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AN EXPERT SYSTEM BASED METHODOLOGY FOR EVALUATING THE COSTS AND BENEFITS OF SOIL CONSERVATION

By

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ABSTRACT

AN EXPERT SYSTEM BASED METHODOLOGY FOR EVALUATING THE COSTS AND BENEFITS OF SOIL CONSERVATION

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An expert system knowledge-base for assessing the costs and benefits of soil conservation practices was developed. Based on existing conditions, the system gives advice on the best conservation practice and computes its equivalent cost. EXSYSP, an expert system shell was used to develop the knowledge base. Files from Lotus and AGNPS were accessed by the main program to provide some of the necessary inputs; other input information were provided by the user.

The program was aimed at reducing on-site soil erosion. This was accomplished by comparing the area's actual soil loss (TA) with the allowable soil loss limit (TR). In cases where TA was greater than TR, a change in crop rotation was applied. An additional conservation practice was recommended for soil still eroding above TR after the change in rotation. A finally, financial analysis of the two systems ("Rotation Alone" versus "Rotation plus Practice") were compared.

The expert system rule-base was designed for Michigan conditions and tested on fourteen of the highest sediment-producing cells from the lower portion of the Sycamore Watershed. The major crops in the study were Corn, Wheat, Soybean, and Alfalfa, represented in eight crop rotations. Recommendations made

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by the rule-base were compared with the recommendations made by the SCS district conservationist. Although SCS and EXSYSP have different methods of recommending conservation practices, the analysis showed that there was no statistically significant difference in the soil loss resulting from following either recommendation. Financial analysis of EXSYSP showed that both the farmer and society benefited from the application of soil conservation practices.

Testing revealed that the knowledge-based system's method of recommendation was as good as that of the SCS, sometimes even better. Based on these results, it was concluded that an expert system can be used successfully as a decision support tool for decision making with the goal of reducing soil erosion.

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DEFINITION OF TERMS

Best Management Practices (BMP) - These are methods, measures or practices designed to prevent or reduce pollution. They include structural or nonstructural controls as well as operation and maintenance procedures. The practices can be combined variously to prevent or control pollution from a particular source.

Cash Expenses - These represent the money spent during the production of a crop.

a. Variable Cash Expense - Include seed, fertilizer, chemicals, custom operations, hired labor, fuel, irrigation water, drying, technical services. Variable Cash Expense depends upon production practices and quantities of input used and their prices.

b. Fixed Cash Expense - Includes taxes and insurance, general farm overhead, and interest paid on operating loans and real estate loans. These expenses are difficult to attribute directly to a specific enterprise, they are allocated to each crop based on their relative value of production.

Chemical Oxygen Demand (COD) - The measure of the oxygen required to oxidize organic and oxidizable inorganic compounds in water. It is used as an indicator of the degree of pollution.

Conservation Tillage - Chisel plow, no-till or any other tillage systems that leave a protective mulch of crop residues at the surface. It also refers to minimum disturbance of the soil surface.

Contouring - A conservation practice where plowing or planting is done perpendicular to the slope of the field.

Cost Effectiveness - The amount of money spent for a given reduction in pollutant runoff (the less money spent, the more cost-effective the practice is).

Diversion - Simple ridges or channel ridges across a slope. often located at the bottom or top of steep slopes.

Erosion - The wearing-away of land by the action of water, wind, gravity or a combination thereof.

Expert System - A branch of artificial intelligence which exhibits, within a specific domain, a degree of expertise in problem solving that is comparable to that of a human expert.

EXSYSP - The expert system shell developed by EXSYSP Inc. used to develop the knowledge base in this study.

Gross Erosion - The volume of soil movement on the field, not necessarily soil removed from a site.

Gross Value of Production - Value of the primary and secondary crops at the time of harvest.

Interrill Erosion - The loss of soil between the rills, principally caused by raindrop impact.

Knowledge

a. Deep - Knowledge obtained through formal study, usually in the public domain. Mostly theories and principles found in books.

b. Shallow - Knowledge learned through experience and rule of thumbs. Shallow knowledge are the sources of heuristic rules.

Knowledge Acquisition - Method for eliciting facts and rules for the knowledge-base. This can be accomplished either from the domain expert or historical records.

Knowledge Engineer - One who identifies appropriate applications of expert systems and who performs the process of development and implementation.

Knowledge-Based Systems - A computer program that employs knowledge and inferencing to solve problems. When knowledge and inference procedures are modeled after human experts, we call such a knowledge-based system an expert system.

Knowledge Representation - Manner in which data or information is represented within the digital computer.

Resource Management System (RMS) - A combination of conservation practices and management, identified by the primary use of land or water that, if installed, will at minimum protect the resource base by meeting acceptable losses, maintaining acceptable water quality, and maintaining acceptable ecological and management levels for the selected resource use. (SCS National Conservation Planning manual, USDA-NCPM 1984).

Rill Erosion - Formation of small channels as a result of runoff. These channels are several inches deep and can be easily erased by normal tillage practice.

Rule-Based Expert Systems - A class of expert systems where the main constituent of the knowledge-base is a set of rules. Each rule represents a body of knowledge.

Sediment - Solid particles, mineral or organic, that have been deposited in water, are in suspension in water, are being transported, or have been removed from the site of origin by the process of soil erosion.

Sedimentation - Action or process of depositing particles of waterborne or windborne soil, rock or other materials.

Shell - Software containing all the components of an expert system except the knowledge-base.

Sheet Erosion - Removal of thin layers of soil by water acting over the whole soil surface. It is caused by raindrop splash and surface flow.

Slope - A degree of deviation of a surface from the horizontal, usually expressed in percentages or degrees.

Sod - A closely knit ground cover growth, primarily of grasses.

Soil Textural Class

1. Sand - Soil particles between 0.05-2.0 mm diameter. Classified into five soil separates, namely: very coarse, coarse, medium, fine, very fine.
2. Silt - Soil separate consisting of particles between 0.002-0.05 mm in diameter.
3. Clay - Soil separate consisting of particles less than 0.002 mm diameter

Sustainable Agriculture - A system in which the goal is permanence achieved through the utilization of renewable resources. The permanence sought is dynamic because some resources (e.g., population increases and cost increases for a diminishing supply of resources) are not controllable.

Surface Soil - The uppermost part of the soil, ordinarily moved in tillage, or its equivalent in uncultivated soils, ranging in depth from 5 to 8 inches. (Frequently designated as the plow layer).

Terraces - Earth embankments, channels or combinations of the two, constructed across the slope of the land for the purpose of minimizing soil erosion on sloping land.

Tolerable Soil Loss - Also known as the T-value, this is the maximum rate of annual soil loss that may occur without affecting crop productivity. The T-value is set at 2-5 tons/acre/year. This was established in 1961 based on the rate of topsoil formation.

Topography - The configuration of the earth's surface, including the shape and position of its natural and man-made features.

Watershed Area - All land and water within the confines of a drainage divide or a water problem area, consisting in whole or in part of land needing drainage or irrigation.

I. INTRODUCTION

The science of soil conservation was virtually unknown before the beginning of the present century although evidence of land degradation is found throughout the 7,000 years of recorded human history (Helms et al., 1985). Helms stated that the understanding and awareness of the erosion problem developed very slowly. In the Old Testament there are passing references to erosion, mainly threats of streams drying up. Occasionally, Greek writers mention the problem; e.g., Homer recommended fallow to prevent deterioration; Plato saw the connection between floods and deforestation in Attica, a province of Greece. One of the earliest centers of civilization was the fertile crescent, the land between the Tigris and Euphrates rivers in Mesopotamia, in what is now Syria and Iraq. It was a prosperous civilization with a population of 17 to 25 million compared with about 4 million in the same area today. There is written evidence that siltation was a major problem in the irrigation canals upon which the Mesopotamian economy depended, and the suggestion is that the decline of this empire was due to the invasion by the nomadic tribes from the desert, and other wars which diverted manpower away from the task of periodically cleaning out the canals.

What is now Jordan and Sinai peninsula was in biblical times the "land of milk and honey". It has been the granary of the Greek and Roman empires, and the main source of their cereals, wine and olives. There, the causes of the erosion varied; sometimes it was caused by the clash between the nomadic pasturalist and the settled agronomist, sometimes it was the attempt to use agricultural practices which had been developed on flat lowlands in upland conditions of steep slopes. Helms and company (ibid) further added that there are examples of early soil conservation works, particularly the construction of bench terraces, but there is little evidence indicating when they were built. In Latin America, the best known are the terraces at Machu, Picchu in Peru. These were built by slave labor in the pre-Inca period, approximately 1,000 years ago. There are also examples of early bench terracing in Ethiopia, and the rice terraces in the Philippines. 4000 years of attempts to control siltation in China's Yellow River are well documented (Troeh et al., 1980). Vast areas are now completely terraced in the middle reaches of the river. The occurrence of bench terracing is more widespread and of earlier origin in the tropics because the more aggressive tropical rainfall leads to a greater risk of soil erosion. However, an example of this conservation practice in a temperate climate is the terraces in southern France which are now used for citrus orchards; the terraces were first built by the Phoenicians about 2,500 years ago.

One of the first assessments of the magnitude of world soil erosion was done by Sheldon Judson who estimated in 1968 that the amount of river-born soil carried into the oceans as a result of agricultural activities has increased to 26.5 billion tons a year (Brown, 1984). It is estimated that the 4 major food-producing countries alone which account for 52% of the world's cropland are losing as much as 13.2 billion tons of soil annually.

In the United States, early perceptive farmers including George Washington and Thomas Jefferson noted the serious consequences of soil erosion. Formal agricultural research began, however, only after the establishment of the U.S. Department of Agriculture (USDA) in 1862. The earliest attempt to measure erosion began in 1912 on overgrazed rangelands in Utah (Helms et al., ibid). Early erosion research focused on finding simple solutions to erosion problems, rather than investigating the cause. Thus, many solutions were cosmetic or at best, mildly successful. Soil conservation programs finally became a reality in the 1930's as a result of the great depression and the drought. The next few decades saw the flowering of U.S. agriculture. Land was cultivated intensively, resulting in surplus crops. According to Herndon (1987), in the early seventies, studies predicted a worldwide food shortage. This prediction, together with poor harvests in this same time period caused the U.S. to respond with intense cultivation. Crop production restrictions were removed, pasture and rangeland were converted to cropland, and many marginal lands were put into crop production. From 1973 to 1974 alone, there was a net increase of 24 million harvested acres, many acres of which had high erosion potential (Helms et al., 1985). Over the years these activities have contributed to widespread soil erosion (Herndon, 1987). The National Resource Inventory estimated that more than one third of all U.S. cropland was losing more than 5 tons of topsoil per acre. Overall, the loss of soil from the U.S. cropland base of 413 million acres totalled 1.68 billion tons (Brown, 1984). In Michigan alone, the USDA-SCS estimates that 40 million tons of soil are lost annually (Turney, 1975).

Agriculture is the most important industry in the world; soil and water are two of its basic resources. In the United States, agriculture is the biggest industry, second to none in terms of assets, workers and exports (Poincelot, 1986). Yet it is threatened. The resource base of agriculture is becoming diminished through overuse and environmental misuse. Pressures on resources stem from population increases, losses from pollution and overuse. The loss of top soil is perhaps the most serious problem in agriculture. This is caused by the dislodging of soil particles from the soil mass by erosive agents such as water and wind.

Soil erosion and sedimentation can be major problems. Sediment degrades water quality and may carry soil-adsorbed polluting chemicals. Erosion causes water pollution; in fact sediment is rated as the biggest agricultural pollutant. The USDA calculates that erosion is decreasing crop productivity equivalent to the loss of 506,072 ha (1.25 million acres) of land per year. This is equal to an annual loss of 0.4% of the land under cultivation. Another way of viewing it is that the loss of 2.54 cm (1 inch) of crop land top soil occurs every 8-10 years compared with the 100 years it takes under agricultural conditions to create the same amount (1 inch) of top soil from bedrock (Poincelot 1986).

Present agricultural practices in many cases amount to the "mining" of the soil. Loss of soil results in decreased productivity of croplands. Although losses can be offset by increased fertilization, the increasing cost and long term implications of heavy usee calls into question the wisdom of this approach. Moreover, offsite damages from cropland erosion cost about four times as much as onsite productivity losses (Crowder and Young, 1987). Sediment carried downstream damages water storage facilities, recreation facilities, navigation, commercial fishing, water conveyance facilities, water treatment facilities, and interferes with municipal and industrial users. Increased flooding related to erosion also causes economic losses. The estimated annual damage from all sources of soil erosion is 8.1 billion -- nearly 3.5 billion of this from eroding cropland (Ribaudo, 1989). Soil is an essential, nonrenewable and limited resource. Even before topsoil is completely eroded, the land may become uneconomical for further use (Schertz, 1983). Because of this, a growing concern that there won't be enough topsoil for the next generation has stimulated changes in policies, laws, and practices with a long range goal of a sustainable agriculture.

A. Scope and Objectives

The scope of this research is to determine how to use soil resources in a way that will maximize human welfare. This maximization means that alternative configurations of how resources are used must be compared in terms of the net benefits that they will generate to the individual farmer and to the society as a whole. Many agricultural lands are being utilized aggressively without regard to the ecosystem. Often, the cash crop being produced does not provide enough ground protection against erosion. A common illustration is the conversion of a hilly pasture into a piggery. The farm will provide profit for the farmers but at the possible expense of soil erosion and reduced water quality in the area. Environmental pollution has been a major issue not of the agricultural community but rather of environmental groups with an urban base. For this reason, it is not surprising that conservation practices will not be adapted willingly by the agricultural community particularly in the absence of cost sharing or a clear economic advantage for the practice (Logan, 1990). Since agricultural resources are not limitless, there is an urgent need to identify a land management strategy that will result in an acceptable level of sediment yield, water quality, and profit to the farmer.

The overall goal of this research is to develop a set of solutions to reduce water-caused erosion. This will be done by developing a methodology for recommending soil conservation practices at the farm level, which is both economically viable for the farmer and beneficial to society. The specific objectives of this research are:

1. To determine the Costs of Production, Costs of Conservation Practices, and the Economic Offsite Benefits of Soil Conservation.
2. To develop an expert system rule-base that will recommend soil conservation practices.
3. To evaluate the expert system as a decision support tool for reducing soil erosion on the lower portion of the Sycamore watershed.

II. REVIEW OF THEORY AND LITERATURE

A. Land Use and Conservation Practices

As reported in the 1990 Fact Book of Agriculture, more than half of the 2.3 billion-acre land area of the United States is used to produce crops and livestock. The rest is distributed among forest land (25%); urban, transportation and other uses (12%); and unused lands. Non-Federal cropland resources in 1987, according to the Soil Conservation Service (SCS)[1] National Resource Inventory, consisted of 422.8 million acres, of which 377 million acres are cultivated for crops, 39 million acres are used for hay, and 7 million acres are used for horticulture. About 55% of these areas is prime farm land. The U.S. has about 991.7 million acres of other non-federal rural land currently being used for pasture, range, forest, and other purposes. About 153 million acres are suitable for conversion to cropland if needed. Of this, 35 million acres have a high potential for conversion to cropland, and 118 million acres have a medium potential. The remaining rural land has little or no potential for conversion to cropland. This means that the cropland reserve is limited to about 14% of the remaining non-Federal land. Most

[1] The name of Soil Conservation Service, also known as SCS has been changed to Natural Resources Conservation Service (NRCS) in 1994. However, in this study the author will still refer to NRCS as SCS.

of this land would require careful soil and water management if brought into intensive agricultural use (USDA, 1991).

The National Agricultural Statistics Service (1992) states that the United States had 2.096 million farms in 1992, 2.197 million in 1988 and 2.407 million in 1982. This decline in farm number continues the downward trend started in 1936. Land in farms continues to decline more slowly, with a total of 980 million acres in 1992, down from 994 million acres in 1988 and 1.027 billion acres in 1982. According to the USDA (1991), land on farms has declined every year since reaching its peak at 1.206 billion acres in 1954. The number of farms has declined at a faster rate than land area in farms, resulting to in average farm size of 468 acres in 1992 (National Agricultural Statistics Service, 1992) as compared to 424 acres in 1981 (USDA, 1991). The National Agricultural Statistics Service (1992) reports that corn was planted on 76 million acres in the U.S. in 1991, resulting in the production of 7,474.5 million bushels of corn for grain and 80.5 million tons for silage. In Michigan, there were 54,000 farms with a total of 10.8 million acres in 1992. Corn was planted on 2.7 million acres in the production of 253 million bushels for grain and 3.99 million tons for silage.

U.S. farms produce more per unit area than most of their counterparts in the rest of the world. The U.S. accounted for 12.6% of world agricultural production (by dollar value) in 1988, even though it has less than 5% of the world's population and less than 7% of the world's land area. U.S. output in 1988 included nearly 15% of the world's livestock production and more than 11% of the crops. Consistently, U.S. farmers grow about 50% of the world's soybean, 40% of the corn and 25% of grain sorghum (USDA, 1991). Even though there are fewer farms growing crops, farmers are cultivating more intensively at the expense of over-using soil resources.

In many areas, the rate of erosion seriously threatens long-term agricultural productivity. Of the 423 million acres of cropland in the U.S., 171 million acres (40%) are eroding at intolerable rates. About 27 million acres (6%) are eroding at rates exceeding five times the tolerable level (USDA, 1991). Soil losses from cropland in the U.S. alone are some 2 billion tons annually (Poincelot, 1986). Sediment, the greatest single water pollutant by volume, is an end product of soil erosion (USDA, 1991). Present average rates of erosion usually exceed the average rate of soil formation by 10:1, causing a serious decrease in top soil volume (Larson 1981). Sheet and rill are the major sources of soil loss (Dregne, 198). Some valuable reviews on soil erosion include those of Prestegaard (1985), and Williams et al. (1981).

Soil erosion is a result of many factors. Troeh et al. (1980) mentioned that soil properties such as topography, depth, permeability, texture, structure and fertility are important considerations in erosion control. Soil topography (gradient, length, shape, and aspect/direction of slope) controls the concentration or dispersion of erosive forces such as runoff water and wind. Soil depth, the nature and thickness of soil horizons, and the underlying rock material affect the rate of soil formation and the tolerable rate of erosion. Troeh added that soil permeability and the rate of rainfall or irrigation determine how much water will run off and cause erosion. Conditions that most commonly limit soil permeability are a soil surface puddled by raindrops or traffic, plowsoles or other highly compacted layers, heavy subsoils devoid of large pores for water passage, frozen soil, and bedrock or cemented layers. The closer a restrictive layer is to the surface, the less water is required to saturate the soil above it and cause runoff to begin. Soil detachability is inversely related to soil strength; strength is generally low at high water contents and high at low water contents (Mutchler et al., 1983). Troeh added that soil texture and structure both influence permeability and erodability. The clay in soil helps it cohere either into a solid mass or into structural units with pore space between them. Individual clay particles are difficult to detach from a soil but, once detached, can be easily moved long distances. Sand particles are easily detached from sandy soil, but a high velocity of water is required to move them very far. Silty soils are the most erodable by water because the silt particles are too large to stick together well and are small enough to be transported readily. Thornes (1989) added that the finer particles of organic matter, clay and silts that are rich in nutrients are eroded first, leaving behind the coarser, sandier particles. This finding explains why sheet erosion is the most damaging form of water erosion, it takes away the finer soil particles. Troeh et al. (1980) explained that there are two major agents active in water erosion: falling raindrops and running water. From this information, the principles of reducing water erosion are formulated: 1.Reduce raindrop impact on the soil; 2.Reduce runoff volume and velocity; 3.Increase the soil's resistance to erosion. Management practices that effect one or more of these principles will help control water erosion.

The USDA has assigned a soil loss tolerance (T) which for most cultivated soil is 5 tons/acre/year. Some tolerances are lower depending upon soil quality and depth (Larson, 1981). According to Schertz (1983), maintaining productivity over a period of time and preventing gullies were the criteria used for setting 5 tons/acre/year as the maximum soil loss tolerance. An estimate of the rate of soil formation was also an important factor. Scientists suggested that soil forms at the rate of 1 inch in 300 to 1000 years. Under farming conditions however, soil may form at the rate of 1 inch in 100 years. The A horizon formation exceeds 1 inch in 30 years in medium-to moderately-coarse-textured soils but forms at a slower rate in finer soils. In 1973, SCS issued "Advisory Notice Soils-6" requesting each state to update soil loss tolerances based on specific guidelines (Schertz, 1983). These guidelines are still used. Schertz added that although the effect of excessive erosion is not immedietly felt in farms with deep loess soils, the offsite result downstream is just as bad regardless of the source.

Logan (1990) discussed the different approaches to controlling agricultural non-point source pollution which include structural control, source control, and land and pest management practices. He also noted that the nitrate-nitrogen concentration allowable for drinking water is 10 ppm, yet there is no established nitrate concentration limit for the soil.

Studies indicate that erosion associated with conventional tillage can be reduced 50-90% by a switch to conservation tillage (Crosson 1981). An 11-year study (USDA, 1985) shows that conservation tillage cuts soil erosion by 70% compared with conventional tillage. Crosson (1981) discussed the economic and environmental advantages of using conservation tillage instead of conventional tillage. The most widely used conservation tillage tool is the chisel plow. Other implements include subsoilers, disks, cultivators, mulch spreaders, strip rotary tillers, and no-till planters. These implements have been adapted to five basic methods of conservation tillage. In chisel plowing, the bed is prepared with a chisel plow which leaves crop residues in the top 2 inches and on the surface of the soil. Planting can be carried out at the same time as plowing or later. Disk planting is very similar, except the seedbed is prepared by disking the soil. In till-plant, plowing and planting are both done in one operation, leaving crop residues mixed into the soil surface between rows. Strip tillage also involves one step for plowing and planting of strips, with undisturbed crop residues left in place between the strips. The least disturbance is with no-till, where only the immediate row is disturbed for planting by slotting or slicing through the undisturbed crop residue. Weed control for all tillage methods involves herbicide application, crop rotation and plant competition.

Reduce tillage is being utilized not only to conserve energy but most importantly to reduce erosion and increase water infiltration. No-till is even more effective than reduced tillage. Herbicide, however, is required to control weeds normally eliminated by cultivation; increased amounts of pesticides are often needed to control insects harbored in the large amount of crop residue. Other advantages and disadvantages of reduced tillage or no-till have been noted by Fluck and Baird (1980), and Frye and Phillips (1981).

Terraces are the most effective mechanical means of erosion control on slopes planted continuously with row crops. Efficiency is high; terraces can trap up to 85% of the sediment otherwise eroded from a field. On the average, erosion is reduced 71% on the approximately 7% of the U.S. cropland with terraces (Office of Technology Assessment 1982). According to Troeh (1980), cropped slopes should be no steeper that 10:1 (10%). Any slopes steeper than 4:1 (25%) should be seeded to perennial grasses. Terraces should not be longer than 600 meters, and no longer than 375 meters on land already gullied. Several types of terrace exist and are discussed by Troeh et al. (1980). Installation cost is high, about $1000/ha ($400/acre). Other problems include compaction and loss of topsoil during construction. In addition, some sites are not suitable for terraces. These include sandy soil, stony soil, shallow soil over bedrock of fine-textured impermeable subsoils, areas with complex slopes and slopes in excess of 12% (Poincelot, 1986).

Diversions protect cropland from erosion and flooding by intercepting runoff which is then slowed and carried away. Diversions protect 0.7% of U.S. cropland (Poincelot, 1986).

Contour plowing and planting are done perpendicular to the farm. They are more popular than terraces because of lower cost and the potential to reduce soil loss up to 60%. Troeh et al. (1980) covered the details of contour-farming practices. A variation of this practice is contour strip cropping. The contour plowing and planting is used but continuous row crops are replaced by strips of row crops alternating with strips of forage crops. Row crops are sized to minimize runoff and erosion while forage strips are wide enough to slow and filter the runoff. Erosion reduction is about 50% greater than the conventional contour planting. Another approach is to alternate a perennial legume strip with a row crop. This will eliminate the cost of annual seeding, contributes nitrogen, provides year-round erosion protection, and still provides renewable animal feed. The practice is covered by Troeh et al. (1980).

Cover crops and crop rotation both help to keep a continuous cover on fields, thus reducing susceptibility to erosion. Wischmeier et al. (1978) discussed further the effects of crop cover and rotation in the control of soil erosion. He said that cover and management effects can not be independently evaluated because their combined effect is influenced by many significant interrelations. Almost any crop can be grown continuously, or it can be grown in rotations. Crop sequence influences the length of time between successive crop canopies, and it also influences the benefits obtained from residual effects of crops and management. The erosion control effectiveness of meadow sod turned under before a row crop depends on the type and quality of the meadow and on the length of time elapsed since the sod was turned under. According to a study made by Jennings and Jarrett (1985), any form of surface cover reduces erosion but mulches which have no absorptive capacity tended to reduce erosion the least.

In grassed waterways, strips of land covered with grass are utilized as paths for transporting surface runoff from fields at non-erosive velocities. Maintenance can be difficult though, as herbicides in the runoff can destroy the grass (Poincelot, 1986). Other practices include reduction of field length, strip cropping, windbreaks, shelterbelts, and mulches. Wind erosion can be reduced by shortening field lengths along the direction of the prevailing wind. Alternation of strips of crops susceptible and resistant to wind erosion at right angles to the prevailing winds is termed strip cropping. Trees can be planted as windbreaks and shelterbelts to lower windspeed. Mulches can be used to cover and protect the soil against wind erosion (Poincelot, 1986). These practices are detailed by Troeh et al. (1980).

Besides water depletion through overuse and the escalating costs of irrigation, another problem is the contamination of water. The appearance and persistence of pesticides in groundwater has been documented. Contamination of groundwater by pesticide has been reported in Arizona, California, Maine, Massachusetts, New Jersey, New York and Texas (Pye et al., 1983; Office of Technology Assessment 1982). DDT has appeared in groundwater in Texas, arsenate in Maine, and chlorinated hydrocarbons in Massachusetts (Office of Technology Assessment 1982). Toxaphene (a chlorinated hydrocarbon insecticide) and fluometron (a substituted urea herbicide) were monitored in a field study by LaFleur (1973). Some insecticides in surface water kill fish or may destroy part of the fish's food chain (National Academy of Sciences 1974). Degradation of pesticides occurs more readily in surface water than in groundwater. Some organic chemicals that are readily degraded are removed before the water enters the aquifer. Some organic compounds may be adsorbed or absorbed by mineral materials in the aquifer. This may cause the accumulation of some organics, while others may travel through the aquifer at rates slower than rates of organics not adsorbed. Organic compounds that move slowly are susceptible to microbial degradation. Surface water is known to contain a complex microbial ecosystem, but it was not shown until recently that groundwater also contains such an ecosystem. Groundwater microbial ecosystems are dark and oxygen-poor, thus anaerobic organisms predominate.

According to Poincelot (1986), the effects of nutrients on an aquatic ecosystem are known better than the effects of pesticides. Nutrients, especially nitrogen and phosphorous, lead to eutrophication of water. These nutrients accelerate algal growth; in turn, the death of the increased algal mass leads to oxygen depletion as oxygen-consuming microorganisms consume the dead algae. Eventually, fish die. Nitrate in the water poses a serious health problem, since nitrate sensitivity (methemoglobinemia) occurs in infants under three months of age. Continuous drinking of nitrate contaminated water may also lead to the formation of carcinogenic nitrosamine. Nitrates in groundwater are due to certain conditions: high rate of fertilizer use, sandy soil, shallow rooted crops, and heavy rainfall or irrigation (Singh and Sekhon 1978). The actual extent of fertilizer nitrate in groundwater is not resolved (OTA, 1982).

Drip irrigation offers the least disturbance of soil as compared with surface and sprinkler irrigation. Troeh et al., (1980) noted other advantages such as high efficiency (under careful management, efficiency of water use reaches 60% for surface irrigation, 75% for sprinkler irrigation and 90% for trickle or drip irrigation), conservation of fuel and fertilizer, reduced weed growth, and reduced seedling mortality. Most of all, drip irrigation can be used on steep slopes where other irrigation methods are not possible. Drawbacks include high initial cost and labor-intensive maintenance.

Summary of Practices to Reduce Soil Erosion

1. Continuous cropping is replaced by rotation that includes meadow, legumes and small grains along with row crops.
2. Cover crops, green manure crops and reduced tillage decreases erosion. Cover crops also help prevent soil losses during the unproductive part of the growing season.
3. Maintaining or increasing soil organic matter by the application of manures and other organic waste increases water infiltration and storage, therefore decreasing surface water runoff and wind blowoff. Increased water storage and runoff also reduces the contamination of the water supply with nutrients and pesticides.
4. The use of a chisel plow and disk instead of a moldboard can reduce soil erosion by 20-75%. The effectiveness of this practice results from the placement of crop residue at or near the surface.
5. The use of reduced (conservation) tillage or no-tillage system will avoid disturbance of soil.
6. The application of low pressure irrigation will prevent soil splashing and disattachment of individual particles.
7. Terracing, diversions,contour plowing and planting, cover crops and crop rotation, strip cropping and grassed waterways also reduces erosion.
8. Other practices include reduction of field length, wind breaks, shelterbelts and use of mulches.

B. Economics of Conservation

Barbarika (1987) said that the adoption of conservation practices is a considerable burden to farmers, especially when benefits are primarily off-farm, and on-farm benefits are realized only over long periods of time. Thus, even though total social benefits of erosion control may ultimately exceed total cost, it is likely that, without assistance from other entities, producers will refrain from using conservation measures.

There are important differences between the private and public benefits of erosion control. Private benefits are realized on the farm (on-site) and are enjoyed by the farmer, while public benefits occur offsite, with all of society as beneficiary. Public benefits are often higher than private benefits. When public benefits are positive and private benefits are not, public financial assistance is justified (Stults et al., 1987).

According to Massey (1987) the federal government has been offering various types of financial incentives to farmers to install conservation practices. Farmers may receive cost-sharing between 50 and 75% of the cost of conservation practices under the agricultural conservation program (ACP). The Rural Clean Water Program (RCWP) provides long-term cost-sharing of up to 75% for establishing best management practices. Farmers in some states are also eligible for cost-sharing under the Soil Conservation Service's Great Plains Conservation Program (GPCP). In addition, the federal government offers income tax incentives for soil and water conservation programs. State and local governments are also offering financial incentives in the form of cost-share funds, interest-free loans, low interest loans and income (and property) tax credits or deductions. Massey (1987) further stated that the Food Security Act of 1985 (1985 Farm Bill) takes highly erodible and marginal cropland out of agricultural production, or forces it to comply with a conservation plan if it is already in production. Massey (1987) also discussed how these programs operate.

Studies have been made on the economics of conservation practices. The USDA's Conservation Reporting and Evaluation System (CRES) provides estimates for installation costs of conservation practices implemented with USDA assistance (Barbarika, 1987). The Interactive Conservation Evaluation (ICE) is a computer program designed to assist users in selecting alternative conservation systems by providing a summary of benefits and costs of all choices being evaluated (Christensen, 1987). Christensen (ibid) discussed how the Interactive Conservation Evaluation (ICE) makes an economic evaluation of the onsite benefits and costs of soil conservation. ICE goes through three steps. First it identifies the area, the dominant soil and the major resource problem. Second, it determines the of physical and economic conditions presently existing without treatment, accounting for changes in this condition over time. This step produces a summary of land use, acres, yield, net return and soil loss for the present condition. The third step consists of selecting the alternative conservation system in treating the problem of individual land user. ICE provides summaries of installation costs, life expectancy, operation and maintenance, and total average annual costs for each alternative. The data used in ICE are divided into three categories. The fixed data (land user, mapping, state) require only a one time input and are preserved throughout the entire evaluation. The variable data (crops and practices) can be changed from alternative to alternative, it can also be fixed throughout the entire analysis. The calculated data is generated automatically by the computer. Christensen (1987) concluded that the basic concept of the ICE software is to be able to compare the "with" and "without" conservation practices.

Two other models relating to the economics of conservation practices are COSTS and SOILEC. Raitt (1983) explained how the COSTS computer model relates cost of conservation practices and rates of soil erosion. It calculates and displays the annual costs and rates of soil loss under various combinations of conservation practices on a particular soil and slope. SOILEC is a computerized, long-run, physical and economic simulation model. It estimates sheet and rill erosion using the Universal Soil Loss Equation (USLE). The input requirements are somewhat detailed and technical in nature; hence, it is used mainly by district conservationists and not by farmers. Eleveld (1983) discussed the model more in detail.

The principal benefit from adoption of conservation practices may stem from reduced erosion. But it also offer farmers short-term changes in net returns. For example, researchers have found that many of the farmers adopting conservation tillage methods are attracted more by the associated cost reduction than they are by the soil savings. The on-site benefits include increased yield and decreased production cost while the economic damage to the farmer is the sum of the value of the reduced yields and the net cost of changing the application rate of fertilizer or other inputs (Colacicco et al., 1989). A model called EPIC (Erosion-Productivity

Impact Calculator) describes a method of assessing erosion's effect on soil productivity. EPIC is composed of physically based components for simulating erosion, plant growth and related processes. EPIC also includes economic components for assessing the cost of erosion and determining optimal management strategies. Williams (1983) discussed EPIC in detail. Troeh and colleagues (1980) developed a method of computing the fertility value of a ton of soil. According to them, each ton of soil has a total nutrient value of $5.00. If the commonly accepted estimate of 3.6 billion metric tons of soil occurs annually, this would result in a loss of $18 billion annually. An important discovery was that the relationship between farm productivity and the amount of on-site soil loss is exponential and not linear. The implication is that conservation is most effective and critical when erosion is just beginning rather than when it is already in its advanced stage (Thornes, 1989).

The effects of on-farm soil loss can be expressed in a monetary equivalent. Offsite damages, however, are harder to quantify. According to Stults (1987), offsite damage is difficult to measure for several reasons. First, the nature of biological systems, fishery resources and recreation makes it difficult to estimate the value of damage even when the nature and the extent of physical damage is known. Second, the relationship between sediment and erosion is complex and reliable estimates are unavailable. Ribaudo (1986) says that there are no observed prices with which to measure the value of the off-site effects of erosion. Instead, economic effects are measured through observed changes in the behavior of water users. Colacicco et al. (1989) mentioned that the recent quantitative measure of the damages of sheet, rill, and wind erosion show that the main damage from erosion is not to the farmer or future generations of food consumers, but rather to off-farm users of surface water. Ribaudo refined the Clark data and estimated that soil erosion causes over $7 billion in annual off-farm damages to water-based recreation, navigation, water storage facilities, municipal and industrial water users, water conveyance systems, and from increased flooding. Ribaudo (1986) equated the offsite benefits with the reduction in offsite damage. Damage reduction is in the form of reduced dredging costs, reduced operating cost to industry and offstream water users, reduced flooding damages, and increased consumption in the recreation industry. There are also damages resulting from wind erosion. They include higher maintenance of building and landscaping, pitting of automobile finishes and glass, greater wear on machinery parts, increased soiling and deterioration of retail inventories, cost of removing blown sand and dust from roads and ditches, and increased respiratory and eye disorders (Strohbehn, 1986). Further discussion of the damages caused by soil erosion is made by Batie (1985), Clark (1985), LaRoe (1985), Gray (1985), Ribaudo (1985, and 1986), Strohbehn et al. (1986), and Stults (1987).

Strohbehn (1986) suggested that conservation practices offer higher benefits offsite than onsite. Offsite benefits account for two thirds of total erosion control benefits. He added, however, that the benefits of erosion control exceed the cost involved only on land eroding at about 15 tons/acre/year. Strohbehn (1986) explained that when the total tonnage of soil erosion increases, so does the corresponding offsite damage. At present, 40% of the cropland receiving public assistance is eroding at 5 or less tons/acre/year. Conservation measures applied on these lands are mostly for preventive maintenance treatments. Erosion of 5 tons/acre/year is generally considered the level that will not damage long-term soil productivity. This is a physical measure, used as a proxy for socio-economic evaluation in the past because economic and social impacts were not measurable. An erosion of 10 tons/acre/year translates to 1/16 inch of topsoil. Strohbehn (1986) further added that the total mass of soil being moved is not a useful measure of onsite productivity because the same amount of erosion could occur at low rates over a large area or with high rates on a small area. This is then irrelevant to offsite areas where results may be the same. Because soil is constantly forming, net erosion rates are a better measure of onsite damage than gross erosion rates.

Ribaudo (1986) recognized that offsite impacts associated with changes in water quality, such as impact on recreational activities, cannot be measured directly. Furthermore, the link between soil erosion and affected water users is not well defined. Researchers have tried to put value on the social and environmental effects of erosion. One method, called the Contingent Valuation, quantifies the resource value directly according to the individuals who are affected. This method requires a survey sample. Other methods mentioned by Hoehn (1987) are the Hedonic technique and the Travel Cost technique. The Hedonic technique measures the value of resource services that are obtained through the purchase of some market good. The Travel Cost technique measures values using the travel costs that individuals incur to access a resource service.

A more popular method is by estimating water quality benefits resulting from the prevention of sedimentation. Several of these methods were discussed by Ribaudo (1992).

Trapanese et al. (1984) showed that substitution of conservation management practices for erosive conventional practices could be highly cost-effective if the conservation practices were more profitable or only slightly less profitable than the conventional practices. This was illustrated by an example in which a 50% reduction of sediment yield could have been obtained with no loss of income by substituting no-till corn for conventionally tilled corn. In the example, a government income subsidy should not have been necessary to improve water quality because a more profitable, less erosive alternative was available. In another example, where the conventional practice allowed a slightly higher profit but substantially higher erosivity, government cost sharing or income subsidies would have been more cost effective. According to Crowder (1987), soil conservation practices do not provide social benefits of productivity maintenance anywhere near the level of social costs, on the other hand, Strohbehn (1986) said that in many cases offsite benefits exceed the costs of public assistance.

Using the CREAMS model, Crowder et al. (1987) estimated the cost of some soil conservation practices and the cost per unit of pollution reduction. They learned that permanent vegetative cover, such as hay or pasture, is the most effective soil conservation practice for controlling runoff, but it is the least cost-effective. Terrace systems are also effective runoff control measures but are relatively expensive per unit of pollution reduction. By comparison, sod waterway systems are highly cost effective for controlling surface runoff. Conservation tillage (reduced tillage with a chisel plow) and no-till were found to be cost-effective where soil, crop and climate are amenable to their use. Contouring is cost-effective where field shape and slope warrant its use. Using USDA's Conservation Reporting and Evaluation Systems, Barbarika (1987) showed the average annual cost/ha and the cost/ton of soil of selected conservation practices. From the same data, he stated that the cost of controlling wind erosion is less than the cost of water erosion. He showed that the cost/ton decreased while cost per hectare increased as erodability increased. He explained this as follows: a terrace which reduces erosion by 50 tons/ha would not cost twice as much per ha. to install and maintain as a terrace that saves 25 tons/ha. He also pointed out that as the size of a field increases, the cost/ha and the cost/ton decreases. Barbarika (1987) concluded in his report that soil erodability and field size are the two main factors affecting cost. This is because fixed costs can be spread over larger units (field area or tons of soil saved).

Rosenbery et al. (1980) calculated costs for not correcting erosion in terms of reduced yields and increased costs of additional fertilizer and energy. Their conclusion was that additional input (such as fertilizer) can offset the reduced productivity of soil due to erosion. Also, the cost of controlling erosion was three times as expensive as farmer's benefit. Christensen et al. (1987) say otherwise. According to them, onsite benefits of soil conservation alone are two-fold: productivity maintenance and decreased production costs. Maintaining productivity is accomplished by protecting the soil from erosion, while some conservation practices reduce cost of growing a crop. An example: conservation or no-till reduces the number of trips over the field thereby saving time, fuel and machinery. Converting low yielding row crop areas (end rows and water courses) into other land use (grass) will require less fertilizer and chemical inputs. Offsite benefits include control of deposition and maintenance of water quality. Sediment can fill ditches, plug culverts, reduce lifespan of ponds and dams, and destroy fences. As for the costs of conservation, Christensen (1987) identified three. First is the cost of installing the system (materials, labor and equipment); second is operation, maintenance and replacement costs (fertilization of waterway, replacing a pipe, reseeding a terrace backslope); third is the cost of lost production (crops lost from land converted to waterways, increased fertilizer and chemicals in some soil switching to conservation tillage or no-till). Trapanese (1984) noted that the implementation of soil conservation program is ultimately dependent on its perceived benefits and the magnitude of its costs. Benefits and costs associated with non-point source are particularly difficult to asses. This is because evaluation of non-point pollution control benefits is subject to considerable uncertainty due to the spatial and temporal variability of the processes involved.

According to Stults and Strohbehn (1987) allocating erosion control assistance on the basis of economic benefits and costs provides more net benefits than any other allocation system -- more than the general approach of spreading conservation dollars around more or less uniformly, more than first-come first-served basis, more than maximizing soil loss reduction, and even more than using the least-cost method for reducing erosion. They also noted that estimating conservation benefits is difficult because the productivity and environmental benefits per ton of erosion prevented vary widely among soils and across the country. In addition, productivity benefits accrue over a long period and may increase with time.

