IDENTIFYING HIGH-CONTRIBUTING AREAS RELATIVE TO NONPOINT SOURCE POLLUTION USING DIGITAL TERRAIN ANALYSIS OF LiDAR DEM ON LIPADAS WATERSHED, DAVAO CITY, PHILIPPINES

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ABSTRACT: Rainfall and surface water runoff facilitates the transport of contaminants such as sediments, nutrients, and pesticides, depending upon the area involved. With the use of GIS tools such as digital terrain analysis techniques on high resolution DEMs derived from LiDAR, landscapes that are hydrologically connected, either by river networks or simply overland runoff drainages, can be identified with a degree of significance. The identified critical areas are classified: ravines, which are active erosional features that contribute to significant amount of sediments nearby waterways; artificially drained upland depressions, which can be formerly wetlands or accumulate surface water; and riparian areas, which are areas that have greater potential of transporting contaminants during storm events. Actual field validation enabled the calibration of thresholds levels for more accurate classification and identification of critical areas. The result of the study will provide additional input for watershed management practices.

1. INTRODUCTION

In determining and characterizing physical landscapes, Geographical Information System (GIS) tools, such as digital terrain analysis are used. With the use of digital terrain analysis, information regarding hydrological features, soil erosion, sediment transport, and other geomorphological features, can be analyzed and extracted (Wilson, 2000). Applying digital terrain analysis on LiDAR Digital Elevation Models (DEM) with resolutions up to 1 meter, features are classified in more detail. In this study, the area of interest are defined as landscape that have higher probability of conveying contaminants such as sediments, nutrients, pesticides, to nearby surface waters. Identified critical areas are classified: ravines, which are active erosional features that contribute to significant amount of sediments nearby waterways; artificially drained upland depressions, which can be formerly wetlands or accumulate surface water; and riparian areas, which are areas that have greater potential of transporting contaminants during storm events.

Objectives of the Study

The study aims to identify and classify critical areas using digital terrain analysis of LiDAR DEM of the Lipadas watershed, Davao City Philippines. Specifically the study aims to:
1. Calculate primary attributes such as slope, aspect, curvature, flow direction, flow accumulation;
2. Calculate secondary attributes such as Stream Power Index (SPI) and Compound Topographic Index (CTI);
3. Identify and classify critical areas as ravines, upland depressions, or riparian areas.

2. METHODOLOGY

The 1 meter resolutionLiDAR DEM,obtained from the project Phil-LiDAR 1.B.13,were processed using ArcMap 10.2 software. Primary attributes were calculated using built in ArcMap spatial analyst tools. CTI and SPI values are calculated as follows:

$$CTI = \ln(\text{Flow Accumulation} / \text{Slope}),$$
$$SPI = \ln(\text{Flow Accumulation} * \text{Slope}).$$

Areas with slopes greater than 7% are combined with the standard deviation of the aspect greater than 40 and applied with 200-meter buffer are classified as ravines.
For upland depressions and riparian areas, the 95% percentile rank for both CTI and SPI values were applied to identify upland depression and riparian areas respectively (Mulla, 2007).
The classified physical landscapes are detailed, given that a high resolution DEM was used. For further landscape generalization, a density function was used to map out areas with high occurring landscape type. Kernel Density function was used to classify these areas and overlain to their corresponding DEM and Google Earth images.

