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13

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APPLICATION OF EXPERTS SYSTEMS TO SOIL CONSERVATION PLANNING

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ABSTRACT

As a rapidly evolving decision-support technology, Expert Systems, which derive from the field of Artificial Intelligence, are designed to mimic decision-making processes of experts in given knowledge domains. In soil and water conservation engineering, improving water quality and providing a sustainable resource base for agriculture involve the selection of appropriate practices to control soil erosion. This requires making logical decisions based on expertise.

This paper reports the development of a prototype Expert System for soil conservation planning. The USLE was used to establish the general range of possible conservation practices. Then knowledge acquisition was based on the heuristics of selecting the best practice for a given set of conditions. The system provides a means of assessing the attributes of a farm in order to make recommendations in a conservation plan.

KEYWORDS: Expert systems, VP-Expert, Knowledge base, erosion, soil conservation planning, universal soil-loss equation, soil properties.

1. INTRODUCTION

The primary goal of the field of artificial intelligence (AI) is to develop the characteristics of intelligence in a computer. The impact of the digital computer has already produced profound changes in professional work of the technical fields. It has been found, Barrett et al. (1985), that the three areas of AI with the greatest potential for agricultural work in the next several years are Knowledge (Expert) Systems, Robotics, and Natural Language Processing. An expert system is a computer program designed to reason like a human expert in some specific area of expertise identified as the domain of the system. An expert system can solve problems in a way similar to a human expert within its domain. Some of its capabilities include analysis, symbolic logic, diagnosis, design and decision support.

Expert systems are developed by writing computer programmes that mimic human decision-making, by consulting experts who are willing to share their problem-solving skills. While the programmes may not necessarily require any special programming language, their development is made easier with expert system shell. Some of the more common shells are VP-Expert, PC-Easy, EXSYS, PC-Plus and KES II. Shells enable non-programmers to develop expert systems by encoding knowledge in the form of IF-THEN-ELSE rules.

This paper reports the development of an expert system for soil conservation planning. A general description of the system is presented. This prototype is intended for use in training students and non-technical personnel in soil-conservation planning principles using the universal soil loss equation (USLE).

2. THEORETICAL BACKGROUND

The components of an expert system may be described, after Wolfgram et al. (1985), as follows:

(1) The Knowledge Base: This is the space that contains static data as in a conventional data base, which includes given and unchanging information about the problem domain, as well as relationships among the data. Working memory, the space where information is manipulated and modified by the inference engine, is also included in the knowledge base.

(2) The Inference Engine. This is the mechanism that works through the knowledge base, analysing relationships and data, forming hypotheses and monitoring processes according to a predetermined strategy. It embodies the reasoning and search techniques of the system.

(3) The User Interface. This is used to create a user-friendly, interactive environment for the development and/or operation of an expert system. It ranges from simple question-answer types to specialised graphical environments.

(4) Development Editor. This is the <u>shell</u> or knowledge acquisition sub-system that facilitates the encoding of knowledge to "educate" the expert system programme.

The USLE has been traditionally employed in soil conservation planning. Though an empirical technology, with an oversimplification and lumping of the numerous variables involved, the USLE has been widely used for estimating soil loss and sediment yield from farms and fields. Soil conservation can generally be classified into structural and agronomic, which are technically known as supporting practices and cropping-management, respectively. The cropping-management factor includes the effects of cover, crop sequence, productivity level, length of growing season, tillage practices, residue management, and the expected time distribution of erosive rainstorms. The supporting practices include contouring, strip cropping, terracing as well as tillage.

It is not possible to avoid all soil loss from erosion. However, there is a point where the loss will be sufficiently small that crop production can be carried on indefinitely, and productivity is maintained or increased over the years. This reduced soil loss level is known as the soil-loss tolerance (in metric tons per hectare per year), a characteristic of soils depending on physical condition and properties. As a rule of thumb, a deep medium-textured, moderately permeable soil with subsoil characteristics favourable to plant growth was assigned a tolerance of 11.2 metric tons per hectare per year, after Beasley (1972). Soils with a less favourable subsoil were assigned a tolerance of 9 metric tons per hectare per year, while shallow soils and other soils with less desirable physical properties were assigned lower tolerances. Where pollution by sediment is more critical than soil loss, tolerances are established based on sediment yield.

Given the characteristics of agricultural lands to tolerate soil loss at different levels, the levels of high, medium and low may be determined for different soils. A high tolerance roughly implies a deep, fertile soil on a relatively flat slope; a low tolerance a shallow, fragile soil on a relatively steep slope. These correspond to soil capability classes and limitations for vegetable and field crops, as a function of soil properties and condition, which constitute a static knowledge base for the expert system. It provides the basis for the system interpretation of soil survey data.

3. DESCRIPTION OF THE PROTOTYPE EXPERT SYSTEM

The prototype expert system for soil conservation planning was designed for interactive input of the following soil survey data: (1) depth to soil compact layer; (2) soil permeability; (3) flooding susceptibility; (4) available moisture capacity; (5) surface coarse fragments; (6) depth to bedrock; (7) field slope; (8) duration of saturation after rainfall/flooding, and; (9) surface soil texture. After these input are made, the system interprets the information based on an assumed 2-year crop rotation, for the crops specified also by interactive input. Additional inputs requested by the system are field and/or slope length, which are used to calculate the LS factor in the USLE.

