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Knowledge-based Expert System for Stormwater Management in Malaysia

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ABSTRACT

Stormwater is usually susceptible to be polluted due to land disturbance activities like earth work and land clearing. Land clearing and earthwork activities combined with heavy rainfall. And the widely varied topography in Malaysia can result in severe soil loss and sediment generation. Recently knowledge-based systems have been used in many fields especially when human expertise and data are limited. In the current study, a knowledge-based expert system was developed for stormwater management stormwater in Malaysia. This system called the Stormwater Management Control Expert System (SMCES), was developed using the Microsoft Visual Basic 6 environment. The SMCES system can be used by engineers, contractors and decision makers for stormwater management control in Malaysia.

Key words: Control measures, erosion prediction, sediment yield, expert systems, stormwater

INTRODUCTION

Soil erosion is the process by which the land's surface is worn away by the action of wind, water, ice and gravity. Human activities accelerate the erosion process by loosening and pulverizing soil, making it more susceptible to detachment by natural forces. Water generated erosion is unquestionably the most serious and severe type of erosion. Soil erosion not only affects the ambient water bodies but also makes changes in land use and soil management (Soleimani and Modallaldoust, 2008; Arekhi, 2008). Pollution of rivers is attained to point and non-point sources and marine pollution originates mainly from land-based sources (Norizan *et al.*, 2011). Have tested few water quality parameters as the index for determining the water pollution. Total Suspended Solids (TSS) generated from the construction activity can significantly contribute to the degradation of surface water. Heavy metals that are accompanied with the TSS can affect the fish and relevant water (Ahmad and Afzal, 2001). A study of road construction on four California trout streams and the associated effects of logging have been conducted by Burns (1972) and he has concluded when the sediment and turbidity increased substantially, decreases in most aquatic invertebrates were indicated. A period of two years after the construction is completed; the densities of the macroinvertebrates have recovered by 100%.

In urban construction alone, the estimates indicated that 15 million tons of sediment is released every year in close proximity to water bodies (Bhutani *et al.*, 1975). Twenty two million tons of sediment are released from highway construction sites each year appear to be the highest rate of pollutant release for any type of hydrologic modification for which quantitative estimates have been accomplished. The effects of construction on the receiving water can be essential even though the area involved may cover only a small portion of a watershed. (US. Geological Survey, 2000) had conducted a study in the Dane County, Wisconsin for two small construction sites (less than 5 acres), one is commercial and the other one is residential. Results had showed that the sediment load from these two small construction sites was 10 times greater than typical loads from urban and rural land uses in Wisconsin. Cleveland and Fashokun (2006) were monitored selective water quality parameters before construction, during construction and post construction. They have indicated that the construction activity resulted in a six times increase in total solids leaving the construction site compared to pre-construction values and the construction activity affected the distribution of particles in a suspension leaving the construction site. It has been concluded that the vegetation cover plays the most important role in soil erosion control (Mahmoudzadeh, 2007). Farid *et al.* (2002) conducted a study on the water pollution and its effects on human health in rural areas of Faisalabad.

Expert systems are generally considered a branch of artificial intelligence with a knowledge base and it is considered as the most important branch of artificial intelligence. These systems can function as expert to make higher-level decisions based on varying performance levels (Basri, 1999). An expert system is able to give recommendations at a level comparable to, or above an expert. Expert systems are most useful when the knowledge is based on heuristics. Expert systems has been used in many fields like air pollution (Kabbashi *et al.*, 2006); urban land use planning (Main and Mesgari, 2009); flexible pavement design (Amiruddin and Atiq, 2009); highway construction (Basri *et al.*, 2009); Diagnosis Osteoarthritis (Blessia *et al.*, 2011); Plant disease diagnosis (Abu-Naser *et al.*, 2008).

The aim of the current study is to develop a knowledge-based expert system for stormwater management in Malaysia due to construction activities.