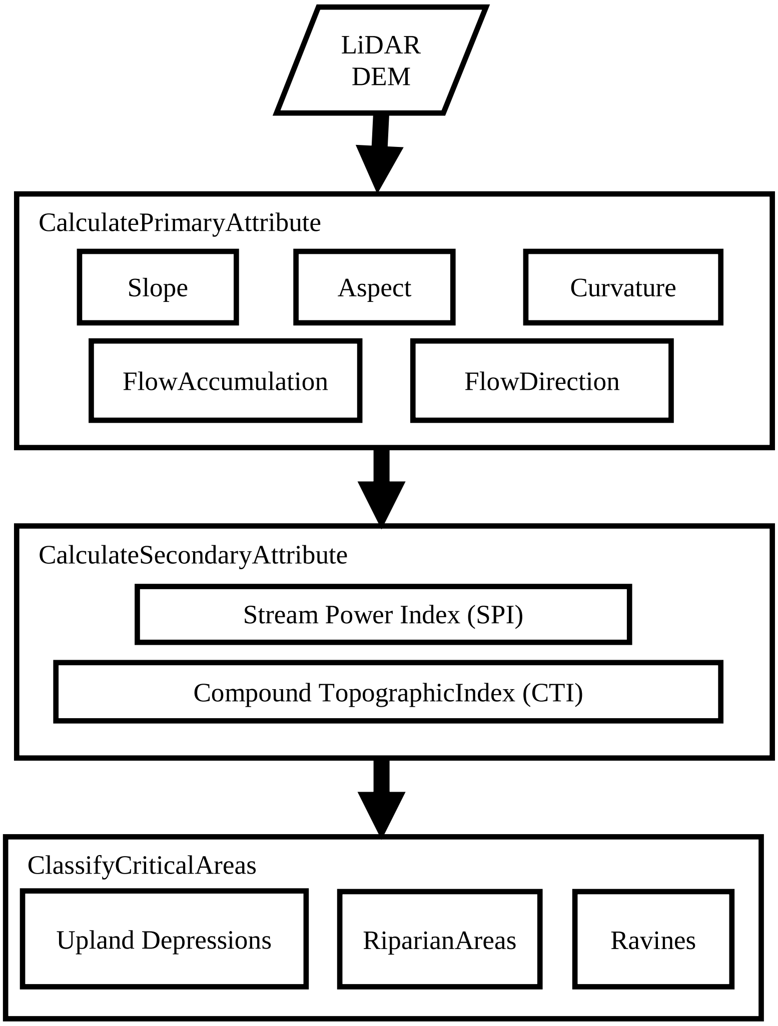

Figure 1. Methodology Flowchart

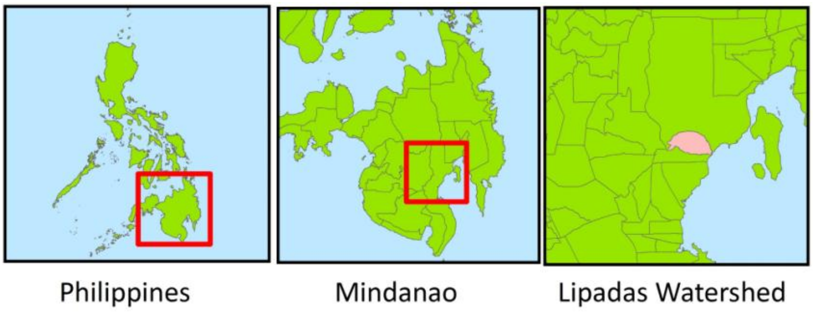

Figure 2. Lipadas Watershed Davao City Philippines

3. RESULTS AND DISCUSSION

For visualization purposes, sample data were taken on a magnified portion of the DEM with the corresponding Google Earth images. Figures 3 and 4 show the upland depression classification sample data. Figures 5 and 6 show the ravine classification sample data. Figures 7 and 8 show the riparian classification sample data.

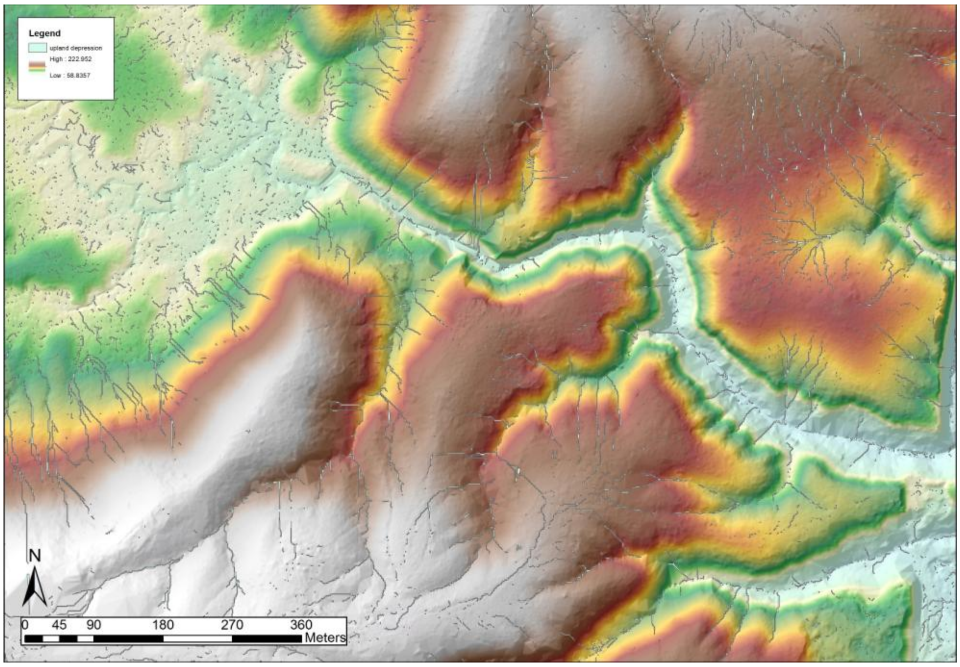

Figure 3. Upland Depression data sample overlay on DEM.

