiDAR, IfSAR, land surveying, etc. The accuracy of DEM data depends on the source and resolution of the data samples. Earlier studies have found that spatially distributed hydrological models are sensitive to DEM horizontal resolution, due especially to its influence on computed slopes and related model-derived quantities such as surface saturation extent (Zhang and Montgomery, 1994; Wolock and Price 1994).

The effects of DEM resolution and data source have been examined for many processes such as soil erosion (Zhang et al., 2008), landslide (Claessens et al., 2005), solar radiation (Cebecauer et al., 2007), watershed, and hydrological models to test if an optimum DEM resolution exists so the model output can be accurate enough without the need to significantly increase data storage space and computation ability. O'Loughlin, (1986) found that a spatially distributed model based on a steady state drainage condition using TOPOG was sensitive to DEM grid scale.

Phuket is a selected area which is located in the south of Thailand with an area about 543square kilometers. Tourism section is the main income as it is a world class of tourism place. Phuket has been rapidly developing and recently facing a problem on flooding in rainy season because of land-use/land cover changes, consequently, many tourist places and commercial areas are affected. Aforementioned, the accurately hydrological model is an importance for water management and flood protecting. Figure 1 shows stream network in the area. The aim of study is investigates the effects of DEM resolutions on deriving topographic and hydrological attributes in Phuket Thailand. Contour line interval 5 m and Global Digital Elevation (GDEM) 30 m were the main source for generating new resolution of DEMs in the study. Contour lines have been used to create DEMs a sit covers the whole area in different scales (Prima and Ryuzo, 2002).The results of this study would deliver insights into the determination of an optimum DEM resolution needed for analyzing hydrological model in the study area.

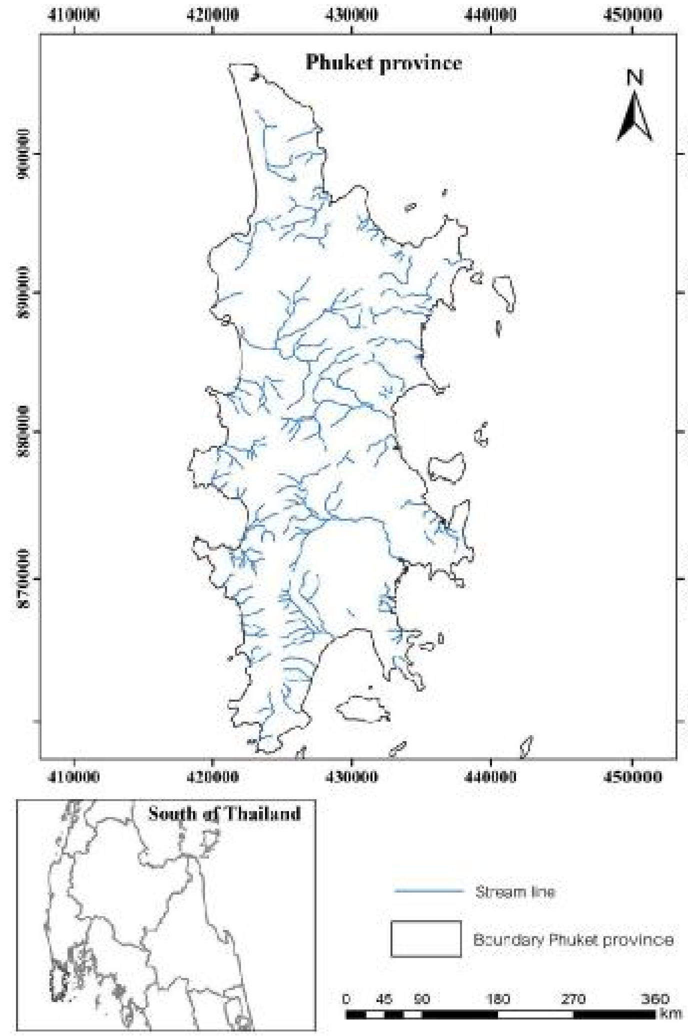

Figure 1: Character of stream network in Phuket,Thailand.

DATA AND METHODOLOGY

Dataset

The following data were collected for this study.