C. Agricultural Pollution Models

According to Young et al. (1989), managing non-point sources of pollution, in addition to being politically, economically and socially difficult, is technically complex. Pollutant sources often are located over a large geographic area and are not readily identifiable. By locating and targeting specific areas with high potential for soil and nutrient losses, funds and efforts can be used more efficiently to reduce soil loss and protect water quality. There are several computer models which estimate watershed response to rainfall events, including ANSWERS (Areal Non-point Source Watershed Environmental Response Simulation), SWRRB (Simulator for water resources in Rural Basins), AGNPS (Agricultural Non-point Source), and CREAMS (Chemical Runoff and Erosion from Agricultural Management Systems).

CREAMS is a simulation model for runoff and pollutant transport in and from agricultural fields. It predicts the effect of agricultural management practices on non-point or distributed pollution sources from field size areas. It is based on the physics of water flow in the soil profile and on the surface and uses the SCS curve number to estimate runoff. CREAMS includes the processes of sediment transport, soil heat flow, crop growth and residue decay. The management practices include all type of tillage operations, irrigation, fertilizer addition, grazing, pesticide application, terracing, tile drainage and farm pond effects. CREAMS' scope is limited to those areas which can be characterized by a single soil profile regime, whose hydraulic description does not require channel networks of order greater than 2, and within which a single cropping system is contained. Data input is organized into two files: rainfall information, field and management input. A third file is used if real measured data is used to supplement the built-in rainfall simulator (CREAMS manual, 1985).

Agricultural Non-point Source Pollution Model (AGNPS) is another computer simulation model developed to analyze the water quality of runoff. The model predicts runoff volume and peak rate, eroded and delivered sediment, and nitrogen, phosphorous, and chemical oxygen demand concentration in both the runoff and the sediment for all points in the watershed. It is intended for watersheds under 23,000 acres in size (Young et al., 1987). The output from AGNPS can be used to recommend remedial measures on the basis of an assessment of the effects of applying alternative management practices. This is accomplished by varying input data consistent with alternative management practices being investigated and analyzing the resulting watershed response (Young et al., 1989). AGNPS is event-based. It simulates runoff, sediment and nutrient transport. Basic model components include hydrology, erosion, sediment and chemical transport. The model also considers point sources of sediment from gullies and inputs of water, sediment nutrients and chemical oxygen demand (COD) from feedlots, springs and other point sources. The model works on a cell basis. These cells are uniform squares subdividing the watershed, allowing analysis at any point within the study area. Potential pollutants are routed through cells from the watershed divide to the outlet in a stepwise manner so that flow at any point may be examined. All watershed characteristics and inputs are expressed at the cell level (Young et al., 1989).

Inputs and parameter values used in AGNPS may be obtained from published data, available watershed records, or on-site inspection. The model's manual (Young et al., 1987) contains tables listing standard values for the required parameters. A preliminary output given for all watersheds being analyzed includes watershed area and cell size, storm precipitation and erosivity (EI), estimates of runoff volume and peak flow rate at the watershed outlet, and area-weighted erosion, both upland and channel. Output includes estimates of the sediment delivery ratio, the sediment enrichment ratio, the mean sediment concentration, and total sediment yield for each of five sediment particle size classes. Also available is a nutrient analysis, which includes N, P, and COD mass per unit area for both soluble and sediment adsorbed-nutrients, and N, P, and COD concentrations in the runoff (Young et al., 1989).

AGNPS uses the Universal Soil Loss Equation (USLE) to predict erosion based on a single storm event, and the SCS curve number to determine the runoff volume. Although it was intended primarily for agricultural watersheds in the state of Minnesota, the principles on which the model is based are not limited to that state. For uniform comparison among watersheds, the precipitation input value should be for a 24-hour, 25-year storm frequency. If further analysis is desired, different storms can be simulated by the model (Young et al., 1987). AGNPS was written in FORTRAN IV computer language and developed for use on an IBM-PC computer system with 256K, 2 disk drives, and DOS 2.0 or greater. Further technical information on the model is available from the AGNPS manual (Young et al., 1987).

The AGNPS model has been used in several states to prioritize watersheds according to their quality problems, to pinpoint critical areas within a watershed contributing to pollution, and to evaluate the effects of applying alternative management practices. Applications of AGNPS includes the determination of sediment and nutrient loads being delivered to the trout stream by the Garvin Brook Watershed. Another application of AGNPS is the identification of critical areas in Salmonson Creek subwatershed where excessive upland erosion and runoff has resulted in high contributions of sediment and nutrients at the outlet into Big Stone Lake (Young, 1989).

Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) is an erosion model designed to compute longtime average soil losses from sheet and rill erosion under specified conditions. It does not predict deposition and sediment yields from gully, streambank, and streambed erosion (Wischmeier, 1978). Despite its simplification of the many variables involved, it is the most widely accepted method of estimating sediment loss (Schwab, 1981). The average annual soil loss, as determined by Wischmeier (1976), can be estimated from the equation

$$A = R\ K\ L\ S\ C\ P \tag{1}$$

where A = average annual soil loss (tons/acre)

R = rainfall and runoff factor

K = soil erodability factor

L = slope length factor

S = slope-steepness factor

C = cover and management factor

P = support practice factor

The computed soil loss, **A** is expressed in the units selected for **K** and for the period selected for **R**. The rainfall and runoff factor **R** is the number of rainfall erosion index units, plus a factor for runoff from snowmelt or applied water where such runoff is significant. The soil erodability factor **K** is the average soil loss in t/a per unit of erosion index for a particular soil in cultivated continuous fallow with an arbitrary selected slope length l of 22 m (73 ft) and slope steepness S, of 9 percent (if **K** is Mg/ha, change constant 2.24 to 1.0). The slope length factor **L** is the ratio of soil loss from the field slope length to that from 22 m length under identical conditions. The slope-steepness factor **S** is the ratio of the soil loss from the field slope gradient to that from a 9 percent slope under otherwise identical conditions. The **C** factor is the ratio of soil loss from an area with specified cover and management to that from an identical area in clean-tilled, continuous fallow. Plant cover provides different level of protection at different growing stages so Wischmeier (1978) distinguished six growth stage periods for crops in order to evaluate the canopy protection over the year. They are defines as follows:

Period F (rough fallow) - Inversion plowing to secondary tillage

Period SD (seedbed) - Secondary tillage for seedbed preparation until the crop has developed 10% canopy cover.

Period 1 (establishment) - End of SB until crop to 50% canopy cover.

Period 2 (development) - End of Period 1 to 75% canopy cover.

Period 3 (maturing crop) - End of period 2 until harvest. This period was evaluated for 3 levels of final crop canopy.

Period 4 (residue or stubble) - Harvest to plowing or new seeding.

Each stage has a corresponding soil loss ratio; this, multiplied by the erosivity index of that stage, then multiplied again by a sod factor will yield a cropstage C-value. The cropstage C-values are added to make up the whole crop year. The **P** factor is the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope. Figures and look-up tables for most of these variables are available in Soil and Water Conservation Engineering handbook by Schwab (1981) or Agriculture Handbook No. 537.

Smith and Wischmeier (1962) adjusts the soil loss of the **L** and **S** topographic factors from the standard length of 22 m (73 ft) and 9 percent slope. These factors can be calculated from the equations:

$$L = \left(\frac{l}{73}\right)^{x} \tag{2}$$

$$S = \frac{(0.43 + 0.30s + 0.43s^{2})}{6.574} \tag{3}$$

where x = a constant, 0.5 for slope >4 percent, 0.4 for 4 percent, and 0.3 for <3 percent.

l = slope length (feet)

s = field slope in percent

Soil loss is affected by 2 major categories, those that can't be controlled and those that can be controlled. Some soils are more erodible by nature, this is an inherent property of the soil and cannot be manipulated. It is represented as **K** in the USLE formula. Erosion due to rainstorm characteristics (**R**) also falls in the first category. Land slope (**LS**), cropping pattern (**C**), and management (**P**), however, falls in the second category which can be controlled (Wischmeier, 1978).

Since each variable can be change one at a time, the USLE is a valuable tool for trying combinations of crop systems and management practices and observing their corresponding effects on soil erosion.

D. Expert System

An Expert system (ES) is a problem-solving method that simulates the behavior of a human expert. It can store knowledge for a defined subject area and solve problems by making logical deductions. It is one way of approaching real-world problems which cannot be solved by other, more orthodox methods (Ignizio, 1991). A knowledge-based expert system uses knowledge derived from experts to solve problems, much as a human expert would do (King et al., 1991).

Klein (1990) explained that expertise is developed by training and experience. This is called "shallow knowledge" because it consists of all the peculiar heuristics and shortcuts that trained professionals have learned to use in order to perform well. In the cognitive domain, however, experts normally have their practice anchored in theory, principles, axioms and laws. This latter is called "deep knowledge" and tends to be more general than shallow knowledge. A true expert system represents shallow knowledge. The advantage of computing this knowledge is that a computer program that behaves like an expert can be developed; the disadvantage is that expert systems are tailor-made for very specific or narrowly-defined problem domains.

The typical ES is a knowledge-based system. The knowledge-base does not only store facts; it also contains complex objects, their attributes, relations between the objects, rules for processing knowledge and for deriving new knowledge from existing knowledge. An expert system has certain characteristics that makes it unconventional:

1. It simulates human reasoning about a problem domain

2. It reasons over representations of human knowledge

3. It solves problems by heuristic or approximate methods

An Algorithm is a method of solving a problem using operations from a given set of basic operations (addition, subtraction, etc), which produces an answer in a finite number of iterations (it always reaches an optimum answer). Heuristics are rules developed through intuition, experience and judgement, mere guidelines that do not necessarily result in best or optimum results. Heuristics are often called "rules of thumb" (Ignizio, 1991).

Ignizio (1991) explained that "production rule-base" is the most popular mode of knowledge representation, although there are other forms of knowledge representation such as OAV triplets, semantic networks, frames, logic programming or combinations of these. Each of these methods is explained well by Ignizio (1991). Production rule-base is the mode of knowledge representation obtained through the use of rules. Such rules are referred to as IF-THEN, or "production rules". In some instances, IF-THEN-ELSE rules are included. Other designations for the IF-THEN rules are "condition-action" or "premise-conclusion" statements.

The basic components of an expert system are the knowledge base, the inference engine and the user interface. The knowledge base contains the rules expressing an expert's heuristic for the domain. The inference engine is the controller which determines how the rules are used or processed. The user interface allows interaction between the user and the expert system (Ignizio, 1991).

The knowledge base is the heart of the expert system. Typically it contains two types of knowledge: facts and rules. The facts within a knowledge base represent various aspects of a specific domain that are known prior to the consultation session of the expert system. The rules are the heuristics in a rule-based format entered by the knowledge engineer. The inference engine performs the tasks of determining which knowledge is required, when and how. It controls the action taken by the system. It also provides the problem solving method by which the rules, networks, or frames are processed. An important feature of an ES is its user interface, across which the user and the system communicates. The interface interprets the messages from the explanation component. It is also used for presenting the result and for the conveyance of messages from the system.

Olson and Courtney (1992) mention that there are a variety of means of organizing logical rules, but the two most common methods used are forward and backward chaining. An inference mechanism can also employ a combination of the two. In forward chaining, the system starts with the set of known facts and tests all the hypotheses in which these facts play a part. In backward chaining a hypothesis is proposed and then the system tries to prove the hypothesis using the known facts.

An ES also has an explanation component which provides support to the user during a consultation; it gives reasons for the questions asked by the system, justifies inferences, and can specify attributes of objects. The explanation component can also reproduce the solution path and provide reasons as to why other possible solution paths were not pursued. The acquisition component is used by the knowledge engineer to implement the knowledge base.

According to Jackson (1990), development support exists in the form of:

1. High-level programming languages, such as production rule interpreters and object-oriented systems, which provide basic building blocks for representation and control;
2. Mixed-paradigm programming environments which provide a wide range of representational devices and control mechanisms;
3. Problem-solving architectures, such as blackboard systems, where task-oriented frameworks can be instantiated for particular applications;
4. Useful package for subtasks such as simulation or truth maintenance, which can be interfaced to the main problem-solving program;
5. Expert system shells, which provide a single representation language control and regime combination.

Hybrid expert systems are those that combine two or more approaches to problem solving, where at least one of the approaches is that of the expert system (Ignizio, 1991). For example, one might combine an expert system with a simulation package. The combination enhances the operating performance of the expert system .

An Expert System SHELL is a highly specialized tool for building ES in a special domain. Shells already contain all the components of an ES, except for the knowledge base. The requirements of the user interface and the explanation component also vary (Klein, 1990). Ignizio (1991) discussed the advantages and disadvantages of using a shell, and some of the important features in selecting one. He also compared the performance of 11 of the most popular ES shells on the market today (Arity Compiler, Arity Interpreter, EXSYS, EXSYSP, GURU, Level 5, M.1, Nexpert, PC Easy, PC Plus, and VP-Expert). He found that EXSYS was superior for all four benchmark knowledge bases. In terms of the largest possible sequential knowledge base, EXSYSP was able to solve the largest number of rules. Level 5 has the fastest execution time in terms of rules per second. Despite EXSYSP having one of the lowest ratings in terms of the number of rules in its largest sequential knowledge base, Ignizio (1991) concluded that either version of EXSYSP (or EXSYS) represents a top-of-the-line expert systems shell.

EXSYSP uses Conditions, Qualifiers, Values and Choices. EXSYSP permits the solution of up to 5000 rules. Options are displayed on the screen. A rule compiler makes it possible to create or edit rules with a word processor and then compile them with EXSYSP runtime compiler. The rule compiler also allows other programs to generate rules which can then be compiled into the EXSYS professional form. All inputs are in English text, algebraic expressions or menu selections. For more complex applications and increased control, there is a command language that is used to control the execution of the ES. Most default operations can be changed through the command language. It can be used in conjunction with the report generator specifications for even greater control. EXSYSP has standard output presentation, but output can be controlled and presented in any form by manipulating the report generator. Rule subsets, looping and conditional tests are part of the command language. The program can read directly from (or write to) dBase III or Lotus 123 files, without calling the external programs. Multiple fields in the record can be read or written in a single call. It is possible to run against every record in a database or spreadsheet sequentially. When running large external programs, EXSYSP can be called from a batch file which allows the user to run external programs that are too large to fit into memory. In such a case, EXSYSP saves certain information, takes itself out of memory, runs the external program, reloads itself into memory and then returns to its previous state.

"Choices" are all the possible solutions to the problem among which EXSYSP will decide. The goal of the ES is to select the most likely choice based on the input, or to provide a list of possible choices arranged in order of likelihood. When output is generated, the text of the choice is displayed followed by "Probability=" or "Confidence=". In EXSYSP, there are 5 options for how the program will use the probability data, namely:

1. 0 or 1 - Choices gets a 0 or 1 value. This is equivalent to "yes" and "no". There is no probability involved. It is generally used in knowledge bases that simply select multiple items from a list. This system will display values of 0 or 1, not ratios.
2. 0-10 - The choices are given a value between 0 to 10. Values in this system are always displayed as ratios; the denominator of the ratio is always 10. This system is used to provide some level of confidence factor. Values of each choice are compared to determine which is the most likely.
3. -100 to +100 - A system which assigns an integer value of -100 to +100 to each choice. Values of 0 or 100 do not lock the final values. the final

combined values may be calculated in 3 ways. First, a simple averaging of values of all choices found to be true. Second, combining probabilities as if they were dependent probabilities. third, combining values as if they were independent probabilities.

4. Increment/Decrement System - points are added or subtracted from a total point for a particular choice. A threshold is set; it determines if a choice is displayed with the conclusion.

5. Custom Formulas - Most complex and powerful of all systems. It allows for the development of formulas for the combination of confidence values.

EXSYSP shell is equipped with hypertext which assist the user with multilevel help based on key words in the text of rules,qualifiers, questions, etc. This allows graphics, text or external programs to be called to assist the user. EXSYSP is the basic call name for the program. But when an external program needs to allocate memory to run, EXSYSPB is used. EDITXSP is the call name for editing rules that are already made. NULLCHOICE is a command line option that turns off error messages if condition choices have no values. When a choice is used in the IF part of the rule, EXSYSP attempts to determine a value for the choice to test if the condition is true. If no value for the choice can be derived. It issues a message that the condition is indeterminate.

System requirements include 640K RAM, hard disk or high density floppy disk drive, DOS 2.0 or higher. EXSYSP can be run on IBM, XT, AT or compatible machines. The full 640K RAM is used when running the program, an additional 64K is needed for every 500 rules, each rule having 6 to 7 conditions on the average (EXSYS Professional manual, 1990).

The design of an expert system in soil degradation has been started by P.F. Fisher (Dregne, 1989). This is a computer-based expert system that would provide individual responses on cause, type, extent, and severity of water erosion; effects on crop yields, management practices, and socially/economically acceptable erosion control practices. According to King et al. (1991), applications of knowledge-based systems in agricultural engineering are limited and few survive past the research stage. Much of the literature consists of conceptual discussion and fairly simple experimental work. Peart et al., (1986) suggested three primary areas in agricultural engineering for applications of knowledge-based systems: diagnosis, control systems and tactical management. Whittaker et al. (1986) grouped the applications for knowledge-based systems in agriculture as planning, diagnosis, management, and university/government. Plant et al. (1989) described a knowledge-based system called CALEX. CALEX is a shell program which is coupled to knowledge-base modules specific to a given crop, providing complete support for managing that crop. King et al. (1991) discussed a knowledge-based system for malting barley management. The system gives advice on fertilizer and water applications to maximize crop yield.

E. Synopsis

A review of the literature shows that soil loss is a global problem. Soil erosion is serious, but it can be contained. The best solutions are preventive measures at the origin, the farm. To begin, a farmer must know how much soil is being removed from his farm, next is knowing what are the economically viable options for preventing soil loss.

The literature on land use and conservation defined the extent and depth of the erosion problem. Musser(1981), Logan(1990), Crosson(1981), Gilbertson (1979), Troeh(1980), and others showed that by offering management systems and practices, erosion can be reduced. These practices are feasible from an economic point of view (Trapanese, 1984, and Crowder, 1987). The benefits of conservation are long-term and wide-ranged. Conservation practices maintain crop productivity longer, reduce production costs for the farmer (Christensen et al., 1987), and provide cleaner/safer water for society (Ribaudo, 1986).

The literature on Agricultural Pollution Models compared different models for measuring the extent of erosion. Young et al. (1989) discussed the application of AGNPS for predicting runoff volume and sedimentation rate. The erosion rate output is categorized into two: sediment coming from outside the cell and sediment generated within the cell. AGNPS also computes how much of this is deposited in the cell and how much is eroding to the next cell. AGNPS estimates are based on the Universal Soil Loss Equation (USLE). Wischmeier (1978) explained in detail the application of the USLE in measuring average annual soil loss. The USLE considers variables such as cropping (C) and conservation practice factors (P) - variables which can be manipulated and controlled.

According to King et al. (1991) expert tactical management can help farmers improve their operations, but sources for expert advice are often difficult to find, are of doubtful accuracy or are incomplete. An expert system can provide advice in a portable and easily accessible medium, allowing farmers extensive access to agricultural expertise. Expert systems are also well suited to applications in cultivated agriculture because they can be designed to handle the uncertainty and incomplete knowledge associated with weather and crop behavior (Smith et al., 1985). The disadvantage of the ES method, though, is that it is tailor-made for very specific and narrowly-defined problem domains (Klein, 1990). Shells are expert system computer programs for building an expert system rule base. The shell already contains all the components of an expert system except the knowledge base. Ignizio (1991) compared and discussed the features of different shells and concluded that the EXSYSP represents a top-of-the-line expert system shell.

In summary, it is evident from the review of literature that an expert system rule-base is a promising tool for evaluating the different techniques available for reducing soil erosion. As Herndon (1987) said "The use of artificial intelligence concepts such as an expert system, is one of the areas needing further studies and research to assist in planning and applying conservation systems".

III. METHODOLOGY

A. Research Approach

The overall research objective will be accomplished by following the proposed approaches for each of the three objectives.

Objective 1. To determine the Costs of Production, Costs of Conservation Practices, and the Economic Offsite Benefits of Soil Conservation.

The approach followed under Objective 1 will be to develop three data spreadsheets. The first spreadsheet will be composed of the costs of producing crops (corn, wheat, soybean, alfalfa) in Michigan. The 1987 condensed crop budgets developed by SCS will be used as a basis. Crop rotation will be selected by the user. Production costs of all crops in rotation selected will be used to derive the estimated income of the system. No additional input will be needed from the user. A second spreadsheet related to the costs of various conservation practices will be developed. Costs such as flat rate installation cost, annual operating cost and maintenance cost will be included. The spreadsheet will also provide the cost per unit acre, and the lifespan of each practice. The 1987 Soil Conservation

Service Technical Guide will be used for the cost estimates of each practice. Values will be adjusted according to the year of study. No additional input will be needed from the user. The Economic Offsite Benefit of soil conservation will be a fixed value. It is a measure of public benefits resulting from applying erosion control practices, measured in dollars. Since there are no observed prices to measure the value of offsite effects of erosion, the economic effects are measured through the observed changes in the behavior of downstream water users. This value is the "value of damage per ton of erosion", which reflects the demand for a certain level of water quality. A single value ($3.89 per ton of soil eroded) based on a study made by Ribaudo (1989) will be used for Michigan. This value will be adjusted for the year of the study using the Consumer Price Index (CPI).

Objective 2. To develop an expert system rule-base that will recommend soil conservation practices.

The approach to be followed under Objective 2 will be to use three off-the-shelf software packages; Agricultural Non-point Source Pollution (AGNPS), Lotus 123, and Expert System Professional (EXSYSP) shell. Several interface programs will be developed to allow data exchange and manipulation among the software. EXSYSP will be the main program linking data from the spreadsheets and output from AGNPS. Based on the conditions adopted for the evaluation, EXSYSP will recommend an optimal soil conservation practice. The initial step in this approach is the identification of the study area. AGNPS will determine the soil loss level of the study area and pass this information and other variables as input to EXSYSP. If the field is eroding below the allowable soil loss set by SCS, the program will stop. If, however, it is eroding above the limit, EXSYSP will ask the user for more information such as crop rotation, yield level desired and study year. The crop rotation affects the C-factor in the soil loss equation. If the rotation alone does not reduce the erosion to an acceptable level, the program will recommend a practice that will reduce the P-factor. An economic analysis will be produced at the end of the run. This step will estimate farmer's income and society's benefit for the rotation alone, and for the rotation together with the practice. This process is outlined in FIGURE 1.

Program input will be supplied by Lotus spreadsheets (CROPPROD, CONSPRAC, ROTATION), user inputs, and the output generated by AGNPS. All costs will be measured on a per acre per year basis.

Objective 3. To evaluate the expert system as a decision support tool for reducing soil erosion on the lower portion of the Sycamore watershed.

The approach to be followed under Objective 3 will be to use the expert system rule base to reduce soil erosion in the Sycamore watershed (FIGURE 2). The test areas will be taken from the southern portion of the watershed having an approximate size of 22,400 acres. Each study area called cell will be in 40-acre blocks. The expert system program will determine how much soil is eroding.

Given the description of that area, an appropriate soil conservation method will be recommended and its equivalent cost will be estimated. The expert system result will be compared with the recommendations of the Soil Conservation Service on record. The comparison will be based on:

1. recommended practice
2. number of tons of soil erosion prevented

Statistical and financial analysis will be performed on the results.

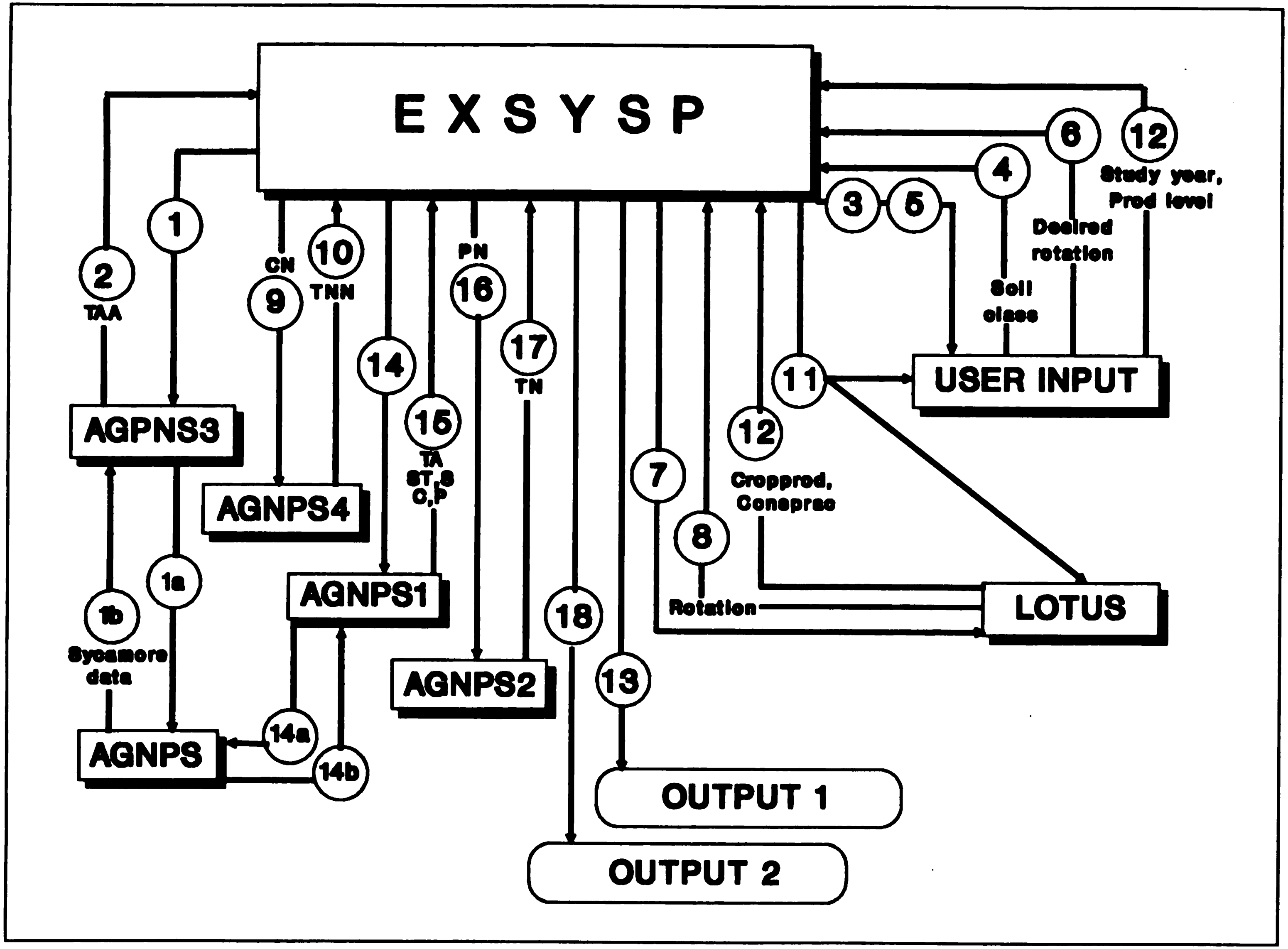

FIGURE 1. Flow Diagram of the Expert System Model

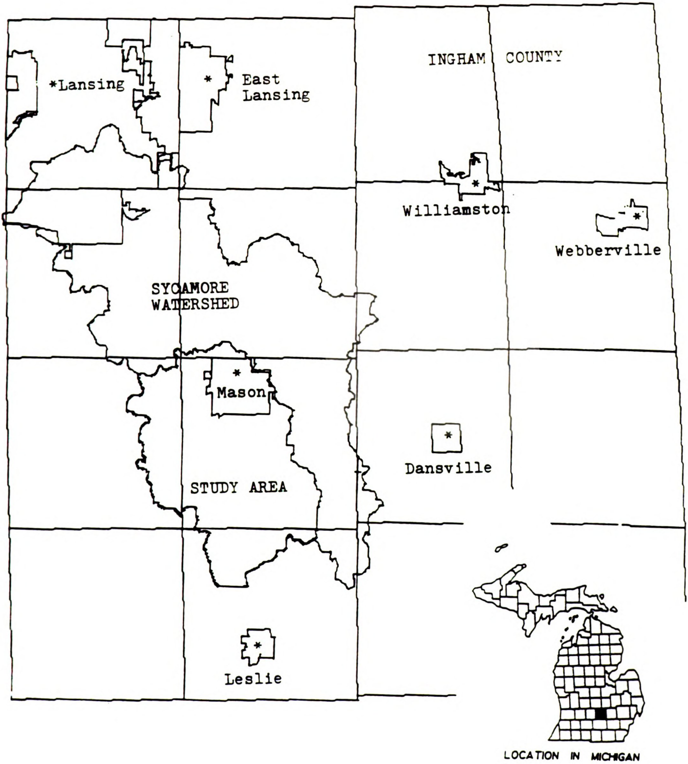

FIGURE 2. Location map of Ingham County and Sycamore Watershed

B. Theoretical Development

Spreadsheets

Three spreadsheets will be developed using the Lotus software. The first contains data on the Costs of Crop Production in Michigan. It will be called CROPPROD. The second is the Costs of Conservation Practices and will be called CONSPRAC. The third is ROTATION, which will provide the C-value for all the crops in a given rotation. The Lotus program will be the spreadsheet used in this study because EXSYSP can access Lotus files with minimal data interface adjustments.

A. CROPPROD

The cost of production will be based on the 1987 condensed crop budgets of SCS (SCS Technical Guide, Section V-C-4). To be consistent with other values (i.e. costs of conservation practices, offsite benefits of erosion control), 1987 prices will be used. Crops to be included are corn, soybean, wheat, alfalfa, red clover. Crop rotations in the study will be limited to 8 choices and contain only the crops mentioned above. There will be a separate crop budget for conservation tillage and conventional tillage of each crop. Furthermore, the budgets will be separated according to yield level. The yield levels per acre are listed below:

1. High
   - Corn - 150 bushels
   - Soybean - 50 bushels
   - Wheat - 60 bushels
   - Alfalfa - 8 tons

2. Average Corn - 120 bushels

Soybean - 40 bushels

Wheat - 50 bushels

Alfalfa - 6 tons

3. Low Corn - 90 bushels

Soybean - 30 bushels

Wheat - 40 bushels

Alfalfa - 4 tons

All costs will be based on a per-planted-acre basis. Although the prices reflect the 1987 value of dollars, these will be adjusted to reflect the present values for any year desired by the user, based on the consumer price index. The Cost of Crop Production will be constructed as a spreadsheet in Lotus and will be named "CROPPROD.WK1" (APPENDIX A1). CROPPROD will contain default values which and cannot be changed by the user.

B. CONSPRAC

CONSPRAC.WK1 (APPENDIX A2) contains data on the costs of conservation practices. It will be based on a 1987 flat rate schedule compiled by the Michigan State Soil Conservation Service, but will be adjusted for the study year using the consumer price index. This spreadsheet will be divided into seven columns, namely, practice, indicator unit, flat rate installation cost, life span, annual operating (including maintenance) cost, average annual total cost, annual cost/acre. The flat rate installation cost will include all labor, material and equipment needed to install one unit. The rate will be based on average sized jobs done by contractors, operators and vendors. It will include the taxes, insurance and any other overhead costs. The rate will be based on quoted prices, actual costs experienced by cooperators, market research by universities and federal agencies. Each practice will have an appointed standardized lifespan. Considerations will be the number of years for which the practice is ordinarily designed for, a reasonable period for the owner to recover the investment and the possibility of obsolescence. The operation and maintenance costs will be estimated as a percentage of the installation cost. The total annual cost combines the installation cost amortized at 9% interest and the operation and maintenance costs. The annual cost/acre will have the same values for practices that have acres as their indicator unit. For other indicator units, a proportional value will be assigned based on the installation cost. In this study, the cost of conservation will be added to the cost of crop production to obtain the total system cost.

C. ROTATION

For each crop rotation that will be recommended by the program, a corresponding C-value will be given; ROTATION.WK1 (APPENDIX A3) is a Lotus spreadsheet developed to provide this value. The computation of C is based on the method discussed by Wischmeier et al. (1978). It is based on the principle that each crop stage has a corresponding soil loss ratio. The soil loss ratio multiplied by the erosivity index of the crop stage, then multiplied by a sod factor will yield a cropstage C-value. The cropstage C-values will be added to make up the whole crop year. The C-value of the rotation is the total of the C-values of each crop in the rotation divided by the number of years to complete one cycle of that rotation. Corresponding values needed for the computation will be taken from Table 5, pages 22-24 of Wischmeier, 1978. The 8 rotations in this study will be based on the rotations commonly recommended by SCS in the Sycamore watershed area. They are:

1. Rotation1: Corn/Corn/Soybean/Wheat with Red clover
2. Rotation2: Corn/Soybean/Wheat
3. Rotation3: Corn/Corn/Corn/Soybean/Wheat
4. Rotation4: Corn/Corn/Soybean/Wheat/Alfalfa for 6 years
5. Rotation5: Corn/Corn/Soybean/Wheat/Alfalfa for 4 years
6. Rotation6: Corn/Soybean
7. Rotation7: Corn/Wheat/Alfalfa for 6 years
8. Rotation8: Continuous Alfalfa for 6 years

The crop yield range will be divided by 5, this is to determine the value of the corresponding soil loss ratio. Below is a list of the five (5) ranges and the expected crop residue per acre produced by this yield:

1. High (>=126 bushels) = 6000 lbs crop residue
2. Medium high (100-125 bu) = 4500 lbs crop residue
3. Average (75-99 bu) = 3400 lbs crop residue
4. Medium low (60-74 bu) = 2600 lbs crop residue
5. Low (<=59 bu) = 2000 lbs crop residue

Economic Offsite Benefit of Soil Conservation

The offsite economic benefits of reduced soil erosion are equal to the reduction in offsite economic damages caused by erosion (Ribaudo, 1985). This is the principle from which values of offsite benefits will be derived. In a study done by Ribaudo (1989) and Strohbehn et al. (1986) the offsite damages from all sources of erosion were estimated for the ten (10) different farm production regions in the U.S. (FIGURE 3). Damage that could not be measured included effects on the aesthetic appearance of the environment, ecosystem, and human health. Measurable erosion damages include flood damages, clogged water conveyances, and damages which affect recreational facilities, water storage, navigation, commercial fishing, and treatment of municipal and industrial water. The 1986 estimates of damages from all sources is $8.79 billion (TABLE 1), excluding damages from wind erosion. Erosion sources included cropland, pastureland, rangeland, forestland, construction sites, roads, pit mines, gullies, quarries, and streambanks. The estimated damage is caused only by pollution from sediment, not chemical fertilizers. The erosion considered here is from non-point sources, caused only by rill and sheet erosion, not gully erosion. In 1982, the total erosion on the 10 regions was 4.925 billion tons. The damage per-ton was then computed by dividing the value of damages by the corresponding tons of erosion. This is done on a regional basis and then averaged to represent the whole U.S. The damage per ton of erosion reflects the demand for water services. It is also a measure of the value of each ton of erosion that can be prevented.

FIGURE 3. Ten Farm Production Regions in the United States

TABLE 1. Annual Total Damages from Soil Erosion by Farm Production Region (1986 Prices).[2]

Farm Production Region	Damages from all Sources (thousand dollars)	Erosion from all Sources (thousand tons)	Damages ($/ton)
Appalachian	688,000	485,900	1.41
Corn Belt	1,111,000	967,400	1.15
Delta	592,000	242,100	2.44
Lake States	676,000	180,600	3.74
Mountain	871,000	774,900	1.12
Northeast	1,317,000	186,600	7.06
Northern Plains	381,000	669,000	0.57
Pacific	1,680,000	678,600	2.48
Southeast	479,000	249,700	1.92
Southern Plains	990,000	490,100	2.02
TOTAL	8,785,000	4,925,000	1.78

Further explanation of these values can be found in Ribaudo (1985), and Strohbehn et.al. (1986). Michigan was grouped under the Lake States region, therefore, the average value for the damage per ton of erosion in that region will be used in this study. The average damage per ton of erosion in Michigan is $3.74 in 1986. It will be adjusted to $3.89 for 1987, the base year for all the costs in this study. This can be adjusted accordingly to any year desired using the consumer price index.

[2] Source: Ribaudo, Marc. 1989. Water quality benefits from the conservation reserve program, pages 6 and 12.

Agricultural Non-point Source Pollution Model (AGNPS)

The test areas will be taken from the lower portion of Sycamore watershed. These test areas, divided in 40-acre block each, will be represented as individual cells in the AGNPS program. This will allow the model to provide information for each specific location within the watershed. Only those cells with more than 50% of their area within the watershed boundaries will be included. Cells will be numbered consecutively, beginning at the cell in the Northwest corner and proceeding from west to east then southward (FIGURE 4). The numbering system will aid in quickly identifying the cells in program output. Using the topographic lines of the map, the drainage pattern of each cell will be established. The cell drainage direction is the direction of flow leaving the cell. It is one of eight possible directions, directly out of the sides of the cells or out of the corners. The value for this parameter is between 1 and 8. Once this step is completed, the input data file can be established. The data file parameters and the required format for this file are shown as TABLE 2 and TABLE 3.

TABLE 2. Data File Parameters for Whole Watershed (AGNPS)

LINE	PARAMETERS
1	Watershed Identification
2	Description
3	Area of each cell (acres)
4	Number of cells (up to 1900)
5	Precipitation (inches)
6	Energy Intensity Value
	OR
	Duration (hours)
	Storm Type (I, Ia, II, III)

TABLE 3. Data File Parameters for Individual Cells (AGNPS)

COLUMN	CONTENT
1	Cell Number
2	Receiving Cell Number
3	Receiving Cell Division
4	Aspect
5	SCS Curve Number
6	Field Slope (%)
7	Slope Shape
8	Slope Length
9	Manning's Roughness Coefficient
10	Soil Erodability (K-Factor)
11	Cover and Management (C-Factor)
12	Practice (P-Factor)
13	Surface Condition Constant
14	Soil Texture
15	Fertilizer Level
16	Availability Factor
17	Point source Indicator
18	Gully Source (tons)
19	Chemical Oxygen Demand (COD Factor)
20	Impoundment Factor
21	Channel Indicator

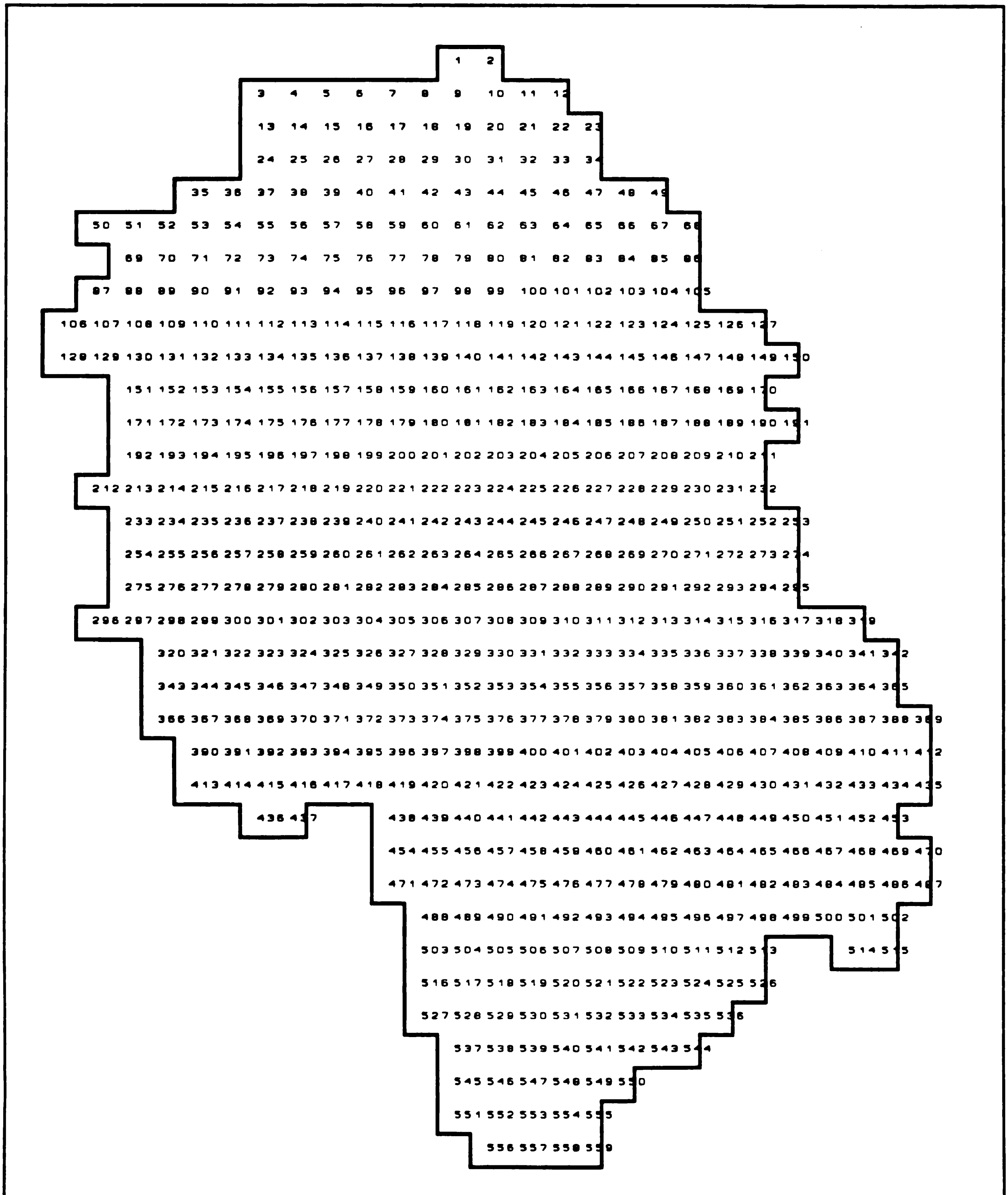

FIGURE 4. AGNPS Cell Division of Sycamore Watershed in 40-acres block

An AGNPS data file for the lower Sycamore watershed has already been established by SCS. This 24,000-acre part of the watershed was divided into 559 cells. The study cells will come from this file. For this research, AGNPS will be run as an accompanying program for the expert system shell. It will be treated as an external program which will be accessed by EXSYSP. Only one cell will be studied at a time, therefore other programs were developed. Four batch files - AGNPS3, AGNPS4, AGNPS1, AGNPS2 were created to access the AGNPS output. The batch files below are presented in the order they will be used by EXSYSP.