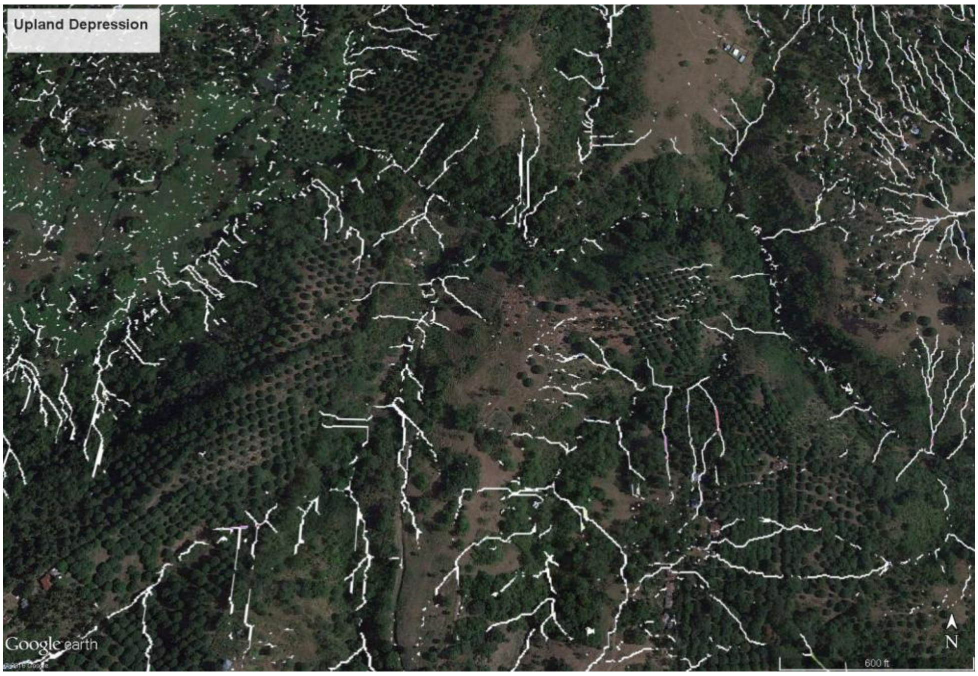

Figure 4. Upland Depression data sample overlay on Google Earth image.