(1) DEM 30 m data from GDEM. Aster GDEM is a new global 1 arcs elevation dataset that was released in June 2009 by METI (Ministry of Economy, Trade and Industry), Japan and NASA (National Aeronautics and Space Administration), USA. The ASTER DEM covers land surfaces between 83 N and 83 S. The data was downloaded from the website (www.-gdem.-aster.-ersdac.-or.-jp/-search.-jsp).
(2) Contour line interval 5m (1:10,000) from Thailand Local Administrative in Phuket, Thailand.

All DEMs needed to be resampled to difference resolutions, including 5 m, 10 m, 20 m and 30 m, where 30 m was the original resolution from GDEM. The resampling method was bilinear interpolation using ArcGIS software package.

Analysis

The 4 DEM resolution which mentioned before were generated. The DEMs were also tested for sinks (single pixels whose neighbors are all of higher elevation).Figure 2 shows the processing outline of the study.There were 4 main processes in the study as follow.

1) Generating DEMs from contour line in Triangulated Irregular Network (TIN) format. Since TIN based method, linear or higher order function can be applied to compute DEM future (Prima and Ryuzo, 2002).
2) Resampling GDEM in the same resolutions above using control points which were extracted from nodes of contour line 5 m interval.
3) Sinking DEMs from both datasets. Sinks are normally considered to be a result of errors in the DEM interpolation and need to be removed before the DEM can be used for hydrological analysis.
4) Comparing stream networks and watershed boundaries from both datasets using ArcHydro tool in ArcGIS software. Stream network and watershed boundary from different datasets were compared to evaluate the effects of data spatial resolution and data source.

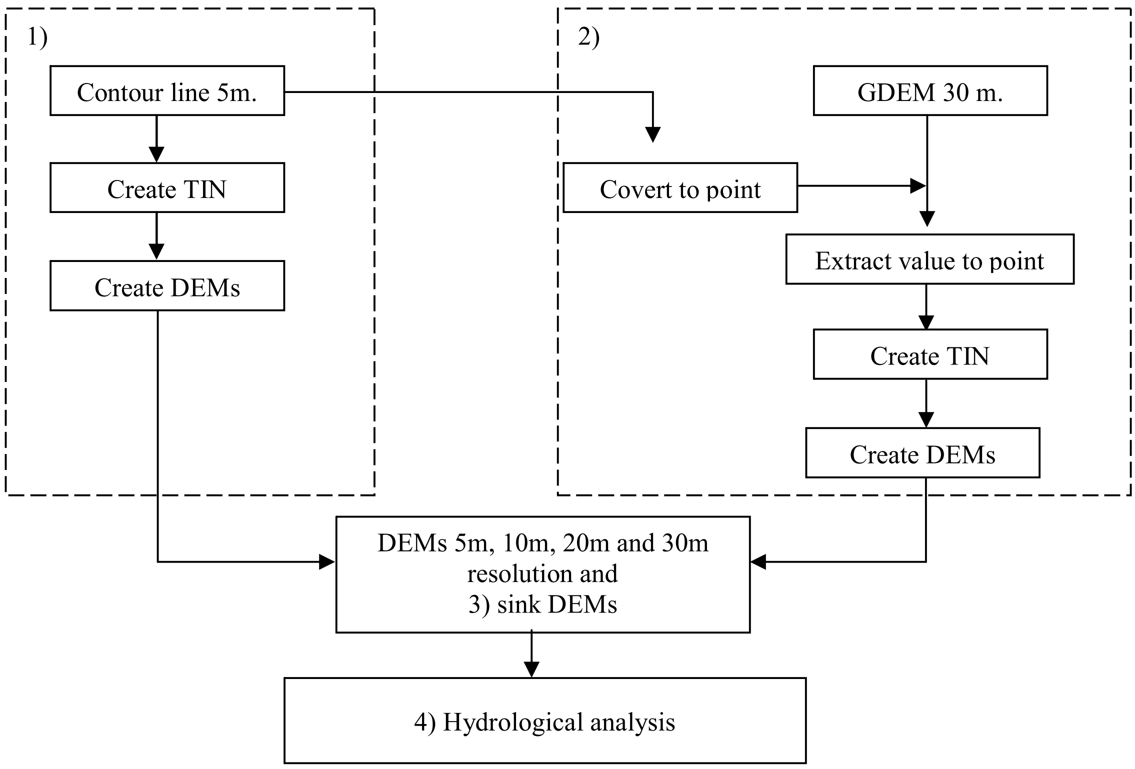

Figure 2: Processing outline.