AGNPS3 (APPENDIX B1) is a batch file that will always be accessed at the start of each run. It will do several things by accessing executable files specifically developed for this expert system. First it will extract a cell from a data file (the user will be asked the name of the watershed to be studied, then the cell number). It will then creates a temporary file (Temp.dat) where it will dump all the needed input data from the study cell. AGRUN (AGNPS' executable file) will be executed and TAA (original soil loss), the only output will be produced. It will then be kept in another temporary file (Temp.nps). AGNPS3 then passes the TAA value to Return.dat, a file which EXSYSP can access. AGRUN output includes an array of information but AGNPS3 will only keep the data needed by EXSYSP. At this point, EXSYSP will only need the variable TAA.

AGNPS4 (APPENDIX B2) will replace the C (original c-value) in AGNPS3 with CN. The value of CN will be provided by Lotus, it is based on the crop rotation picked by the user. The new input data will be kept in Temp2.dat. AGRUN will be executed and the output kept in Temp2.nps. TNN (resulting soil loss from the crop rotation picked by user) will be the only output passed back to EXSYSP.

AGNPS1 (APPENDIX B3) is "variable specific". It will only be called if the variable ST is needed. It will pass all the other variables kept in Temp.dat (C, CN, P, S, K, ST) and Temp2.nps (TNN) to EXSYSP where they will be used by the rules. The variables and their corresponding meaning are listed below:

1. Soil loss with crop rotation (TNN)
2. Old cropping factor (C)
3. New cropping factor (CN)
4. Old practice factor (P)
5. Slope (S)
6. Soil erodability factor (K)
7. Soil texture (ST)

AGNPS2 (APPENDIX B4) will replace C with CN and P (old p-value) with PN (new p-value). The PN value will be dependent on EXSYSP's recommended practice, it will be stored in Temp2.dat. AGRUN will be executed and the resulting Temp2.nps will produce TN (resulting soil loss with crop rotation and practice combined). TN will be copied to Result.dat where EXSYSP can read it.

The AGNPS program takes three measurements of erosion. The first is the erosion generated "above the area". Eventually part of the detached soil ends up in the study cell. The second is the soil generated "within the area". Some of this will stay on the same 40 acre plot while part will be deposited on the downstream cell. The third measurement is the soil deposition from the first and second sources. Table 4, line 14 shows the three different measurements of erosion for cell 26. Sediment generated within the cell averaged 5.77 tons/acre, or 231 tons for the whole 40-acre plot which is the total area of the cell. Outside cells were contributing 371 tons of sediment to cell 26. Therefore, in principle, cell 26 has a total of 602 tons of loose soil. Of this, 19% (115 tons) stayed within cell 26 while the remaining 81% (487 tons) moved on to the next cell. For the purpose of simplifying the study, the soil loss measurement that will be considered in this study is the one generated within the cell, whether it stayed or left the cell (corresponding to the 602 tons in the example above).

TABLE 4. Soil Loss Measurements By AGNPS (Sycamore, Cell 26)[3]

-HYDR- Cell Num Div	Drainage Area (acres)	Overland Runoff (in.)	Upstream Runoff (in.)	Peak Flow Upstream (cfs)	Downstream Runoff (in.)	Peak Flow Downstr (cfs)
26 000	1240	1.79	1.55	931.00	1.56	908
2 000	40	1.94	0.00	000.00	1.94	115
-SED- Cell Num Div	Particle Type	Cell Erosion (t/a)	Upstream Above (tons)	Within (tons)	Yield (tons)	Deposition (%)
26 000	CLAY	0.29	051.54	011.55	063.04	00
	SILT	0.46	059.73	018.48	076.72	02
	SAGG	2.89	233.56	115.49	320.22	08
	LAGG	1.79	022.61	071.60	023.37	75
	SAND	0.35	003.81	013.86	003.80	78
	TOTL	5.77	371.26	230.98	487.16	19
	CLAY	0.14	000.00	005.63	005.64	00
	SILT	0.23	000.00	009.02	008.51	06
	SAGG	1.41	000.00	056.35	043.67	22
	LAGG	0.87	000.00	034.94	002.63	92
	SAND	0.17	000.00	006.76	000.38	94
	TOTL	2.82	000.00	112.69	060.83	46

[3] Actual AGNPS output from Sycamore.dat , Cell# 26.

Expert System Rule-Base

The rule-base mode of knowledge representation will be employed in this study. The rules will be developed using an expert system shell called EXSYSP. The rule base structure developed will be called "CONSERVE". It will have 158 rules, 11 choices and 15 qualifiers. The "0-1" (also known as yes/no) probability mode will be used for generating the final answer (choice). The system will have three input sources: 4 external programs in the form of batch files - AGNPS3, AGNPS4, AGNPS1, AGNPS2; 3 lotus spreadsheets; and user input (FIGURE 5). The program can be called by typing "EXSYSPB CONSERVE NULLCHOICE FORWARD" or "TEMP" from the Exsysp directory. The reason for this long call name is previously explained in the review of literature. EXSYSP has a standard form of presenting the output to the user. However, the data output form can be controlled by a report generator. The report output specification is an ASCII file with the same file name as the rule base with an ".OUT" extension. Two report generators namely CONSERVE.OUT and CONS.OUT (APPENDIX C.1.A and C.2.B) will be written specifically for this program.

The rule-base can be presented by a tree diagram (FIGURE 6). The basic objective of the rule-base is to determine if soil erosion is occurring. This is accomplished by initially determining what kind of soil is predominant in the area. SCS (Soil Survey of Ingham County) has set an acceptable soil loss for each soil type. For example, the limit for Aurelius (Au) is only 1 ton/acre, anything more than 1 is considered unacceptable. However, Spinks (and most other soil) can

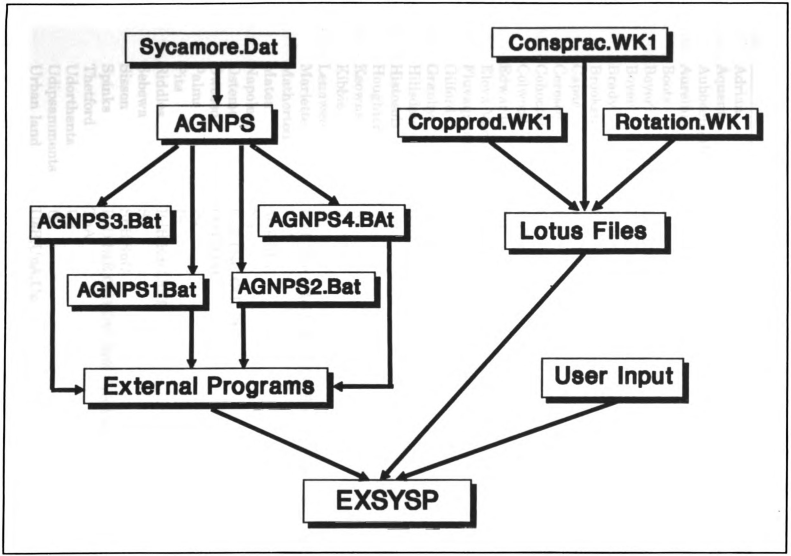

FIGURE 5. EXSYSP Input Source

TABLE 5. Acceptable Soil Erosion Based from Soil Classification

Soil Name	Map Symbol	Acceptable Erosion (t/a)
Adrian	Ad	4
Aquents	Ha	
Aubbeenaubbee	AnA	5
Aurelius	Au	1
Boots	Bo	5
Boyer	BrB,Moe,UeB	4
Boyer	BsD,BsE	4
Brady	ByA	5
Brookston	Co	5
Capac	AnA,CaA,UpA	5
Ceresco	Ce	5
Cohoctah	Ch	5
Colwood	Co,UpA	5
Edwards	Ed	4
Eleva Variant	EvB	3
Fluvaquents	Uu	
Gilford	Gf	4
Granby	Gr	5
Hillsdale	RdB,RdC,RdD	5
Histosols	Ha	2
Houghton	Hn	5
Keowns	Ka	5
Kibbie	KbA	5
Lenawee	Ln	3
Marlette	MaB,MaC,MeD2,MoE,OwB,OwC,UtB	5
Matherton	MrA	4
Matea	MtB,MtC	5
Napoleon	Na	5
Ostemo	OsB,OsC,OtB,OtC	5
Owosso	OwB,OwC	5
Palms	Pa	5
Pits	Pt	
Riddles	RdB,RdC,RdD	5
Sebewa	Sb	4
Sisson	SnB,SnC	5
Spinks	BsD,BsE,OtB,OtC,SpB,Spc,UeB	5
Thetford	ThA	5
Udorthents	Ud	
Udipsamments	Ud	
Urban land	UeB,UpA,Uu	

erode up to 5 tons/acre and still be acceptable. Based on the standards set by SCS, the program will determine if the soil is eroding (TABLE 5). The type of soil is an information provided by the user. If the soil is not eroding excessively, the system will recommend no changes in the existing practice. If it is, EXSYSP will proceed to check the two parameters (cropping factor and slope) that might be causing the sedimentation. Since changing the crop rotation is easier than physical conservation measures (contouring, terracing, etc), the program will check first if a mere improvement of the ground cover will reduce the erosion to an acceptable level. The program will accomplish this by asking the user the desired crop rotation and the expected crop yield range. Based on this information, it reads the corresponding C-factor (CN) from Lotus (ROTATION.WK1) and replaces the old C value. Next, it computes the total cost of crop production. Based on the crop yield range (FIGURES 7 and 8) and the tillage method presently employed by the user (FIGURE 9), the system reads the cost of production of each crop in the rotation from Lotus (CROPPROD.WK1). Depending on the crop rotation and the tillage practice, the total cost is computed using one of the following formulas:

$$CPCR11 = \frac{(SCOR * 2) + SSOY + SWHE + SCLO}{4} \qquad (4)$$

$$CPCR11 = \frac{(VCOR * 2) + VSOY + VWHE + VCLO}{4} \tag{5}$$

$$CPCR22 = \frac{SCOR + SSOY + SWHE}{3} \tag{6}$$

$$CPCR22 = \frac{VCOR + VSOY + VWHE}{3} \tag{7}$$

$$CPCR33 = \frac{(SCOR * 3) + SSOY + SWHE}{5} \tag{8}$$

$$CPCR33 = \frac{(VCOR * 3) + VSOY + VWHE}{5} \tag{9}$$

$$CPCR44 = \frac{(SCOR * 2) + SSOY + SWHE + SALB + (SALS * 5)}{10} \tag{10}$$

$$CPCR44 = \frac{(VCOR * 2) + VSOY + VWHE + VALB + (VALS * 5)}{10} \tag{11}$$

$$CPCR55 = \frac{(SCOR * 2) + SSOY + SWHE + SALB + (SALS * 3)}{8} \tag{12}$$

$$CPCR55 = \frac{(VCOR * 2) + VSOY + VWHE + VALB + (VALS * 3)}{8} \tag{13}$$

$$CPCR66 = \frac{SCOR + SSOY}{2} \tag{14}$$

$$CPCR66 = \frac{VCOR + VSOY}{2} \tag{15}$$

$$CPCR77 = \frac{SCOR + SWHE + SALB + (SALS * 5)}{8} \tag{16}$$

$$CPCR77 = \frac{VCOR + VWHE + VALB + (VALS * 5)}{8} \tag{17}$$

$$CPCR88 = \frac{SALB + (SALS * 5)}{6} \tag{18}$$

$$CPCR88 = \frac{VALB + (VALS * 5)}{6} \tag{19}$$

where:

CPCR** - Total cost of crop production for crop rotation*
SCOR - Cost of crop production for corn, conservation tillage
VCOR - Cost of crop production for corn, conventional tillage
SSOY - Cost of crop production for soybean, conservation tillage
VSOY - Cost of crop production for soybean, conventional tillage
SWHE - Cost of crop production for wheat, conservation tillage
VWHE - Cost of crop production for wheat, conventional tillage
SCLO - Cost of crop production for clover, conservation tillage
VCLO - Cost of crop production for clover, conventional tillage
SALB - Cost of crop prod for alfalfa-beginning year, conservation
VALB - Cost of crop prod for alfalfa-beginning year, conventional
SALS - Cost of crop prod for alfalfa-succeeding years, conservation
VALS - Cost of crop prod for alfalfa-succeeding years, conventional

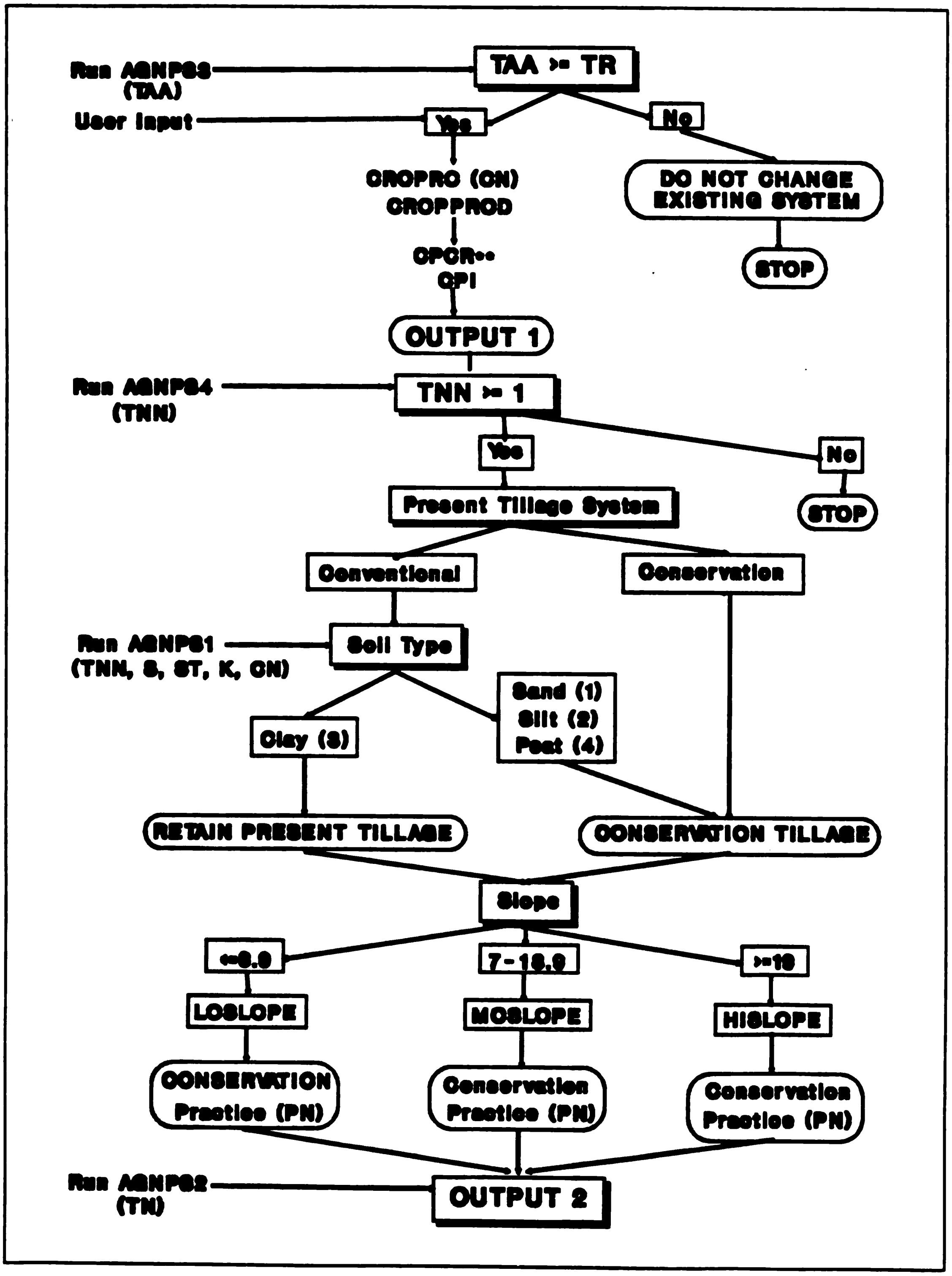

FIGURE 6. Tree Diagram of the Expert System Rule Base

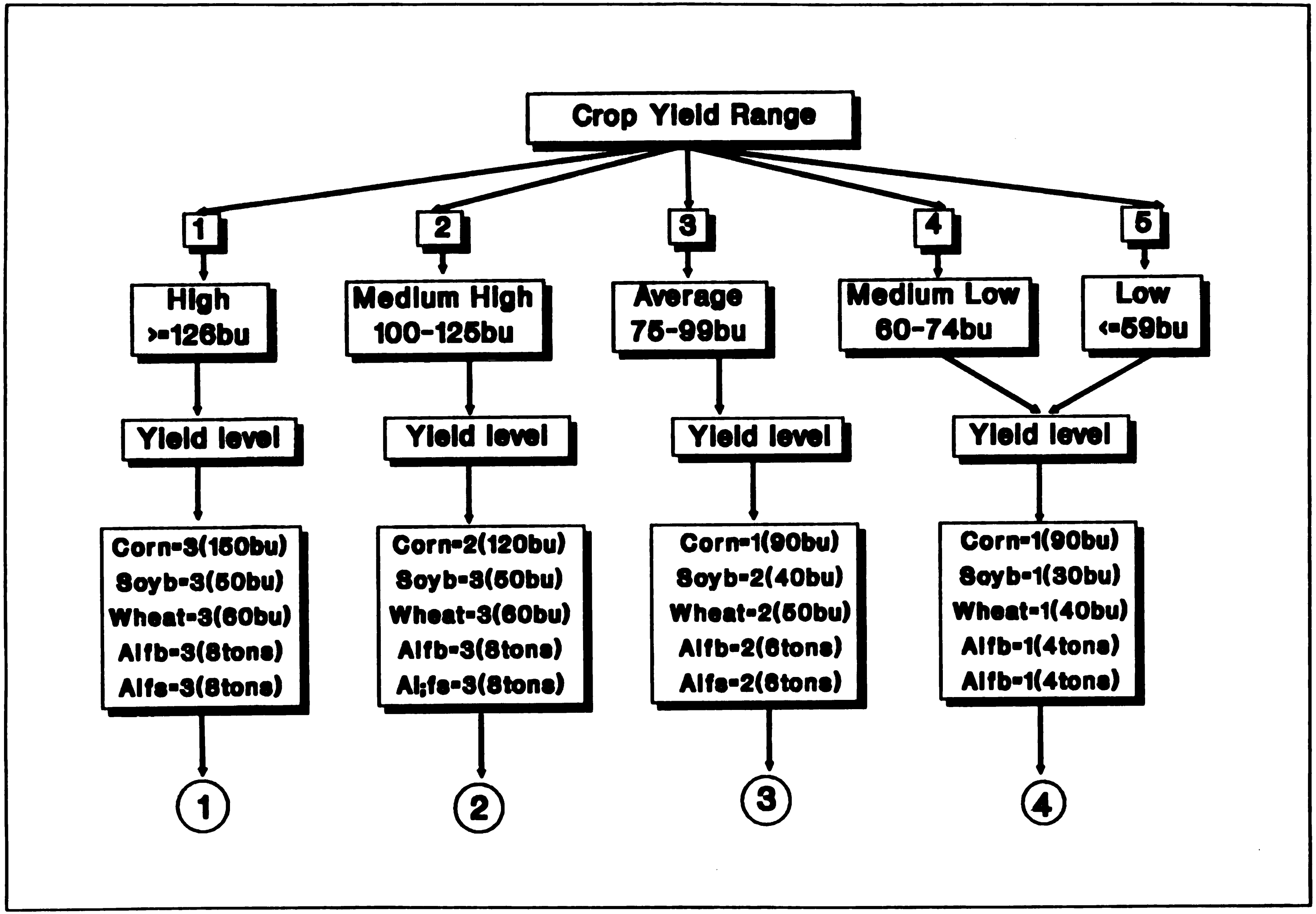

FIGURE 7. The Five different Crop Yield Ranges and their equivalent Yield Levels.

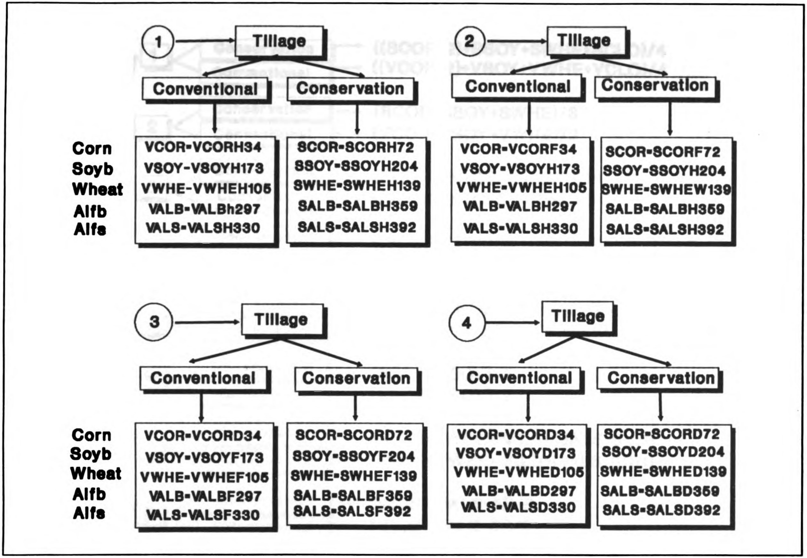

FIGURE 8. Production costs sources (CROPPROD.WK1) of each crop depending on the tillage method employed.

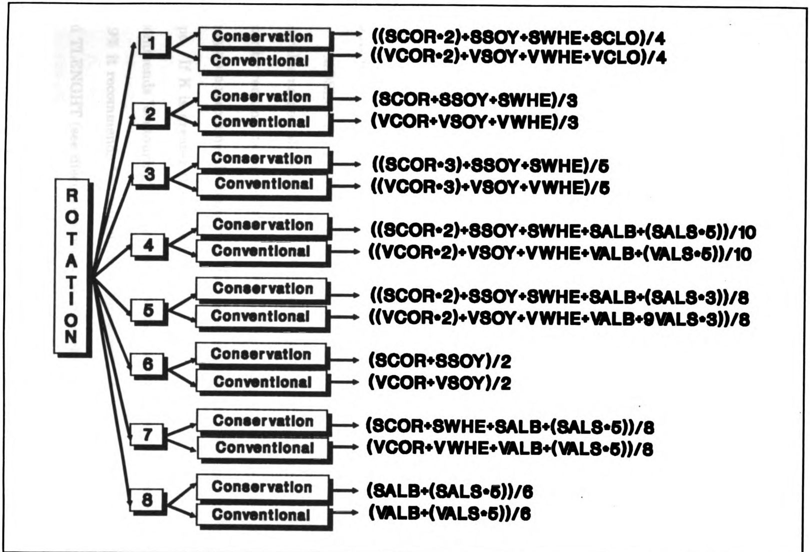

FIGURE 9. Formulas used for the computation of each crop rotation based on the tillage method employed.

The system then passes CN to AGNPS which computes the new soil loss (TNN). If the soil loss is equal or less than 1 ton/acre, the program stops and does not recommend an additional conservation practice. At this point, 1.0 is set as the limit for acceptable erosion regardless of the soil type. If, however, the field is eroding more than 1 ton/acre, EXSYSP will check the slope and other variables. Slope is categorized as: Loslope (<= 6.9%); Moslope (7-18.9%); Hislope (19-25.9%).

LOSLOPE*

LOSLOPE* (FIGURE 10) is a series of 2 rules that will be accessed only if the field slope is less than 7%. The system recommends "contouring" for this slope range and a new practice value (PN) is given depending on the slope.

MOSLOPE*

MOSLOPE* (FIGURE 12) is a series of 9 rules for slopes between 7-18.9%. The rules named MOSLOPE1,...MOSLOPE9. MOSLOPE* will determine the K-factor by reading its value from AGNPS1. If K is less than or equal to 0.23, then the system recommends contouring then assigns a value for PN depending on the slope. If K is greater than or equal to 0.24 and the slope is 7 to 9.9%, it still recommends "contouring" and a new PN value. But if K is >=0.24 with slope 10-18.9% it recommends "contouring with terracing". A new PN value is assigned and TLENGHT (see discussion below) is computed.

HISLOPE*

HISLOPE* (FIGURE 11) is a series of 4 rules accessed only if field slope is greater than or equal to 19%. These rules are named HISLOPE1,...HISLOPE4. HISLOPE* initially checks the slope of the field by reading the variable S from AGNPS1. If slope is 19-25.9%, "contouring with terracing" is recommended and a new practice value (PN) given. A computation of the recommended maximum horizontal length of terrace using equation 20 follows.

$$TLENGTH = \frac{73\ (LS)^{\frac{1}{x}}}{\left(\frac{(0.43\ +\ 0.30S)\ +\ (0.043S^{2})}{6.574}\right)^{\frac{1}{x}}} \tag{20}$$

$$LS = \frac{TR}{R\ K\ CN\ PN} \tag{21}$$

where:

TLENGHT - Recommended maximum horizontal length of terrace (ft)

S - slope (%)

x - 0.3 if S<4, 0.4 if S=4, 0.5 if S>4

LS - Length-slope factor (ft.)

TR - Recommended soil loss based on soil type (tons/acre)

R - rainfall-factor, set as 95 in this program for Ingham County, MI

K - Soil erosivity-factor

CN - Value for the recommended cropping-factor

PN - Value for the recommended practice-factor

The recommended soil loss (TR) will be used for the computation of TLENGHT instead of the actual soil loss (TN). This is because the use of TR will be less expensive. Example, the actual soil loss might only be 3 tons while the soil type in the area has an allowable soil loss of 5 tons. If TLENGHT is base on TN, the practice will become more expensive because the terrace is being built for a 3 ton soil loss limit when a 5 ton limit will suffice.

For slopes greater than or equal to 26%, the system will recommend "seeding to perennial grass". CN will be given a value of 0.016 while PN will maintain the original value of P since no new practice will be recommended.

The cost of the recommended conservation practice is a data provided by Lotus (CONSPRAC). If the system recommends changing the tillage method, the cost is zero. This is because the cost of tillage is already incorporated in the cost of crop production. If the recommendation is "contouring" or "seeding to perennial grass", a corresponding value is provided. If the recommendation is "contouring with terracing", the cost of conservation practice is equal to the value read from CONSPRAC.WK1 plus the computed value of ACTER which is:

$$ACTER = \left(\left(\frac{200}{TLENGHT}\right) * 217.8\right) * 0.04534 \tag{22}$$

$$CONSPRACCP^{1} = CONSPRAC * CPI \tag{23}$$

$$CONSPRACCPI^{2} = (ACTER + CONSPRAC) * CPI \tag{24}$$

where:

ACTER - Cost of terracing ($/acre)

TLENGHT - Recommended maximum horizontal length of terrace (feet)

$CONSPRACCPI^1$ - Cost of conservation practice for the study year ($/acre)

$CONSPRACCPI^2$ - Cost of conservation practice (contouring and terracing only) for the study year ($/acre).

CONSPRAC - Cost of conservation practice on the base year ($/acre).

CPI - Consumer price index

Since the conservation cost of terracing was given in "per foot" ($45.35/1000ft) unit, this is converted to a cost per acre because all computations are on a per acre basis. This is done by assuming a fixed length and width (L=217.8' W=200'). "W" is be divided by the recommended horizontal terrace length (TLENGHT) to get the number of terraces in an acre field. The resulting value is multiplied by "L" to get the total length of the terrace in the one acre plot. The result will be multiplied by 0.4534 ($45.34/1000ft) to get the convert the cost from per "1000ft" to "per acre".

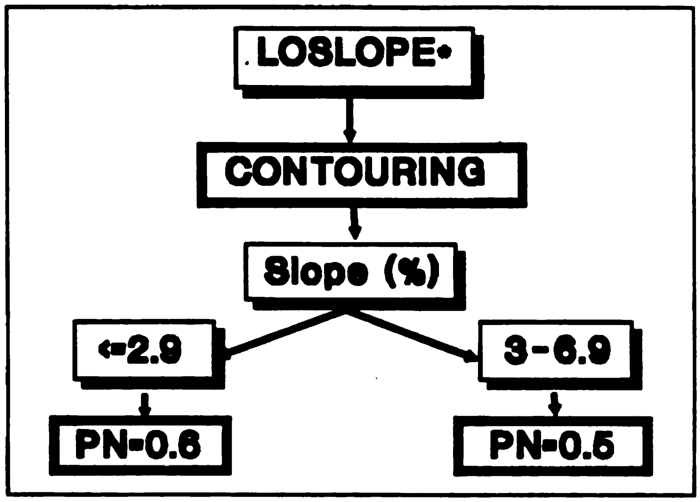

FIGURE 10. LOSLOPE* - Portion of the Expert System Rule-base which shows the flow of rules when field slope is less than 7 percent.

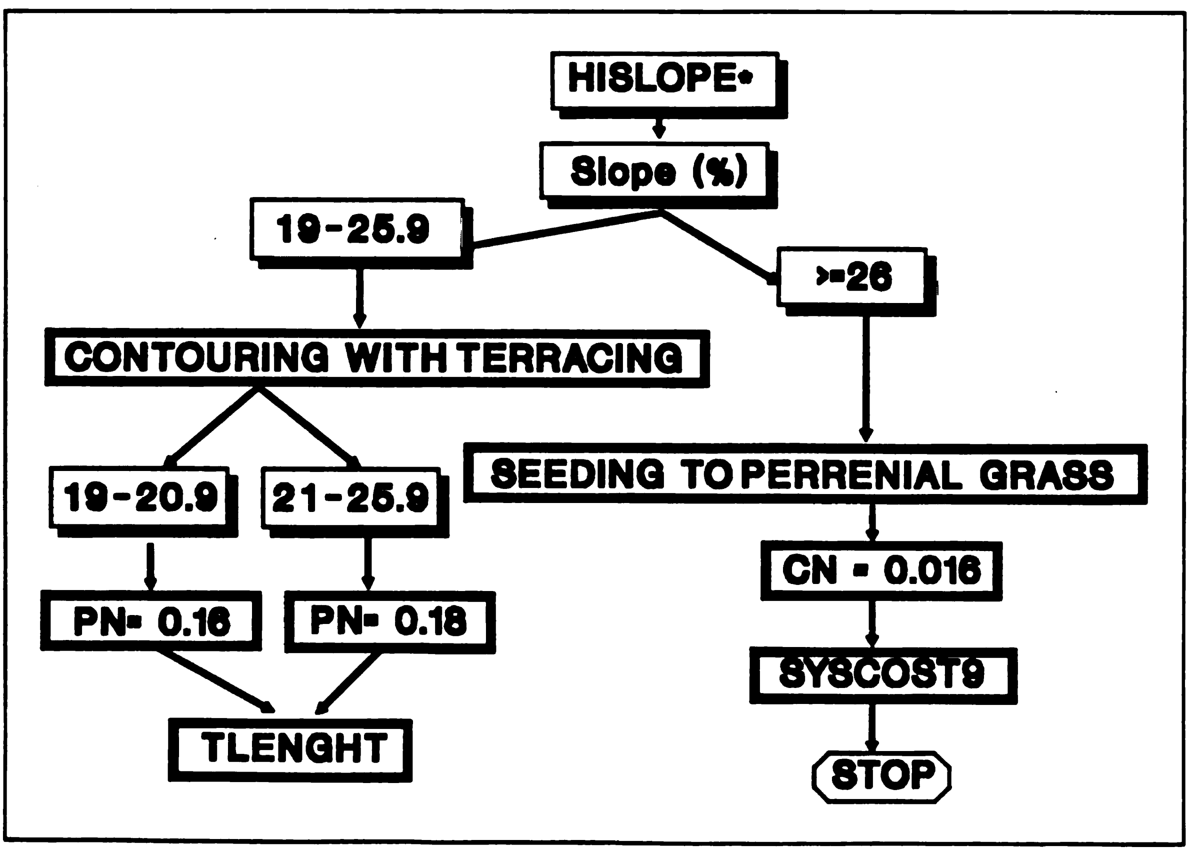

FIGURE 11. HISLOPE* - Portion of Expert System Rule-base which shows the flow of rules when field slope is greater than 18.9 percent.

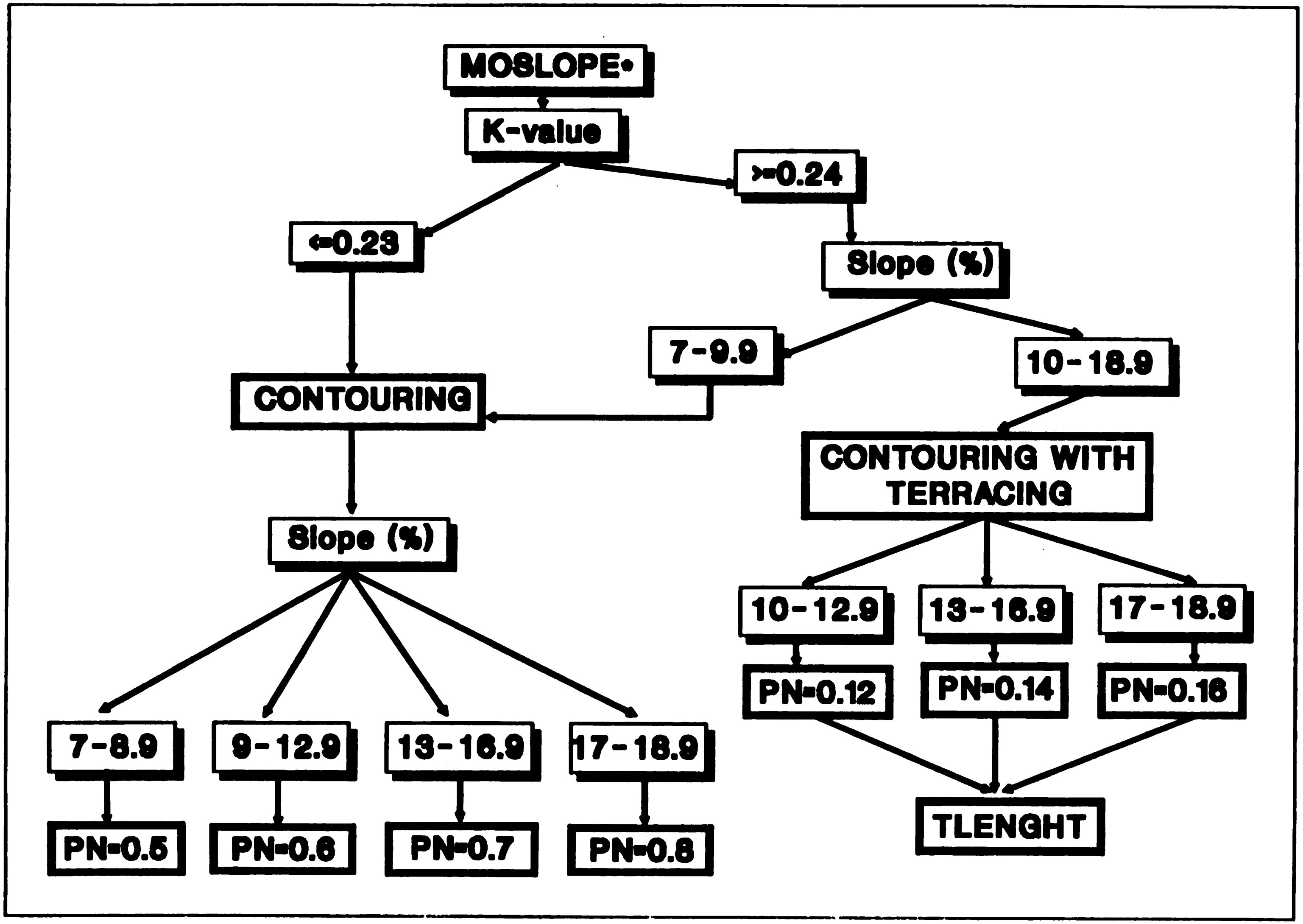

FIGURE 12. MOSLOPE* - Portion of the Expert System Rule-base which shows the flow of rules when field slope is between 7 to 18.9 percent.

EXSYSP then passes PN to AGNPS where a new soil loss (TN) is computed. The system stops making recommendation at this point and performs financial analysis on the resulting farming system. It computes the estimated farmer's income per acre per year for applying the rotation only (equation 25), as compared with rotation with the recommended conservation practice (equation 26). Based from the tons of soil saved as a result of the rotation and practice, benefits to society (equations 27 and 28) are also computed. Depending on the desired crop rotation, the program triggers only the equations needed.

$$NOSYSCOST = CPCR * CPI \tag{25}$$

$$YESYSCOST = (CPCR* - CONSPRAC) * CPI \tag{26}$$

$$SYSCOST = (TAA - TNN) * 3.89 * CPI \tag{27}$$

$$SSYSCOST = (TAA - TN) * 3.89 * CPI \tag{28}$$

where:

NOSYSCOST - Estimated farmer's income from rotation only ($/acre/year)

YESYSCOST - Estimated farmer's income from rotation and conservation practice ($/acre/year)

SYSCOST - Society's benefit from rotation only ($/acre/year)

SSYSCOST - Society's benefit from rotation and conservation practice ($/acre/year)

CPCR* - Cost of crop production with conservation /acre/year for crop rotation* ($)

CPCR** - Cost of crop production without conservation /acre/year for crop rotation* ($)

TAA - Original soil loss before recommendation (tons/acre)

TNN - Soil loss from crop rotation only (tons/acre)

TN - Soil loss from rotation and conservation practice (tons/acre)

CPI - Consumer price index

CONSPRAC - Cost of conservation practice ($)

The AGNPS batch files are accessed by the program to provide values for TAA, TNN and TN. CPCR* and CONSPRAC values are computed by the program. Although all costs are computed from 1987 values, the financial analysis may reflect the cost of any desired year of study.

To adjust all the dollar values into any specific year, the program asks the user to enter the desired year of study. Based on this information, the program assigns a value to the variable CPI. The CPI values will be based on an Economic Forecasting Model (Ferris, 1987) which originally used 1983 as the base year. CPI for this study will be computed and adjusted using 1987 as the base year (TABLE 6). The years included in the study will be from 1987-2010.

TABLE 6. Consumer Price Index

YEAR	CPI	YEAR	CPI	YEAR	CPI
1987	1.00	1995	1.35	2003	1.81
1988	1.04	1996	1.39	2004	1.88
1989	1.09	1997	1.45	2005	1.96
1990	1.15	1998	1.50	2006	2.04
1991	1.19	1999	1.56	2007	2.11
1992	1.23	2000	1.61	2008	2.19
1993	1.27	2001	1.68	2009	2.29
1994	1.31	2002	1.75	2010	2.39

Description of the Study Area

The Sycamore Creek Watershed is located in Ingham County in south-central lower Michigan. The watershed drainage area is approximately 67,740 acres across the townships R1W-R2W and T1N-T3N. The northern half of the watershed covers parts of the cities of Holt and Lansing. Approximately 1,500 acres of Michigan State University farmland is located in the northern part of the watershed. The Sycamore Creek is a tributary of the Red Cedar River. The Red Cedar Flows into the Grand River, which flows into Lake Michigan. The type of land uses identified by Michigan Resource Information Service (MIRIS) ranges from agriculture to residential. The agricultural land use represents more than 50% of the whole area (TABLE 7).

TABLE 7. Land Uses in Sycamore Watershed

LAND USE	AREA
Agricultural uses (cropland, orchard, pasture)	53,453 acres
Residential land	9,336 acres
Forest land	8,017 acres
Idle land	6,381 acres
Commercial and Industrial land	2,562 acres
Wetland	2,324 acres
Transportation, communication and utilities	1,349 acres
Open land - recreation and cemeteries	826 acres
Gravel pits and wells	806 acres
Water - streams and lakes	359 acres
Other	325 acres
TOTAL:	67,738 acres

Several problems have been identified in the watershed. The major types of pollutants to be controlled were sediment from soil erosion, phosphorus fertilizers, nitrate fertilizers and agricultural pesticides. These pollutants cause sedimentation, turbidity problems, nuisance algae and groundwater contamination. Approximately 1,800 acres of cropland have a very severe erosion problem.