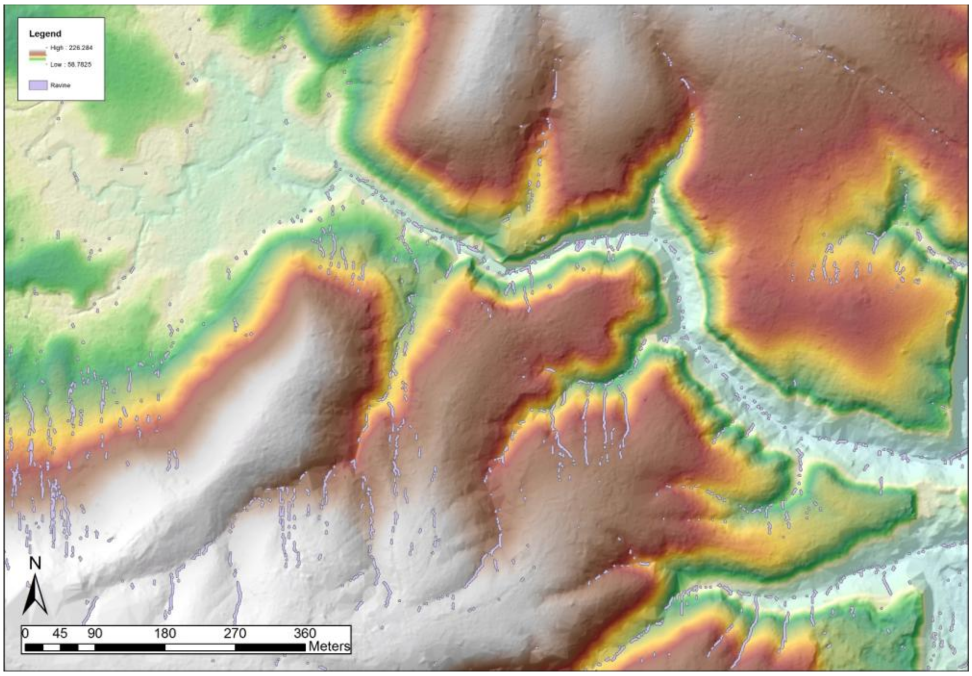

Figure 5. Ravines data sample overlay on DEM.

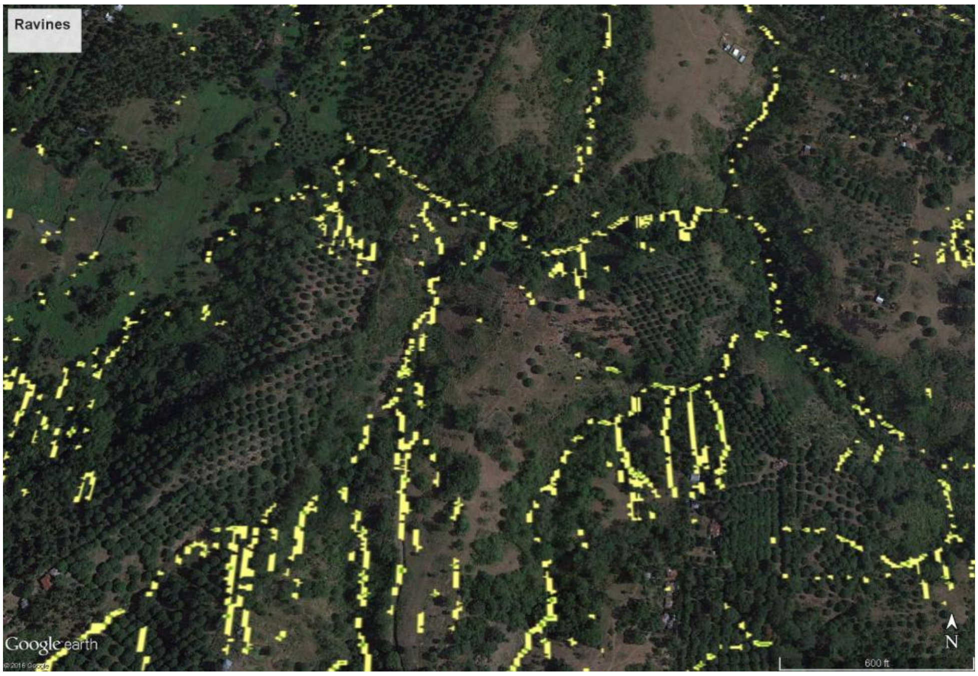

Figure 6. Ravines data sample overlay on Google Earth image.

