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Bedload transport of small rivers in Malaysia

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Abstract

Numerous time-consuming equations, based on the relationship between the reliability and representativeness of the data utilized in defining variables and constants, require complex parameters to estimate bedload transport. In this study the easily accessible data including flow discharge, water depth, water surface slope, and surface grain diameter (d_{50}) from small rivers in Malaysia were used to estimate bedload transport. Genetic programming (GP) and artificial neural network (ANN) models are applied as complementary tools to estimate bed load transport based on a balance between simplicity and accuracy in small rivers. The developed models demonstrate higher performance with an overall accuracy of 97% and 93% for ANN and GP, respectively compared with other traditional methods and empirical equations.

Key Words: Bedload transport, Small rivers, Genetic programming, Artificial neural network

1 Introduction

Bedload transport is an important physical process in determining the morphologic development of alluvial river reaches (Barry et al., 2008). Bedload transport refers to the movement of bed sediments along the stream bed by rolling, sliding, or jumping and is absolutely dependent on the river's morphological characteristics (Turowski et al., 2010; Wang et al., 2011). Bedload transport rate estimation is essential for the realistic computations of river morphological variations because the transport of sediment through river channels has a major effect on public safety, water resources management, and environmental sustainability (Frey and Church, 2011; Yeganeh-Bakhtiary et al., 2009).

Bedload transport in small rivers (Molinas and Wu, 2001) is diverse and highly variable due to the various characteristics of channel morphology. River channel morphology is completely affected by the environmental conditions of the stream. The hydraulic geometry of channels in small rivers is affected by various parameters. Each channel section is in many ways unique because it is influenced by its own particle history of flow conditions, sediment transport, distribution of channel roughness elements and management activities, all of which should be considered in bedload transport estimation (Beschta and Platts, 1986).

The difficulties associated with bedload field measurement have caused a long history of interest in developing equations for bedload transport prediction (Schoklitsch, 1934; Bagnold, 1980).Various literatures on bedload transport estimation have been formulated under limited laboratory or field conditions (Habersack and Laronne, 2002).

The application of many bedload transport equations is mostly limited to the specific conditions in which they were developed. Computations from various equations often differ from one another in derivation and form, and even from a measured data set, because changes in channel morphology in small rivers behave in a complex manner. Consequently, the proposed equations need to be adopted for the new condition (Khorram and Ergil, 2010).

The new mathematical modeling methods can be used to improve the sensitivity and performance of prediction equations in overcoming the difficulties of developing such equations based on a balance between simplicity and accuracy. The simple formula can estimate the bedload transport of small rivers. Genetic programming (GP) and artificial neural network (ANN) are powerful tools for pattern recognition and data interpretation. They were employed and compared with the nonlinear regression (NLR) method to present an explicit predictive equation for bedload transport in small rivers.

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Artificial intelligence techniques and the genetic algorithm cannot assure constant optimisation response times. Even more, the difference between the shortest and the longest optimisation response time is much larger than with conventional gradient methods. This unfortunate artificial intelligence and genetic algorithm property limits these methods' use in real time applications.

Genetic algorithm and artificial intelligence techniques applications in controls which are performed in real time because of random solutions and convergence are limited, in other words this means that the entire population is improving, but this could not be said for an individual within this population. Therefore, it is unreasonable to use genetic algorithms for on-line controls in real systems without testing them first in a simulation model (Šafarič and Rojko, 2006).

This study aims to estimate the bedload transport rate based on a balance between simplicity and accuracy by developing a GP and ANN river system model. Data from six sediment stations on Kurau River in Perak and two sediment stations in Lui and Semenyih River in Selangor (Ariffin, 2004), Malaysia, were compiled to obtain the formula as well as for comparison with other existing bedload transport formulas. The performances of the GP, ANN, and statistical (MLR) models were evaluated and compared with six common bedload transport formulas such as Meyer-Peter and Muller (1948) based on the energy slope method; Rottner (Yang, 1996), Chang (Cheng, 2002), Julien (2002) and van Rijn (1993) based on the regression method; and Wong and Parker (2006) based on the shear stress method.