RESULTS

Ranges of elevation extracted from DEMs in each resolution are shown in Table 1. Elevation ranges from original GDEM, resampled GDEM and Contour line 5 m interval were 0.00– 549.00m, 0.00 – 548.64 m and 5.00– 540.00m respectively.

Table 1: Characteristics of each DEM dataset.

DEMs	Resolution (m)	Elevation			
		Min	Max	Mean	Std dev.
Original GDEM	30	0.00	549.00	68.18	50.51
	5	0.00	548.64	62.28	91.19
GDEM	10	0.00	548.64	69.30	91.23
	20	0.00	548.51	69.30	91.23
	30	0.00	548.64	62.28	91.19
	5	5.00	540.00	67.74	90.17
Contour line	10	5.00	540.00	67.74	90.71
	20	5.00	537.89	67.74	90.70
	30	5.00	540.00	67.72	90.70

Correlation analysis is applied to reveal the strength of relationships between terrain derivatives based on the two independent data sources. The Pearson correlation coefficient is a measure of the strength of the linear relationship between all datasets. A grid resolution of GDEM 30 m was chosen as the benchmark to compare the relationship of DEM in different resolutions including 5 m, 10 m and 20 m regularly sampled elevation points respectively.

Comparisons of DEMs were very similar spatial distribution over the study area (Figure 3). In this figure shows the tendency for this approach to retain the terrain in the coarser DEMs. Coarsening resolution may have a smoothing effect on representation of hydrological model. This study investigated the effects of DEM resolutions on generating stream network and watershed boundary in Phuket area. An example of stream networks at Bang Yai canal was extracted from each DEM in different resolutions and they are shown in Figure 3. The Figure 3 shows (a) stream network generated from DEMs which derived from GDEMs in different resolutions, (b) stream network generated from DEMs which derived from contour line 5 m in different resolutions (c) shows the stream network derived from topographic map (1: 50,000). After analyzed hydrological model to create stream network and watershed boundary, the higher resolution DEMs seemed to provide more details of stream network than coarser resolutions (Figure 4).