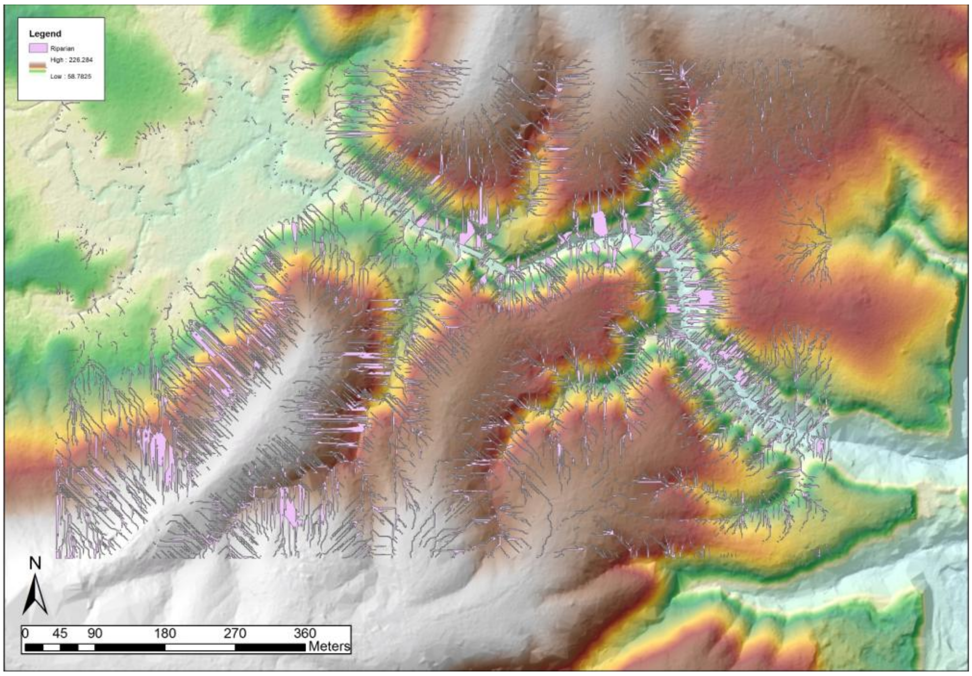

Figure 7. Riparian data sample overlay on DEM.

Figure 8. Riparian data sample overlay on Google Earth image.

Using a Kernel density function, the classified landscape details were further mapped out to describe areas that have highly occurring critical landscape type. These were overlain on Google Earth images as seen on Figures 9-12. These areas are not easily identified using satellite images alone, neither by simply looking at the high resolution DEMs.

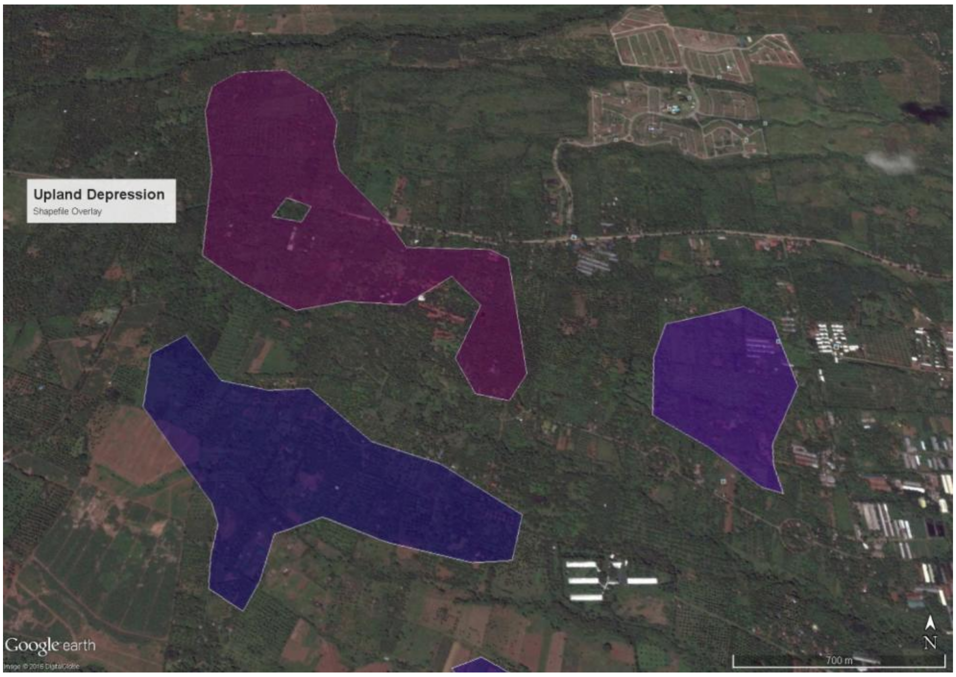

Figure 9.Upland Depression area overlay on Google Earth image classified using Kernel Density