2 Study sites and field measured data

Kurau River sub-basin (Fig.1a) lies between latitude 530,000 (N) and 570,000 (N), longitude 683,342 (E) and 723,342 (E) in Zone 47, UTM coordinate system. The catchment area consist of two main river tributaries namely Kurau River and Ara River. Kurau River represents the main drainage artery of the basin, draining an area of approximately 682 km^2 which is generally low lying. Mid valleys of the river are characterized by low to undulating terrain, which give way to broad and flat floodplains. Ground elevations at the river headwaters are moderately high, being 1,200 m and 900 m. The slopes in the upper 6.5 km of the river averaged 12.5% whilst those lower down the valleys are much lower, of the order from 0.25% to 5%.

Field measurements were obtained along the selected cross section at the six study sites at Kurau River Catchment (Table 1) by referring Hydrological Procedure (DID, 1976) and recent manuals (Yuqian, 1989; USACE, 1995; Edwards and Glysson, 1999). The current study was conducted only in six cross sections because of the difficulty in sampling and possibility of wading in the water in these areas. Owing to bank erosion and severe bed degradation, other locations were either inaccessible or impossible to wade into the water.

A range of flow discharge measurements covering low and high regime were carried out using current meter. The procedure of flow discharge measurement is based on Hydrology Procedure No. 15: River Discharge Measurement by Current Meter (DID, 1976). Measurements taken include flow depth (y_0), velocity (v), river width (B) and water surface slope (S_0) for a detailed analysis of the river.

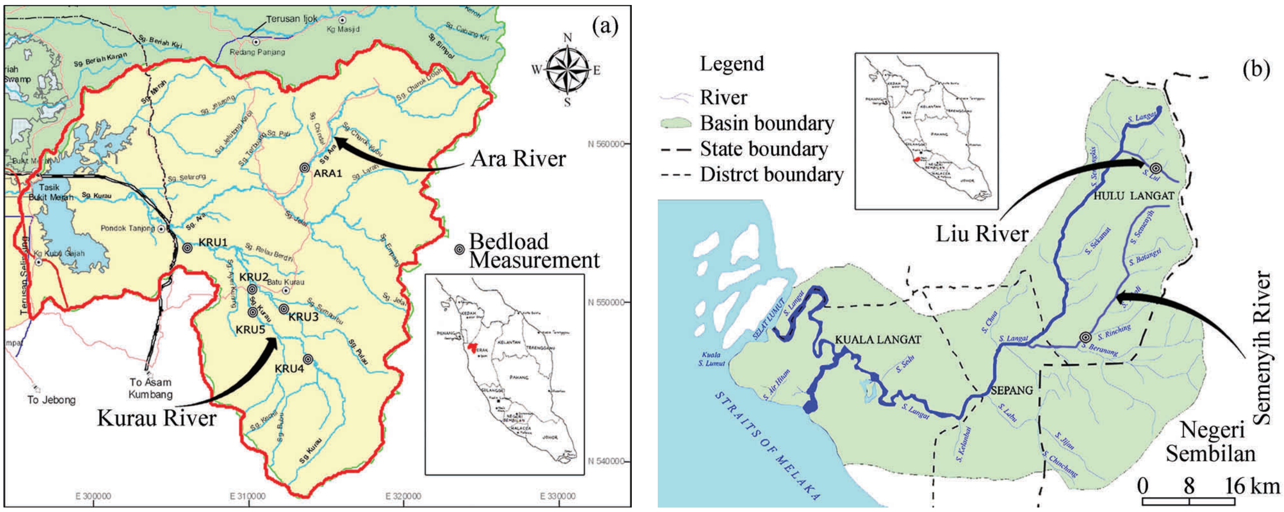

Fig. 1 a) Kurau River sub basin, b) Lui and Semenyih River basin

Each cross section was sampled eight times during the field measurement season. The channel cross-section was then divided into eight equally spaced increments on the basis of flow width at time sampling. Flow depth (y_0) and velocity (V) were measured at each increment. Bedload was sampled immediately after velocity at seven measuring points with 3 times repeated. Bedload was collected using a Helley-Smith bedload sampler with a square 7.6 cm orifice and 0.25

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