METHODOLOGY FOR KNOWLEDGE BASED SYSTEM DEVELOPMENT

The SMCES system is developed according to standard knowledge-based expert system development methods. The system development process is guided by a five-step process, namely, task analysis, knowledge acquisition, prototype development, expansion and refinement and verification and validation (Islam, 2004; Terry, 1991; Waterman, 1986).

Task analysis: Task analysis is a methodology tool that can be used to describe the functions of expert performance in problem solving and determine the relationship of each task to the overall job. The current knowledge-based expert system to minimize stormwater pollution in Malaysian construction sites involves several manifold tasks. Each of these tasks has one or more sub-tasks, which form the basis of the knowledge-based modules that make up the components of the entire system. The tasks and subtasks within the SMCES system are as follows:

- Task 1: BMPs consultation
- Subtasks: Site construction facilities
- Site clearance

- Site building
- Task 2: Predict soil erosion and sediment yield
- Subtasks: Predict soil erosion using USLE
- Predict sediment yield using MUSLE
- Task 3: Inspection and maintenance plan
- Subtasks: Inspection and maintenance for erosion control measures
- Inspection and maintenance for sediment control measures
- Inspection and maintenance for drainage control measures

Knowledge acquisition: The knowledge acquisition stage can be considered the most important, difficult and time consuming phase of expert system development (Basri, 1999). The knowledge involved in the SMCES system was acquired from many sources like text books, journals and guidelines. For the current study, the authors acquired knowledge and information through the following:

- Review of various factors affecting the soil erosion and sediment yield
- Understanding the different construction stages and their impact on adjacent water bodies and the identification of suitable BMPs that can be adopted to minimize impact and the suitable site characteristics for each BMP
- Review of construction site erosion, sediment control and methodologies for the development of expert systems from relevant books, guidelines, and documented manuals
- Attendance in seminars and national and international conferences that cover different topics, such as erosion and sediment control, stormwater pollution, stormwater management, water resources in general
- Review of the architecture of various expert systems that have been developed in many fields and
- Review of some knowledge-based expert system prototypes developed for fields related to water resources and erosion and sediment control

Meetings with experts from the Department of Irrigation and Drainage, the Department of Environment and the Department of Public Works as well as university academics were established.

Another form of knowledge acquisition was conducted via an on-site observation method, wherein in which the knowledge engineer visited some construction sites and observed firsthand how experts solve a realistic problem rather than learning from plain description. The experts in the construction site identified the suitable BMPs for each construction and sub-construction stage and conducted installation, inspection and maintenance of the BMPs. Using multiple sources to establish a knowledge base has many advantages because no bias is shown toward a single view: the reliance on single expert knowledge elicitation is low and the conflicting views gained represent the actual field situation, which often requires. In the development of the SMCES system, many sources of knowledge were tapped and integrated.

Prototype development: At this stage, the knowledge engineer uses the acquired knowledge to develop a working computer program. The SMCES system consists of three major tasks. The first is BMP consultation, which selects the existing site characteristics for any development project in

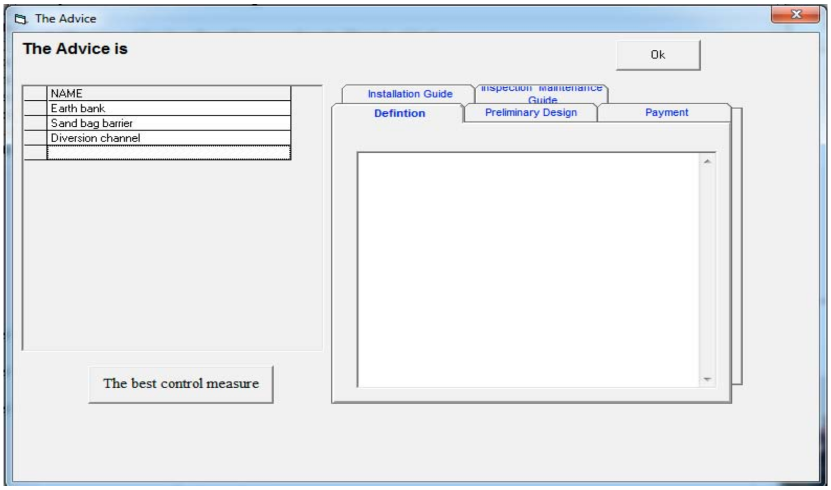

Fig. 1: Advices obtained following the user selections of site characteristics for the control of the surface runoff surrounding the disturbed site