Once soil survey data is interpreted to assign a soil loss tolerance level, the USLE is solved for the cropping-management combinations and supporting practices, if necessary, to keep average annual soil loss below the tolerance level. This is done interactively also, to accommodate the farmer's preferences as much as possible. Considering the fact that expert system shells do not have computational ability, the expert system required linkage with an executable FORTRAN file to solve the USLE for the evaluation of conservation options.

The development work of the prototype is fully reported in Arbour et al. (1990). A flow chart of its knowledge base is shown in the attached figure. The prototype is based on the VP-EXPERT Shell Version 1.2 of 1987.

4. APPLYING THE EXPERT SYSTEM

As mentioned earlier, in Section 1, this expert system is intended primarily for use as a teaching tool. A copy of the system is available for demonstration. The user-friendly nature of the system, and its interactive input specification, make it easy to use with little computer literacy. A screen menu guides the operation of the system from the start to the end of a run.

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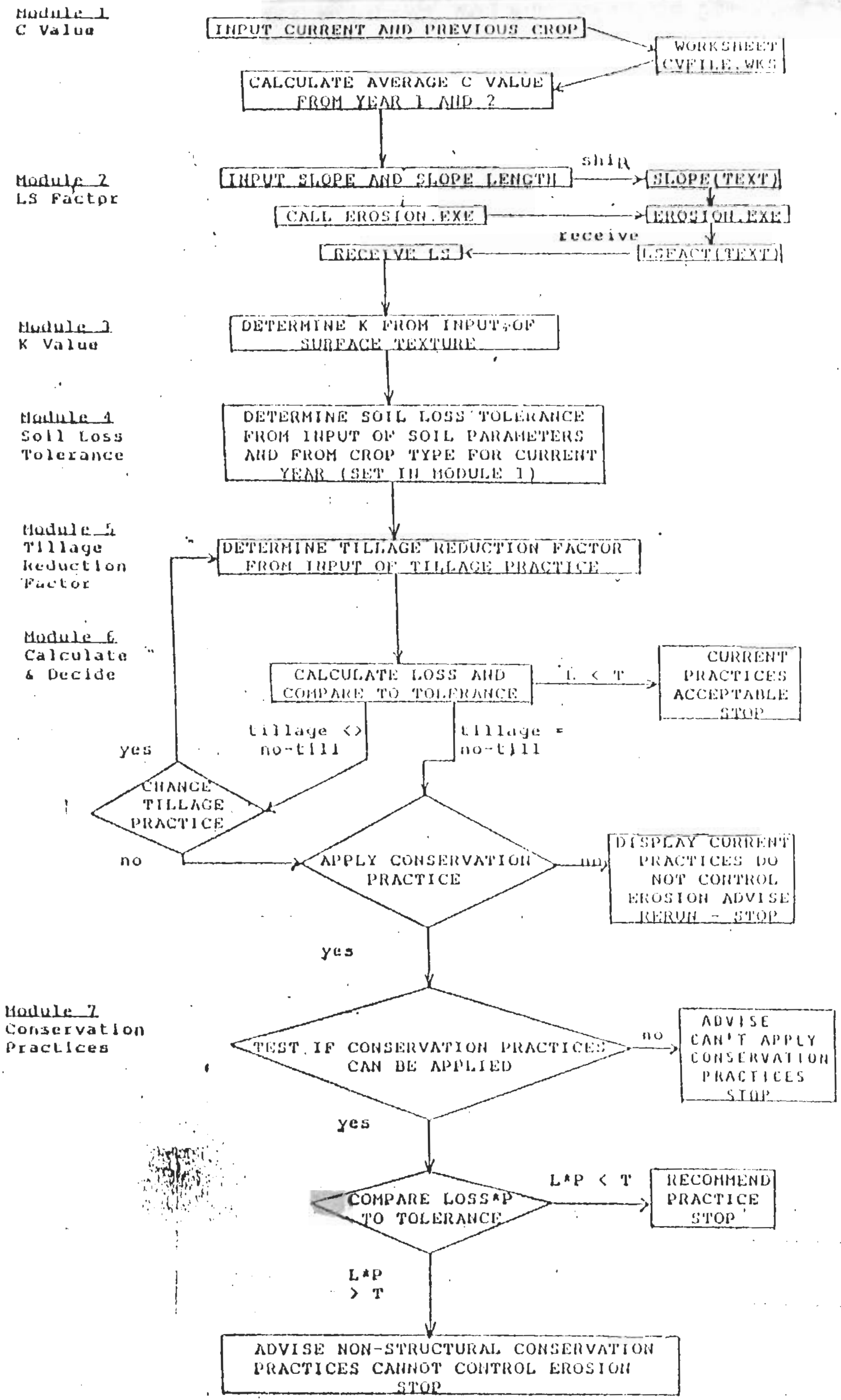

Fig. 1: Knowledge Base Flow Chart