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SLOPE INVENTORY AND HAZARD ASSESSMENT ALONG MOUNTAINOUS ROAD USING AIRBORNE LASER SCANNING DATA AND ORTHOPHOTOS IN PENINSULAR MALAYSIA IN 2010
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ABSTRACT
Malaysia is a country located in Southeast Asia. There are two distinct parts to this country being Peninsular Malaysia to the west and East Malaysia to the east. Peninsular Malaysia is located south of Thailand, north of Singapore and east of the Indonesian island of Sumatra. East Malaysia is located on the island of Borneo and shares borders with Brunei and Indonesia.
Peninsular Malaysia is more populated than East Malaysia where 79.2% of the population lives in the Peninsular. In 2007,62% of Malaysian population lived in urban areas, while the rest live in rural areas. The largest city is Kuala Lumpur with a population of 2 million people in the city, and about 7 million in the metropolitan area known as Klang Valley. Other major cities include Georgetown, Johor Bahru, Ipoh, Kuching, and Kota Kinabalu.
Located near the equator, Malaysia's climate is categorised as equatorial, being hot and humid throughout the year. The average rainfall is 250 centimetres (98 in) a year and the average temperature is 27 °C (80.6 °F). The climates of the Peninsula and the East differ, as the climate on the peninsula is directly affected by wind from the mainland, as opposed to the more maritime weather of the East. Malaysia is exposed to the El Nino effect, which reduces rainfall in the dry season. Climate change is likely to have a significant effect on Malaysia, increasing sea levels and rainfall, increasing flooding risks and leading to large landslides.
Malaysia faces two monsoon winds seasons, the Southwest Monsoon from late May to September, and the Northeast Monsoon from November to March. The Northeast Monsoon brings in more rainfall compared to the Southwest Monsoon, originating in China and the north Pacific. The southwest monsoon originates from the deserts of Australia. March and October form transitions between the two monsoons.
Local climates are affected by the presence of mountain ranges throughout Malaysia, and climate can be divided into that of the highlands, the lowlands, and coastal regions. The coasts have a sunny climate, with temperatures ranging between 23 °C (73.4 °F) and 32 °C (89.6 °F), and rainfall ranging from 10 centimetres (4 in) to 30 centimetres (12 in) a month. The lowlands have a similar temperature, but follow a more distinctive rainfall pattern and show very high humidity levels. The highlands are cooler and wetter, and display a greater temperature variation. A large amount of cloud cover is present over the highlands, which have humidity levels that do not fall below 75%.
Regarding geology, Malaysia is located on the Sunda shelf, and is tectonically inactive. The oldest rocks in the country dated back from 540 million years ago, and are mostly sedimentary. The most common form of rock is limestone, formed during the Paleozoic era. Limestone laid down in East Malaysia during the Tertiary period has since eroded, and such erosion forms basins of sedimentary rocks rich in oil and natural gas. The mountain ranges in Malaysia were formed through orogenesis beginning in the Mesozoic era.
Malaysia is situated between two major boundaries of tectonic plates, Australian Plate and Eurasian Plate in the west of Peninsular Malaysia and Philippine Sea Plate and Eurasian Plate in the East of Malaysia. Tremors, mostly non-lethal can be felt in Malaysia, caused by earthquakes in Sumatra islands of Indonesia and the Philippines.
Due to its complex geological-geomorphological activities and topography, combining with the global climate uncertainties, have created an immature and rugged landscape and climate which in turn imposes various natural disaster such as erosion and landslide hazard to both the people and its property. In order to address these problems

both in a big or regional scale, the DEM (Digital Elevation Model) and orthophotos could be used in conjunction with selected field visit during which parameter such as landuse, land cover, soil type, lineament etc. are observed and measured.
Over the years, a visual approach has been used in road slope inventory and hazard assessment in PWD (Public Works Department) Malaysia. This method is quite laborious, time consuming and prone to error. Paper forms are used to fill in the slope attributes while kilometer posts along the roads are used as benchmark with relative to the slope location. The kilometer post is not reliable as it is open to damage and missing due to many reasons such as accidents, road widening, vandalism etc.

Today, the use of Geographical Information Technologies (GIT) for inventorizing assets has increased due to the rapid development in commercial GIS modeling software and the quick access to data obtained through Global Positioning System (GPS) and remote sensing.

Taking these opportunities, facts and its ability to improve on slope management, PWD Malaysia in 2010, has acquired road slope data through airborne laser scanning (LiDAR) and middle range digital camera thus producing Digital Elevation Model (DEM) and orthophotos. At the same time, PWD also developed and customized a GIS based system using commercial off the shelf software to incorporate and manipulate this spatial data.

With this system, PWD are able to inventory the slope digitally and at the same time, analyze and rank the slope according to the level of hazard and eventually published the slope hazard maps through the internet. With these maps the slope can be monitored more systematically and annual slopes maintenance program can be planned and managed properly. In other words, besides hazard, the risk to people and property are being taken care considerably.

In this paper, I would like to emphasize on the methodology used to produce road slopes hazard map using airborne laser scanning data and orthophotos which utilize GIS (Geographic Information System) and GPS (Global Positioning System) technology.

Keywords: Landslide; Road slope hazard assessment; GIS; GPS; DEM; Orthophotos