The available AGNPS data base for the watershed covers 22,360 acres. This area represents the lower portion of the watershed where most of the agricultural activities take place. It represents 33% of the whole and was divided into 559 cells of 40 acres each. For this study 14 cells have been selected from the subwatershed. The selection was based on an initial AGNPS run which determined the highest sediment-producing cells. The cells and their location are as follows:

#26 Location: SE1/4 NW1/4 of Section 6, T2N R1W

#166 Location: NW1/4 NE1/4 of Section 16, T2N R1W

#173 Location: SE1/4 NW1/4 of Section 13 T2N R2W

#186 Location: SW1/4 NE1/4 of Section 16 T2N R1W

#243 Location: NE1/4 NW1/4 of Section 20 T2N R1W

#272 Location: SE1/4 NW1/4 of Section 22 T2N R1W

#320 Location: NW1/4 NW1/4 of Section 27 T2N R2W

#327 Location: NE1/4 NE1/4 of Section 30 T2N R1W

#340 Location: NW1/4 NW1/4 of Section 26 T2N R1W

#440 Location: SE1/4 NW1/4 of section 32 T2N R1W

#467 Location: NW1/4 SW1/4 of Section 35 T2N R1W

#489 Location: NE1/4 NW1/4 of Section 5 T1N R1W

#539 Location: NE1/4 NE1/4 of Section 8 T1N R1W

#547 Location: SE1/4 NE1/4 of Section 8 TiN R1W

FIGURE 4 shows the division of cells in the watershed while FIGURE 13 shows the location of each study cell in the same area.

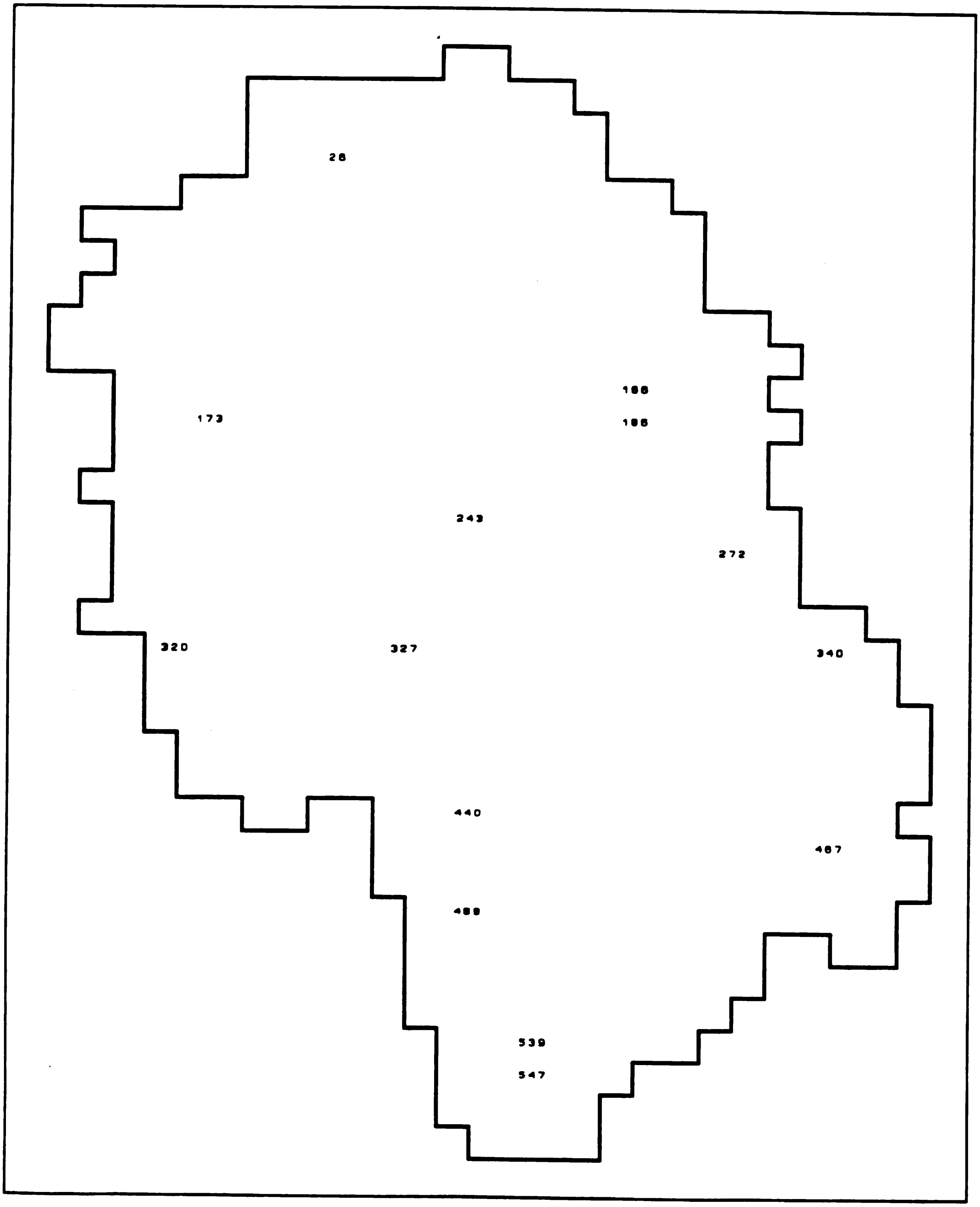

FIGURE 13. Location of the fourteen (14) highest sediment producing cells in the study area in Sycamore Watershed.

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C. Experimental Methods

The proposed experimental method is composed of two parts, each relating to the validity of the expert system rule-base. In part one, a statistical method is be used to compare the ES and SCS results. Part two will be a sensitivity analysis of the expert system model. The expert system program will be run for each of the study cells using data files from the Sycamore watershed. Input variable by users will be maintained as constant as possible; this includes soil type, yield level, tillage method originally practiced by farmer, crop rotation and year of study. As for the SCS results, historical recommendations will be used. The ES recommendations were mostly on physical practices like contouring, terracing, tillage methods. These practices affect the P-factor in the Universal soil loss equation used in most of the computations. Crop rotation, which affects the C-factor will be a user input. On the otherhand, SCS recommendations were mostly on crop rotation and tillage methods. It is therefore hard to compare the two recommendations as is. Instead, the soil loss resulting from both recommendations will be used for comparison.

A. Statistical Method

A verification of the expert system result will be made by comparing the two results using the Wilcoxon Rank Sum Test. This non-parametric statistical method provides a procedure for testing if two populations are identical or different. The Wilcoxon rank sum test jointly ranks the measurements from the combined samples and test the null hypothesis for a similarity in the two data. The hypothesis will be defined as:

H_o: $P_1 = P_2$

H_a: $P_1 > P_2$ (P_1 is shifted to the right of P_2)

$P_1 < P_2$ (P_1 is shifted to the left of P_2)

where:

H_o - Null hypothesis

H_a - Alternative hypothesis

P_1 - Population1, soil loss using SCS recommendation

P_2 - Population2, soil loss using ES recommendation

The rejection of the hypothesis will be set at $|Z| > Z_{\frac{\alpha}{2}}$. The equations for computation are listed below:

$$\mu_T = \frac{n_1(n_1 + n_2) + 1)}{2} \tag{29}$$

$$\sigma_T = \sqrt{\frac{n_1 n_2}{12}\left((n_1 + n_2 + 1) - \frac{\sum t_j\,(t_j^2 - 1)}{(n_1 + n_2)\,(n_1 + n_2 - 1)}\right)} \tag{30}$$

$$Z = \frac{T - \mu_T}{\sigma_T} \tag{31}$$

where:

μ_T - Mean

σ_T - Variance

Z - Computed Z

$Z_{a/2}$ - Z-value from table

T - Sum of the ranks in sample 1

n_1 - Sum of population 1

n_2 - Sum of population 2

t_j - Number of tied ranks in the group

The hypothesis that will be tested is if there is a significant difference in the amount of soil loss reduced when using the SCS recommendation (P_1) as compared to ES recommendation (P_2). If there is, which of the two reduces soil loss better?

An initial AGNPS run was conducted to determine which of the 559 40-acre block cells in the study area have the highest sedimentation rate. Fourteen cells eroding at 4 tons/acre or more will be used for the statistical analysis. Six of the study cells were classified by SCS as two different fields (meaning there are two owners), while two of the fourteen cells have no SCS recommendation since owners of those farms are not participants in the SCS program. Because of this, 18 will be the sample size instead of 14. The soil type Aurelius (Au) with a "T" value of 1 ton will be used on all EXSYSP runs to get results comparable to that of SCS.

B. Sensitivity Analysis

Variation in the combination of inputs changes the outcome significantly. To develop an overall strategy, one has to study how the result will change with changes in the input. Crop rotations, Yield level and tillage practice are input data that will be provided by the user in the ES model. These three variables affect sediment loss and the overall cost of the recommendation. In this study a detailed analysis of Expert system rule-base will be made by changing four input variables: Cell number, Crop rotation, Yield level and Tillage practice by the farmer before the recommendation. Slope will also be changed to measure its overall effect on the program's recommendation.

Cell Number

Fourteen cells will be used for the analysis. All input data including the desired crop rotation will be the same for all. Even though each cell has a different soil type, Aurelius Muck (Au) which has 1 ton/acre allowable soil limit will be used for all. "Crop rotation1" which is Corn/Corn/Soybean/Wheat seeded to Red Clover will be the test crop. Yield level to be used will be "high" and "Conventional" will be the assumed original tillage practice of the farmer. "1995" will be the assumed study year.

Crop Rotation

Each of the eight crop rotations included in this study is a combination of different crops. The sum of production cost of all crops in the rotation divided by the total number of years to complete one cycle equals the annual production cost

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of that rotation. Another consideration, though, is how much ground cover the rotation provides. Each rotation will be applied on the same conditions to find out which results to the lowest C-value. As shown in equations 25 and 26, soil loss is a function of societal benefit. All inputs will be the same in this part of the sensitivity analysis, only the crop rotation will be changed. By doing so, it will be determined which of the 8 rotations in the study is best for the farmer and which is best for the society.

Yield Level

The five yield ranges will be: High (>=126 bushels), Medium High (100-125 bu), Average (75-99 bu), Medium Low (60-74 bu), and Low (<=59 bu). Again, the same input will be used for this part of the sensitivity analysis, only the yield range will be changed to establish which crop yield level is most beneficial to the farmer and to society as well. It will be assumed in the study that the yield level of previous crop is the same as the yield level presently chosen by the user.

Tillage Practice

The effect of tillage method (either conventional or conservation) practiced by the farmer before the recommendation will also be analyzed. In this study Conservation tillage is defined as no-till performed or minimum tillage using chisel with at least 30% of previous crop residue incorporated in the soil. As before, all inputs will be the same; only the tillage method will be changed.

IV. RESULTS AND DISCUSSION

The Result and Analysis section consists of the EXSYSP results, SCS recommendations, and their analysis. Comparisons were made between the two to verify the validity of the expert system rule base.

A. SCS and ES Recommendation

Information provided by SCS[4] were: Location, Practice Number, Recommendation, and Soil loss (TABLE 10). The exact locations of the study cells were determined by a topographic map. Included were the tract number, field number, township and section. The practice number is a code which SCS uses to keep track of their different practices. The recommendations were either a crop rotation, physical field practice, or both. The soil loss included the Allowable, Before, and After. The recommendations of SCS[5] were based on the allowable/tolerable soil loss. Off-site water quality effects were also considered. A field might already be at a soil loss below T, but if it was still causing water quality problems (a sediment was able to move directly into a surface drain or

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[4] SCS information provided by Ruth Schaffer.

[5] This information was based from personal letter from Ruth Schaffer dated April 12, 1995.

stream through a gully or ruptured tile), on-site treatment(s) were recommended. All the study cells except cells 489 and 320 (field1), were below T but individual field recommendations were made nonetheless to meet the water quality goal in the Sycamore watershed. USLE was used to estimate the average annual soil loss; results were rounded to the nearest whole number, with 1 as the smallest possible value. The most frequent recommendation called for change in crop rotation which affected the C-factor. Cell 320 had the highest erosion at 14 tons/acre/year; it was reduced to 3 tons/acre following the recommended rotation of Corn/drilled Soybean/Wheat seeded to Red Clover with minimum tillage. The SCS recommendations have reduced erosion to 1 ton/acre on all areas except cells 320 and 547 (field1).

By comparison, the EXSYP recommendation (Table 11) reduced erosion on all cells, without exception, to less than 1 ton/acre. A change of crop rotation alone brought down the soil loss to less than 1 ton/acre on 10 of the cells (Table 10). Cells 26, 327, 489 and 539 were still eroding at 1.04, 1.32, 1.22 and 129 tons respectively after crop rotation had been applied. But with the added practice of contouring with conservation tillage, soil loss was further reduced to 0.52, 0.66, 0.61 and 0.69 respectively. Although the "BEFORE" soil loss of SCS and EXSYSP were different, they have no effect on the "AFTER" soil loss computations of the two.

B. Statistical Analysis

TABLE 8. Soil Loss Measurements/Ranks for SCS and ES

	Soil Loss (tons/acre)		Ranking	
Cell#	SCS(P_1)	ES(P_2)	SCS	ES
26	1	1	1 (17)	1 (17)
26	1	1	1 (17)	1 (17)
166	1	1	1 (17)	1 (17)
173	1	1	1 (17)	1 (17)
173	1	1	1 (17)	1 (17)
186	1	1	1 (17)	1 (17)
186	1	1	1 (17)	1 (17)
272	1	1	1 (17)	1 (17)
320	3	1	3 (36)	1 (17)
320	2	1	2 (34.5)	1 (17)
327	1	1	1 (17)	1 (17)
340	1	1	1 (17)	1 (17)
467	1	1	1 (17)	1 (17)
489	1	1	1 (17)	1 (17)
489	1	1	1 (17)	1 (17)
539	1	1	1 (17)	1 (17)
547	1	1	1 (17)	1 (17)
547	2	1	2 (34.5)	1 (17)

T = 360

X_1= 22/18 = 1.22 X_2= 18/18 = 1

TABLE 9. Grouping of Measurements With Tied Ranks

Rank	Group	t_j	$t_j(t_j^2-1)$
17	1	33	35,904
34.5	2	2	6
36	3	1	0
	TOTAL:		35,910

Given:

n_1	= 18
n_2	= 18
$t_j(t_j^2-1)$	= 35,904 and 6
T	= 360
$Z_{a/2}$	= .05/2 for 95% conf, Appendix A-3 (Lyman Ott, 1988)
	= 1.96

Solution:

From equation (27) $U_t = 333$

From equation (28) $O_t = 15.149$

From equation (29) $Z = 1.78$

Rejection level: $|Z| > Z_{a/2}$
But: $1.78 < 1.96$
Therefore: Accept hypothesis $P_1 = P_2$

The result showed that there was no statistical difference in the resulting soil loss when using either SCS recommendation or the EXSYSP rule-base. The hypothesis that sample 1 is equal to sample 2 was accepted. EXSYSP recommendations have resulted in an average soil loss of 1 ton/acre, which is better than the 1.25 tons/acre average by SCS.

C. Sensitivity Analysis

By Cell

EXSYSP output by cell is presented in Table 12. It shows the input data, the recommendation(s), the output and the economic analysis. For example Cell 26 was originally eroding at 5.77 tons (TAA) based on C=0.5 and P=1. Crop rotation was Corn/Corn/Soybean/Wheat, with a high yield range production level.

The rotation chosen had a C-value of 0.091617, thereby reducing soil loss to 1.04 tons/acre. This system brought the farmer an income of $69.02/acre, and $24.84/acre to society. However, the program was designed to reduce the erosion to equal or less than 1 ton, therefore EXSYSP recommended an additional practice of "Contouring" and "conservation tillage". This practice had a P=0.5 which when applied will further reduce the soil loss to 0.52 tons. In this new system the farmer got $75.28/acre while society benefitted $27.57/acre. An extra $6.26 and $2.73/acre was earned by the farmer and society respectively just by doing the recommended practice.

FIGURE 14 was developed from TABLE 12. The cells were arranged according to the amount of soil saved starting with the highest to lowest. Cell 489 was originally eroding at 6.62 tons (TAA). EXSYSP reduced soil loss to 0.61 tons (TN), which equates to 6.01 tons (TAA-TN) of soil prevented from leaving the field. 3.18 tons of soil erosion was prevented from leaving cell 186. Cell 186 had the smallest amount of soil saved among all the cells. TAA represents "BEFORE" soil loss and TN for "AFTER" soil loss, therefore the distance between "TAA" and "TAA-TN" in FIGURE 14 is TN, the soil erosion taking place in the cell after the recommendation. The shorter the distance, the lower is the erosion, as shown by cells 489 and 26 (0.61, 0.52 ton erosion after recommendation) compared to cells 243, 320 and 186 (0.94, 0.99, 0.95). As "TAA-TN" decreases, so does society's benefit (SB). On the other hand, farmer's income (FI) stayed the same because crop rotation and yield were the same. Cells with practice recommended (Cells 489, 26, 539, 327) have a higher FI than cells with rotation only. This is because crops raised using conservation tillage have higher net income than crops in conventional systems.

FIGURE 15 shows that cells with a recommended practice (aside from just crop rotation) have the highest percentage of soil saved as shown by cells 489, 26, 539, and 327.

By Crop Rotation

TABLE 13 indicates that rotation 8 (Continuous Alfalfa for 6 years) has the lowest C-value at 0.0296 while rotation 6 (Corn/Soybean) has the highest at 0.13985. Rotation 8 was best in reducing soil loss, and increasing SB and FI. Rotation 3 produced the lowest FI and had one of the lowest SB. While rotation 6 reduced erosion the least and had the lowest SB, its FI was decent. Consequently as CN increased, the percentage of soil saved decreased (FIGURE 16). In general, the lower the C-value, the lower will be the soil loss. The TNN line in the same graph supports this finding. SB went down as soil loss went up although there was no pattern for FI (FIGURE 17). This was because crop production cost varies for each rotation. As each crop has a different annual net income, the rotation with crop(s) producing the highest net income fared best.

TABLE 13 and FIGURE 16 also shows that rotations that had the lowest CN (Rotation 8, 7, 4, 5) had a "no practice necessary" recommendation. On the otherhand, "Contouring" and "Conservation tillage" were recommended to bring down the soil loss to less than 1 ton on rotations 1, 2, 3, and 6.

By Yield Level

TABLE 14 shows that the highest yield level (meaning more ground cover), resulted in the lowest CN. An exception was yield 1. This was because in yield 1, the contribution of Wheat , 6000 Lbs. spring residue was not included in the computation of CN. Because of this the resulting final CN for this level on this crop was higher. If a corresponding value was available, CN for yield 1 would have been the lowest among the 5.

Once again FIGURE 18 proved that as CN increased, so did the soil loss. As the yield level increases, so will the ground cover. More ground cover means less erosion. Yield 2 which had a C-value of 0.090714 eroded at 1.04 tons, and 0.52 tons when practice was added. Yield 5 with C=0.118866 eroded at 1.39 tons, 0.69 tons with practice. FIGURE 19 showed that FI and SB went down with increased soil loss. Yield 1 and 2 had basically the same SB. Yield 4 and 5 ("medium low" and "low") were both at $-0.64, which means that the farmer lost $0.64/acre when he raised his crops at this yield level. As the yield level increases, production expenses are expected to increase, but so does the income. This is true in normal conditions where net income is positive in the base year, but if net income of the crop is negative, the contribution of crop production to the total cost will also be a negative value. The higher the net income, the higher will be the farmer's income. However, its effect on societal benefit is indirect.

By Tillage Method

TABLE 15 presents the EXSYSP output by tillage method. The results were tabulated just like the EXSYSP output by rotation, except each rotation was differentiated by tillage: conventional and conservation. There were no differences in EXSYSP recommendation, TN, TNN or SB on both tillage method. FIGURE 20 and 21 explained the table further. As shown earlier there was no pattern between FI and crop rotation since net income varied with each crop. However, there was a difference on FI on the same crop depending on the tillage method applied. For example in Rotation 1, FI for conventional tillage ("rotation" only) was $69.02 as compared to $79.69 when changed to conservation tillage. FIGURE 21 shows that the highest FI came from the farmer already doing conservation tillage and backed it up with crop rotation only (Cons(R)), followed by farmer doing either tillage method with the recommended rotation and practice (Conv/Cons(R/P)) at the same time. The farmer who did conventional tillage and used "rotation" alone (Conv(R)) earned the least. FI for both conventional and conservation doing "rotation with practice" (Conv/Cons(R/P)) were the same. It was less though than Cons(R). The difference was the cost of the recommended practice. Example, Rotation 6 had Conv/Cons(R/P)=$107.85, and Cons(R)=112.26. $4.41 which was the difference between the two values was the cost per acre of "contouring".

Miscellaneous Results

Table 16 shows the effect of slope on soil erosion. When slope was reduced to 0.2% on cell #26, soil loss was only 0.95 tons/acre. Because the field was eroding below the acceptable range, EXSYSP recommended that "no change on the farming system" was needed. When slope was changed to 26%, the program recommended that the field be "seeded to perennial grass" (TABLE 16, col 3). At this slope erosion was at a high rate of 83 tons/acre. When a rotation of C/C/Sb/W was applied sedimentation was reduced to 14.9 tons. When EXSYSP recommendation was applied, the resulting erosion was only 2.66 tons. Although crop rotation gave a few cents more to the farmer than "seeding to perennial grass" ($69.02 versus $68.65) per acre, the return to society showed otherwise. SB for the rotation was $357.63/acre as compared to $421.93 when EXSYSP recommendation was followed.

Columns 4 to 12 is a comparison of the best crop rotation (col 4-6) to the middle (col 7-9) and the worst (col 10-12). The slope was changed to 10, 14.5 and 18.9% for each rotation. A slope of 10%, 14.5% and 18.9% resulted to 17.2, 30.7, and 47.7 tons of erosion respectively. EXSYSP had recommended "contouring with terracing" plus "conservation tillage" in all cases. TNN and TN were lowest on the best cases scenarios, meaning lower slopes and better crop rotation. For example, soil loss after recommendation on a 10% slope (col 10) was only 0.54 ton. On exactly the same condition except slope was increased to 18.9% (col 12), soil loss was still 1.99 after the recommendation. Continuous Alfalfa for 6 years also had a lower soil loss which was only 1.03 tons (col 4) as compared to C/C/C/Sb/W (col 10) which was still eroding at 4.47 tons. FIGURE 22 supports this claim.

Soil loss resulting from rotation backed by EXSYSP recommendation were also a lot lower than soil from "rotation" alone as seen from TABLE 16 (TNN versus TN). In col 12, crop rotation had a soil loss of 12.4 tons and only 1.99 tons if "contouring with terracing" was added with the rotation. Again, this was shown in FIGURE 22.

The recommended maximum horizontal length (TLENGHT) were shorter on steeper slopes. TLENGHT for 10% (col 7) was 716 ft compared to 52 ft for 18.9% (col 9). Results also showed that better cropping rotations increases TLENGHT as shown in col 4 versus col 10. Continuous Alfalfa for 6 years had a TLENGHT = 6859.36 ft, while C/C/C/Sb/W had a TLENGHT = 338.86 ft. As TLENGHT increases the cost of practice decreases, see FIGURE 23. For example, $4.80/acre for continuous Alfalfa and $12.28/acre for C/C/C/Sb/W. As for economic return to farmer and society when "Contouring with Terracing" was recommended, TABLE 16 showed that FI was higher with "rotation" only (FIGURE 24). However, SB was always greater when practice was added with crop rotation (FIGURE 25).

At some point the user starts wondering whether "contouring" alone would suffice when "contouring with terracing" is recommended. Table 17 showed the effect of "contouring with terracing" versus "contouring" alone. The actual EXSYSP recommendation for slopes 10%, 14.5%, and 18.9% was "contouring w/ terracing". However, when "contouring" alone was applied, TN increased in all cases. FI was lower at 10% slope then gradually increased at 14.5% up when terracing was omitted. This is because the cost of terracing was pulling the farmer's net income down. When terracing was omitted, SB went down in all cases. Since "terracing" decreased soil loss, SB therefore went up.

An extreme case of financial loss to farmer when recommended practice was applied is shown in TABLE 16, Col 12. The field was originally eroding at 47.7 tons. With improved rotation of C/C/C/Sb/W, erosion was reduced to 12.4 tons. This system gave the farmer a net income of $62.89/acre while society benefited $185.38/acre. Since the field was still eroding above the acceptable limit, EXSYSP recommended an additional practice of "contouring with terracing". However, this practice is expensive. It resulted to a negative net income for the farmer ($-38.65/acre) but an increased benefit to society ($240.05/acre). When recommendation was changed from "contouring with terracing" to "contouring" only, the financial results were much better. The comparison is shown in TABLE 18. Computations for Column 3, TABLE 18 are as follows:

A. From Equation 1:
TN = R K L S C P where: P = 0.16 (contouring with terracing)
= 12.4 * 0.16
= 1.98 tons (TN for column 2)

B. From Equation 1:
TN = R K L S C P where: P = 0.8 (contouring)
= 12.4 * 0.8
= 9.92 tons (TN for column 3)

C. From Equation 23:
CONSPRACCPI = CONSPRAC * CPI
= 3.27 * 1.35
= $4.41/acre

D. From Equation 9:
CPCR33 = ((VCOR*3) + VSOY + VWHE)/5
= ((21.91*3) + 125.78 +41.40)/5
= 232.91/5
= 46.58

From Equation 25:
NOSYSCOST = CPCR33 * CPI
= 46.58 * 1.35
= $62.98/acre

E. From Equation 8:

CPCR33 = ((SCOR*3) + SSOY + SWHE)/5
= ((29.87*3) + 136.45 + 46.43)/5
= 272.49/5
= 54.50

From Equation 25:

YESYSCOST = CPCR33 * CPI
= 54.50 *1.35
= $73.57/acre

F. From Equation 27:

SYSCOST = (TAA - TNN) * 3.89 * CPI
= (47.7 - 12.4) * 3.89 * 1.35
= $185.38/acre

G. From Equation 28:

SSYSCOST = (TAA - TN) * 3.89 * CPI
= (47.7 - 9.92) * 3.89 * 1.35
= $198.40/acre

With "contouring" only as practice, farmer's net income rose from $-38.65 to $73.57 per acre. Society's benefit went down from $240.05 to $198.40 per acre. However, the field was still eroding at 9.92 tons. A solution to this problem is to settle for a middle ground. Originally this field was defined as having a T-value of 1 ton/acre. Because of this, the recommended TLENGHT was so short, thereby making the cost of terracing very expensive. When the user settled for 5 tons as the acceptable soil loss limit (TABLE 18, col 4), TLENGHT went up from 24.73 ft. to 618.28 ft. As a result the cost of terracing went down from $112.22/acre to $8.73/acre. Farmer income improved tremendously from $-38.65 to $64.85. Society's benefit was maintained. Just by reducing the acceptable level of erosion, both farmer and society benefited.

TABLE 10. Soil Conservation Service (SCS) Recommendation

CELL#	LOCATION	PRACTICE NUMBER	RECOMMENDATION	ALLOW (ton/ac)	BEFORE (ton/ac)	AFTER (ton/ac)
#26	Tract 2426 Fields 1,2,3A Vevay Twp, Section 6	#328	For Field#1: Rotation of C/C/S/W seeded to red clover	5	2	1
		#329	Fields2, 3A: Rotation of C/C/S/Small grain/A(4)	5	2	1
		#329	Tillage: spring chiseling or disking except following Alfalfa (conservation tillage)			
		#340	Cover and green manure crop frost seeded into wheat			
		#342	Field#1: Critical area treatment			
		#633	Manure was applied to all fields at agronomic rate. Waste mgt plan was developed.			
#166	Tract 1689, Field 1 Vevay Twp, Section 16. Part of cell is owned by Mason-Jewett Airport	#328	C(1-2)/S(1-2)/wheat seeded to clover	5	2	1
		#590	Nitrogen fert use dropped from 121 to 115 #/ac in 1991.			
#173	Tract 1919, Fields1,2 Aurelius Twp, Section 13	#328	Rotation of C/S/W seeded to red cloverfor both fields.	(1) - 5 (2) - 5	5 3	1 1
		#329	No-till on both fields			
#186	Tract 1608, Fields1, 2 Vevay Twp, Section 16	#328	Rotation of C/S/W seeded to red clover	(1) - 5 (2) - 5	4 4	1 1
		#329	No-till tillage			
#243	Tract 1362 Fields 1,2 Vevay Twp, Section 20		Owners of fields are not cooperators (no conservation plan). "Gentlemen Landowners" Likely under pasture or not cropped.			
#272	Vevay Twp, Section 22	#328	Rotation of C/C/S/SG	5	3	1
		#329	No-till system			
#320	Tract 2490, Fields 1,2 Aurelius Twp, Section 25	#328	Field#1: Rotation is C/S(drilled)/W or Canola seeded to red clover.	(1) - 5 (2) - 5	14 4	3 2
			Field#2: C/C/S(drilled)/W seeded to red clover			
		#329	Field#1: Chisel for corn, no-till for Soybean and Wheat			
			Field#2: All chisel-plowed, 30% residue minimum			

TABLE10 (cont'd).

CELL#	LOCATION	PRACTICE NUMBER	RECOMMENDATION	ALLOW (ton/ac)	BEFORE (ton/ac)	AFTER (ton/ac)
#327	Tract 1399 Field 1 Vevay Twp, Section 30	#328	Rotation is S/C or W	5	4	1
		#329	No-till system			
#340	Tract 1498 Fields 2a,2,3	#328	Rotation is C/C/S/S/SG	5	2	1
		#329	Use Conservation tillage - Chisel plow with 30% crop residue use.			
			Pest and nutrient management			
#440	Tract 1374 Fields 1-7 Vevay Twp, Section 32	#328	Rotation is C/C/S(drilled)/W			
		#329	No-till system			
			Plans were applied in 1990-93, the new owner is not a cooperator			
#467	Tract 1492 Field 1, Vevay Twp Section 35	#328	Rotation is A(5)/C(1-2)/ S91-2)/A	5	1	1
#489	Tract 2474 Fields 7b, 7c Leslie Twp, section 5	#328	C/C/S(drilled)/W	(7b) - 5 (7c) - 5	6 6	1 1
		#329	Conservation tillage: could be no-till or chisel plow.			
#539	Tract 1429 Field 7, Leslie Twp, Section5	#328	Rotation is S(2, drilled)/W	5	3	1
		#329	Use no-till method			
#547	Tract 2729 Fields 1,2 Leslie Twp Section	#328	Rotation is C/S/W seeded to red clover. Two years of corn may be grown on some portion to maintain corn base.	(1) - 5 (2) - 5	4 4	1 2
		#329	No-till planned for all crops			

TABLE11. Comparison of SCS and EXSYSP Recommendations

Cell#	RECOMMENDATION		SOIL LOSS (Tons/Acre/Year)				
	SCS	ES		SCS		ES	
			ALLOWABLE	BEFORE	AFTER	BEFORE	AFTER
#26	Rotation (Field#1): C/C/Sb/W seeded to Red Clover	Rotation: C/C/Sb/W seeded to Red Clover.	5	2	1	5.77	0.52
	Rotation (Field# 2, 3A): C/C/Sb/Small grain/A(4)	Practice: 1. Conservation tillage 2. Contouring	5	2	1	5.77	0.52
	Tillage: spring chiseling or disking except following Alfalfa (conservation tillage)						
	Cover and green manure crop frost seeded into wheat						
	Field#1: Critical area treatment						
	Manure was applied to all fields at agronomic rate. Waste mgt plan was developed.						
#166	Rotation: C(1-2)/Sb(1-2)/W seeded to Clover.	Rotation: C/C/Sb/W seeded to Red Clover	5	2	1	4.13	0.81
	Nitrogen fert use dropped from 121 to 115 #/ac in 1991.	Practice: No practice necessary					
#173	Rotation: C/Sb/W seeded to Red Clover.	Rotation: C/C/Sb/W seeded to Red Clover	1 - 5	5	1	4.17	0.66
			2 - 5	3	1	4.17	0.66
	No-till on both fields	Practice: No practice necessary					
#186	Rotation: C/Sb/W seeded to Red Clover	Rotation: C/C/Sb/W seeded to Red Clover	1 - 5	4	1	4.13	0.95
			2 - 5	4	1	4.13	0.95
	No-till tillage	Practice: No practice necessary					
#243	Owners of fields are not cooperators (no conservation plan). "Gentlemen Landowners" Likely under pasture or not cropped.	Rotation: C/C/Sb/W seeded to Red Clover Practice: No practice necessary				5.31	0.94
#272	Rotation: C/C/Sb/S(g)	Rotation: C/C/Sb/W seeded to Red Clover	5	3	1	4.29	0.77
	No-till system	Practice: No practice necessary					

TABLE11 (cont'd).

Cell#	RECOMMENDATION SCS	RECOMMENDATION ES	SOIL LOSS (Tons/Acre/Year) ALLOWABLE	SCS BEFORE	SCS AFTER	ES BEFORE	ES AFTER
#320	Rotation (Field#1): C/Sb(drilled) /W or Canola seeded to Red Clover. Rotation (Field#2): C/C/Sb(drilled) /W seeded to Red Clover Field#1: Chisel for corn, no-till for Corn and Wheat Field#2: All chisel-plowed, 30% residue minimum	Rotation: C/C/Sb/W seeded to Red Clover Practice: No practice necessary	1 - 5 2 - 5	14 4	3 2	4.72 4.72	0.99 0.99
#327	Rotation: Sb/C or W No-till system	Rotation: C/C/Sb/W seeded to Red Clover Practice: 1. Conservation tillage 2. Contouring	5	4	1	4.98	0.66
#340	Rotation: C/C/Sb/Sb/S(g) Conservation tillage - Chisel Pest and nutrient management	Rotation: C/C/Sb/W seeded to Red Clover Practice: No practice necessary	5	2	1	5.48	0.86
#440	Rotation: C/C/Sb(drilled)/W No-till system Plans were applied in 1990-93, new owner not a cooperator	Rotation: C/C/Sb/W seeded to Red Clover Practice: No practice necessary				4.91	0.78
#467	Rotation: A(5)/C(1-2)/Sb(1-2)/A	Rotation: C/C/Sb/W seeded to Red Clover Practice: No practice necessary	5	1	1	4.37	0.71
#489	Rotation: C/C/Sb(drilled)/W Conservation tillage: could be no-till or chisel plow.	Rotation: C/C/Sb/W seeded to Red Clover Practice: 1. Conservation tillage 2. Contouring	7b- 5 7c- 5	6 6	1 1	6.62 6.62	0.61 0.61
#539	Rotation: Sb(2, drilled)/W No-till method	Rotation: C/C/Sb/W seeded to Red Clover Practice: 1. Conservation tillage 2. Contouring	5	3	1	5.09	0.69
#547	Rotation: C/Sb/W seeded to Red Clover. Two years of corn may be grown on some portion to maintain corn base. No-till for all crops	Rotation: C/C/Sb/W seeded to Red Clover Practice: No practice necessary	1 - 5 2 - 5	4 4	1 2	4.61 4.61	0.9 0.9

TABLE 12. Tabulated EXSYSP Output (By Cell)

CELL NUMBER	#26	#166	#173	#186	#243	#272	#320	#327	#340	#440	#467	#489	#539	#547
INITIAL DATA														
User Input														
Desired Rotation	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W	C/C/Sb/W
Yield Range	high	high	high	high	high	high	high	high	high	high	high	high	high	high
Study Year	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995
Soil Type	CaA	AnA	CaA	AnA	MaB	Sb	MaB	MaB	MrA	Co	Gf	CaA	Co	CaA
External Programs														
Slope(S)	4.7	6	3.2	6.8	4.3	3.6	4.5	6.3	4.3	3.5	4.9	4.5	5	3.9
K-value(K)	0.26	0.17	0.27	0.17	0.26	0.28	0.26	0.26	0.24	0.29	0.17	0.32	0.3	0.3
Soil Texture(ST)	2	1	1	1	2	2	1	2	2	2	1	2	2	2
C-value(C)	0.5	0.46	0.57	0.39	0.51	0.5	0.43	0.34	0.57	0.57	0.55	0.49	0.33	0.46
P-value(P)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Soil loss (TAA)	5.77	4.13	4.17	4.13	5.31	4.29	4.72	4.98	5.48	4.91	4.37	6.62	5.09	4.61
OUTPUT														
New C-Val(CN)	0.091617	0.091617	0.091617	0.091617	0.091617	0.091617	0.091617	0.091617	0.091617	0.091617	0.091617	0.091617	0.091617	0.091617
New P-val(PN)	0.5	-	-	-	-	-	-	0.5	-	-	-	0.5	0.5	-
New soil loss														
Rotation (TNN)	1.04	0.81	0.66	0.95	0.94	0.77	0.99	1.32	0.86	0.78	0.71	1.22	1.39	0.9
Rot.and Prac.(TN)	0.52	-	-	-	-	-	-	0.66	-	-	-	0.61	0.69	-
RECOMMENDATION	Contouring Conserve tillage	No prac. necessary	No prac. necessary	No prac. necessary	No prac. necessary	No prac. necessary	No prac. necessary	Contouring Conserve tillage	No prac. necessary	No prac. necessary	No prac. necessary	Contouring Conserve tillage	Contouring Conserve tillage	No prac. necessary
ECONOMIC ANALYSIS ($/Acre/Year)														
Offsite Benefit	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89
Cost of Practice	4.41	-	-	-	-	-	-	4.41	-	-	-	4.41	4.41	-
Farmer's Income														
Rotation	69.02	69.02	69.02	69.02	69.02	69.02	69.02	69.02	69.02	69.02	69.02	69.02	69.02	69.02
Rot. and Prac.	75.28	-	-	-	-	-	-	75.28	-	-	-	75.28	75.28	-
Society's Benefit														
Rotation	24.84	17.43	18.43	16.7	22.95	18.49	19.59	19.22	24.26	21.69	19.22	28.36	19.43	19.48
Rot. and Prac.	27.57	-	-	-	-	-	-	22.69	-	-	-	31.56	23.11	-

Legend:
- AnA - Aubbeenaubbee Capac Sandy Loam (0-3% slope)
- CaA - Capac Loam (0-3% slope)
- Co - Colwood Brookston Loam
- Gf - Gilford Sandy Loam
- MaB - Marlette Fine Sandy Loam (2-6% slope)
- MrA - Matherton Sandy Loam (0-3% slope)
- Sb - Sebewa Loam

Note:
The soil type dictates the allowable soil loss, but for the purpose of comparing the EXSYSP's results to SCS, the allowable soil loss for all cells will be set at 1 ton/acre/year.