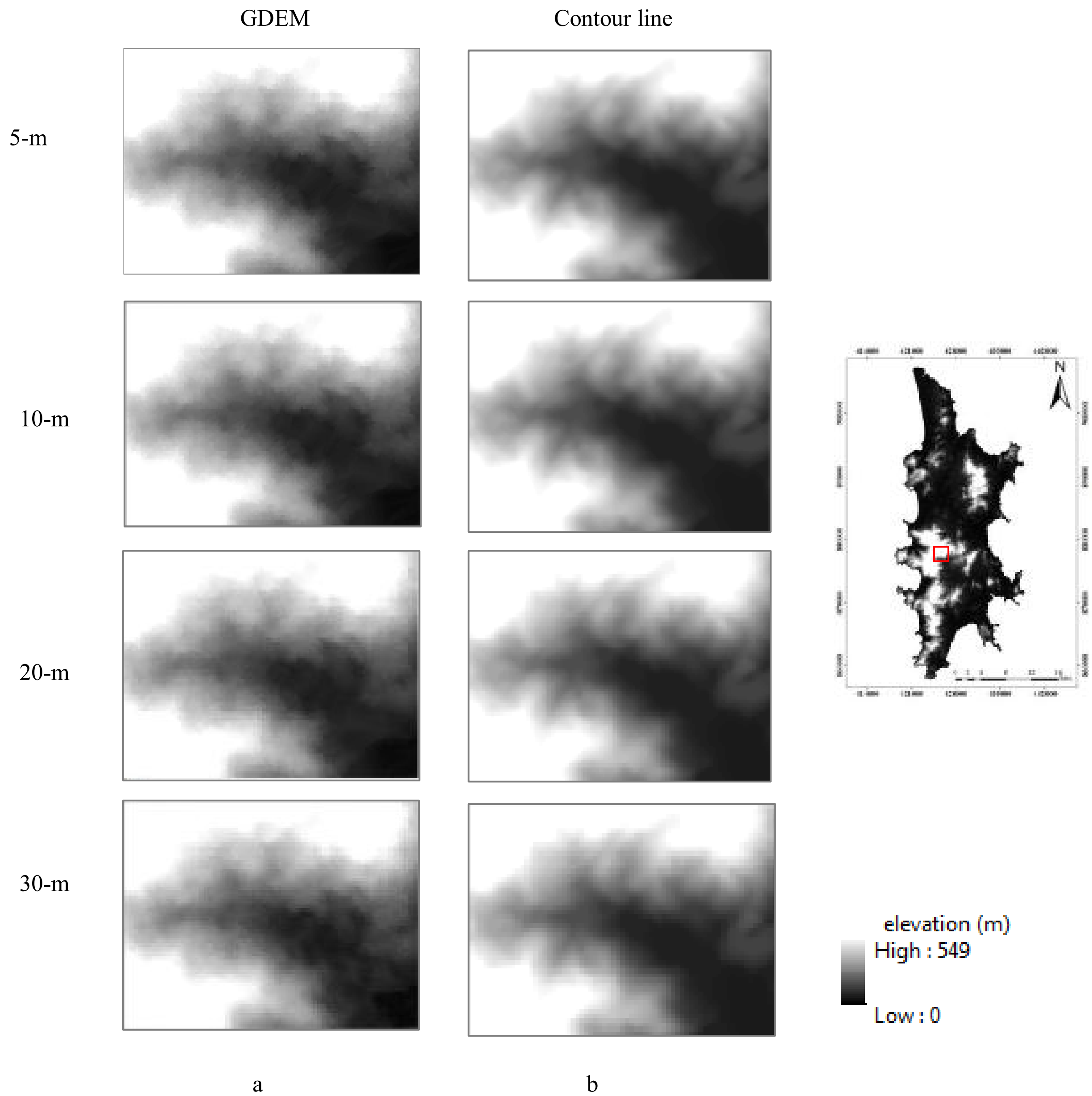

Figure3: Sample of generalized DEMs in different resolution from (a) GDEM 30 m and (b) Contour line 5 m interval.

Stream networks which generated from contour line 5 m interval did not show an appropriate stream network in the area (Figure 4.). Characteristic of watershed shape in different DEM resolutions were similar. However DEM 30 m resolution seemed to provide different shape from other resolutions. Watershed shape from DEMs derived from GDEM seems to be very similar when compared with the shape of Bang Yai canal (Figure 3 (a)). The results indicated that resampled GDEM which generated stream network and watershed batter DEMs from contour line. Although there are small different between the stream network and watershed derived from different resolutions, but not same source rather different.