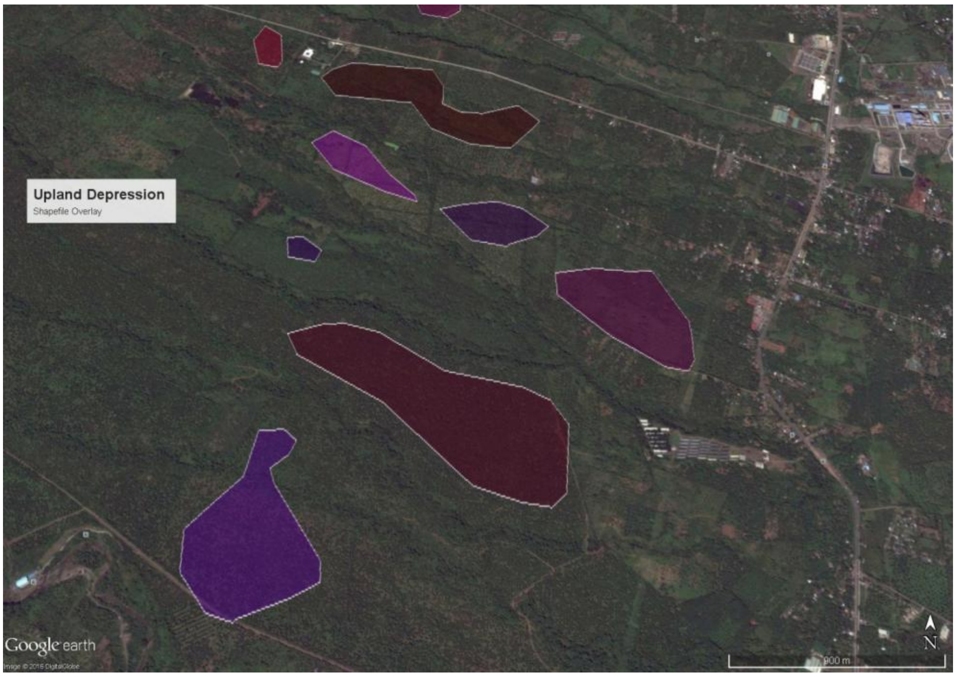

Figure 10.Another Upland Depression area overlay on Google Earth image classified using Kernel Density

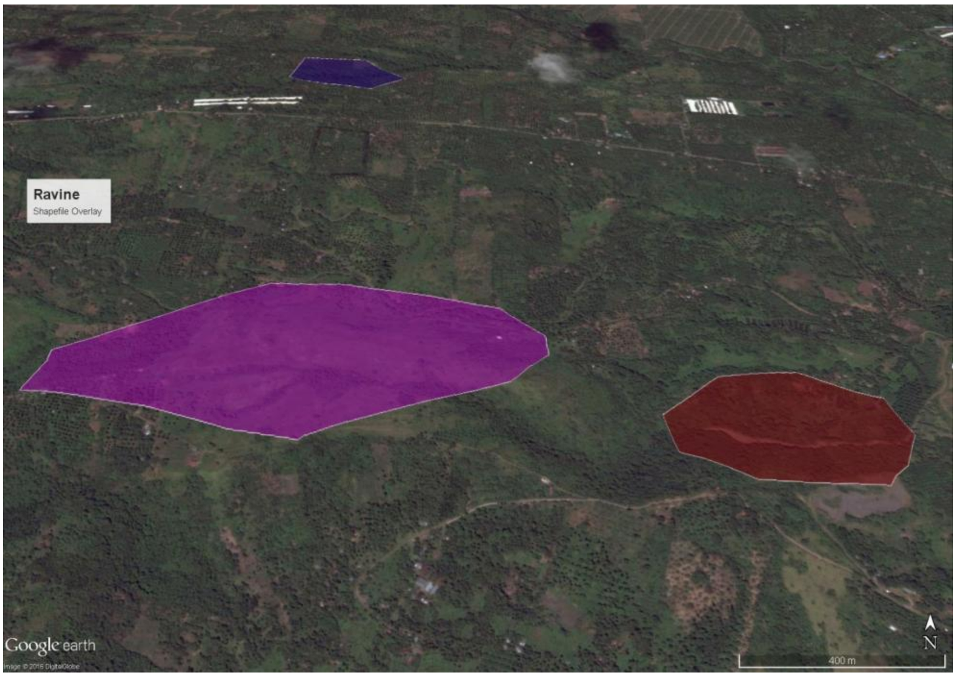

Figure 11.Ravine area overlay on Google Earth image classified using Kernel Density

Figure 12. Riparian area overlay on Google Earth image classified using Kernel Density

CONCLUSION

This study calculated primary and secondary attributes based on LiDAR DEM of Lipadas watershed. The calculated attributes were used to further identify and classify, initially critical areas, whether ravines, upland depressions, and riparian areas. Due to the high resolution of LiDAR DEM, critical areas that were classified are detailed. This study is only limited to the process of digital terrain analysis. Actual field validation enables the calibration of threshold levels for more accurate classification and identification of the critical areas. The whole Lipadas watershed stretches up to 152.84 sq.km. and with the aid of the google earth images, the digital terrain analysis allows users to see the features of the landscape they could not otherwise see. This study can be extended to identify priority agricultural lands for implementing best managements practices to reduce soil loss or sedimentation.

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