TABLE13. Tabulated EXSYSP Output (By Rotation)

ROTATION#	1	2	3	4	5	6	7	8
INITIAL DATA								
User Input								
Cell#	26	26	26	26	26	26	26	26
Yield Range	high	high	high	high	high	high	high	high
Study Year	1995	1995	1995	1995	1995	1995	1995	1995
Soil Type	Au	Au	Au	Au	Au	Au	Au	Au
External Programs								
Slope(S)	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
K-value(K)	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Soil Texture(ST)	2	2	2	2	2	2	2	2
C-value(C)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
P-value(P)	1	1	1	1	1	1	1	1
Soil loss(TA)	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77
OUTPUT								
New C-Val(CN)	0.091617	0.12485	0.133175	0.066067	0.079229	0.13985	0.044929	0.0296
New P-val(PN)	0.5	0.5	0.5	-	-	0.5	-	-
New soil loss								
Rotation(TNN)	1.04	1.39	1.5	0.81	0.92	1.62	0.46	0.35
Rot.and Prac.(TN)	0.52	0.69	0.75	-	-	0.81	-	-
RECOMMENDATION								
	Contouring Conserve tillage	Contouring Conserve tillage	Contouring Conserve tillage	No prac. necessary	No prac. necessary	Contouring Conserve tillage	No prac. necessary	No prac. necessary
ECONOMIC ANALYSIS ($/Acre/Year)								
Offsite benefit	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89
Cost of prac.	4.41	4.41	4.41	-	-	4.41	-	-
Farmer's income								
Rotation only	69.02	85.09	62.89	174.17	135.77	99.69	192.79	242.81
Rot. and Prac.	75.28	91.32	69.16	-	-	107.85	-	-
Society's benefit								
Rotation only	24.84	23	22.42	26.05	25.47	21.79	27.89	28.46
Rot. and Prac.	27.57	26.68	26.36	-	-	26.05	-	-

Legend:
- Rotation1 - C/C/Sb/W seeded to red clover
- Rotation2 - C/Sb/W
- Rotation3 - C/C/C/Sb/W
- Rotation4 - C/C/Sb/W/A(6)
- Rotation5 - C/C/Sb/W/A(4)
- Rotation6 - C/Sb
- Rotation7 - C/W/A(6)
- Rotation8 - Continuous Alfalfa for 6 years

TABLE14. Tabulated EXSYSP Output (By Yield Level)

YIELD LEVEL	1	2	3	4	5
INITIAL DATA					
User Input					
Cell#	26	26	26	26	26
Rotation#	1	1	1	1	1
Study Year	1995	1995	1995	1995	1995
Soil Type	Au	Au	Au	Au	Au
External Programs					
Slope(S)	4.7	4.7	4.7	4.7	4.7
K-value(K)	0.26	0.26	0.26	0.26	0.26
Soil Texture(ST)	2	2	2	2	2
C-value(C)	0.5	0.5	0.5	0.5	0.5
P-value(P)	1	1	1	1	1
Soil loss(TAA)	5.77	5.77	5.77	5.77	5.77
OUTPUT					
New C-Val(CN)	0.091617	0.090714	0.102764	0.109431	0.118866
New P-val(PN)	0.5	0.5	0.5	0.5	0.5
New soil loss					
Rotation(TNN)	1.04	1.04	1.15	1.27	1.39
Rot.and Prac(TN)	0.52	0.52	0.58	0.64	0.69
RECOMMENDATION					
	Contouring Conserve tillage	Contouring Conserve tillage	Contouring Conserve tillage	Contouring Conserve tillage	Contouring Conserve tillage
COSTS($/acre/year)					
Offsite benefit	3.89	3.89	3.89	3.89	3.89
Cost of practice	4.41	4.41	4.41	4.41	4.41
Farmer's income					
Rotation only	69.02	54.99	18.03	-0.64	-0.64
Rot. and Prac.	75.28	61.24	24.23	5.55	5.55
Society's benefit					
Rotation only	24.84	24.84	24.26	23.63	23
Rot. and Prac.	27.57	27.57	27.26	26.94	26.68

Legend:

Yield level1 - High (>=126 bushels)
Yiled level2 - Medium high (100-125 bushels)
Yield level3 - Average (75-99 bushels)
Yield level4 - Medium low (60-74 bushels)
Yield level5 - Low (<=59 bushels)

TABLE 15. Tabulated EXSYSP Output (By Tillage Practice)

TILLAGE METHOD	Conv	Cons	Conv	Cons	Conv	Cons	Conv	Cons	Conv	Cons	Conv	Cons	Conv	Cons	Conv	Cons
ROTATION	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8
INITIAL DATA																
User Input																
Cell#	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Yield Range	high	high	high	high	high	high	high	high	high	high	high	high	high	high	high	high
Study Year	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995
Soil Type	Au	Au	Au	Au	Au	Au	Au	Au	Au	Au	Au	Au	Au	Au	Au	Au
External Programs																
Slope(S)	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
K-value(K)	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Soil Texture(ST)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
C-value(C)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
P-value(P)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Soil loss(TA)	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77	5.77
OUTPUT																
New C-Val(CN)	0.091617	0.091617	0.12485	0.12485	0.133175	0.133175	0.066067	0.066067	0.079229	0.079229	0.13985	0.13985	0.044929	0.044929	0.0296	0.0296
New P-val(PN)	0.5	0.5	0.5	0.5	0.5	0.5	-	-	-	-	0.5	0.5	-	-	-	-
New soil loss																
Rotation(TNN)	1.04	1.04	1.39	1.39	1.5	1.5	0.81	0.81	0.92	0.92	1.62	1.62	0.46	0.46	0.35	0.35
Rot.and Prac.(TN)	0.52	0.52	0.69	0.69	0.75	0.75	-	-	-	-	0.81	0.81	-	-	-	-
RECOMMENDATION	Contouring Conserve tillage	Contouring Conserve tillage	Contouring Conserve tillage	Contouring Conserve tillage	Contouring Conserve tillage	Contouring Conserve tillage	No prac. necessary	No prac. necessary	No prac. necessary	No prac. necessary	Contouring Conserve tillage	Contouring Conserve tillage	No prac. necessary	No prac. necessary	No prac. necessary	No prac. necessary
ECONOMIC ANALYSIS ($/Acre/Year)																
Offsite benefit	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89
Cost of prac.	4.41	4.41	4.41	4.41	4.41	4.41	-	-	-	-	4.41	4.41	-	-	-	-
Farmer's income																
Rotation only	69.02	79.69	85.09	95.74	62.89	73.57	174.17	183.17	135.77	141.98	99.69	112.26	192.79	195.86	242.81	243.97
Rot. and Prac.	75.28	75.28	91.32	91.32	69.16	-	-	-	-	-	107.85	-	-	-	-	-
Society's benefit																
Rotation only	24.84	24.84	23	23	22.42	22.42	26.05	26.05	25.47	25.47	21.79	21.79	27.89	27.89	28.46	28.46
Rot. and Prac.	27.57	27.57	26.68	26.68	26.36	26.36	-	-	-	-	26.05	26.05	-	-	-	-

Legend:
- Rotation1 - C/C/Sb/W seeded to red clover
- Rotation2 - C/Sb/W
- Rotation3 - C/C/C/Sb/W
- Rotation4 - C/C/Sb/W/A(6)
- Rotation5 - C/C/Sb/W/A(4)
- Rotation6 - C/Sb
- Rotation7 - C/W/A(6)
- Rotation8 - Continuous Alfalfa for 6 years
- Conv - Conventional Tillage
- Cons - Conservation Tillage

TABLE16. Tabulated EXSYSP Output (Miscellaneous Results)

COLUMN 1	2	3	4	5	6	7	8	9	10	11	12
CELL NUMBER	#26	#26	#26	#26	#26	#26	#26	#26	#26	#26	#26
INITIAL DATA											
User Input											
Desired Rotation	C/C/SbW	C/C/SbW	A(6)	A(6)	A(6)	C/C/SbW	C/C/SbW	C/C/SbW	C(3)/SbW	C(3)/SbW	C(3)/SbW
Yield Range	high	high	high	high	high	high	high	high	high	high	high
Study Year	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995
Soil Type	Au	Au	Au	Au	Au	Au	Au	Au	Au	Au	Au
External Programs											
Slope(S)	0.2	26	10	14.5	18.9	10	14.5	18.9	10	14.5	18.9
K-value(K)	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Soil Texture(ST)	2	2	2	2	2	2	2	2	2	2	2
C-value(C)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
P-value(P)	1	1	1	1	1	1	1	1	1	1	1
Soil loss (TAA)	0.95	83	17.2	30.7	47.7	17.2	30.7	47.7	17.2	30.7	47.7
OUTPUT											
New C-Val(CN)	-	0.016	0.0296	0.0296	0.0296	0.091617	0.091617	0.091617	0.133175	0.133175	0.133175
New P-val(PN)	-	1	0.12	0.14	0.16	0.12	0.14	0.16	0.12	0.14	0.16
New soil loss											
Rotation (TNN)	-	14.9	1.03	1.85	2.87	3.1	5.54	8.6	4.47	8	12.4
Rot.and Prac.(TN)	-	2.66	0.12	0.26	0.46	0.37	0.78	1.38	0.54	1.12	1.99
RECOMMENDATION	Do not change existing system	Seeding to peren grass	Conserv tillage Contour w/ terr.	Conserv tillage Contour w/ terr.	Conserv tillage Contour w/ terr.	Conserv tillage Contour w/ terr.	Conserv tillage Contour w/ terr.	Conserv tillage Contour w/ terr.	Conserv tillage Contour w/ terr.	Conserv tillage Contour w/ terr.	Conserve tillage Contour w/ terr.
TLENGHT (ft)	-	-	6,859.36	1,576.47	500.62	716 .01	164.56	52.26	338.86	77.88	24.73
Offsite Benefit	-	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89
Cost of Practice	-	0	4.8	6.11	9.74	8.14	20.62	55.44	12.28	38.65	112.22
Farmer's Income											
Rotation	-	69.02	242.81	242.81	242.81	69.02	69.02	69.02	62.89	62.89	62.89
Rot. and Prac.	-	68.65	239.17	237.87	234.23	71.55	59.07	24.25	61.29	34.92	-38.65
Society's Benefit											
Rotation	-	357.63	84.92	151.51	235.42	74.05	132.13	205.33	66.65	119.21	185.38
Rot. and Prac.	-	421.93	89.7	159.86	248.08	88.38	157.12	243.25	87.49	155.34	240.05

Note:

1. When "Seeding to perennial grass (SPG)" is recommended, the income or benefit from "rotation and practice" is actually the income or benefit from SPG.
2. TLENGHT is the recommended maximum horizontal lenght of the terrace.
3. Columns 2 and 3 shows the effect of changing slope on EXSYSP's recommendation.
4. Columns 4 to 12 is a comparison of the Best crop rotation (col 4-6) to the middle (col 7-9) and the worst (col 10-12). To further compare effects on soil loss and finances, the slopes were changed to 10, 14.5 and 18.9% on each scenario.

TABLE17. Tabulated EXSYSP Output (Contouring w/ Terracing Vs. Contouring)

	COLUMN					
1	2	3	4	5	6	7
CELL NUMBER	#26		#26		#26	
INITIAL DATA						
User Input						
Desired Rotation	A(6)		A(6)		A(6)	
Yield Range	high		high		high	
Study Year	1995		1995		1995	
Soil Type	Au		Au		Au	
External Programs						
Slope(S)	10		14.5		18.9	
K-value(K)	0.26		0.26		0.26	
Soil Texture(ST)	2		2		2	
C-value(C)	0.5		0.5		0.5	
P-value(P)	1		1		1	
Soil loss (TAA)	17.2	17.2	30.7	30.7	47.7	47.7
OUTPUT						
New C-Val(CN)	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296
New P-val(PN)	0.12	0.6	0.14	0.7	0.16	0.8
New soil loss						
Rotation (TNN)	1.03	1.03	1.85	1.85	2.87	2.87
Rot.and Prac.(TN)	0.12	0.6	0.26	1.3	0.46	2.3
RECOMMENDATION	Conserv tillage Contour w/ terr.	Conserv tillage Contour	Conserv tillage Contour w/ terr.	Conserve tillage Contour	Conserv tillage Contour w/ terr.	Conserv tillage Contour
TLENGHT (ft)	6,859.36		1,576.47		500.62	
Offsite Benefit	3.89	3.89	3.89	3.89	3.89	3.89
Cost of Practice	4.8	4.41	6.11	4.41	9.74	4.4
Farmer's Income						
Rotation	242.81	242.81	242.81	242.81	242.81	242.81
Rot. and Prac.	239.17	238.02	237.87	242.97	234.23	246.58
Society's Benefit						
Rotation	84.92	84.92	151.51	151.51	235.42	235.42
Rot. and Prac.	89.7	87.17	159.86	154.39	248.08	238.41

Note:
1. Columns 2, 4 and 6 shows the effect on soil loss and finances (FI, SB) when slope was changed on the same cell.
2. Columns 3, 5 and 7 shows the effect on soil loss and finances (FI, SB) when "Contouring" was applied instead of the recommended "Contouring with terracing".

TABLE18. Tabulated EXSYSP Output (Adjusting the Allowable Soil Loss Limit)

	COLUMN		
1	2	3	4
CELL NUMBER	#26	#26	#26
INITIAL DATA			
User Input			
Desired Rotation	C(3)/Sb/W	C(3)/Sb/W	C(3)/Sb/W
Yield Range	high	high	high
Study Year	1995	1995	1995
Soil Type	Au	Au	CaA
External Programs			
Slope(S)	18.9	18.9	18.9
K-value(K)	0.26	0.26	0.26
Soil Texture(ST)	2	2	2
C-value(C)	0.5	0.5	0.5
P-value(P)	1	1	1
Soil loss (TAA)	47.7	47.7	47.7
OUTPUT			
New C-Val(CN)	0.133175	0.133175	0.133175
New P-val(PN)	0.16	0.8	0.16
New soil loss			
Rotation (TNN)	12.4	12.4	12.4
Rot.and Prac.(TN)	1.99	9.92	1.99
RECOMMENDATION			
	Conservation tillage Contouring w/ terracing	Conservation tillage Contouring	Conservation tillage Contouring w/ terracing
TLENGHT (ft)	24.73		618.28
Offsite Benefit	3.89	3.89	3.89
Cost of Practice	112.22	4.41	8.73
Farmer's Income			
Rotation	62.89	62.89	62.89
Rot. and Prac.	-38.65	73.57	64.85
Society's Benefit			
Rotation	185.38	185.38	185.38
Rot. and Prac.	240.05	198.4	240.05

Note:

1. The worst farmer income was selected from Table 16, Col 12. This is shown as Col 2 in this table.
2. Col 3 shows the effect on soil loss and finances (FI, SB) when "Contouring" was applied instead of the recommended "Contouring with terracing".
3. Col 4 shows the effect on soil loss and finances (FI, SB) when the acceptable soil loss was changed from 1 ton to 5 tons.

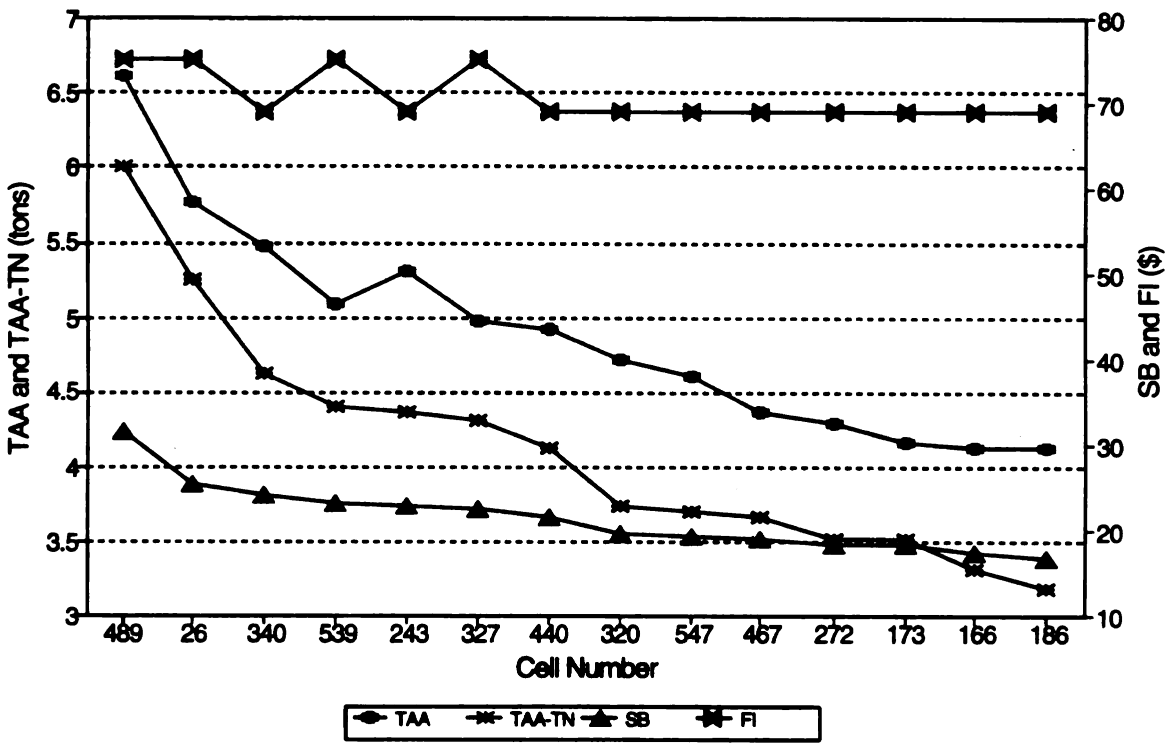

FIGURE 14. Left Y-axis shows the original soil loss (TAA) and the amount of soil loss saved (TAA-TN) by EXSYSP. Right Y-axis is society's benefit (SB) and farmer's income (FI) as a result of EXSYSP recommendations. Cells arranged according to the amount of soil saved, from highest to lowest.

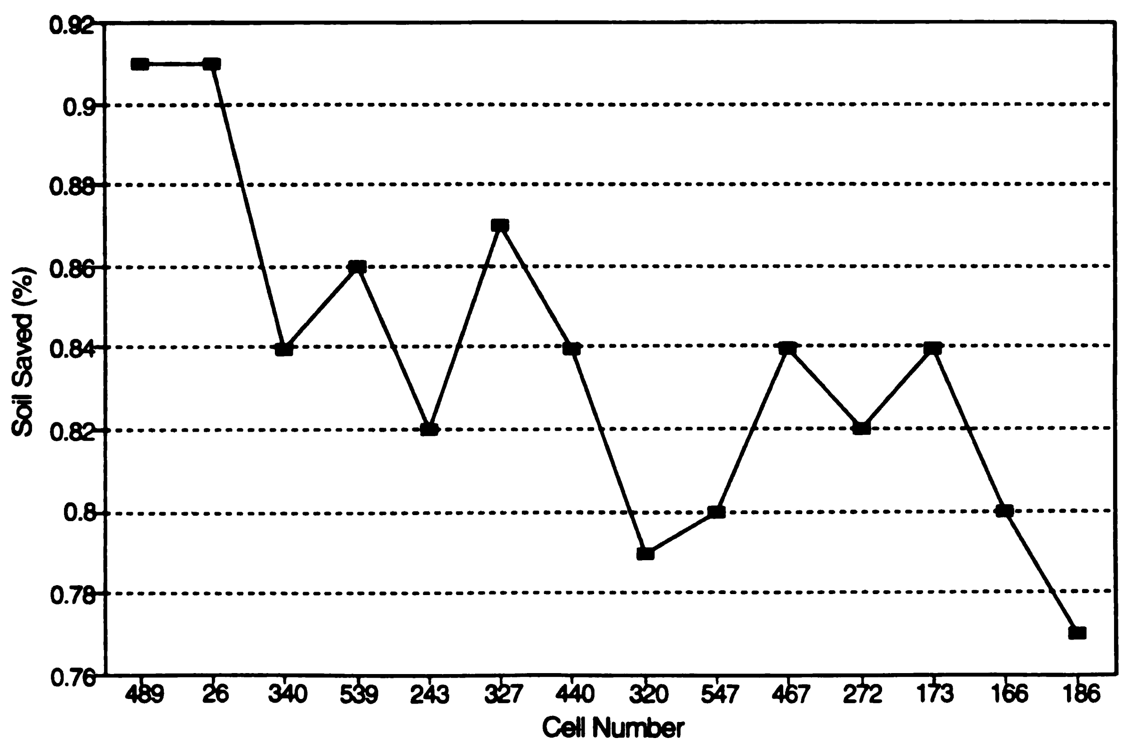

FIGURE 15. Percent of soil saved (%) for each of the study cells.

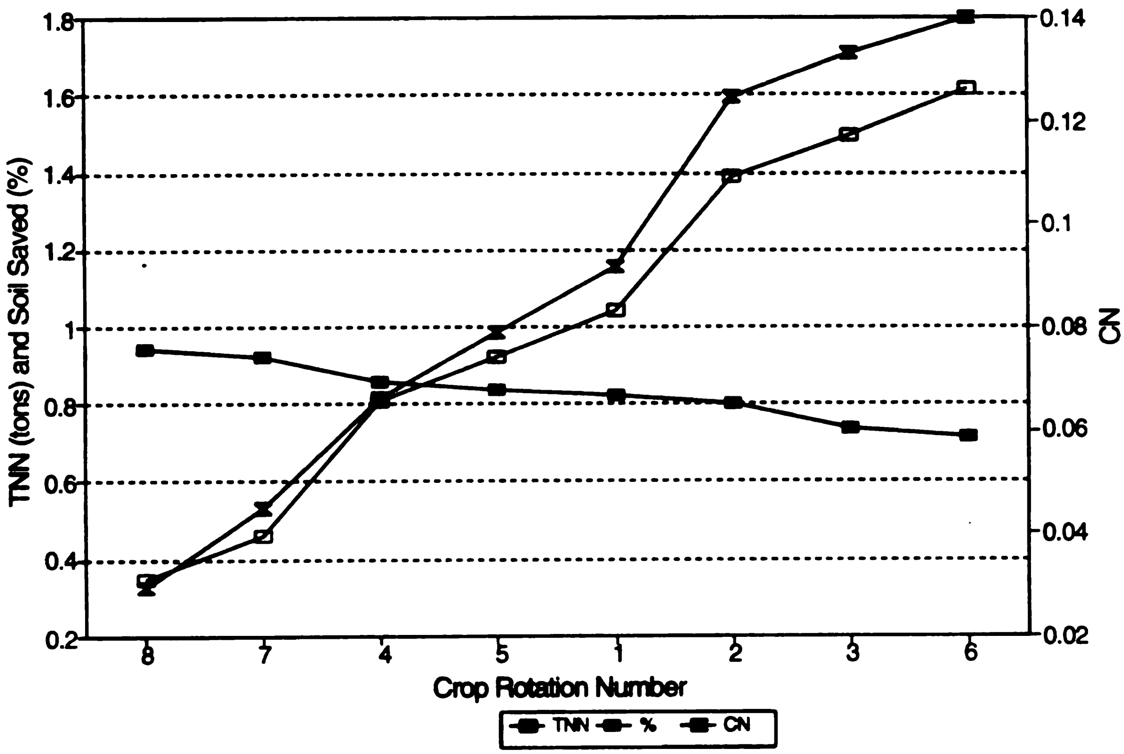

FIGURE 16. Left Y-axis shows resulting soil loss (TNN) and soil saved (%) by using "rotation" only. Right Y-axis shows C-value (CN) for each rotation. Crop rotations arranged according to their corresponding C-value, from lowest to highest.

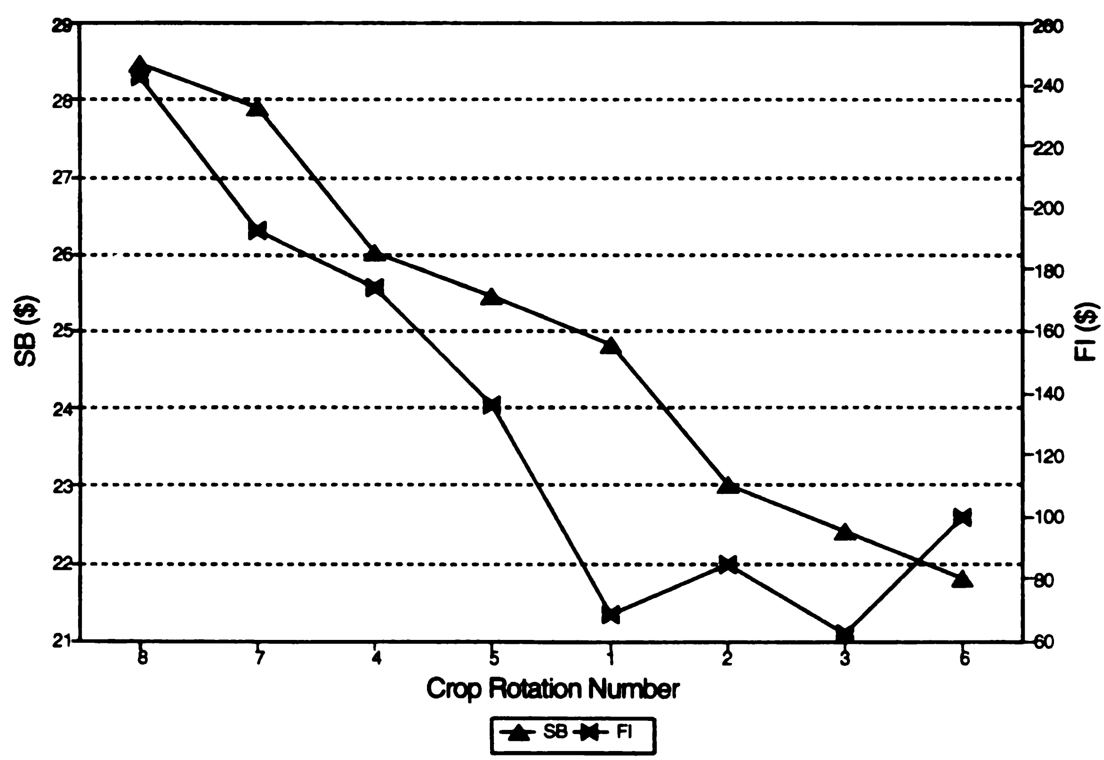

FIGURE 17. Society's benefit (SB) and farmer's income (FI) for each rotation.

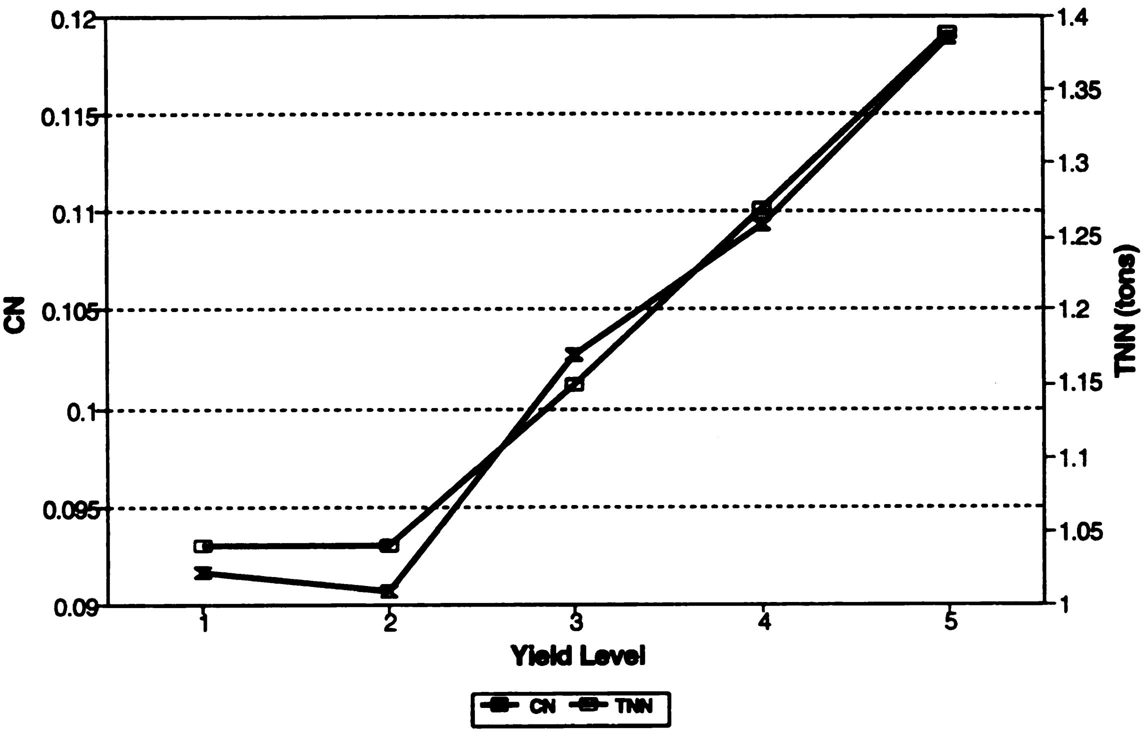

FIGURE 18. C-value (CN) and resulting soil loss (TNN) for each of the five yield levels. Yield levels arranged from highest to lowest.

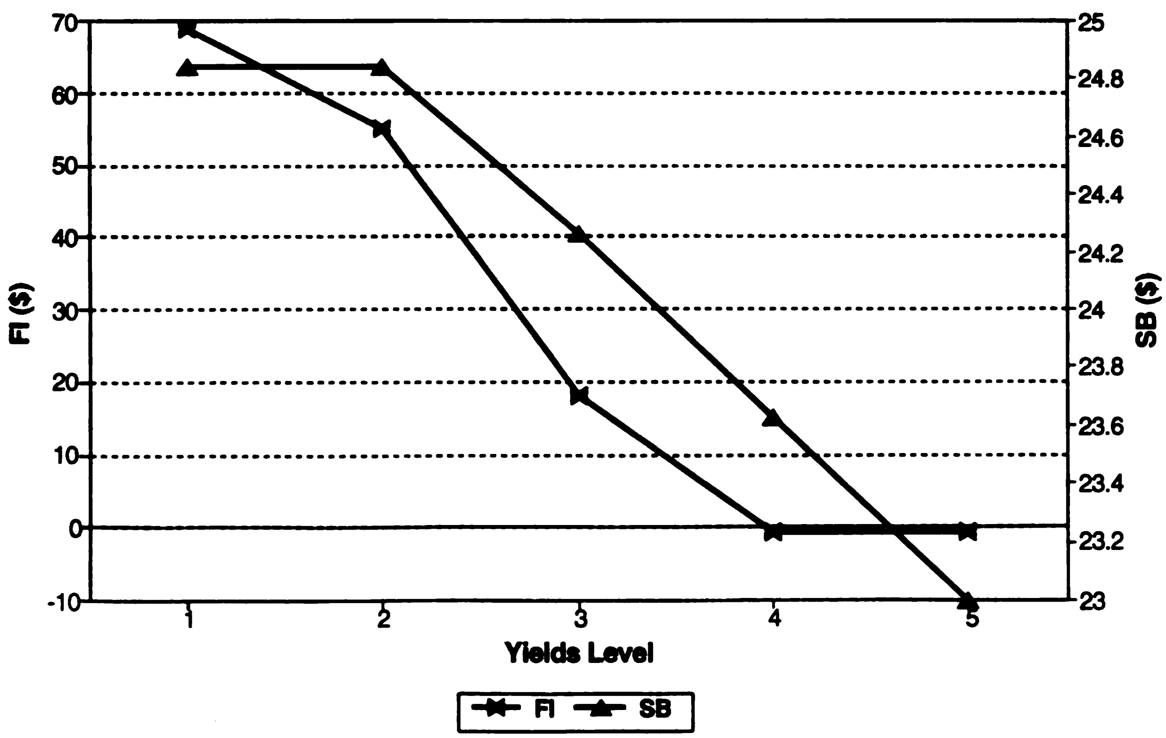

FIGURE 19. Farmer's income (FI) and society's benefit for each yield level.

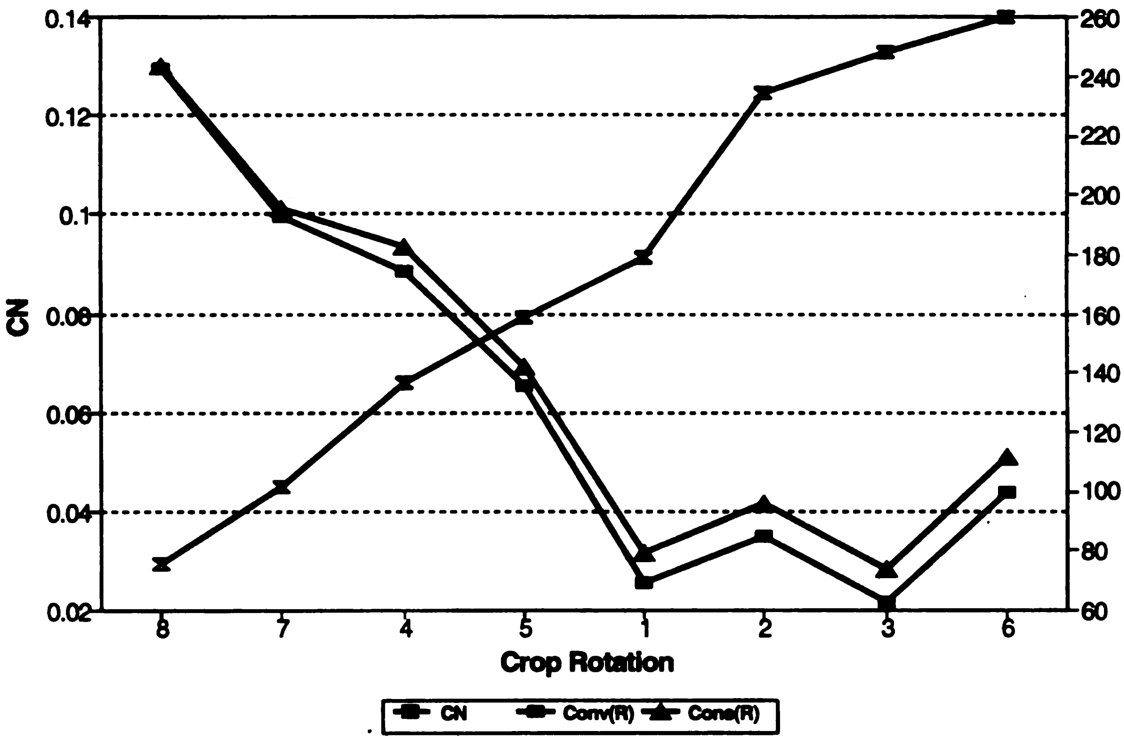

FIGURE 20. Left Y-axis shows the C-value for each rotation. Right Y-axis shows farmer' income if original tillage practice was conventional (ConvR) and farmer's income if original tillage was conservation (ConsR) for each rotation.

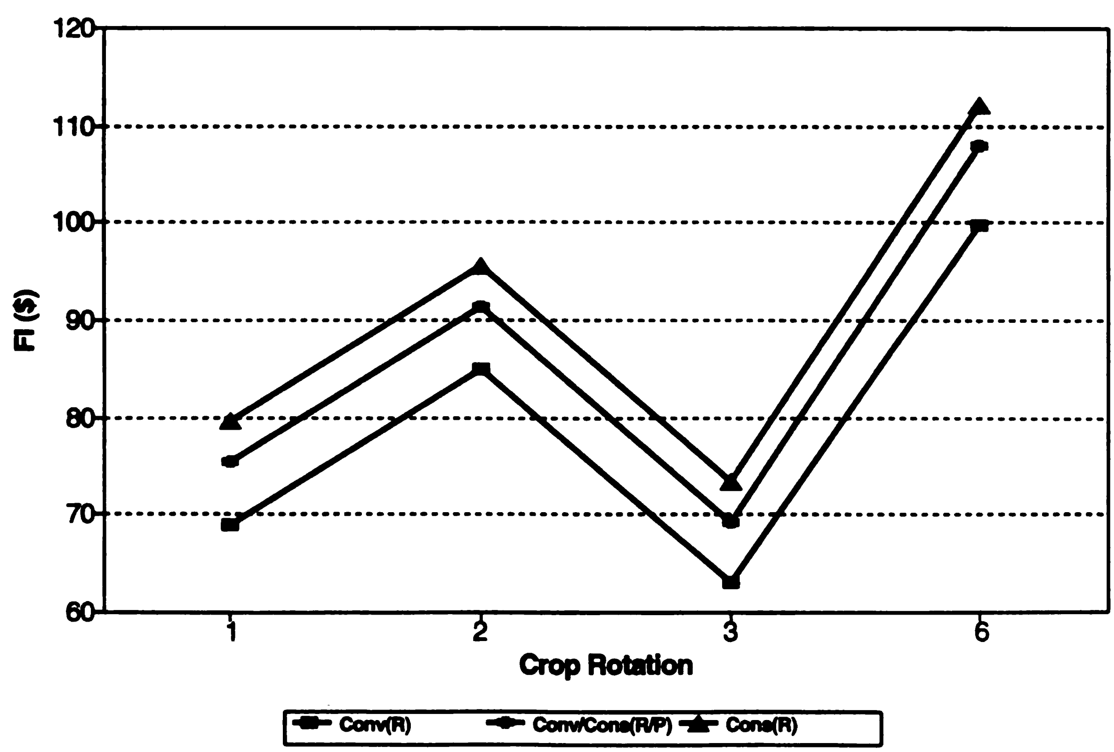

FIGURE 21. Farmer's income (FI) using conventional tillage with "rotation" only (ConvR) versus FI using conservation tillage with "rotation" only (ConsR) versus FI using either tillage practice but backs it up with "rotation and practice" (Conv/ConsR/P).

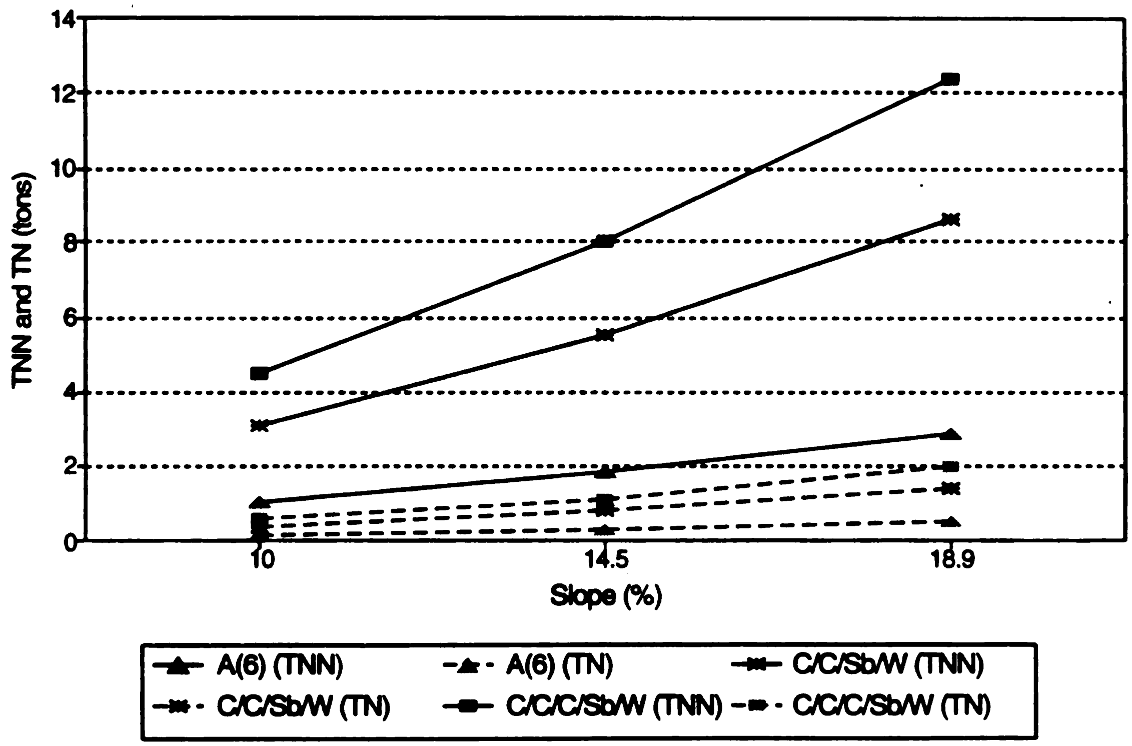

FIGURE 22. The TNN (soil loss from "rotation only") and TN (soil loss from "rotation with practice") of three different rotations, namely: A(6), C/C/Sb/W, and C/C/C/Sb/W are compared.

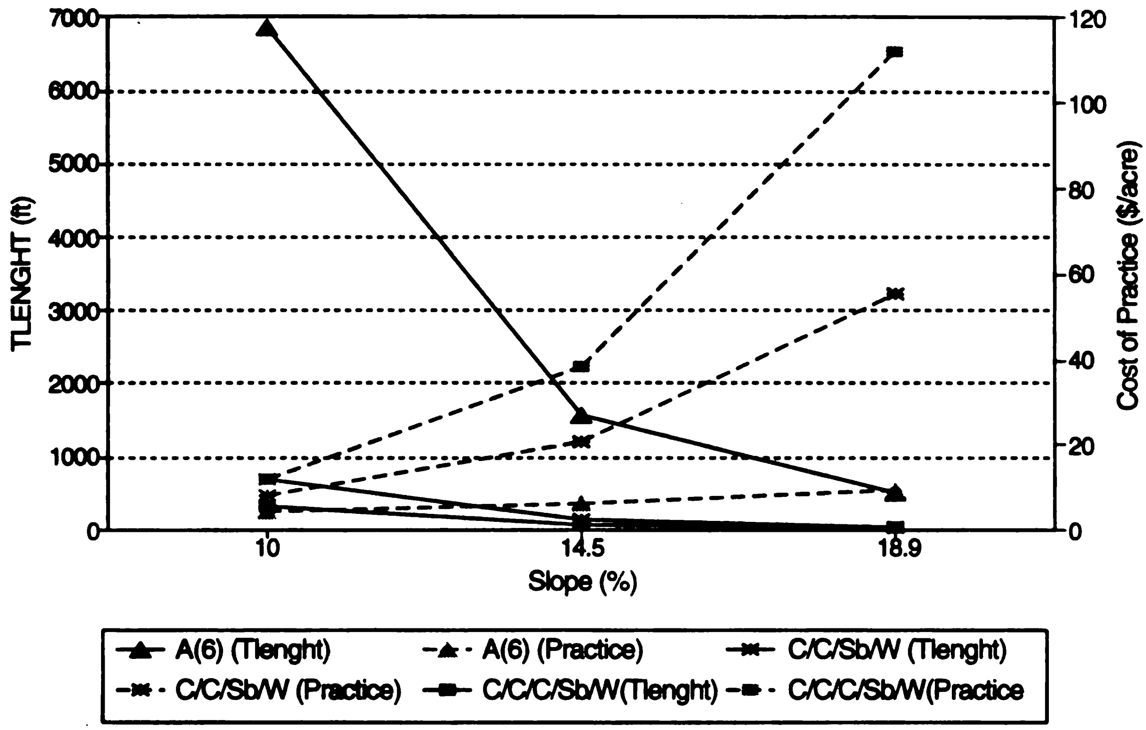

FIGURE 23. Left Y-axis shows the comparison of the recommended maximum horizontal lenght (TLENGHT) for the three crop rotations. Right Y-axis shows the effect of increased TLENGHT on the cost of "Contouring with terracing".