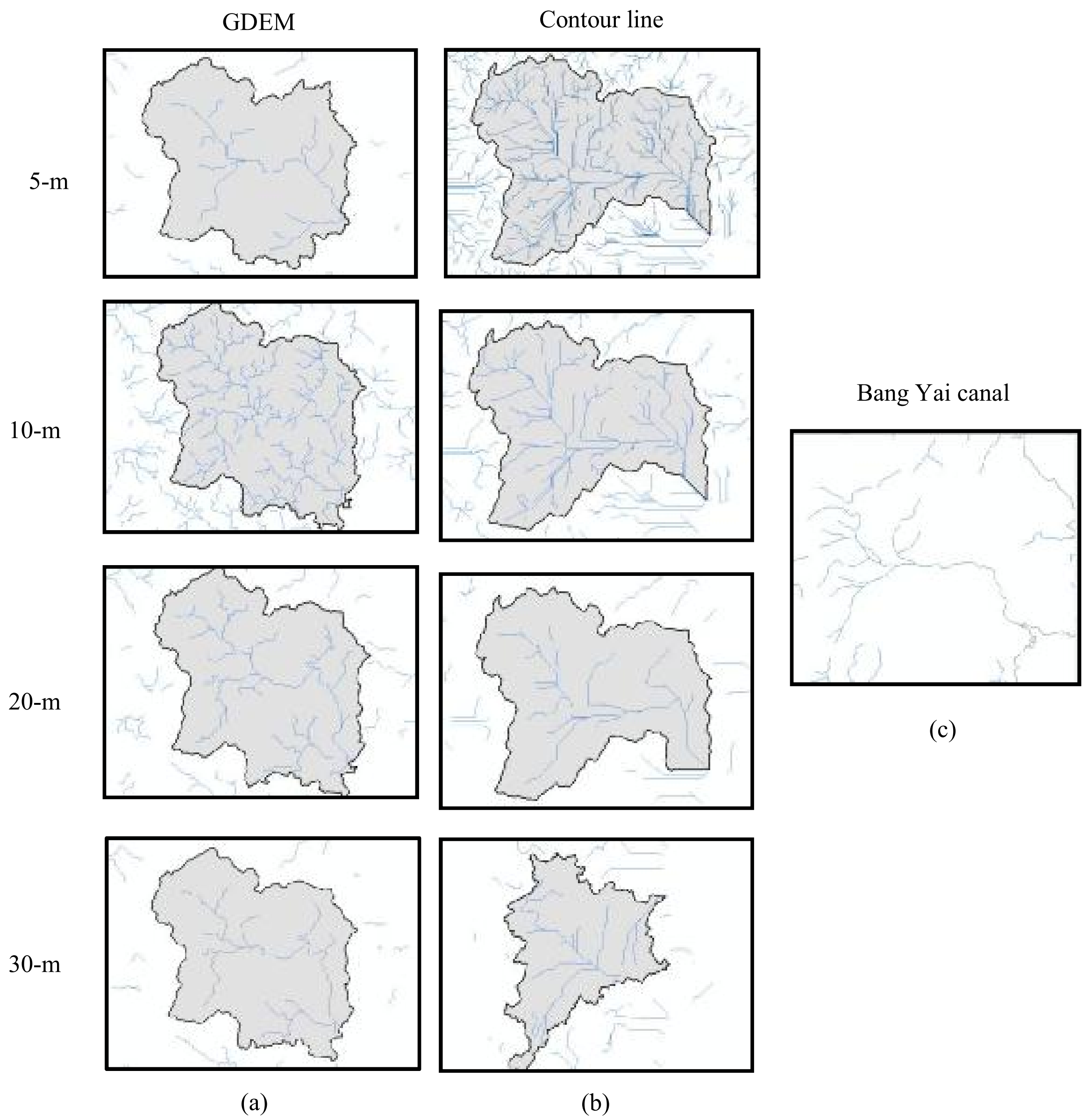

Figure 4: Stream network and watershed of Bang Yai area, (a) stream network and watershed generated from DEMs using GDEM, (b) stream network and watershed generated from DEMs using contour line, (c) Bang Yai canal, Phuket Thailand.

DISCUSSION&CONCLUSIONS

The hydrological model structure becomes increasingly complicated to satisfy the requirements of the gradually complicated environment problems we are facing. However, complicated hydrological model structure is easy to produce more uncertainties within the hydrological modeling results. Many hydrologic studies fail to provide consistent results. One of reason is a quality of DEM as it is convenient for representing the continuously varying topographic surface of the Earth. Some studies attribute the difference to factors such as data sources, spatial resolution of its, and the adopted algorithms in analyzing the data.

In this study, we evaluated how different sources and resolution of DEM data may affect the outcomes of hydrological model in term of stream network and watershed extractions. There were 2 data sources including GDEM 30 m and contour line 5 m interval that used in the study. Resampling technique was used to generate DEM in 5 m, 10 m, 20 m and 30 m resolutions. The higher resolution data are generally preferred as they are often resampled to lower resolutions, or are used in analyses performed at lower resolution in order to be spatially compatible with other lower resolution data layers involved in the analysis. It is perilous to undertake that such derived lower resolution data are superior to other lower resolution data from a different source.

The results presented here have shown that DEMs generated from coarsely sampled elevation points may have severe limitations in their use for hydrological analysis as shown in the Figure 3 and 4. Findings reported here are valid for the world flat to moderately sloped terrain. Analysis of the effect of grid cell size on DEM has strengthened findings reported by other authors that the stream network and watershed boundary are depended on the grid cell size. With the variety of DEM sources and variety of grid cell sizes used, it is very difficult to directly compare the results. For the further work, the appropriate interpretation based on DEM resolution, which should contain essential details about the DEM source, such as sampled point elevations, and any algorithms applied.

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