Malaysia and helps the user identify the suitable stormwater control measures for minimizing erosion and sedimentation. The second task involves the prediction of erosion loss and sediment yield for construction sites. The third task of the SMCES system is the inspection and maintenance plan for various erosion and sediment control measures. The SMCES system can provide the user with the necessary information to develop an erosion and sediment control plan, which includes information on the submission requirements for the construction activity, who should obtain approval, deadlines, minimum soil erosion and top soil prevention and other assets. The following sections provide a detailed explanation of each task within the SMCES system.

Task 1: BMP consultation: In this task, the SMCES system user can choose the relevant main and sub-construction activities. Figure 1 shows the advice obtained regarding the control of the runoff surrounding the disturbed site following the user selections for the site characteristics.

The SMCES system provides an explanation facility, preliminary design, inspection and maintenance plan and installation guide for each selected BMP.

Task 2: Predicting soil loss and sediment yield: Here, the prediction of soil loss using USLE and the sediment yield using MUSLE has been adopted and described. For the prediction of soil loss, the user is required to estimate values for the soil erodibility factor (K), rainfall erosivity factor (R), slope length and steepness factor (LS) and cover and management practice factor (CP). For estimating each of these factors, there are certain kind of selections and data required to be inserted. For estimating the R factor, maps for all Malaysian states were provided in which the relevant R factor for each place within the state available as shown in Fig. 2.

For estimating the K factor, there are three scenarios available, either from the soil survey data, from soil map or from soil erodibihty table. LS factor can be estimated by inserting the average slope

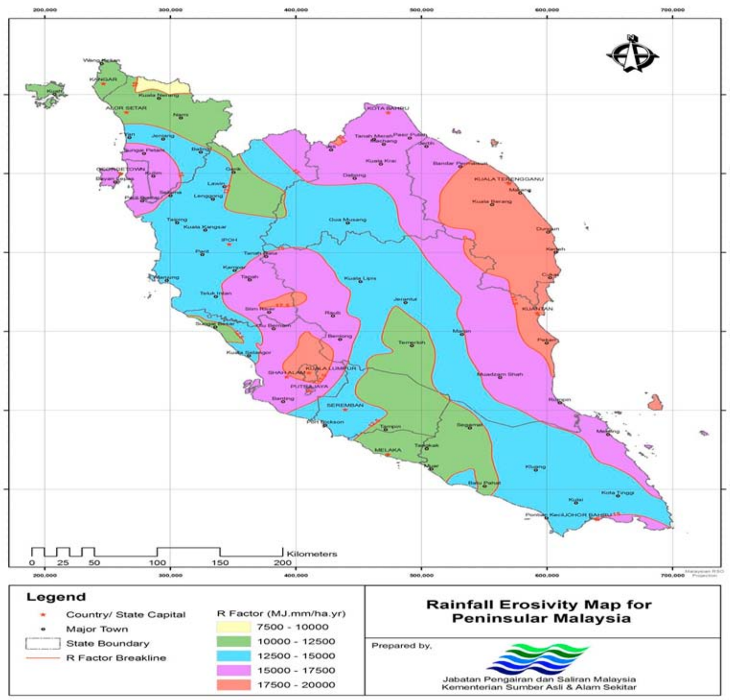

Fig. 2: R factor values for the states of Negeri Sembilan and Melaka

length and slope steepness values of the catchment. Eventually, for estimating the CP factor, the user is required to select the kind of land use and the management practice factor available in the catchment. The soil loss can be estimated from Eq. 1:

$$A = R.K.LS.CP \quad (1)$$

where, A is annual soil loss, in units of tonnes/ha/year; R is Rainfall factor converted to erosion index units (EI- units) for the period of consideration. K is a soil erodibility factor depending on soil types. The erosion rate per unit of erosion index for a specific soil, on a plot of 9% slope and 22.1 m (72.6 ft) long. S is slope length factor, the ratio of soil loss from the field slope length to that from 22.1 m length on the same soil type and gradient. L is slope length factor, the ratio of soil loss from the field slope length to that from 22.1 m length on the same soil type and gradient. C is cropping management factor, the ratio of soil loss from a field with specific cropping and management to that from the fallow condition on which the factor K is evaluated. P is erosion control practice factor; the ratio of soil loss with contouring, strip-cropping or terracing to that with straight row farming, up-and-down slope.

The estimation of sediment yield requires the estimation of the time of concentration (Tc) for the catchment, rainfall intensity, rainfall depth, runoff depth and peak runoff. SMCES relies on Eq. 2 to predict the sediment yield:

$$Y = 89.6\ (V\ Q_p)^{0.56}\ (K.\ LS.\ C.\ P) \quad (2)$$

where, Y is sediment yield per storm event (tonnes), V is runoff volume in cubic meter, Q_P is peak discharge in m^3 sec^{-1}.

The estimation of the rainfall intensity, rainfall depth, time of concentration and the peak runoff was based on Department of Irrigation and Drainage (2000).

Task 3: Inspection and maintenance plan: The objective of inspection and maintenance is to develop a program that monitors the efficiency of the BMPs work and to evaluate whether additional BMPs are required. The inspection includes the evaluation of erosion, sediment and conveyance control measures. The regular inspections and expected repairs for erosion and sediment control are provided. The inspection location, inspection frequency, inspection and maintenance submission checklist, erosion and sediment control plan review and modification, typical inspection program, BMP monitoring, inspection report form, and the monitoring report are provided for all BMPs.

Expansion and refinement: This step involves evaluating the performance and utility of the prototype program and revising it as necessary. It also involves checking for mistakes in knowledge acquisition to ensure that the knowledge base correctly reflects that of expert information and that the system performs at an acceptable level of accuracy, user-friendliness and overall usefulness.

The SMCES system was presented to the experts who monitored how it solves problems; provide solutions for different site characteristics, and the prediction of soil loss and sediment yield. Afterward, the experts were asked to fill up a questionnaire form regarding their comments and opinions on software performance and user friendliness. Results from the questionnaire were very satisfactory.

Verification and validation: Systems verification ensures that the software is syntactically and logically correct and performs functionally as specified. In the expert system's context, verification ensures that the compile time and runtime errors are eliminated (El-Drandaly *et al.*, 2009). Validation is the process of inserting real data to the software to indicate the software's functionality in solving certain problems. Bryant (2001) reviewed some expert systems and indicated that many of them did not survive their implementation into an organisation due to number of reasons and one of them is the inadequate validation.

In the current study, a construction site in Malaysia was chosen as the case study for the testing and validation of the SMCES system modules developed. The results obtained from the SMCES system is almost similar to the recommendations given by the on-site engineers, indicating that the system performs like a human expert.

CONCLUSIONS

The current study presented a knowledge-based expert system (SMCES) for stormwater management in Malaysia. Three major tasks were adopted in SMCES. The first one is BMP consultation, the second task is the prediction of soil loss and sediment yield and the third is the inspection and maintenance program (applicable to any construction site in Malaysia). Based on a comparison of the results obtained from the on-site engineer and the SMCES results, SMCES proves to behave like human expert. The SMCES system can save time that is otherwise wasted when a consultant is not available. Furthermore, a consultation is costly and requires further financial allocations to the project. The programming language used to develop the system is Visual

Basic version 6, which provides greater flexibility and adaptability in rapidly developing this prototype. The programming languages require more time for development because the developer must first become familiar with the computer languages and he/she must still develop the program codes. In addition, debugging the program is often difficult. The target end users of the system are engineers, consultants, contractors, and decision makers.

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