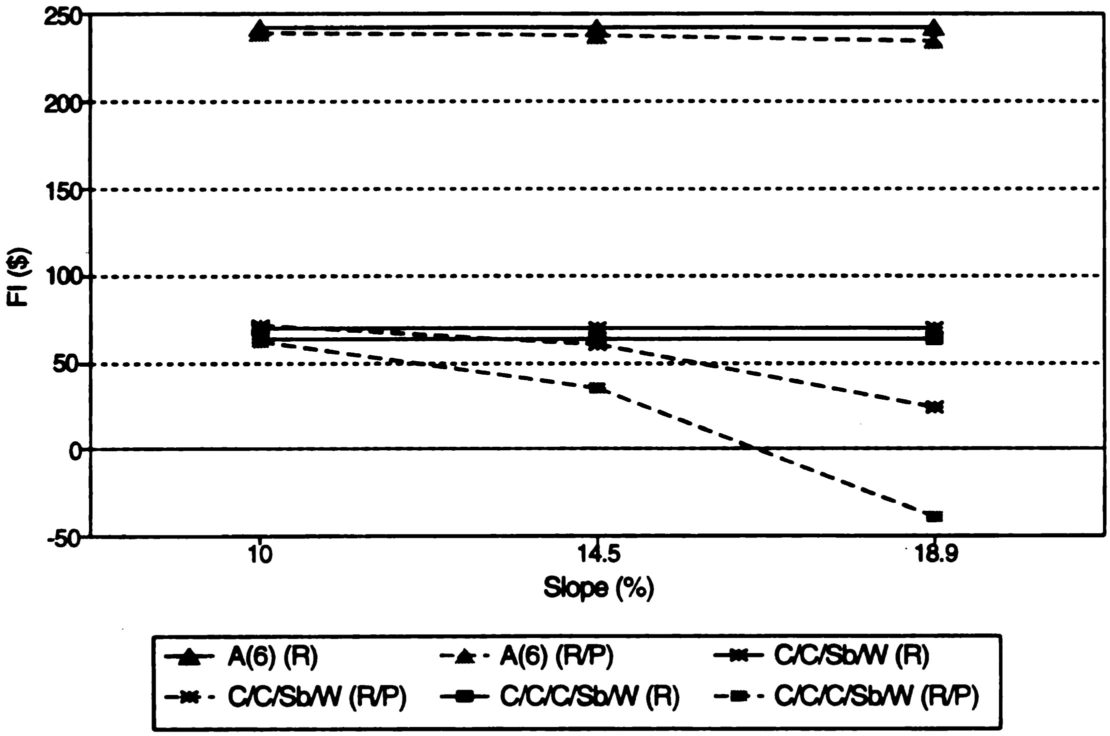

FIGURE 24. The effect of rotation only (R) and rotation with practice (R/P) on the 3 crop rotations, at 3 different slopes on farmer's income (FI).

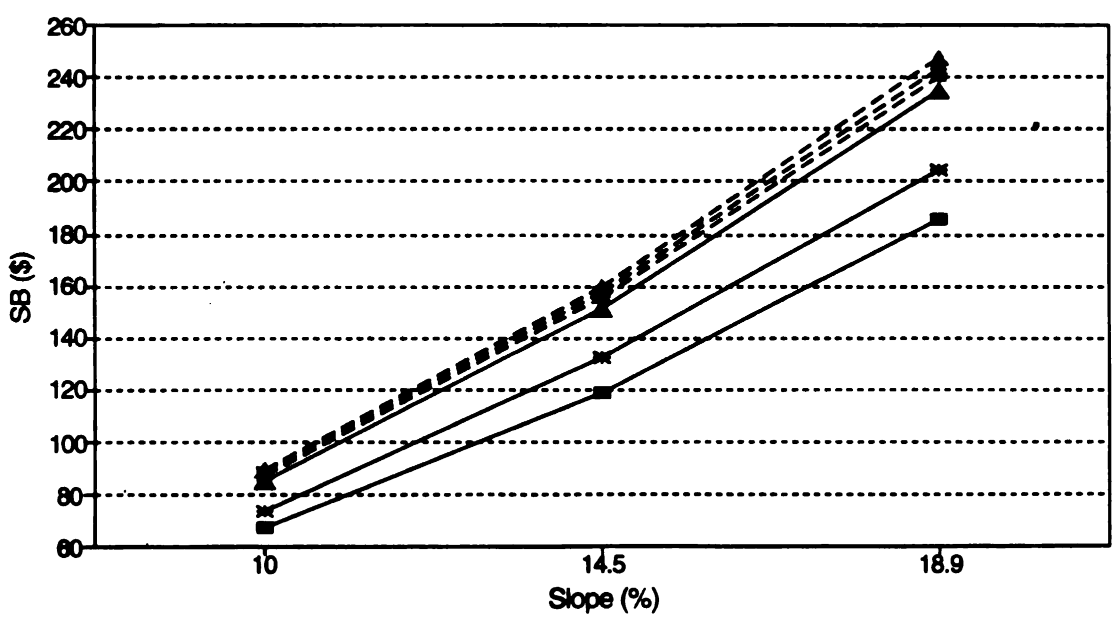

FIGURE 25. The effect of rotation only (R) and rotation with practice (R/P) on the 3 crop rotations, at 3 different slopes, on society's benefit (SB).

D. Summary

Conservation recommendation given by the ES did not always match the recommendation given by SCS. This is because SCS focused more on recommending crop rotations and changes in tillage practice. In contrast, crop rotation was a user input in EXSYSP. An additional practice supported by change in tillage was recommended by EXSYSP when soil loss limit was not met. Mostly, ES recommendations were limited to conservation tillage and contouring because the test areas (including most of Michigan) have a flat topography. Since it was very difficult to compare the historical recommendation of SCS to the recommendation of the ES, the soil loss resulting from both recommendations were used. Statistical analysis showed that there was no significant difference in the resulting soil loss when using either SCS recommendation or the EXSYSP rule-base. In some cases EXSYSP had a lower soil loss than SCS after the recommendation. Analysis of EXSYSP results have demonstrated the following:

1. Rotations that had Alfalfa fared best in reducing soil erosion, increasing both Society's Benefit ($), and Farmer's Income ($). In fact rotation 8 which is purely Alfalfa had the lowest C-value and highest income.
2. The higher the yield level is, the dramatic the effect of erosion control. Income was highest at the highest yield level.
3. For a farmer already doing conservation tillage, additional practices did not increase Farmer's Income. Doing rotation alone brought bigger net income (as in the case of rotations 1,2,3,6 - FIGURE 20). The only way a

practice will be economical is when the value of soil saved is greater than the cost of practice.

4. In cases where farmers income (FI) became lower when a practice was added, the resulting increase in society's benefits was adequate to cover the difference in FI. Example of these are shown in Table 16, (Columns 3, 4, 5, 6, 8, 10, and 11).
5. Since "Contouring w/ terracing" is an expensive practice, the economic return to farmer was basically lower when applying "rotation with practice" than when doing "rotation" alone. Society's benefit, however, was always greater when a practice was applied with rotation than when using rotation alone (Table 16). "Contouring" resulted in a better economic return both for the farmer and society when applying "practice with rotation" than with "rotation" alone (Table 14).
6. "Contouring" alone will suffice for a "contouring with terracing" recommendation having a TLENGHT that exceeds 1000 ft. as in the case of columns 4 and 5, Table 16 (TLENGHT is equal to 6859.36 and 1576.47 ft. respectively).

Although improved rotation alone reduced erosion, additional conservation measures such as "contouring" and "terracing" were sometimes needed. They not only increased farmer's income, but increased society's benefit as well. The actual societal benefits were actually much greater than what was computed here because only the clean-up cost per ton of sediment was considered in the computation of the value per ton of soil saved. If the effect of erosion on human health, ecosystem, and the aesthetic appearance of the environment were considered, the value of each ton of soil saved would increase dramatically.

The Expert System proved to be an effective approach in the development of a decision support for reducing soil erosion. It is useful both at the farm and policy maker's level. The economic analysis portion of EXSYSP could be used as a guide for offering financial incentives to farmers for implementing conservation practices.

V. CONCLUSIONS AND RECOMMENDATIONS

The objectives of the proposed research have been addressed in full. A methodology that will recommend soil conservation practices and estimate the resulting costs and benefits was developed. This method was compared with the traditional SCS method of recommending conservation practices. Although the actual recommendations were not the same, the resulting soil loss have no significant difference between the two methods.

The rule base was developed to make its recommendation based on the physical features of the field (i.e. slope, soil type, soil erodability index, etc.) without regard to the cost of the practice. Therefore, it is up to the program user to accept the result as a guide and not to take all the recommendations literally is. The financial analysis of EXSYSP shows the practicality of using soil conservation practices in addition to improved crop rotation.

The specific conclusions of the research are:

1. Study cells with improved crop rotation plus the recommended practice have lower soil erosion compared with cells having crop rotation alone. Farmer's income and society's benefit are also greater for the former.
2. Application of a soil conservation measure is economically viable for the farmer. In cases where the cost of conservation is too high for the farmer,

the resulting societal benefit is usually more than enough to cover the shortfall.

3. An expert system Knowledge base can be developed and used as a decision support system for reducing soil erosion.

Recommendations for further research are:

1. Financial incentives for implementing conservation programs should consider the resulting societal benefit as a basis for cost sharing instead of basing it on a percentage of the cost of the conservation practice itself.
2. Further research is needed for the development of equivalent P-values for additional conservation practices. At present, the recommended practices were limited to "contouring" and "contouring with terracing" because corresponding "P-value" were not available for other practices.
3. The data base must be expanded to include a broader coverage of the expert system knowledge base. The present knowledge base is specific to Michigan conditions and limited to four crops.
4. Use of another type of probability mode in the development of future knowledge-base. The real strength of expert system lies in its ability to rate or set some level of confidence factor in its recommendations. The simplest confidence level (0-1 or yes /no) was used in this research.
5. Continue investigation on a better method of measuring the value per ton of soil saved.

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APPENDICES

APPENDIX A. LOTUS SPREADSHEETS PRINTOUT

A.1 CROPPROD.WK1

1.1 Corn - Conventional (90-120-150 Bushels Yield Level)

Yield (bushels)	90.00		120.00		150.00	
Price (dollars)	1.40		1.40		1.40	
Gross Returns	126.00		168.00		210.00	
Cash Expenses						
A. Operation						
Plow	10.51		10.51		10.51	
Disk	5.56		5.56		5.56	
Planter w/ Fert.	10.01		10.01		10.01	
Sprayer	1.73		1.73		1.73	
Cultivator	5.70		5.70		5.70	
S.P. Combine	31.38		31.38		31.38	
Grain Wagon	11.64		15.65		19.56	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($80/100000)	17.60	0.22	19.20	0.24	20.80	0.26
Anhy Ammonia (.10)	7.50	75	12.50	125	17.50	175
Nitrogen (.15)	3.75	25	3.75	25	3.75	25
Potash (.05/lb)	2.50	50	2.50	50	5.00	100
Phosphate (.16/lb)	4.00	25	4.00	25	8.00	50
Furadan (1.28/lb)	12.80	10	12.80	10	12.80	10
Atrazine1.72/lb)	2.58	1.5	2.58	1.5	2.58	1.5
Dual (5.50/lb)	11.00	2	11.00	2	11.00	2
Drying Cost (.124/bu)	11.15	90	14.87	120	18.59	150
Int on Op Cap (9%)	2.90		3.14		3.62	
Total Production Costs	152.31		166.88		188.09	
Net Return	-26.31		1.12		21.91	

Note:
Seed cost based on planting 22,000, 24,000 or 26,000 kernels
Price of Nitrogen based on granular urea
All operations are performed one time over

1.2 Corn - Conservation (90-120-150 Bushels Yield Level)

Yield (bushels)	90.00		120.00		150.00	
Price (dollars)	1.40		1.40		1.40	
Gross Returns	126.00		168.00		210.00	
Cash Expenses						
A. Operation						
Chisel	7.51		7.51		7.51	
Disk	5.56		5.56		5.56	
Planter w/ Fert.	10.01		10.01		10.01	
Sprayer	1.73		1.73		1.73	
S.P. Combine	31.38		31.38		31.38	
Grain Wagon	11.74		15.65		19.56	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($80/100000)	17.60	0.22	19.20	0.24	20.80	0.26
Anhy Ammonia (.10)	7.50	75	12.50	125	17.50	175
Nitrogen (.15)	3.75	25	3.75	25	3.75	25
Potash (.05/lb)	2.50	50	2.50	50	5.00	100
Phosphate (.16/lb)	4.00	25	4.00	25	8.00	50
Furadan (1.28/lb)	12.80	10	12.80	10	12.80	10
Atrazine1.72/lb)	3.44	2	3.44	2	3.44	2
Dual (5.50/lb)	11.00	2	11.00	2	11.00	2
Drying Cost (.124/bu)	11.15	90	14.87	120	18.59	150
Int on Op Cap (9%)	2.78		3.03		3.50	
Total Production Costs	144.45		158.93		180.13	
Net Return	-18.45		9.07		29.87	

Note:
Seed cost based on planting 22,000, 24,000 or 26,000 kernels
Price of nitrogen based on granular urea
All operatios are performed one time over

2.1 Wheat - Conventional (40-50-60 Bushels Yield Level)

Yield (bushels)	40.00		50.00		60.00	
Price (dollars)	2.30		2.30		2.30	
Gross Returns	92.00		115.00		138.00	
Cash Expenses						
A. Operation						
Fert Spreader (2X)	7.82		7.82		7.82	
Disk	4.09		4.09		4.09	
Field Cultivator	3.62		3.62		3.62	
Spring Tooth	3.27		3.27		3.27	
Grain Drill	7.38		7.38		7.38	
S.P. Combine	21.02		21.02		21.02	
Grain Wagon	3.92		4.90		5.88	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($4.80/bu.)	7.20	1.5	7.20	1.5	8.40	1.75
Nitrogen (.15/lb)	9.00	60	12.00	80	15.00	100
Phosphate (.16/lb)	4.00	25	8.00	50	12.00	75
Potash (.05/lb)	2.50	50	3.75	75	5.00	100
Int on Operating Cap (9%)	2.06		2.54		3.12	
Total Production Costs	75.88		85.59		96.60	
Net Return	16.12		29.41		41.40	

Note:
All operations are performed once except the fert spreader which is twice

2.2 Wheat - Conservation (40-50-60 Bushels Yield Level)

Yield (bushels)	40.00		50.00		60.00	
Price (dollars)	2.30		2.30		2.30	
Gross Returns	92.00		115.00		138.00	
Cash Expenses						
A. Operation						
Fert Spreader (2X)	7.82		7.82		7.82	
Sprayer	1.09		1.09		1.09	
Disk	4.09		4.09		4.09	
Grain Drill	7.38		7.38		7.38	
S.P. Combine	21.02		21.02		21.02	
Grain Wagon	3.92		4.90		5.88	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($4.80/bu.)	7.20	1.5	7.20	1.5	8.40	1.75
Nitrogen (.15/lb)	9.00	60	12.00	80	15.00	100
Phosphate (.16/lb)	4.00	25	8.00	50	12.00	75
Potash (.05/lb)	2.50	50	3.75	75	5.00	100
2-4-D (1.00/pt)	1.00	1	1.00	1	1.00	1
Int on Operating Cap (9%)	1.84		2.32		2.89	
Total Production Costs	70.86		80.57		91.57	
Net Return	21.14		34.43		46.43	

Note:
All operations are performed once except the fert spreader which is twice

3.1 Soybeans - Conventional (30-40-50 Bushels Yield Level)

Yield (bushels)	30.00		40.00		50.00	
Price (dollars)	4.70		4.70		4.70	
Gross Returns	141.00		188.00		235.00	
Cash Expenses						
A. Operation						
Plow	10.51		10.51		10.51	
Disk	3.91		3.91		3.91	
Planter w/Fert	10.01		10.01		10.01	
Sprayer	1.46		1.46		1.46	
Cultivator	5.70		5.70		5.70	
S.P. Combine	31.38		31.38		31.38	
Grain Wagon	3.91		4.41		4.90	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($.14/lb)	7.00	50	8.40	60	9.80	70
Phosphate (.16/lb)	4.00	25	6.40	40	8.00	50
Potash (.05/lb)	2.50	50	3.00	60	3.75	75
Lorox (10.90/lb)	8.17	0.75	8.17	0.75	8.17	0.75
Lasso (1.63/qt)	9.26	2	9.26	2	9.26	2
Int on Operating Cap (9%)	2.10		2.25		2.37	
Total Production Costs	99.91		104.86		109.22	
Net Return	41.09		83.14		125.78	

3.2 Soybeans - Conservation (30-40-50 Bushels Yield Level)

Yield (bushels)	30.00		40.00		50.00	
Price (dollars)	4.70		4.70		4.70	
Gross Returns	141.00		188.00		235.00	
Cash Expenses						
A. Operation						
Chisel	5.72		5.72		5.72	
Disk	3.91		3.91		3.91	
Planter w/Fert	10.39		10.39		10.39	
Sprayer	1.46		1.46		1.46	
S.P. Combine	31.38		31.38		31.38	
Grain Wagon	3.91		4.41		4.90	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($.14/lb)	7.00	50	8.40	60	9.80	70
Phosphate (.16/lb)	4.00	25	6.40	40	8.00	50
Potash (.05/lb)	2.50	50	3.00	60	3.75	75
Lorox (10.90/lb)	8.17	0.75	8.17	0.75	8.17	0.75
Lasso (1.63/qt)	9.26	2	9.26	2	9.26	2
Int on Operating Cap (9%)	1.51		1.67		1.81	
Total Production Costs	89.21		94.17		98.55	
Net Return	51.79		93.83		136.45	

4.1 Oats - Conventional (60-80-100 Bushels Yield Level)

Yield (bushels)	60.00		80.00		100.00	
Price (dollars)	1.20		1.20		1.20	
Gross Returns	72.00		96.00		120.00	
Cash Expenses						
A. Operation						
Fert. Speader	5.26		5.26		5.26	
Disk	4.09		4.09		4.09	
Field Cultivator	3.62		3.62		3.62	
Spring Tooth	3.27		3.27		3.27	
Grain Drill	7.38		7.38		7.38	
S.P. Combine	21.02		21.02		21.02	
Grain Wagon	8.26		11.01		13.77	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($3.20/bu)	6.40	2	8.00	2.5	9.60	3
Nitrogen (.15/lb)	6.00	40	7.50	50	9.00	60
Phosphate (.16/lb)	4.00	25	8.00	50	12.00	75
Potash (.05/lb)	1.25	25	1.25	25	2.50	50
Int on Operating Cap (9%)	0.89		1.10		1.34	
Total Production Costs	71.44		81.50		92.85	
Net Return	0.56		14.50		27.15	

4.2 Oats - Conservation (60-80-100 Bushels Yield Level)

Yield (bushels)	60.00		80.00		100.00	
Price (dollars)	1.20		1.20		1.20	
Gross Returns	72.00		96.00		120.00	
Cash Expenses						
A. Operation						
Fert. Speader	5.26		5.26		5.26	
Disk	4.09		4.09		4.09	
Field Cultivator	3.62		3.62		3.62	
Spring Tooth	3.27		3.27		3.27	
Grain Drill	7.38		7.38		7.38	
S.P. Combine	21.02		21.02		21.02	
Grain Wagon	8.26		11.01		13.77	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($3.20/bu)	6.40	2	8.00	2.5	9.60	3
Nitrogen (.15/lb)	6.00	40	7.50	50	9.00	60
Phosphate (.16/lb)	4.00	25	8.00	50	12.00	75
Potash (.05/lb)	1.25	25	1.25	25	2.50	50
Int on Operating Cap (9%)	0.89		1.10		1.34	
Total Production Costs	71.44		81.50		92.85	
Net Return	0.56		14.50		27.15	

5.1.1 **Alfalfa - Conventional (4-6-8 Tons Yield Level)**
Establishment Year

	4		6		8	
Yield (bushels)	4		6		8	
Price (dollars)						
Gross Returns	0.00		0.00		0.00	
Cash Expenses						
A. Operation						
Plow	10.51		10.51		10.51	
Disk	4.35		4.35		4.35	
Harrow	3.10		3.10		3.10	
Culti-packer	0.31		0.31		0.31	
Grain Drill	7.38		7.38		7.38	
Fert. Spreader	7.37		7.37		7.37	
Sprayer	1.09		1.09		1.09	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($2.25/lb)	27.00	12	31.50	14	36.00	16
Phosphate (.16/lb)	4.00	25	8.00	50	12.00	75
Potash (.05/lb)	5.00	100	7.50	150	10.00	200
Lime (7.50/ton)	22.50	3	30.00	4	30.00	4
2-4DB (3.75/qt)	7.50	2	7.50	2	7.50	2
Int on Operating Cap.	3.90		4.77		5.25	
Total Production Costs	104.01		123.38		134.86	
Net Return	-104.01		-123.38		-134.86	

Note:
Multi-packer is pulled behind grain drill, no separate power unit needed
Establishment cost amortized at 9% for 5 years

5.1.2 **Alfalfa - Conventional (4-6-8 Tons Yield Level)**
Maintenance After Conventional Establishment

	4		6		8	
Yield (bushels)	4		6		8	
Price (dollars)	55.00		55.00		55.00	
Gross Returns	220.00		330.00		440.00	
Cash Expenses						
A. Operation						
Fert Spreader	7.37		7.37		7.37	
Conditioner (3X)	15.21		15.21		15.21	
Side Del. Rake (3X)	19.29		19.29		19.29	
PTO Baler w/kikr (3X)	36.64		54.98		73.31	
Hay Wagon (3X)	28.59		28.59		28.59	
Sprayer	1.09		2.18		2.18	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Phosphate (.16/lb)	4.00	25	8.00	50	12.00	75
Potash (.05/lb)	5.00	100	7.50	150	10.00	200
Baler Twine (1.95/ton)	7.80	4	11.70	6	15.60	8
Insecticide (3.45/lb)	5.17	1.5	10.35	3	10.35	3
Int on Operating Cap.	2.01		2.92		3.30	
Total Production Costs	132.17		168.09		197.20	
Net Return	87.83		161.91		242.80	

5.2.1 Alfalfa - No-Till (4-6-8 Tons Yield Level)
Establishment Year

Yield (bushels)	4		6		8	
Price (dollars)						
Gross Returns	0.00		0.00		0.00	
Cash Expenses						
A. Operation						
No-till drill	14.11		14.11		14.11	
Fert Spreader	7.37		7.37		7.37	
Sprayer (2X)	2.19		2.19		2.19	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Seed ($2.25/lb)	27.00	12	31.50	14	36.00	16
Phosphate (.16/lb)	4.00	25	8.00	50	12.00	75
Potash (.05/lb)	5.00	100	7.50	150	10.00	200
Lime (7.50/ton)	22.50	3	30.00	4	30.00	4
Paraquat (3.69/pt)	3.69	1.00	3.69	1.00	3.69	1.00
Wetting Agent 1.53/pt	1.53	1.00	1.53	1.00	1.53	1.00
2-4DB (3.75/qt)	7.50	2	7.50	2	7.50	2
Int on Operating Cap.	3.92		4.79		5.28	
Total Production Costs	98.81		118.18		129.67	
Net Return	-98.81		-118.18		-129.67	

5.2.2 Alfalfa - No-till (4-6-8 Tons Yield Level)
Maintenance After No-till Establishment

Yield (bushels)	4		6		8	
Price (dollars)	55.00		55.00		55.00	
Gross Returns	220.00		330.00		440.00	
Cash Expenses						
A. Operation						
Fert Spreader	7.37		7.37		7.37	
Conditioner (3X)	15.21		15.21		15.21	
Side Del. Rake (3X)	19.29		19.29		19.29	
PTO Baler w/kkr (3X)	36.64		54.98		73.31	
Hay Wagon (3X)	28.59		28.59		28.59	
Sprayer	1.09		2.18		2.18	
B. Cost of Inputs		(Amount)		(Amount)		(Amount)
Phosphate (.16/lb)	4.00	25	8.00	50	12.00	75
Potash (.05/lb)	5.00	100	7.50	150	10.00	200
Baler Twine (1.95/ton)	7.80	4	11.70	6	15.60	8
Insecticide (3.45/lb)	5.17	1.5	10.35	3	10.35	3
Int on Operating Cap.	2.01		2.92		3.30	
Total Production Costs	132.17		168.09		197.20	
Net Return	87.83		161.91		242.80	

Note:
Hay wagon is pulled behind baler, no separate power unit needed

6.1 ALFALFA, GRASS - No-till (Pasture Establishment Year)
(Seeding to Perennial Grass)

	Unit	(Price) Cost/Unit	Quantity	(Value) Cost/Ac	Cost/Unit of Prod.
A. Gross from Production					
Grass-legume pasture	TON	35.00	2.50	87.50	
Total Receipts				87.50	
B. Variable Costs					
Preharvest					
Paraquet	PT	3.69	1.00	3.69	1.48
Whetting agent	PT	1.53	0.50	0.76	0.31
2-4-D3	PT	3.75	0.20	0.75	0.30
Nitrogen	LBS	0.15	100.00	15.00	6.00
Legume seeds	LBS	2.25	12.00	27.00	10.80
Grass seeds	LBS	1.25	3.00	3.75	1.50
Tractor fuel, lube	ACRE			3.88	1.55
Tractor repairs	ACRE			2.12	0.85
Machinery repairs	ACRE			3.44	1.37
Machinery labor	HRS	6.07	0.95	5.76	2.31
Interest on op. cap.	DOLS	0.09	42.78	3.85	1.54
Total Preharvest				70.00	28.00
Harvest					
Interest on op. cap.	DOLS	0.09	0.00	0.00	0.00
Total Harvest				0.00	0.00
Total Var. Prod Costs				70.00	28.00
C. Ownership Costs (dep., taxes, interest, ins.)					
Tractors				5.42	2.17
Machinery and Eqpt				5.50	2.20
Total Ownership Costs				10.92	4.37
D. Total Enterprise Prod Cost				80.93	32.37
E. Return to Land, Overhead, Risk and Management				6.57	2.63
F. Other Charges					
Land charge				0.00	0.00
Management (10% var prod cost)				7.00	2.80
G. Cost of Conservation Measure (Ave, annual cost at 8.625%) Total Resource Mgt System				0.00	0.00
H. Total Cost of Treatment, other Charges, and Enterprise Production Costs				87.93	35.17
I. Net Returns				-0.43	-0.17

6.2 ALFALFA, NATIVE GRASSES (Pasture harvest Year)
(Seeding to Perennial Grass)

	Unit	(Price) Cost/Unit	Quantity	(Value) Cost/Ac	Cost/Unit of Prod.
A. Gross from Production					
Grass-legume pasture	TON	35.00	2.50	87.50	
Total Receipts				87.50	
B. Variable Costs					
Preharvest					
Nitrogen	LBS	0.15	100.00	15.00	6.00
Tractor fuel, lube	ACRE			1.40	0.56
Tractor repairs	ACRE			0.81	0.32
Machinery repairs	ACRE			0.68	0.27
Machinery labor	HRS	6.07	0.39	2.40	0.96
Interest on op. cap.	DOLS	0.09	4.69	0.42	0.17
Total Preharvest				20.70	8.28
Harvest					
Interest on op. cap.	DOLS	0.09	0.00	0.00	0.00
Total Harvest				0.00	0.00
Total Var. Prod Costs				20.70	8.28
C. Ownership Costs (dep., taxes, interest, ins.)					
Tractors				1.96	0.78
Machinery and Eqpt				1.66	0.66
Total Ownership Costs				3.62	1.45
D. Total Enterprise Prod Cost				24.32	9.73
E. Return to Land, Overhead, Risk and Management				63.18	25.27
F. Other Charges					
Land charge				0.00	0.00
Management (10% var prod cost)				2.07	0.83
G. Cost of Conservation Measure (Ave, annual cost at 8.625%) Total Resource Mgt System				0.00	0.00
H. Total Cost of Treatment, other Charges, and Enterprise Production Costs				26.39	10.56
I. Net Returns				61.11	24.44

NOTE: #9.1 and #9.2 are budgets prepared by SCS.
AREA CODE: 2/26 0/97; 2/26 0/97
ENTERPRISE CODE: 811330000; 811330000
BUDGET ID NUMBER: 26293; 26294

A.2 CONSPRAC.WK1

Conservation Practice	Indi-cator Unit	Flat Rate Install Cost ($)	Life Span (Yrs)	Annual O & M Costs (%)	Average Annual Total Cost(87) ($)
Access Road (one-way traffic)					
Gravel	Ft.	10.00	25	15	2.52
Blacktop	Ft.	20.00	25	5	3.04
Pavement	Ft.	33.00	25	3	4.35
Access Road (two-way traffic)					
Gravel	Ft.	12.00	25	15	3.02
Blacktop	Ft.	25.00	25	5	3.80
Pavement	Ft.	36.00	25	3	4.75
Bedding	Acre	120.00	20	10	25.15
Brush Management					
Mechanical-light mgt.	Acre	14.00	10	3	2.60
Mechanical-moderate	Acre	31.00	10	5	6.38
Mechanical-severe	Acre	73.00	10	10	18.67
Chemical	Acre	12.00	5	3	3.45
Channel Vegetation	Acre	120.00	25	3	15.82
Clearing and Snagging	Job Est	100.00	15	5	17.41
Commercial Fish Ponds	Job Est	1000.00	10	10	255.82
Contour Farming	Acre	3.00	1	0	3.27
Cover & Green Manure Crop	Acre	17.00	1	0	18.53
Critical Area Planting					
Shaping	Acre	170.00	25	3	22.41
Cover crop	Acre	17.00	25	0	1.73
Seed, seeding and fert.	Acre	120.00	25	3	15.82
Mulching	Acre	230.00	25	3	30.32
Sodding	1000 yd2	2300.00	25	3	303.15
Dam, Diversion	Job Est	1000.00	25	3	131.81
Dam, Flood Water Retarding	Ac Ft/St	2200.00	50	2	244.70
Dam, Multiple Purpose	Job Est	1000.00	25	3	131.81
Diversion	1000 ft	1000.00	20	5	159.55
Farmstead and Feedlot Windbreak	1000 tree	390.00	25	3	51.40

Fencing					
Four-wire barb	Mile	3200.00	20	5	510.55
Woven wire and barb	Mile	4400.00	20	5	702.01
Suspension	Mile	1700.00	20	5	271.23
Field Border-1 Rod Wide					
Grass-legume	1/2 mile	100.00	10	5	20.58
Shrub	1/2 mile	150.00	20	5	23.93
Field Windbreak					
Bare root	1/2 mile	200.00	25	5	30.36
Potted	1/2 mile	330.00	25	4	46.80
Filter Strip	Acre	1500.00	10	3	278.73
Fire Break					
Grass	1/2 mile	50.00	10	2	17.79
Bare soil	1/2 mile	10.00	1	0	10.90
Fish Raceway	Job Est	1000.00	10	5	205.82
Fish Stream Improvement	Job Est	1000.00	25	10	201.81
Fish Pond Management	Per Pond	120.00	1	0	130.80
Grade Stabilization Structure	Job Est	1000.00	25	3	131.81
Grassed Waterway or Outlet	Acre	1200.00	20	3	167.46
Heavy Use Area Protection					
Gravel	100 Ft2	60.00	10	5	12.35
Blacktop	100 Ft2	110.00	25	3	14.50
Paving	100 Ft2	125.00	50	1	12.65
Hedgerow Planting-per Row	1/2 Mile	100.00	25	5	15.18
Irrigation Pit	Job Est	1000.00	15	2	144.06
Irrigation Storage Reservoir	Job Est	1000.00	25	3	131.81
Irrigation Sprinkler					
Drip, Winbreak Estab.	1000 tips	1900.00	25	5	288.43
Skid Tow	140 Acre	36000.00	15	22	12386.13
Travelling Gun	100 Acre	36000.00	15	24	13106.13
Center Pivot	130 Acre	60000.00	10	11	15949.25
Center Pivot	150 Acre	75000.00	10	10	19186.56
Land Clearing	Acre	850.00	20	0	93.11
Land Smoothing	Acre	100.00	20	2	10.95
Mulch Anchor					
By treading	Acre	220.00	5	0	56.56
By netting	100 Yd2	30.00	5	0	7.71
By asphalt emulsion	Acre	230.00	5	0	59.13

Obstruction Removal	Job Est	1000.00	20	0	109.55
Open Channel	1000 Yd3	1000.00	25	3	101.81
Pasture and Hay Mgt.					
Continuous grazing	Acre	25.00	1	0	27.25
Rotation grazing	Acre	35.00	1	0	38.15
Low management	Acre	15.00	1	0	16.35
High management	Acre	35.00	1	0	38.15
Pasture and Hay Planting	Acre	90.00	8	5	20.76
Pipeline - Plastic					
1" diameter	1000 Ft	700.00	20	1	83.68
1-1/2" diameter	1000 Ft	1150.00	20	1	191.27
2" diameter	1000 Ft	1600.00	20	1	291.27
Pond - embankment					
With pipe	1000 Yd3	2000.00	20	3	279.09
Without pipe	1000 Yd3	1000.00	20	3	139.55
Excavated	1000 Yd3	1200.00	20	3	167.46
Pond Sealing or Lining					
Flexible menbrane 8 mi	1000 Ft2	275.00	20	1	32.88
Soil dispersant	1000 Ft2	44.00	20	3	6.14
Bentonite, 2lbs/ft2	1000 Ft2	110.00	20	3	15.35
Pumping Plant/Water Ctrl	Job Est	1000.00	10	5	205.82
Sediment Basin	Job Est	1000.00	10	10	255.82
Spoil Spreading at Excavation	1000 Yd3	110.00	25	0	11.20
Soil Spreading Old Spoilbanks	1000 Yd3	550.00	25	0	55.99
Spring Development	Job Est	1000.00	10	5	205.82
Stripcropping					
Contour	Acre	10.00	10	5	2.06
Field	Acre	5.00	10	5	1.03
Wind	Acre	4.00	10	5	0.82
Structure for Water Ctrl	Job Est	1000.00	25	5	151.81
Subsurface Drain					
4" tile	1000 Ft	500.00	25	1	55.90
5" tile	1000 Ft	800.00	25	1	89.45
6" tile	1000 Ft	1100.00	25	1	122.99
8" tile	1000 Ft	1400.00	25	1	156.53
10" tile	1000 Ft	1750.00	25	1	195.66
12" tile	1000 Ft	2100.00	25	1	234.79
Field Ditch	1000 Ft	550.00	10	3	102.20
Main/Lateral	1000 Yd3	1000.00	25	5	151.81

Terrace Grade					
Regular	1000 Ft	350.00	20	2	45.34
Grassed, Back slope	1000 Ft	360.00	20	2	466.64
Tree Planting					
Hardwoods	1000 tree	200.00	80	1	20.02
Conifers	1000 tree	110.00	50	1	11.13
Trough or Tank	1000 gal	700.00	25	1	78.26
Vegetative Barriers, Tall					
Wheatgrass, 60'spacing	40 Acre	400.00	10	5	82.33
Waste Storage Structure					
Concrete Tank	1000 ft3	1700.00	25	3	224.07
Waste Storage Stacking Facility	1000 ft3	1100.00	25	5	166.99
Waste Utility Liquid Injection	100 AU	1700.00	10	8	400.90
Water and Sediment Control Basin	1000 Yd3	1000.00	25	5	151.81
Well Livestock 4" dia.	100 Ft	730.00	20	1	87.27
Well	Job Est	1000.00	20	1	119.55
Wildlife Upland Habitat					
Mgt Preservation	Acre	1.00	1	0	1.09
Wildlife Wetland Habitat					
Mgt Preservation	Acre	1.00	1	0	1.09
Windbreak Renovation	Acre	550.00	25	3	72.49
Woodland					
Direct Seeding	Acre	20.00	50	0	1.82
Improvement	Acre	40.00	50	1	4.05
Pruning - Pine	Acre	100.00	30	0	9.73
Pruning - Walnut	Acre	75.00	30	0	7.30
Woodland Site Preparation					
Mechanical, light veg.	Acre	30.00	1	0	32.70
Herbicide, light veg.	Acre	18.00	1	0	19.62
Herbicide, heavy veg.	Acre	28.00	1	0	30.52

A.3 ROTATION.WK1

A.3 ROTATION.WK1

Rotation 1: Corn/Corn/Soybean/Wheat

EVENT	DATE	TABLE6	CRPSTA	EI	SOIL LOSS					SODFAC	C-VALUE					CROP YEAR				
1	2	3	4	5	6					7	8					9				
					(6000#)	(4500#)	(3400#)	(2800#)	(2000#)		(6000#)	(4500#)	(3400#)	(2800#)	(2000#)	(6000#)	(4500#)	(3400#)	(2800#)	(2000#)
Disk	5/05	12	SB	0.10	0.180	0.210	0.230	0.250	0.270	0.40	0.0072	0.0084	0.0092	0.0100	0.0108					
Plant Corn1	5/10																			
10%	6/01	22	1	0.12	0.150	0.180	0.210	0.230	0.250	0.40	0.0072	0.0086	0.0101	0.0110	0.0120					
50%	6/20	34	2	0.12	0.130	0.150	0.190	0.220	0.240	0.45	0.0070	0.0081	0.0103	0.0119	0.0130					
75%	7/10	46	3	0.48	0.120	0.130	0.140	0.140	0.150	0.50	0.0288	0.0312	0.0336	0.0336	0.0360					
Harvest Corn1	10/15	94	4	0.04	0.200	0.210	0.260	0.320	0.390	0.60	0.0048	0.0050	0.0062	0.0077	0.0094	0.0550	0.0614	0.0694	0.0742	0.0811
Chisel	11/15	98	F	0.13	0.180	0.210	0.230	0.250	0.270	0.70	0.0164	0.0191	0.0209	0.0228	0.0246					
Disk	5/01	11	SB	0.11	0.180	0.210	0.230	0.250	0.270	0.80	0.0158	0.0185	0.0202	0.0220	0.0238					
Plant Corn2	5/10																			
10%	6/01	22	1	0.12	0.150	0.180	0.210	0.230	0.250	0.80	0.0144	0.0173	0.0202	0.0221	0.0240					
50%	6/20	34	2	0.12	0.130	0.150	0.190	0.220	0.240	0.85	0.0133	0.0153	0.0194	0.0224	0.0245					
75%	7/10	46	3	0.48	0.120	0.130	0.140	0.140	0.150	0.90	0.0518	0.0562	0.0605	0.0605	0.0648					
Harvest Corn2	10/15	94	4	0.04	0.200	0.210	0.260	0.320	0.390	0.95	0.0076	0.0080	0.0099	0.0122	0.0148	0.1193	0.1343	0.1511	0.1619	0.1764
Chisel	11/15	98	F	0.12	0.180	0.210	0.230	0.250	0.270	0.25	0.0054	0.0063	0.0069	0.0075	0.0081					
Disk	4/25	10	SB	0.07	0.180	0.210	0.230	0.250	0.270	0.80	0.0101	0.0118	0.0129	0.0140	0.0151					
Plant Soybean	5/01																			
10%	5/20	17	1	0.05	0.150	0.180	0.210	0.230	0.250	0.80	0.0060	0.0072	0.0084	0.0092	0.0100					
50%	6/01	22	2	0.18	0.130	0.150	0.190	0.220	0.240	0.85	0.0199	0.0230	0.0291	0.0337	0.0367					
75%	7/01	40	3	0.53	0.120	0.130	0.140	0.140	0.150	0.90	0.0572	0.0620	0.0668	0.0668	0.0716					
Harvest Soybean	10/10	92	4	0.01	0.200	0.210	0.260	0.320	0.390	0.95	0.0019	0.0020	0.0025	0.0030	0.0037	0.1005	0.1122	0.1265	0.1342	0.1452
Disk	10/12	93	SB	0.03		0.250	0.320	0.360	0.380	0.60		0.0045	0.0058	0.0065	0.0068					
Plant Wheat	10/15																			
10%	11/01	98	1	0.03		0.180	0.250	0.290	0.300	0.60		0.0032	0.0045	0.0052	0.0054					
50%	12/01	99	2	0.09		0.130	0.180	0.210	0.230	0.70		0.0082	0.0113	0.0132	0.0145					
75%	4/15	8	3	0.41		0.020	0.030	0.030	0.040	0.85		0.0070	0.0105	0.0105	0.0139					
Harvest Wheat	7/15	49	4	0.10		0.260	0.260	0.260	0.260	0.95		0.0247	0.0247	0.0247	0.0247					
Seed Clover	3/15																			
Maturity	8/01	59	4	0.49		0.015	0.015	0.015	0.015	1.00		0.0074	0.0074	0.0074	0.0074		0.0550	0.0641	0.0674	0.0727
Chisel	4/15	8																		
	Rotation Total:			3.97							0.2749	0.3629	0.4111	0.4377	0.4755					
							Average Annual C-Value for Rotation:				0.0916	0.0907	0.1028	0.1094	0.1189					

NOTE: 1. No value for Wheat, 6000# spring residue.
2. Value for wheat, 4500# spring residue, 30% cover is an approximation based from other values on that range.

Rotation 2: Corn/Soybean/Wheat

		SOOEAS	C VALUE	CROP YEAR

Rotation 2: Corn/Soybean/Wheat

EVENT	DATE	TABLE6	CRPSTA	EI	SOIL LOSS					SODFAC	C-VALUE					CROP YEAR				
1	2	3	4	5	6					7	8					9				
					(6000#)	(4500#)	(3400#)	(2600#)	(2000#)		(6000#)	(4500#)	(3400#)	(2600#)	(2000#)	(6000#)	(4500#)	(3400#)	(2600#)	(2000#)
Disk	5/01	11	SB	0.11	0.180	0.2100	0.2300	0.2500	0.2700		0.0198	0.0231	0.0253	0.0275	0.0297					
Plant Corn1	5/10																			
10%	6/01	22	1	0.12	0.150	0.1800	0.2100	0.2300	0.2500		0.0180	0.0216	0.0252	0.0276	0.0300					
50%	6/20	34	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	7/10	46	3	0.48	0.120	0.1300	0.1400	0.1400	0.1500		0.0576	0.0624	0.0672	0.0672	0.0720					
Harvest Corn1	10/15	94	4	0.04	0.200	0.2100	0.2800	0.3200	0.3900		0.0080	0.0084	0.0104	0.0128	0.0156	0.1190	0.1335	0.1509	0.1615	0.1761
Chisel	11/15	98	F	0.12	0.180	0.2100	0.2300	0.2500	0.2700		0.0216	0.0252	0.0276	0.0300	0.0324					
Disk	4/25	10	SB	0.07	0.180	0.2100	0.2300	0.2500	0.2700		0.0126	0.0147	0.0161	0.0175	0.0189					
Plant Soybean	5/01																			
10%	5/20	17	1	0.05	0.150	0.1800	0.2100	0.2300	0.2500		0.0075	0.0090	0.0105	0.0115	0.0125					
50%	6/01	22	2	0.18	0.130	0.1500	0.1900	0.2200	0.2400		0.0234	0.0270	0.0342	0.0396	0.0432					
75%	7/01	40	3	0.53	0.120	0.1300	0.1400	0.1400	0.1500		0.0636	0.0689	0.0742	0.0742	0.0795					
Harvest Soybean	10/10	92	4	0.01	0.200	0.2100	0.2800	0.3200	0.3900		0.0020	0.0021	0.0026	0.0032	0.0039	0.1307	0.1469	0.1652	0.1760	0.1904
Disk	10/12	93	SB	0.03		0.2500	0.3200	0.3800	0.3800		0.0000	0.0075	0.0096	0.0108	0.0114					
Plant Wheat	10/15																			
10%	11/01	96	1	0.03		0.1800	0.2500	0.2900	0.3000			0.0054	0.0075	0.0087	0.0090					
50%	12/01	99	2	0.09		0.1300	0.1800	0.2100	0.2300			0.0117	0.0162	0.0189	0.0207					
75%	4/15	8	3	0.41		0.0200	0.0300	0.0300	0.0400			0.0082	0.0123	0.0123	0.0164					
Harvest Wheat	7/15	49	4	0.59		0.2600	0.2600	0.2600	0.2600			0.1534	0.1534	0.1534	0.1534		0.1862	0.1990	0.2041	0.2109
Chisel	4/15	8																		
	Rotation Total:			2.98							0.2497	0.4666	0.5151	0.5416	0.5774					
							Average Annual C-Value for Rotation:				0.1249	0.1555	0.1717	0.1805	0.1925					

Note: 1. Column 7 is omitted for meadowless system.

Rotation 3: Corn/Corn/Corn/Soybean/Wheat

EVENT	DATE	TABLE6	CRPSTA	EI	SOIL LOSS					SODFAC	C-VALUE					CROP YEAR				
1	2	3	4	5	6					7	8					9				
					(6000#)	(4500#)	(3400#)	(2600#)	(2000#)		(6000#)	(4500#)	(3400#)	(2600#)	(2000#)	(6000#)	(4500#)	(3400#)	(2600#)	(2000#)
Disk	5/05	12	SB	0.10	0.180	0.2100	0.2300	0.2500	0.2700		0.0180	0.0210	0.0230	0.0250	0.0270					
Plant Corn1	5/10																			
10%	6/01	22	1	0.12	0.150	0.1800	0.2100	0.2300	0.2500		0.0180	0.0216	0.0252	0.0276	0.0300					
50%	6/20	34	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	7/10	46	3	0.48	0.120	0.1300	0.1400	0.1400	0.1500		0.0576	0.0624	0.0672	0.0672	0.0720					
Harvest Corn1	10/15	94	4	0.04	0.200	0.2100	0.2600	0.3200	0.3900		0.0080	0.0084	0.0104	0.0128	0.0156	0.1172	0.1314	0.1486	0.1590	0.1734
Chisel	11/15	98	F	0.13	0.180	0.2100	0.2300	0.2500	0.2700		0.0234	0.0273	0.0299	0.0325	0.0351					
Disk	5/01	11	SB	0.11	0.180	0.2100	0.2300	0.2500	0.2700		0.0198	0.0231	0.0253	0.0275	0.0297					
Plant Corn2	5/10																			
10%	6/01	22	1	0.12	0.150	0.1800	0.2100	0.2300	0.2500		0.0180	0.0216	0.0252	0.0276	0.0300					
50%	6/20	34	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	7/10	46	3	0.48	0.120	0.1300	0.1400	0.1400	0.1500		0.0576	0.0624	0.0672	0.0672	0.0720					
Harvest Corn2	10/15	94	4	0.04	0.200	0.2100	0.2600	0.3200	0.3900		0.0080	0.0084	0.0104	0.0128	0.0156	0.1424	0.1608	0.1808	0.1940	0.2112
Chisel	11/15	98	F	0.13	0.180	0.2100	0.2300	0.2500	0.2700		0.0234	0.0273	0.0299	0.0325	0.0351					
Disk	5/01	11	SB	0.11	0.180	0.2100	0.2300	0.2500	0.2700		0.0198	0.0231	0.0253	0.0275	0.0297					
Plant Corn3	5/10																			
10%	6/01	22	1	0.12	0.150	0.1800	0.2100	0.2300	0.2500		0.0180	0.0216	0.0252	0.0276	0.0300					
50%	6/20	34	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	7/10	46	3	0.48	0.120	0.1300	0.1400	0.1400	0.1500		0.0576	0.0624	0.0672	0.0672	0.0720					
Harvest Corn3	10/15	94	4	0.04	0.200	0.2100	0.2600	0.3200	0.3900		0.0080	0.0084	0.0104	0.0128	0.0156	0.1424	0.1608	0.1808	0.1940	0.2112
Chisel	11/15	98	F	0.12	0.180	0.2100	0.2300	0.2500	0.2700		0.0216	0.0252	0.0276	0.0300	0.0324					
Disk	4/25	10	SB	0.07	0.180	0.2100	0.2300	0.2500	0.2700		0.0126	0.0147	0.0161	0.0175	0.0189					
Plant Soybean	5/01																			
10%	5/20	17	1	0.05	0.150	0.1800	0.2100	0.2300	0.2500		0.0075	0.0090	0.0105	0.0115	0.0125					
50%	6/01	22	2	0.18	0.130	0.1500	0.1900	0.2200	0.2400		0.0234	0.0270	0.0342	0.0396	0.0432					
75%	7/01	40	3	0.53	0.120	0.1300	0.1400	0.1400	0.1500		0.0636	0.0689	0.0742	0.0742	0.0795					
Harvest Soybean	10/10	92	4	0.01	0.200	0.2100	0.2600	0.3200	0.3900		0.0020	0.0021	0.0026	0.0032	0.0039	0.1307	0.1469	0.1652	0.1760	0.1904
Disk	10/12	93	SB	0.03		0.2500	0.3200	0.3600	0.3800			0.0075	0.0096	0.0108	0.0114					
Plant Wheat	10/15																			
10%	11/01	96	1	0.03		0.1800	0.2500	0.2900	0.3000			0.0054	0.0075	0.0087	0.0090					
50%	12/01	99	2	0.09		0.1300	0.1800	0.2100	0.2300			0.0117	0.0162	0.0189	0.0207					
75%	4/15	8	3	0.41		0.0200	0.0300	0.0300	0.0400			0.0082	0.0123	0.0123	0.0164					
Harvest Wheat	7/15	49	4	0.59		0.2600	0.2600	0.2600	0.2600			0.1534	0.1534	0.1534	0.1534		0.1862	0.1990	0.2041	0.2109
Chisel	4/15	8																		
	Rotation Total:			4.97							0.5327	0.7861	0.8744	0.9271	0.9971					
					Average Annual C-Value for Rotation:						0.1332	0.1572	0.1749	0.1854	0.1994					

Note: 1. Column 7 is omitted for meadowless system.

Rotation 4 Corn/Corn/Soybean/Wheat/Alfalfa(6 years)

EVENT 1	DATE 2	TABLE6 3	CHPST 4	EI 5	SOIL LOSS 6 (6000#)	(4500#)	(3400#)	(2600#)	(2000#)	SODFAC 7	C-VALUE 8 (6000#)	(4500#)	(3400#)	(2600#)	(2000#)	CROP YEAR 9 (6000#)	(4500#)	(3400#)	(2600#)	(2000#)
Dsk	5/05	12	SB	0.10	0.180	0.2100	0.2300	0.2500	0.2700		0.0180	0.0210	0.0230	0.0250	0.0270					
												[illegible]	[illegible]	0.0278	0.0300					

Rotation 4: Corn/Corn/Soybean/Wheat/Alfalfa(6 years)

EVENT 1	DATE 2	TABLE6 3	CRPST 4	EI 5	SOIL LOSS 6 (6000#)	(4500#)	(3400#)	(2600#)	(2000#)	SODFAC 7	C-VALUE 8 (6000#)	(4500#)	(3400#)	(2600#)	(2000#)	CROP YEAR 9 (6000#)	(4500#)	(3400#)	(2600#)	(2000#)
Disk	5/05	12	SB	0.10	0.180	0.2100	0.2300	0.2500	0.2700		0.0180	0.0210	0.0230	0.0250	0.0270					
Plant Corn1	5/10																			
10%	6/01	22	1	0.12	0.150	0.1800	0.2100	0.2300	0.2500		0.0180	0.0216	0.0252	0.0276	0.0300					
50%	6/20	34	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	7/10	48	3	0.48	0.120	0.1300	0.1400	0.1400	0.1500		0.0576	0.0624	0.0672	0.0672	0.0720					
Harvest Corn1	10/15	94	4	0.04	0.200	0.2100	0.2600	0.3200	0.3900		0.0080	0.0084	0.0104	0.0128	0.0156	0.1172	0.1314	0.1486	0.1590	0.1734
Chisel	11/15	98	F	0.13	0.180	0.2100	0.2300	0.2500	0.2700		0.0234	0.0273	0.0299	0.0325	0.0351					
Disk	5/01	11	SB	0.11	0.180	0.2100	0.2300	0.2500	0.2700		0.0198	0.0231	0.0253	0.0275	0.0297					
Plant Corn2	5/10																			
10%	6/01	22	1	0.12	0.150	0.1800	0.2100	0.2300	0.2500		0.0180	0.0216	0.0252	0.0276	0.0300					
50%	6/20	34	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	7/10	48	3	0.48	0.120	0.1300	0.1400	0.1400	0.1500		0.0576	0.0624	0.0672	0.0672	0.0720					
Harvest Corn2	10/15	94	4	0.04	0.200	0.2100	0.2600	0.3200	0.3900		0.0080	0.0084	0.0104	0.0128	0.0156	0.1424	0.1608	0.1808	0.1940	0.2112
Chisel	11/15	98	F	0.12	0.180	0.2100	0.2300	0.2500	0.2700		0.0216	0.0252	0.0276	0.0300	0.0324					
Disk	4/25	10	SB	0.07	0.180	0.2100	0.2300	0.2500	0.2700		0.0126	0.0147	0.0161	0.0175	0.0189					
Plant Soybean	5/01																			
10%	5/20	17	1	0.05	0.150	0.1800	0.2100	0.2300	0.2500		0.0075	0.0090	0.0105	0.0115	0.0125					
50%	6/01	22	2	0.18	0.130	0.1500	0.1900	0.2200	0.2400		0.0234	0.0270	0.0342	0.0396	0.0432					
75%	7/01	40	3	0.53	0.120	0.1300	0.1400	0.1400	0.1500		0.0636	0.0689	0.0742	0.0742	0.0795					
Harvest Soybean	10/10	92	4	0.01	0.200	0.2100	0.2600	0.3200	0.3900		0.0020	0.0021	0.0026	0.0032	0.0039	0.1307	0.1469	0.1652	0.1760	0.1904
Disk	10/12	93	SB	0.03		0.2500	0.3200	0.3600	0.3800			0.0075	0.0096	0.0108	0.0114					
Plant Wheat	10/15																			
10%	11/01	98	1	0.03		0.1800	0.2500	0.2900	0.3000			0.0054	0.0075	0.0087	0.0090					
50%	12/01	99	2	0.09		0.1300	0.1800	0.2100	0.2300			0.0117	0.0162	0.0189	0.0207					
75%	4/15	8	3	0.41		0.0200	0.0300	0.0300	0.0400			0.0082	0.0123	0.0123	0.0164					
Harvest Wheat	7/15	49	4	0.03		0.2600	0.2600	0.2600	0.2600			0.0078	0.0078	0.0078	0.0078		0.0406	0.0534	0.0585	0.0653
Disk	7/20	52	SB	0.43	0.190	0.2600	0.3200	0.3600	0.3800		0.0817	0.1118	0.1376	0.1548	0.1634					
Harrow	7/25																			
Seeding alfalfa	8/15																			
1st Cutting	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044					
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.1061	0.1362	0.1620	0.1792	0.1878
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.13	0.020	0.020	0.020	0.020	0.020		0.0026	0.0026	0.0026	0.0026	0.0026	0.0182	0.0182	0.0182	0.0182	0.0182
Chisel	4/15	8																		
	Rotation Total:			9.97							0.5946	0.7141	0.8082	0.8649	0.9263					
								Average Annual C-Value for Rotation:			0.0661	0.0714	0.0808	0.0865	0.0926					

Note: Soil Loss value for disking before alfalfa is based on values of grain after corn for 30% cover after plant. Approximation is used when values are missing (0.19, 0.26, 0.32, 0.36, 0.38 respectively).

Rotation 5: Corn/Corn/Soybean/Wheat/Alfalfa (4 years)

EVENT	DATE	TABLE6	CRPSTA	EI	SOIL LOSS					SODFAC	C-VALUE					CROP YEAR				
1	2	3	4	5	6					7	8					9				
					(6000#)	(4500#)	(3400#)	(2600#)	(2000#)		(6000#)	(4500#)	(3400#)	(2600#)	(2000#)	(6000#)	(4500#)	(3400#)	(2600#)	(2000#)

Rotation 5: Corn/Corn/Soybean/Wheat/Alfalfa(4 years)

EVENT 1	DATE 2	TABLE6 3	CRPSTA 4	EI 5	SOIL LOSS 6 (6000#)	(4500#)	(3400#)	(2800#)	(2000#)	SODFAC 7	C-VALUE 8 (6000#)	(4500#)	(3400#)	(2800#)	(2000#)	CROP YEAR 9 (6000#)	(4500#)	(3400#)	(2800#)	(2000#)
Disk	5/05	12	SB	0.10	0.180	0.2100	0.2300	0.2500	0.2700		0.0180	0.0210	0.0230	0.0250	0.0270					
Plant Corn1	5/10																			
10%	6/01	22	1	0.12	0.150	0.1800	0.2100	0.2300	0.2500		0.0180	0.0216	0.0252	0.0276	0.0300					
50%	6/20	34	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	7/10	46	3	0.48	0.120	0.1300	0.1400	0.1400	0.1500		0.0576	0.0624	0.0672	0.0672	0.0720					
Harvest Corn1	10/15	94	4	0.04	0.200	0.2100	0.2600	0.3200	0.3900		0.0080	0.0084	0.0104	0.0128	0.0156	0.1172	0.1314	0.1486	0.1590	0.1734
Chisel	11/15	98	F	0.13	0.180	0.2100	0.2300	0.2500	0.2700		0.0234	0.0273	0.0299	0.0325	0.0351					
Disk	5/01	11	SB	0.11	0.180	0.2100	0.2300	0.2500	0.2700		0.0198	0.0231	0.0253	0.0275	0.0297					
Plant Corn2	5/10																			
10%	6/01	22	1	0.12	0.150	0.1800	0.2100	0.2300	0.2500		0.0180	0.0216	0.0252	0.0276	0.0300					
50%	6/20	34	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	7/10	46	3	0.48	0.120	0.1300	0.1400	0.1400	0.1500		0.0576	0.0624	0.0672	0.0672	0.0720					
Harvest Corn2	10/15	94	4	0.04	0.200	0.2100	0.2600	0.3200	0.3900		0.0080	0.0084	0.0104	0.0128	0.0156	0.1424	0.1608	0.1808	0.1940	0.2112
Chisel	11/15	98	F	0.12	0.180	0.2100	0.2300	0.2500	0.2700		0.0216	0.0252	0.0276	0.0300	0.0324					
Disk	4/25	10	SB	0.07	0.180	0.2100	0.2300	0.2500	0.2700		0.0126	0.0147	0.0161	0.0175	0.0189					
Plant Soybean	5/01																			
10%	5/20	17	1	0.05	0.150	0.1800	0.2100	0.2300	0.2500		0.0075	0.0090	0.0105	0.0115	0.0125					
50%	6/01	22	2	0.18	0.130	0.1500	0.1900	0.2200	0.2400		0.0234	0.0270	0.0342	0.0396	0.0432					
75%	7/01	40	3	0.53	0.120	0.1300	0.1400	0.1400	0.1500		0.0636	0.0689	0.0742	0.0742	0.0795					
Harvest Soybean	10/10	92	4	0.01	0.200	0.2100	0.2600	0.3200	0.3900		0.0020	0.0021	0.0026	0.0032	0.0039	0.1307	0.1469	0.1652	0.1760	0.1904
Disk	10/12	93	SB	0.03		0.2500	0.3200	0.3600	0.3800		0.0000	0.0075	0.0096	0.0108	0.0114					
Plant Wheat	10/15																			
10%	11/01	98	1	0.03		0.1800	0.2500	0.2900	0.3000			0.0054	0.0075	0.0087	0.0090					
50%	12/01	99	2	0.09		0.1300	0.1800	0.2100	0.2300			0.0117	0.0162	0.0189	0.0207					
75%	4/15	8	3	0.41		0.0200	0.0300	0.0300	0.0400			0.0082	0.0123	0.0123	0.0164					
Harvest Wheat	7/15	49	4	0.03		0.2600	0.2600	0.2600	0.2600			0.0078	0.0078	0.0078	0.0078		0.0406	0.0534	0.0585	0.0653
Disk	7/20	52	SB	0.43	0.190	0.2600	0.3200	0.3600	0.3800		0.0817	0.1118	0.1376	0.1548	0.1634					
Harrow	7/25																			
Seeding alfalfa	8/15																			
1st Cutting	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044					
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.1061	0.1362	0.1620	0.1792	0.1878
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.13	0.020	0.020	0.020	0.020	0.020		0.0026	0.0026	0.0026	0.0026	0.0026	0.0182	0.0182	0.0182	0.0182	0.0182
Chisel	4/15	8																		
	Rotation Total:			7.97							0.5546	0.6741	0.7682	0.8249	0.8863					
							Average Annual C-Value for Rotation:				0.0792	0.0843	0.0960	0.1031	0.1108					

Rotation 6: Corn/Soybean

EVENT 1	DATE 2	TABLE6 3	CRPSTA 4	EI 5	SOIL LOSS 6 (6000#)	(4500#)	(3400#)	(2600#)	(2000#)	SODFAC 7	C-VALUE 8 (6000#)	(4500#)	(3400#)	(2600#)	(2000#)	CROP YEAR 9 (6000#)	(4500#)	(3400#)	(2600#)	(2000#)
Disk	5/01	11	SB	0.11	0.180	0.2100	0.2300	0.2500	0.2700		0.0198	0.0231	0.0253	0.0275	0.0297					
Plant Corn1	5/10																			
10%	6/01	22	1	0.12	0.150	0.1800	0.2100	0.2300	0.2500		0.0180	0.0216	0.0252	0.0276	0.0300					
50%	6/20	34	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	7/10	48	3	0.48	0.120	0.1300	0.1400	0.1400	0.1500		0.0576	0.0624	0.0672	0.0672	0.0720					
Harvest Corn1	10/15	94	4	0.04	0.200	0.2100	0.2600	0.3200	0.3900		0.0080	0.0084	0.0104	0.0128	0.0156	0.1190	0.1335	0.1509	0.1615	0.1761
Chisel	11/15	98	F	0.12	0.180	0.2100	0.2300	0.2500	0.2700		0.0216	0.0252	0.0276	0.0300	0.0324					
Disk	4/25	10	SB	0.07	0.180	0.2100	0.2300	0.2500	0.2700		0.0126	0.0147	0.0161	0.0175	0.0189					
Plant Soybean	5/01																			
10%	5/20	17	1	0.05	0.150	0.1800	0.2100	0.2300	0.2500		0.0075	0.0090	0.0105	0.0115	0.0125					
50%	6/01	22	2	0.18	0.130	0.1500	0.1900	0.2200	0.2400		0.0234	0.0270	0.0342	0.0396	0.0432					
75%	7/01	40	3	0.53	0.120	0.1300	0.1400	0.1400	0.1500		0.0636	0.0689	0.0742	0.0742	0.0795					
Harvest Soybean	10/10	92	4	0.16	0.200	0.2100	0.2600	0.3200	0.3900		0.0320	0.0336	0.0416	0.0512	0.0624	0.1607	0.1784	0.2042	0.2240	0.2489
Chisel	4/15	8																		
	Rotation Total:			1.98							0.2797	0.3119	0.3551	0.3855	0.4250					
							Average Annual C-Value for Rotation:				0.1399	0.1560	0.1776	0.1928	0.2125					

Rotation 7: Corn/Wheat/Alfalfa(6 years)

EVENT	DATE	TABLE6	CRPSTA	EI	SOIL LOSS					SODFAC	C-VALUE					CROP YEAR				
1	2	3	4	5	6					7	8					9				
					(6000#)	(4500#)	(3400#)	(2600#)	(2000#)		(6000#)	(4500#)	(3400#)	(2600#)	(2000#)	(6000#)	(4500#)	(3400#)	(2600#)	(2000#)
Disk	4/20	9	SB	0.06	0.180	0.2100	0.2300	0.2500	0.2700		0.0108	0.0126	0.0138	0.0150	0.0162					
Plant Corn1	4/25																			
10%	5/15	15	1	0.10	0.150	0.1800	0.2100	0.2300	0.2500		0.0150	0.0180	0.0210	0.0230	0.0250					
50%	6/05	25	2	0.12	0.130	0.1500	0.1900	0.2200	0.2400		0.0156	0.0180	0.0228	0.0264	0.0288					
75%	6/25	37	3	0.54	0.120	0.1300	0.1400	0.1400	0.1500		0.0648	0.0702	0.0756	0.0756	0.0810					
Harvest Corn1	10/01	91	4	0.02	0.200	0.2100	0.2600	0.3200	0.3900		0.0040	0.0042	0.0052	0.0064	0.0078	0.1102	0.1230	0.1384	0.1464	0.1588
Disk	10/12	93	SB	0.03		0.2500	0.3200	0.3600	0.3800			0.0075	0.0096	0.0108	0.0114					
Plant Wheat	10/15																			
10%	11/01	98	1	0.03		0.1800	0.2500	0.2900	0.3000			0.0054	0.0075	0.0087	0.0090					
50%	12/01	99	2	0.09		0.1300	0.1800	0.2100	0.2300			0.0117	0.0162	0.0189	0.0207					
75%	4/15	8	3	0.41		0.0200	0.0300	0.0300	0.0400			0.0082	0.0123	0.0123	0.0164					
Harvest Wheat	7/15	49	4	0.03		0.2600	0.2600	0.2600	0.2600			0.0078	0.0078	0.0078	0.0078		0.0406	0.0534	0.0585	0.0653
Disk	7/20	52	SB	0.43	0.190	0.2600	0.3200	0.3600	0.3800		0.0817	0.1118	0.1376	0.1548	0.1634					
Harrow	7/25																			
Seeding alfalfa	8/15																			
1st Cutting	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044					
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.1061	0.1362	0.1620	0.1792	0.1878
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.13	0.020	0.020	0.020	0.020	0.020		0.0026	0.0026	0.0026	0.0026	0.0026	0.0182	0.0182	0.0182	0.0182	0.0182
Chisel	4/15	8																		
Rotation Total:				7.99							0.3145	0.3980	0.4520	0.4823	0.5101					
Average Annual C-Value for Rotation:											0.0449	0.0498	0.0565	0.0603	0.0638					

Rotation 8: Cotinuous Alfalfa (minimum of 6 years)

EVENT	DATE	TABLE6	CRPSTA	EI	SOIL LOSS					SODFAC	C-VALUE					CROP YEAR				
1	2	3	4	5	6					7	8					9				
					(6000#)	(4500#)	(3400#)	(2600#)	(2000#)		(6000#)	(4500#)	(3400#)	(2600#)	(2000#)	(6000#)	(4500#)	(3400#)	(2600#)	(2000#)
Disk	4/20	9	SB	0.34	0.190	0.2600	0.3200	0.3600	0.3800		0.0646	0.0884	0.1088	0.1224	0.1292					
Seeding alfalfa	5/01																			
1st Cutting	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
2nd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
3rd Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0794	0.1032	0.1236	0.1372	0.1440
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.22	0.020	0.020	0.020	0.020	0.020		0.0044	0.0044	0.0044	0.0044	0.0044	0.0200	0.0200	0.0200	0.0200	0.0200
1st Cut	5/20	17	4	0.26	0.020	0.020	0.020	0.020	0.020		0.0052	0.0052	0.0052	0.0052	0.0052					
2nd Cut	7/05	43	4	0.21	0.020	0.020	0.020	0.020	0.020		0.0042	0.0042	0.0042	0.0042	0.0042					
3rd Cut	8/10	64	4	0.31	0.020	0.020	0.020	0.020	0.020		0.0062	0.0062	0.0062	0.0062	0.0062					
4th Cut	10/25	95	4	0.13	0.020	0.020	0.020	0.020	0.020		0.0026	0.0026	0.0026	0.0026	0.0026	0.0182	0.0182	0.0182	0.0182	0.0182
Chisel	4/15	8																		
	Rotation Total:			5.99							0.1776	0.2014	0.2218	0.2354	0.2422					
							Average Annual C-Value for Rotation:				0.0296	0.0336	0.0370	0.0392	0.0404					

APPENDIX B. AGNPS BATCH FILES

B.1 AGNPS3.BAT Printout

```
cd c:\karlam
replace2 -d temp.dat -o temp2.dat -c %1
cd c:\agnps
agrun c:\karlam\temp2.dat 0
cd c:\karlam
getdata4 -a temp2.nps -o c:\exsysp\return.dat
cd c:\exsysp
```

B.2 AGNPS4.BAT Printout

```
cd c:\karlam
replace2 -d temp.dat -o temp2.dat -c %1
cd c:\agnps
agrun c:\karlam\temp2.dat 0
cd c:\karlam
getdata4 -a temp2.nps -o c:\exsysp\return.dat
cd c:\exsysp
```

B.3 AGNPS1.BAT Printout

```
cd c:\karlam
getdata1 -d temp.dat -n temp2.dat -a temp2.nps -o c:\exsysp\return.dat
cd c:\exsysp
```

B.4 AGNPS2.BAT Printout

```
cd c:\karlam
replace -d temp.dat -o temp2.dat -c %1 -p %2
cd c:\agnps
agrun c:\karlam\temp2.dat 0
cd c:\karlam
getdata2 -a temp2.nps -o c:\exsysp\return.dat
cd c:\exsysp
```

APPENDIX C. EXSYSP MODEL

C.1.A REPORT GENERATOR (Conserve.Out) Printout

```
FILE CONSERVE
" "
"               EXPERT SYSTEM ON SOIL CONSERVATION PRACTICES"
"                              by"
"                           VIVIAN A. GO"
" "
" "
" "
FIRST "A. INPUT/OUTPUT DATA "
FIRST "-------------------- "
" "
[TR]
INPUT
C "Seeding to perennial grass" 1 /"TN = [[TN]]"
C "Seeding to perennial grass" 1 /"TN = [[CN]]"
" "
"Where:"
"  K   - Soil erodability factor    CN   - Recommended C-value"
"  S   - Land slope (%)             PN   - Recommended P-value"
"  ST  - Soil texture               TNN  - Soil loss with crop"
"  C   - Original C-value                  rotation recommendation only"
"  P   - Original P-value           TN   - Soil loss with crop rotation"
"  TAA - Soil loss before                  and conservation practice (OR"
"        recommendation (tons/acre)          soil loss for seeding to"
"                                   perennial grass (SPG) if the"
"                                   recommendation is SPG.)"
"@@012"
" "
" "
FIRST "B. RECOMMENDATION (Practice)"
FIRST "----------------------------"
" "
C "Conservation Tillage" =1 /T
C "Conservation Tillage" =1 /"  (A minimum of 30% spring residue is required.
                        No-till or minimum tillage" /T
C "Conservation tillage" =1 /"  using chisel should be used for this practice.)" /T
C "Retain present tillage system (Conventional)" =1 /T
C "Contouring" =1 /T
C "Seeding to perennial grass" =1 /T
```

```
C "Seeding to perennial grass" =1 /"  (Any field with slope 26% and above
                              should be seeded to perennial grass." /T
C "Seeding to perennial grass" =1 /"  There is no cost for conservation practice
                              for this system.  However, costs" /T
C "Seeding to perennial grass" =1 /"  considered are initial seeding and
                              maintenance costs.)" /T
C "Contouring with terracing" =1 /T
[TLENGHT] /F10.2 /,
C "Do not change existing system" =1 /T
C "Do not change existing system" =1 /"  (The present soil loss is less than the
                                allowable soil loss, therefore it" /T
C "Do not change existing system" =1 /"  is assumed that the system being used
                               in the area at present doesn't pose" /T
C "Do not change existing system" =1 /"  any risk to soil erosion.)" /T
C "No practice necessary" =1 /T
C "No practice necessary" =1 /"  (The crop rotation alone has reduced the soil
                          loss to an acceptable limit)" /T
" "
" "
" "
" "
FIRST "C. ECONOMIC ANALYSIS"
FIRST "--------------------"
" "
" "
[NOSYSCOST] /F18.2 /,
" "
"Offsite benefit per ton of soil saved ($/Ac/Yr) =          3.89"
" "
[SYSCOST] /F16.2 /,
" "
[YESYSCOST] /F12.2 /,
" "
[CONSPRACCPI] /F23.2 /,
" "
[SSYSCOST] /F8.2 /,
" "
[CPPEREN] /F28.2 /,
" "
V269 /F26.2 /,
[SB] >= .01
/"____________________________________________________________________________"
[SB] >= .01 /"NOTE:  If a farmer applies the recommended practice, "
```

```
[SB] >= .01 /"      a 500 acre farm will result to:"
" "
[FAC] /F11.2 /,
[FACFB] /F13.2 /,
[FB] /F15.2 /,
[SB] /F18.2 /,
[SBSPG] >= .01
/"______________________________________________________________"
[SBSPG] >= .01 /"NOTE: If a farmer seeds his farm to perennial grass instead
of"
[SBSPG] >= .01 /"      the desired crop rotation, a 500 acre farm will result to:"
" "
[FACSPG] /F17.2 /,
[FACFBSPG] /F13.2 /,
[FBSPG] /F15.2 /,
[SBSPG] /F18.2 /,
" "
ENDIF
CLOSE
DISPLAY CONSERVE
EXIT
Press any key to continue
```

C.1.B REPORT GENERATOR (Cons.Out) Printout

```
FILE CONSERVE
"               Expert System on Soil Conservation Practices"
"                              by"
"                          VIVIAN A. GO"
" "
" "
" "
FIRST "A. INPUT/OUTPUT DATA "
FIRST "-------------------- "
" "
[TR]
INPUT
" "
"Where:"
"  K   - Soil erodability factor     "
"  S   - Land slope (%)              "
"  ST  - Soil texture                "
"  C   - Original C-value            "
"  P   - Original P-value            "
"  TAA - Soil loss before            "
"        recommendation (tons/acre)  "
" "
" "
" "
FIRST "B. RECOMMENDATION (Practice)"
FIRST "----------------------------"
" "
C "Do not change existing system" =1 /T
C "Do not change existing system" =1 /"  (The present soil loss is less than the allowable soil loss, therefore it" /T
C "Do not change existing system" =1 /"  is assumed that the system being used in the area at present doesn't pose" /T
C "Do not change existing system" =1 /"  any risk to soil erosion.)" /T
" "
ENDIF
CLOSE
DISPLAY CONSERVE
EXIT
Press any key to continue
```

C.2 EXSYSP RULE-BASE Printout

RULE NUMBER: 1
IF:
The major soil type in the area is {Aurelius muck}

THEN:
[TR] IS GIVEN THE VALUE 1

REFERENCE:
TR (allowable soil loss in tons/acre): Soil Survey of Ingham County, MI. page 140-144, col. 10

RULE NUMBER: 2
IF:
The major soil type in the area is {Histosols and Aquents, ponded}

THEN:
[TR] IS GIVEN THE VALUE 2

REFERENCE:
TR (allowable soil loss in tons/acre): Soil Survey of Ingham County, MI. page 140-144, col. 10

RULE NUMBER: 3
IF:
The major soil type in the area is {Eleva Variant channery sandy loam, 2-6% slopes} OR {Lenawee silty clay loam}

THEN:
[TR] IS GIVEN THE VALUE 3

REFERENCE:
TR (allowable soil loss in tons/acre): Soil Survey of Ingham County, MI. page 140-144, col. 10

RULE NUMBER: 4
IF:
The major soil type in the area is {Adrian muck} OR {Boyer sandy loam, 0-6% slopes} OR {Boyer-Spinks loamy sands, 12-18% slopes} OR {Boyer-Spinks loamy sands, 18-30% slopes} OR {Edwards muck} OR {Gilford sandy loam} OR {Marlette-Boyer complex, 18-25% slopes} OR {Matherton sandy loam, 0-3% slopes} OR {Sebewa loam} OR {Urban land-Boyer-Spinks complex, 0-10% slopes}

THEN:
[TR] IS GIVEN THE VALUE 4

REFERENCE:
TR (allowable soil loss in tons/acre): Soil Survey of Ingham County, MI. page 140-144, col. 10

RULE NUMBER: 5
IF:
The major soil type in the area is {Others}

THEN:
[TR] IS GIVEN THE VALUE 5

REFERENCE:
TR (allowable soil loss in tons/acre): Soil Survey of Ingham County, MI. page 140-144, col. 10

RULE NUMBER: 6
RULE: [tr] > [ta]
IF:
[TR] > [TAA]

THEN:
> Do not change existing system - Confidence=1
and: T> The present soil loss is less than the allowable soil loss, therefore it is assumed that system being used in the area at present doesn't pose any risk of soil erosion.
and: [X] IS GIVEN THE VALUE [ST]
and: X> CLEAR([TA])
and: X> STOP
and: X> REPORT(cons.out)

RULE NUMBER: 7
RULE: cropro1
IF:
The present crop yield range per acre is {High or >= 126 bushels}
and: The desired rotation is {C/C/Sb/W seeded to red clover.}

THEN:
[CN] IS GIVEN THE VALUE ([COR1Q13]+[COR2Q20]+[SOYQ27])/3
and: the rotation is {1}

NOTE:
A yield of 126 bushels or greater will provide an approximate residue of 6000 lbs. Also, there is no C-value for wheat, 6000#.

REFERENCE:
126 bushels or greater yield = 6000lbs: Agriculture Handbook 537, Footnotes from Table5, page 24.

RULE NUMBER: 8
RULE: cropro2
IF:
The present crop yield range per acre is {High or >= 126 bushels}
and: The desired rotation is {C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE ([COR1Q58]+[SOYQ65])/2
and: the rotation is {2}

NOTE:
A yield of 126 bushels or greater will provide an approximate residue of 6000 lbs. Also, there is no C-value for wheat, 6000#.

REFERENCE:
126 bushels or greater yield = 6000lbs: Agriculture Handbook 537, Footnotes from Table5, page 24.

RULE NUMBER: 9
RULE: cropro3
IF:
The present crop yield range per acre is {High or >= 126 bushels}
and: The desired rotation is {C/C/C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE ([COR1Q94]+[COR2Q101]+[COR3Q108]+[SOYQ115])/4
and: the rotation is {3}

NOTE:
A yield of 126 bushels or greater will provide an approximate residue of 6000 lbs. Also, there is no C-value for wheat, 6000#.

REFERENCE:
126 bushels or greater yield = 6000lbs: Agriculture Handbook 537, Footnotes from Table5, page 24.

RULE NUMBER: 10
RULE: cropro4
IF:
The present crop yield range per acre is {High or >= 126 bushels}
and: The desired rotation is {C/C/Sb/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1Q142]+[COR2Q149]+[SOYQ156]+[ALBQ170]+([ALMQ174]*4)+[ALLQ190
])/9
and: the rotation is {4}

NOTE:
A yield of 126 bushels or greater will provide an approximate residue of 6000 lbs. Also, there is no C-value for wheat, 6000#.

REFERENCE:
126 bushels or greater yield = 6000lbs: Agriculture Handbook 537, Footnotes from Table5, page 24.

RULE NUMBER: 11
RULE: cropro5
IF:
The present crop yield range per acre is {High or >= 126 bushels}
and: The desired rotation is {C/C/Sb/W/A(4)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1Q214]+[COR2Q221]+[SOYQ228]+[ALBQ242]+([ALMQ246]*2)+[ALLQ254
])/7
and: the rotation is {5}

NOTE:
A yield of 126 bushels or greater will provide an approximate residue of 6000 lbs. Also, there is no C-value for wheat, 6000#.

REFERENCE:
126 bushels or greater yield = 6000lbs: Agriculture Handbook 537, Footnotes from Table5, page 24.

RULE NUMBER: 12
RULE: cropro6
IF:
The present crop yield range per acre is {High or >= 126 bushels}
and: The desired rotation is {C/Sb}

THEN:
[CN] IS GIVEN THE VALUE ([COR1Q273]+[SOYQ280])/2
and: the rotation is {6}

NOTE:
A yield of 126 bushels or greater will provide an approximate residue of 6000 lbs. Also, there is no C-value for wheat, 6000#.

REFERENCE:
126 bushels or greater yield = 6000lbs: Agriculture Handbook 537, Footnotes from Table5, page 24.

RULE NUMBER: 13
RULE: cropro7
IF:
The present crop yield range per acre is {High or >= 126 bushels}
and: The desired rotation is {C/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1Q299]+[ALBQ313]+([ALMQ317]*4)+[ALLQ333])/7
and: the rotation is {7}

NOTE:
A yield of 126 bushels or greater will provide an approximate residue of 6000 lbs. Also, there is no C-value for wheat, 6000#.

REFERENCE:
126 bushels or greater yield = 6000lbs: Agriculture Handbook 537, Footnotes from Table5, page 24.

RULE NUMBER: 14
RULE: cropro8
IF:
The present crop yield range per acre is {High or >= 126 bushels}
and: The desired rotation is {Continuous Alfalfa for 6 years}

THEN:
[CN] IS GIVEN THE VALUE ([ALBQ351]+([ALMQ355]*4)+[ALLQ371])/6
and: the rotation is {8}

NOTE:
A yield of 126 bushels or greater will provide an approximate residue of 6000 lbs. Also, there is no C-value for wheat, 6000#.

REFERENCE:
126 bushels or greater yield = 6000lbs: Agriculture Handbook 537, Footnotes from Table5, page 24.

RULE NUMBER: 15
RULE: cropro9
IF:
The present crop yield range per acre is {Medium high or 100-125 bu}
and: The desired rotation is {C/C/Sb/W seeded to red clover.}

THEN:
[CN] IS GIVEN THE VALUE ([COR1R13]+[COR2R20]+[SOYR27]+[WHER35])/4
and: the rotation is {1}

NOTE:
A yield range of 100-125 bushels will produce an approximate residue of 4500#.

REFERENCE:
100-125 bu = 4500# residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 16
RULE: cropro10
IF:
The present crop yield range per acre is {Medium high or 100-125 bu}
and: The desired rotation is {C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE ([COR1R58]+[SOYR65]+[WHER71])/3
and: the rotation is {2}

NOTE:
A yield range of 100-125 bushels will produce an approximate residue of 4500#.

REFERENCE:
100-125 bu = 4500# residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 17
RULE: croprol1
IF:
The present crop yield range per acre is {Medium high or 100-125 bu}
and: The desired rotation is {C/C/C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE
([COR1R94]+[COR2R101]+[COR3R108]+[SOYR115]+[WHER121])/5
and: the rotation is {3}

NOTE:
A yield range of 100-125 bushels will produce an approximate residue of 4500#.

REFERENCE:
100-125 bu = 4500# residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 18
RULE: cropro12
IF:
The present crop yield range per acre is {Medium high or 100-125 bu}
and: The desired rotation is {C/C/Sb/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1R142]+[COR2R149]+[SOYR156]+[WHER162]+[ALBR170]+([ALMR174]*4
)+[ALLR190])/10
and: the rotation is {4}

NOTE:
A yield range of 100-125 bushels will produce an approximate residue of 4500#.

REFERENCE:
100-125 bu = 4500# residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 19
RULE: cropro13
IF:
The present crop yield range per acre is {Medium high or 100-125 bu}
and: The desired rotation is {C/C/Sb/W/A(4)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1R214]+[COR2R221]+[SOYR228]+[WHER234]+[ALBR242]+([ALMR246]*2
)+[ALLR254])/8
and: the rotation is {5}

NOTE:
A yield range of 100-125 bushels will produce an approximate residue of 4500#.

REFERENCE:
100-125 bu = 4500# residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 20
RULE: cropro14
IF:
The present crop yield range per acre is {Medium high or 100-125 bu}
and: The desired rotation is {C/Sb}

THEN:
[CN] IS GIVEN THE VALUE ([COR1R273]+[SOYR280])/2
and: the rotation is {6}

NOTE:
A yield range of 100-125 bushels will produce an approximate residue of 4500#.

REFERENCE:
100-125 bu = 4500# residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 21
RULE: cropro15
IF:
The present crop yield range per acre is {Medium high or 100-125 bu}
and: The desired rotation is {C/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1R299]+[WHER305]+[ALBR313]+([ALMR317]*4)+[ALLR333])/8
and: the rotation is {7}

NOTE:
A yield range of 100-125 bushels will produce an approximate residue of 4500#.

REFERENCE:
100-125 bu = 4500# residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 22
RULE: cropro16
IF:
The present crop yield range per acre is {Medium high or 100-125 bu}
and: The desired rotation is {Continuous Alfalfa for 6 years}

THEN:
[CN] IS GIVEN THE VALUE ([ALBR351]+([ALMR355]*4)+[ALLR371])/6
and: the rotation is {8}

NOTE:
A yield range of 100-125 bushels will produce an approximate residue of 4500#.

REFERENCE:
100-125 bu = 4500# residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 23
RULE: cropro17
IF:
The present crop yield range per acre is {Average or 75-99 bu.}
and: The desired rotation is {C/C/Sb/W seeded to red clover.}

THEN:
[CN] IS GIVEN THE VALUE ([COR1S13]+[COR2S20]+[SOYS27]+[WHES35])/4
and: the rotation is {1}

NOTE:
A yield of 75-99 bushels will produce an approximate residue of 3400#.

REFERENCE:
75-99 bushels=3400# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 24
RULE: cropro18
IF:
The present crop yield range per acre is {Average or 75-99 bu.}
and: The desired rotation is {C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE ([COR1S58]+[SOYS65]+[WHES71])/3
and: the rotation is {2}

NOTE:
A yield of 75-99 bushels will produce an approximate residue of 3400#.

REFERENCE:
75-99 bushels=3400# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 25
RULE: cropro19
IF:
The present crop yield range per acre is {Average or 75-99 bu.}
and: The desired rotation is {C/C/C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE
([COR1S94]+[COR2S101]+[COR3S108]+[SOYS115]+[WHES121])/5
and: the rotation is {3}

NOTE:
A yield of 75-99 bushels will produce an approximate residue of 3400#.

REFERENCE:
75-99 bushels=3400# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 26
RULE: cropro20
IF:
The present crop yield range per acre is {Average or 75-99 bu.}
and: The desired rotation is {C/C/Sb/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1S142]+[COR2S149]+[SOYS156]+[WHES162]+[ALBS170]+([ALMS174]*4
)+[ALLS190])/10
and: the rotation is {4}

NOTE:
A yield of 75-99 bushels will produce an approximate residue of 3400#.

REFERENCE:
75-99 bushels=3400# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 27
RULE: cropro21
IF:
The present crop yield range per acre is {Average or 75-99 bu.}
and: The desired rotation is {C/C/Sb/W/A(4)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1S214]+[COR2S221]+[SOYS228]+[WHES234]+[ALBS242]+([ALMS246]*2
)+[ALLS254])/8
and: the rotation is {5}

NOTE:
A yield of 75-99 bushels will produce an approximate residue of 3400#.

REFERENCE:
75-99 bushels=3400# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 28
RULE: cropro22
IF:
The present crop yield range per acre is {Average or 75-99 bu.}
and: The desired rotation is {C/Sb}

THEN:
[CN] IS GIVEN THE VALUE ([COR1S273]+[SOYS280])/2
and: the rotation is {6}

NOTE:
A yield of 75-99 bushels will produce an approximate residue of 3400#.

REFERENCE:
75-99 bushels=3400# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 29
RULE: cropro23
IF:
The present crop yield range per acre is {Average or 75-99 bu.}
and: The desired rotation is {C/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1S299]+[WHES305]+[ALBS313]+([ALMS317]*4)+[ALLS333])/8
and: the rotation is {7}

NOTE:
A yield of 75-99 bushels will produce an approximate residue of 3400#.

REFERENCE:
75-99 bushels=3400# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 30
RULE: cropro24
IF:
The present crop yield range per acre is {Average or 75-99 bu.}
and: The desired rotation is {Continuous Alfalfa for 6 years}

THEN:
[CN] IS GIVEN THE VALUE ([ALBS351]+([ALMS355]*4)+[ALLS371])/6
and: the rotation is {8}

NOTE:
A yield of 75-99 bushels will produce an approximate residue of 3400#.

REFERENCE:
75-99 bushels=3400# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 31
RULE: cropro25
IF:
The present crop yield range per acre is {Medium low or 60-74 bu.}
and: The desired rotation is {C/C/Sb/W seeded to red clover.}

THEN:
[CN] IS GIVEN THE VALUE ([COR1T13]+[COR2T20]+[SOYT27]+[WHET35])/4
and: the rotation is {1}

NOTE:
A yield of 60-74 bushels will produce an approximate residue of 2600#.

REFERENCE:
60-74 bushel yield=2600# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 32
RULE: cropro26
IF:
The present crop yield range per acre is {Medium low or 60-74 bu.}
and: The desired rotation is {C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE ([COR1T58]+[SOYT65]+[WHET71])/3
and: the rotation is {2}

NOTE:
A yield of 60-74 bushels will produce an approximate residue of 2600#.

REFERENCE:
60-74 bushel yield=2600# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 33
RULE: cropro27
IF:
The present crop yield range per acre is {Medium low or 60-74 bu.}
and: The desired rotation is {C/C/C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE
([COR1T94]+[COR2T101]+[COR3T108]+[SOYT115]+[WHET121])/5
and: the rotation is {3}

NOTE:
A yield of 60-74 bushels will produce an approximate residue of 2600#.

REFERENCE:
60-74 bushel yield=2600# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 34
RULE: cropro28
IF:
The present crop yield range per acre is {Medium low or 60-74 bu.}
and: The desired rotation is {C/C/Sb/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1T142]+[COR2T149]+[SOYT156]+[WHET162]+[ALBT170]+([ALMT174]*4
)+[ALLT190])/10
and: the rotation is {4}

NOTE:
A yield of 60-74 bushels will produce an approximate residue of 2600#.

REFERENCE:
60-74 bushel yield=2600# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 35
RULE: cropro29
IF:
The present crop yield range per acre is {Medium low or 60-74 bu.}
and: The desired rotation is {C/C/Sb/W/A(4)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1T214]+[COR2T221]+[SOYT228]+[WHET234]+[ALBT242]+([ALMT246]*2
)+[ALLT254])/8
and: the rotation is {5}

NOTE:
A yield of 60-74 bushels will produce an approximate residue of 2600#.

REFERENCE:
60-74 bushel yield=2600# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 36
RULE: cropro30
IF:
The present crop yield range per acre is {Medium low or 60-74 bu.}
and: The desired rotation is {C/Sb}

THEN:
[CN] IS GIVEN THE VALUE ([COR1T273]+[SOYT280])/2
and: the rotation is {6}

NOTE:
A yield of 60-74 bushels will produce an approximate residue of 2600#.

REFERENCE:
60-74 bushel yield=2600# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 37
RULE: cropro31
IF:
The present crop yield range per acre is {Medium low or 60-74 bu.}
and: The desired rotation is {C/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1T299]+[WHET305]+[ALBT313]+([ALMT317]*4)+[ALLT333])/8
and: the rotation is {7}

NOTE:
A yield of 60-74 bushels will produce an approximate residue of 2600#.

REFERENCE:
60-74 bushel yield=2600# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 38
RULE: cropro32
IF:
The present crop yield range per acre is {Medium low or 60-74 bu.}
and: The desired rotation is {Continuous Alfalfa for 6 years}

THEN:
[CN] IS GIVEN THE VALUE ([ALBT351]+([ALMT355]*4)+[ALLT371])/6
and: the rotation is {8}

NOTE:
A yield of 60-74 bushels will produce an approximate residue of 2600#.

REFERENCE:
60-74 bushel yield=2600# residue: Agriculture handbook 537, page 24.

RULE NUMBER: 39
RULE: cropro33
IF:
The present crop yield range per acre is {Low or <= 59 bu.}
and: The desired rotation is {C/C/Sb/W seeded to red clover.}

THEN:
[CN] IS GIVEN THE VALUE ([COR1U13]+[COR2U20]+[SOYU27]+[WHEU35])/4
and: the rotation is {1}

NOTE:
A yield of <=59 bushels will produce an approximate residue of 2000#.

REFERENCE:
<=59 bushels=2000 lbs residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 40
RULE: cropro34
IF:
The present crop yield range per acre is {Low or <= 59 bu.}
and: The desired rotation is {C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE ([COR1U58]+[SOYU65]+[WHEU71])/3
and: the rotation is {2}

NOTE:
A yield of <=59 bushels will produce an approximate residue of 2000#.
REFERENCE:
<=59 bushels=2000 lbs residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 41
RULE: cropro35
IF:
The present crop yield range per acre is {Low or <= 59 bu.}
and: The desired rotation is {C/C/C/Sb/W}

THEN:
[CN] IS GIVEN THE VALUE
([COR1U94]+[COR2U101]+[COR3U108]+[SOYU115]+[WHEU121])/5
and: the rotation is {3}

NOTE:
A yield of <=59 bushels will produce an approximate residue of 2000#.

REFERENCE:
<=59 bushels=2000 lbs residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 42
RULE: cropro36
IF:
The present crop yield range per acre is {Low or <= 59 bu.}
and: The desired rotation is {C/C/Sb/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1U142]+[COR2U149]+[SOYU156]+[WHEU162]+[ALBU170]+([ALMU174]*4
)+[ALLU190])/10
and: the rotation is {4}

NOTE:
A yield of <=59 bushels will produce an approximate residue of 2000#.

REFERENCE:
<=59 bushels=2000 lbs residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 43
RULE: cropro37
IF:
The present crop yield range per acre is {Low or <= 59 bu.}
and: The desired rotation is {C/C/Sb/W/A(4)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1U214]+[COR2U221]+[SOYU228]+[WHEU234]+[ALBU242]+([ALMU246]*2
)+[ALLU254])/8
and: the rotation is {5}

NOTE:
A yield of <=59 bushels will produce an approximate residue of 2000#.

REFERENCE:
<=59 bushels=2000 lbs residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 44
RULE: cropro38
IF:
The present crop yield range per acre is {Low or <= 59 bu.}
and: The desired rotation is {C/Sb}

THEN:
[CN] IS GIVEN THE VALUE ([COR1U273]+[SOYU280])/2
and: the rotation is {6}

NOTE:
A yield of <=59 bushels will produce an approximate residue of 2000#.

REFERENCE:
<=59 bushels=2000 lbs residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 45
RULE: cropro39
IF:
The present crop yield range per acre is {Low or <= 59 bu.}
and: The desired rotation is {C/W/A(6)}

THEN:
[CN] IS GIVEN THE VALUE
([COR1U299]+[WHEU305]+[ALBU313]+([ALMU317]*4)+[ALLU333])/8
and: the rotation is {7}

NOTE:
A yield of <=59 bushels will produce an approximate residue of 2000#.

REFERENCE:
<=59 bushels=2000 lbs residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 46
RULE: cropro40
IF:
The present crop yield range per acre is {Low or <= 59 bu.}
and: The desired rotation is {Continuous Alfalfa for 6 years}

THEN:
[CN] IS GIVEN THE VALUE ([ALBU351]+([ALMU355]*4)+[ALLU371])/6
and: the rotation is {8}

NOTE:
A yield of <=59 bushels will produce an approximate residue of 2000#.

REFERENCE:
<=59 bushels=2000 lbs residue: Agriculture Handbook 537, page 24.

RULE NUMBER: 47
RULE: cropprod1
IF:
The present crop yield range per acre is {High or >= 126 bushels}

THEN:
yield level for corn is {150 bushels}
and: yield level for soybean is {50 bushels}
and: yield level for wheat {60 bushels}

and: yield level for alfalfa- beginning year is {8 tons}
and: yield level for alfalfa- succeeding years is {8 tons}

RULE NUMBER: 48
RULE: cropprod2
IF:
The present crop yield range per acre is {Medium high or 100-125 bu}

THEN:
yield level for corn is {120 bushels}
and: yield level for soybean is {50 bushels}
and: yield level for wheat {60 bushels}
and: yield level for alfalfa- beginning year is {8 tons}
and: yield level for alfalfa- succeeding years is {8 tons}

RULE NUMBER: 49
RULE: cropprod3
IF:
The present crop yield range per acre is {Average or 75-99 bu.}

THEN:
yield level for corn is {90 bushels}
and: yield level for soybean is {40 bushels}
and: yield level for wheat {50 bushels}
and: yield level for alfalfa- beginning year is {6 tons}
and: yield level for alfalfa- succeeding years is {6 tons}

RULE NUMBER: 50
RULE: cropprod4
IF:
The present crop yield range per acre is {Medium low or 60-74 bu.}
or: The present crop yield range per acre is {Low or <= 59 bu.}

THEN:
yield level for corn is {90 bushels}
and: yield level for soybean is {30 bushels}
and: yield level for wheat {40 bushels}
and: yield level for alfalfa- beginning year is {4 tons}
and: yield level for alfalfa- succeeding years is {4 tons}

RULE NUMBER: 51
RULE: cropprod5
IF:
yield level for corn is {90 bushels}

THEN:
[VCOR] IS GIVEN THE VALUE [VCORD34]
and: [SCOR] IS GIVEN THE VALUE [SCORD72]

RULE NUMBER: 52
RULE: cropprod6
IF:
yield level for corn is {120 bushels}

THEN:
[VCOR] IS GIVEN THE VALUE [VCORF34]
and: [SCOR] IS GIVEN THE VALUE [SCORF72]

RULE NUMBER: 53
RULE: cropprod7
IF:
yield level for corn is {150 bushels}

THEN:
[VCOR] IS GIVEN THE VALUE [VCORH34]
and: [SCOR] IS GIVEN THE VALUE [SCORH72]

RULE NUMBER: 54
RULE: cropprod8
IF:
yield level for soybean is {30 bushels}

THEN:
[VSOY] IS GIVEN THE VALUE [VSOYD173]
and: [SSOY] IS GIVEN THE VALUE [SSOYD204]

RULE NUMBER: 55
RULE: cropprod9
IF:
yield level for soybean is {40 bushels}

THEN:
[VSOY] IS GIVEN THE VALUE [VSOYF173]
and: [SSOY] IS GIVEN THE VALUE [SSOYF204]

RULE NUMBER: 56
RULE: cropprod10
IF:
yield level for soybean is {50 bushels}

THEN:
[VSOY] IS GIVEN THE VALUE [VSOYH173]
and: [SSOY] IS GIVEN THE VALUE [SSOYH204]

RULE NUMBER: 57
RULE: cropprod11
IF:
yield level for wheat {40 bushels}

THEN:
[VWHE] IS GIVEN THE VALUE [VWHED105]
and: [SWHE] IS GIVEN THE VALUE [SWHED139]

RULE NUMBER: 58
RULE: cropprod12
IF:
yield level for wheat {50 bushels}

THEN:
[VWHE] IS GIVEN THE VALUE [VWHEF105]
and: [SWHE] IS GIVEN THE VALUE [SWHEF139]

RULE NUMBER: 59
RULE: cropprod13
IF:
yield level for wheat {60 bushels}

THEN:
[VWHE] IS GIVEN THE VALUE [VWHEH105]
and: [SWHE] IS GIVEN THE VALUE [SWHEH139]

RULE NUMBER: 60
RULE: cropprod14
IF:
yield level for alfalfa- beginning year is {4 tons}

THEN:
[VALB] IS GIVEN THE VALUE [VALBD297]
and: [SALB] IS GIVEN THE VALUE [SALBD359]

RULE NUMBER: 61
RULE: cropprod15
IF:
yield level for alfalfa- beginning year is {6 tons}

THEN:
[VALB] IS GIVEN THE VALUE [VALBF297]
and: [SALB] IS GIVEN THE VALUE [SALBF359]

RULE NUMBER: 62
RULE: cropprod16
IF:
yield level for alfalfa- beginning year is {8 tons}

THEN:
[VALB] IS GIVEN THE VALUE [VALBH297]
and: [SALB] IS GIVEN THE VALUE [SALBH359]

RULE NUMBER: 63
RULE: cropprod17
IF:
yield level for alfalfa- succeeding years is {4 tons}

THEN:
[VALS] IS GIVEN THE VALUE [VALSD330]
and: [SALS] IS GIVEN THE VALUE [SALSD392]

RULE NUMBER: 64
RULE: cropprod18
IF:
yield level for alfalfa- succeeding years is {6 tons}

THEN:
[VALS] IS GIVEN THE VALUE [VALSF330]
and: [SALS] IS GIVEN THE VALUE [SALSF392]

RULE NUMBER: 65
RULE: cropprod19
IF:
yield level for alfalfa- succeeding years is {8 tons}

THEN:
[VALS] IS GIVEN THE VALUE [VALSH330]
and: [SALS] IS GIVEN THE VALUE [SALSH392]

RULE NUMBER: 66
RULE: cropprod21
IF:
The present tillage system is {Conventional}
and: the rotation is {1}

THEN:
[CPCR11] IS GIVEN THE VALUE (([VCOR]*2)+[VSOY]+[VWHE]+[VCLO])/4

RULE NUMBER: 67
RULE: cropprod22
IF:
The present tillage system is {Conservation}
and: the rotation is {1}

THEN:
[CPCR11] IS GIVEN THE VALUE (([SCOR]*2)+[SSOY]+[SWHE]+[SCLO])/4

RULE NUMBER: 68
RULE: cropprod24
IF:
The present tillage system is {Conventional}
and: the rotation is {2}

THEN:
[CPCR22] IS GIVEN THE VALUE ([VCOR]+[VSOY]+[VWHE])/3

RULE NUMBER: 69
RULE: cropprod25
IF:
The present tillage system is {Conservation}
and: the rotation is {2}

THEN:
[CPCR22] IS GIVEN THE VALUE ([SCOR]+[SSOY]+[SWHE])/3

RULE NUMBER: 70
RULE: cropprod27
IF:
The present tillage system is {Conventional}
and: the rotation is {3}

THEN:
[CPCR33] IS GIVEN THE VALUE (([VCOR]*3)+[VSOY]+[VWHE])/5

RULE NUMBER: 71
RULE: cropprod28
IF:
The present tillage system is {Conservation}
and: the rotation is {3}

THEN:
[CPCR33] IS GIVEN THE VALUE (([SCOR]*3)+[SSOY]+[SWHE])/5

RULE NUMBER: 72
RULE: cropprod30
IF:
The present tillage system is {Conventional}
and: the rotation is {4}

THEN:
[CPCR44] IS GIVEN THE VALUE
(([VCOR]*2)+[VSOY]+[VWHE]+[VALB]+([VALS]*5))/10

RULE NUMBER: 73
RULE: cropprod31
IF:
The present tillage system is {Conservation}
and: the rotation is {4}

THEN:
[CPCR44] IS GIVEN THE VALUE
(([SCOR]*3)+[SSOY]+[SWHE]+[SALB]+([SALS]*5))/10

RULE NUMBER: 74
RULE: cropprod33
IF:
> Retain present tillage system (Conventional)- Conf. = 1
and: the rotation is {5}

THEN:
[CPCR55] IS GIVEN THE VALUE
(([VCOR]*2)+[VSOY]+[VWHE]+[VALB]+([VALS]*3))/8

RULE NUMBER: 75
RULE: cropprod34
IF:
The present tillage system is {Conservation}
and: the rotation is {5}

THEN:
[CPCR55] IS GIVEN THE VALUE
(([SCOR]*2)+[SSOY]+[SWHE]+[SALB]+([SALS]*3))/8

RULE NUMBER: 76
RULE: cropprod36
IF:
The present tillage system is {Conventional}
and: the rotation is {6}

THEN:
[CPCR66] IS GIVEN THE VALUE ([VCOR]+[VSOY])/2

RULE NUMBER: 77
RULE: cropprod37
IF:
The present tillage system is {Conservation}
and: the rotation is {6}
THEN:
[CPCR66] IS GIVEN THE VALUE ([SCOR]+[SSOY])/2

RULE NUMBER: 78
RULE: cropprod39
IF:
The present tillage system is {Conventional}
and: the rotation is {7}
THEN:
[CPCR77] IS GIVEN THE VALUE ([VCOR]+[VWHE]+[VALB]+([VALS]*5))/8

RULE NUMBER: 79
RULE: cropprod40
IF:
The present tillage system is {Conservation}
and: the rotation is {7}

THEN:
[CPCR77] IS GIVEN THE VALUE ([SCOR]+[SWHE]+[SALB]+([SALS]*5))/8

RULE NUMBER: 80
RULE: cropprod42
IF:
The present tillage system is {Conventional}
and: the rotation is {8}

THEN:
[CPCR88] IS GIVEN THE VALUE ([VALB]+([VALS]*5))/6

RULE NUMBER: 81
RULE: cropprod43
IF:
The present tillage system is {Conservation}
and: the rotation is {8}

THEN:
[CPCR88] IS GIVEN THE VALUE ([SALB]+([SALS]*5))/6

RULE NUMBER: 82
RULE: cpi1
IF:
The year of study is {1987}

THEN:
[CPI] IS GIVEN THE VALUE 1

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 83
RULE: cpi2
IF:
The year of study is {1988}
THEN:
[CPI] IS GIVEN THE VALUE 1.04

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 84
RULE: cpi3
IF:
The year of study is {1989}

THEN:
[CPI] IS GIVEN THE VALUE 1.09

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 85
RULE: cpi4
IF:
The year of study is {1990}

THEN:
[CPI] IS GIVEN THE VALUE 1.15

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 86
RULE: cpi5
IF:
The year of study is {1991}

THEN:
[CPI] IS GIVEN THE VALUE 1.19

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 87
RULE: cpi6
IF:
The year of study is {1992}

THEN:
[CPI] IS GIVEN THE VALUE 1.23

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 88
RULE: cpi7
IF:
The year of study is {1993}

THEN:
[CPI] IS GIVEN THE VALUE 1.27

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 89
RULE: cpi8
IF:
The year of study is {1994}

THEN:
[CPI] IS GIVEN THE VALUE 1.31

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 90
RULE: cpi9
IF:
The year of study is {1995}

THEN:
[CPI] IS GIVEN THE VALUE 1.35

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 91
RULE: cpi10
IF:
The year of study is {1996}

THEN:
[CPI] IS GIVEN THE VALUE 1.39

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 92
RULE: cpi11
IF:
The year of study is {1997}

THEN:
[CPI] IS GIVEN THE VALUE 1.45

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 93
RULE: cpi12
IF:
The year of study is {1998}

THEN:
[CPI] IS GIVEN THE VALUE 1.50

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 94
RULE: cpi13
IF:
The year of study is {1999}

THEN:
[CPI] IS GIVEN THE VALUE 1.56

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 95
RULE: cpi14
IF:
The year of study is {2000}

THEN:
[CPI] IS GIVEN THE VALUE 1.61

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 96
RULE: cpi15
IF:
The year of study is {2001}

THEN:
[CPI] IS GIVEN THE VALUE 1.68

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 97
RULE: cpi16
IF:
The year of study is {2002}

THEN:
[CPI] IS GIVEN THE VALUE 1.75

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 98
RULE: cpi17
IF:
The year of study is {2003}

THEN:
[CPI] IS GIVEN THE VALUE 1.81

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 99
RULE: cpi18
IF:
The year of study is {2004}

THEN:
[CPI] IS GIVEN THE VALUE 1.88

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 100
RULE: cpi19
IF:
The year of study is {2005}

THEN:
[CPI] IS GIVEN THE VALUE 1.96

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 101
RULE: cpi20
IF:
The year of study is {2006}

THEN:
[CPI] IS GIVEN THE VALUE 2.04

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 102
RULE: cpi21
IF:
The year of study is {2007}

THEN:
[CPI] IS GIVEN THE VALUE 2.11

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 103
RULE: cpi22
IF:
The year of study is {2008}
THEN:
[CPI] IS GIVEN THE VALUE 2.19

REFERENCE:
CPI values are based from Dr. Jake Ferris' Economic Forecasting Model (Ag. Economics Dept, MSU) with 1983 as the base year. CPI for this study are computed and adjusted using 1987 as the base year.

RULE NUMBER: 104
RULE: syscost1
IF:
[TAA] >= 1
and: the rotation is {1}

THEN:
[NOSYSCOST] IS GIVEN THE VALUE [CPCR11]*[CPI]
and: [SYSCOST] IS GIVEN THE VALUE ([TAA]-[TNN])*3.89*[CPI]
and: [X] IS GIVEN THE VALUE [ST]
and: X> CLEAR([TA])

NOTE:
$3.89 is the value of offsite benefits per tons of soil saved.

RULE NUMBER: 105
RULE: syscost2
IF:
[TAA] >= 1
and: the rotation is {2}

THEN:
[NOSYSCOST] IS GIVEN THE VALUE [CPCR22]*[CPI]
and: [SYSCOST] IS GIVEN THE VALUE ([TAA]-[TNN])*3.89*[CPI]
and: [X] IS GIVEN THE VALUE [ST]
and: X> CLEAR([TA])

NOTE:
$3.89 is the value of offsite benefits per tons of soil saved.

RULE NUMBER: 106
RULE: syscost3
IF:
[TAA] >= 1
and: the rotation is {3}

THEN:
[NOSYSCOST] IS GIVEN THE VALUE [CPCR33]*[CPI]
and: [SYSCOST] IS GIVEN THE VALUE ([TAA]-[TNN])*3.89*[CPI]
and: [X] IS GIVEN THE VALUE [ST]
and: X> CLEAR([TA])
NOTE:
~ $3.89 is the value of offsite benefits per tons of soil saved.

RULE NUMBER: 107
RULE: syscost4
IF:
[TAA] >= 1
and: the rotation is {4}

THEN:
[NOSYSCOST] IS GIVEN THE VALUE [CPCR44]*[CPI]
and: [SYSCOST] IS GIVEN THE VALUE ([TAA]-[TNN])*3.89*[CPI]
and: [X] IS GIVEN THE VALUE [ST]
and: X> CLEAR([TA])

NOTE:
$3.89 is the value of offsite benefits per tons of soil saved.

RULE NUMBER: 108
RULE: syscost5
IF:
[TAA] >= 1
and: the rotation is {5}

THEN:
[NOSYSCOST] IS GIVEN THE VALUE [CPCR55]*[CPI]
and: [SYSCOST] IS GIVEN THE VALUE ([TAA]-[TNN])*3.89*[CPI]
and: [X] IS GIVEN THE VALUE [ST]
and: X> CLEAR([TA])

NOTE:
$3.89 is the value of offsite benefits per tons of soil saved.

RULE NUMBER: 109
RULE: syscost6
IF:
[TAA] >= 1
and: the rotation is {6}

THEN:
[NOSYSCOST] IS GIVEN THE VALUE [CPCR66]*[CPI]
and: [SYSCOST] IS GIVEN THE VALUE ([TAA]-[TNN])*3.89*[CPI]
and: [X] IS GIVEN THE VALUE [ST]
and: X> CLEAR([TA])

NOTE:
$3.89 is the value of offsite benefits per tons of soil saved.

RULE NUMBER: 110
RULE: syscost7
IF:
[TAA] >= 1
and: the rotation is {7}

THEN:
[NOSYSCOST] IS GIVEN THE VALUE [CPCR77]*[CPI]
and: [SYSCOST] IS GIVEN THE VALUE ([TAA]-[TNN])*3.89*[CPI]
and: [X] IS GIVEN THE VALUE [ST]
and: X> CLEAR([TA])

NOTE:
$3.89 is the value of offsite benefits per tons of soil saved.

RULE NUMBER: 111
RULE: syscost8
IF:
[TAA] >= 1
and: the rotation is {8}

THEN:
[NOSYSCOST] IS GIVEN THE VALUE [CPCR88]*[CPI]
and: [SYSCOST] IS GIVEN THE VALUE ([TAA]-[TNN])*3.89*[CPI]
and: [X] IS GIVEN THE VALUE [ST]
and: X> CLEAR([TA])

NOTE:
$3.89 is the value of offsite benefits per tons of soil saved.

RULE NUMBER: 112
IF:
[TNN] < 1

THEN:
> No Practice Necessary - Confidence=1
and: X> STOP

RULE NUMBER: 113
RULE: cond21
IF:
[TNN] >= 1
and: The present tillage system is {Conventional}
and: [ST] = 3

THEN:
> Retain present tillage system (Conventional) - Confidence=1
and: X> CLEAR([TA])

RULE NUMBER: 114
RULE: cond22
IF:
[TNN] >= 1
and: The present tillage system is {Conventional}
and: [ST] <= 2 OR [ST] = 4

THEN:
> Conservation Tillage - Confidence=1
and: X> CLEAR([TA])

NOTE:
A minimum of 30% residue cover from previous crop is recommended for conservation tillage.

RULE NUMBER: 115
RULE: cond24
IF:
[TNN] >= 1
and: The present tillage system is {Conservation}
and: [ST] <= 4

THEN:
> Conservation Tillage - Confidence=1
and: X> CLEAR([TA])

RULE NUMBER: 116
RULE: peren1
IF:
[TNN] >= [TR]
and: [S] >= 26

THEN:
X> CLEAR(R 117-158)
and: X> CLEAR([CN])
and: X> [CN] IS GIVEN THE VALUE .016
and: X> CLEAR(C ALL)
and: X> CLEAR [TN]
and: X> [TN] IS GIVEN THE VALUE ([TAA]/[C])*.016
and: > Seeding to Perennial Grass (SPG) - Confidence=1
and: [CONSPRAC] IS GIVEN THE VALUE 0
and: [CONSPRACCPI] IS GIVEN THE VALUE [CONSPRAC]*[CPI]
and: [CPPEREN] IS GIVEN THE VALUE
((([CPPERG450]+([CPPERG500]*5))/6)-[CONSPRAC])*[CPI]
and: [PN] IS GIVEN THE VALUE [P]
and: [syscost9] IS GIVEN THE VALUE ([TAA]-[TN])*3.89*[CPI]
and: [FBSPG] IS GIVEN THE VALUE ([CPPEREN]-[NOSYSCOST])*500
and: [SBSPG] IS GIVEN THE VALUE ([SYSCOST9]-[SYSCOST])*500
and: [FACSPG] IS GIVEN THE VALUE [CONSPRACCPI]*500
and: [FACFBSPG] IS GIVEN THE VALUE [FACSPG]+[FBSPG]
and: X> STOP

NOTE:
There is no cost for conservation practice for seeding to perennial grass. However, the costs considered for this system is the initial seeding and maintenance from year to year, and the income from the pasture grass. It is assumed that the field will be seeded once every 6 years.

REFERENCE:
C-value: SCS Technical Guide, Section I-C. Table 3, page 30. (C=.09 for seeding year, no-till and C=.004 for established grass, Therefore C=.016 for a 7-year rotation). 26% slope recommendation: Troeh. Soil and Water Conservation for Productivity & Environmental Protection. page 326.

RULE NUMBER: 117
IF:
> Conservation Tillage- Conf. = 1
and: the rotation is {1}

THEN:
[CPCR1] IS GIVEN THE VALUE (([SCOR]*2)+[SSOY]+[SWHE]+[SCLO])/4

RULE NUMBER: 118
IF:
> Retain present tillage system (Conventional)- Conf. = 1
and: the rotation is {1}

THEN:
[CPCR1] IS GIVEN THE VALUE (([VCOR]*2)+[VSOY]+[VWHE]+[VCLO])/4

RULE NUMBER: 119
IF:
> Conservation Tillage- Conf. = 1
and: the rotation is {2}

THEN:
[CPCR2] IS GIVEN THE VALUE ([SCOR]+[SSOY]+[SWHE])/3

RULE NUMBER: 120
IF:
> Retain present tillage system (Conventional)- Conf. = 1
and: the rotation is {2}

THEN:
[CPCR2] IS GIVEN THE VALUE ([VCOR]+[VSOY]+[VWHE])/3

RULE NUMBER: 121
IF:
> Conservation Tillage- Conf. = 1
and: the rotation is {3}

THEN:
[CPCR3] IS GIVEN THE VALUE (([SCOR]*3)+[SSOY]+[SWHE])/5

RULE NUMBER: 122
IF:
> Retain present tillage system (Conventional)- Conf. = 1
and: the rotation is {3}

THEN:
[CPCR3] IS GIVEN THE VALUE (([VCOR]*3)+[VSOY]+[VWHE])/5

RULE NUMBER: 123
IF:
> Conservation Tillage- Conf. = 1
and: the rotation is {4}

THEN:
[CPCR4] IS GIVEN THE VALUE
(([SCOR]*2)+[SSOY]+[SWHE]+[SALB]+([SALS]*5))/10

RULE NUMBER: 124
IF:
> Retain present tillage system (Conventional)- Conf. = 1
and: the rotation is {4}

THEN:
[CPCR4] IS GIVEN THE VALUE
(([VCOR]*2)+[VSOY]+[VWHE]+[VALB]+([VALS]*5))/10

RULE NUMBER: 125
IF:
> Conservation Tillage- Conf. = 1
and: the rotation is {5}

THEN:
[CPCR5] IS GIVEN THE VALUE
(([SCOR]*2)+[SSOY]+[SWHE]+[SALB]+([SALS]*3))/8

RULE NUMBER: 126
IF:
The present tillage system is {Conventional}
and: the rotation is {5}

THEN:
[CPCR5] IS GIVEN THE VALUE
(([VCOR]*2)+[VSOY]+[VWHE]+[VALB]+([VALS]*3))/8

RULE NUMBER: 127
IF:
> Conservation Tillage- Conf. = 1
and: the rotation is {6}

THEN:
[CPCR6] IS GIVEN THE VALUE ([SCOR]+[SSOY])/2

RULE NUMBER: 128
IF:
> Retain present tillage system (Conventional)- Conf. = 1
and: the rotation is {6}

THEN:
[CPCR6] IS GIVEN THE VALUE ([VCOR]+[VSOY])/2

RULE NUMBER: 129
IF:
> Conservation Tillage- Conf. = 1
and: the rotation is {7}

THEN:
[CPCR7] IS GIVEN THE VALUE ([SCOR]+[SWHE]+[SALB]+([SALS]*5))/8

RULE NUMBER: 130
IF:
> Retain present tillage system (Conventional)- Conf. = 1

and: the rotation is {7}

THEN:
[CPCR7] IS GIVEN THE VALUE ([VCOR]+[VWHE]+[VALB]+([VALS]*5))/8

RULE NUMBER: 131
IF:
> Conservation Tillage- Conf. = 1

and: the rotation is {8}

THEN:
[CPCR8] IS GIVEN THE VALUE ([SALB]+([SALS]*5))/6

RULE NUMBER: 132
IF:
> Retain present tillage system (Conventional)- Conf. = 1

and: the rotation is {8}

THEN:
[CPCR8] IS GIVEN THE VALUE ([VALB]+([VALS]*5))/6

RULE NUMBER: 133
RULE: loslope1
IF:
[TNN] >= 1
and: [S] >= 1
and: [S] <= 2.9

THEN:
> Contouring - Confidence=1

and: [PN] IS GIVEN THE VALUE 0.60

REFERENCE:
P-value: Agriculture Handbook, Table 13, page 35.

RULE NUMBER: 134
RULE: loslope2
IF:
[TNN] >= 1
and: [S] >= 3
and: [S] <= 6.9

THEN:
> Contouring - Confidence=1

and: [PN] IS GIVEN THE VALUE .50

REFERENCE:
P-value: Agriculture Handbook, Table 13, page 35.

RULE NUMBER: 135
RULE: moslope1
IF:
[TNN] >= 1
and: [K] <= 0.23
and: [S] >= 7
and: [S] <= 8.9

THEN:
> Contouring - Confidence=1
and: [PN] IS GIVEN THE VALUE 0.5

REFERENCE:
K-value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-value: Agriculture Handbook, Table 13 page 35.

RULE NUMBER: 136
RULE: moslope2
IF:
[TNN] >= 1
and: [K] <= 0.23
and: [S] >= 9
and: [S] <= 12.9

THEN:
> Contouring - Confidence=1
and: [PN] IS GIVEN THE VALUE .6

REFERENCE:
K-value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-value: Agriculture Handbook, Table 13, page 35.

RULE NUMBER: 137
RULE: moslope3
IF:
[TNN] >= 1
and: [K] <= .23
and: [S] >= 13
and: [S] <= 16.9

THEN:
> Contouring - Confidence=1
and: [PN] IS GIVEN THE VALUE .7

REFERENCE:
K-value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-value: Agriculture Handbook, Table 13, page 35.

RULE NUMBER: 138
RULE: moslope4
IF:
[TNN] >= 1

and: [K] <= .23
and: [S] >= 17
and: [S] <= 18.9

THEN:
> Contouring - Confidence=1
and: [PN] IS GIVEN THE VALUE .8

REFERENCE:
K-value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-value: Agriculture Handbook, Table 13, page 35.

RULE NUMBER: 139
RULE: moslope5
IF:
[TNN] >= 1
and: [K] >= .24
and: [S] >= 7
and: [S] <= 8.9

THEN:
> Contouring - Confidence=1
and: [PN] IS GIVEN THE VALUE .5

REFERENCE:
K-value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-value: Agriculture Handbook, Table 13, page 35.

RULE NUMBER: 140
RULE: moslope6
IF:
[TNN] >= 1
and: [K] >= .24
and: [S] = 9
and: [S] <= 9.9

THEN:
> Contouring - Confidence=1
and: [PN] IS GIVEN THE VALUE .6

REFERENCE:
K-value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-value: Agriculture Handbook, Table 13, page 35.

RULE NUMBER: 141
RULE: moslope7
IF:
[TNN] >= 1
and: [K] >= .24
and: [S] >= 10
and: [S] <= 12.9

THEN:
> Contouring with Terracing - Confidence=1

and: [PN] IS GIVEN THE VALUE .12

REFERENCE:
K-value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-value: Agriculture Handbook, Table 15, page 37.

RULE NUMBER: 142
RULE: moslope8
IF:
[TNN] >= 1
and: [K] >= .24
and: [S] >= 13
and: [S] <= 16.9

THEN:
> Contouring with Terracing - Confidence=1

and: [PN] IS GIVEN THE VALUE .14

REFERENCE:
K-value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-value: Agriculture Handbook, Table 15, page 37.

RULE NUMBER: 143
RULE: moslope9
IF:
[TNN] >= 1
and: [K] >= .24
and: [S] >= 17
and: [S] <= 18.9

THEN:
> Contouring with Terracing - Confidence=1

and: [PN] IS GIVEN THE VALUE .16

REFERENCE:
K-value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-value: Agriculture Handbook, Table 15, page 37.

RULE NUMBER: 144
RULE: hislope2
IF:
[TNN] >= 1
and: [S] >= 19
and: [S] <= 20.9

THEN:
> Contouring with Terracing - Confidence=1

and: [PN] IS GIVEN THE VALUE .16

NOTE:
Terrace is a graded channel with grassed outlet.

REFERENCE:
Classification of slope to low, medium, high: Mich Soil Erosion and Sedimentation Guidebook, page 52. P=.16: Agriculture Handbook 282, Table 15, page 37.

RULE NUMBER: 145
RULE: hislope3
IF:
    [TNN] >= 1
and: [S] >= 21
and: [S] <= 25.9

THEN:
    > Contouring with Terracing - Confidence=1
and: [PN] IS GIVEN THE VALUE .18

NOTE:
Terrace has graded channel with grassed outlet

REFERENCE:
Classification of slope to low, medium, high: Mich Soil Erosion and Sedimentation Guidebook, page 52. P=.18: Agriculture Handbook 282, Table 15, page 37.

RULE NUMBER: 146
RULE: hislope4
IF:
    > Contouring with Terracing- Conf. = 1

THEN:
    [TLENGHT] IS GIVEN THE VALUE
    (([TR]/(95*[K]*[CN]*[PN]))^2*73)/((.43+(.3*[S])+(.043*[S]^2))/6.5
    74)^2
and: [ACTER] IS GIVEN THE VALUE ((200/[TLENGHT])*217.8)*.04534

NOTE:
TLENGHT is the recommended maximum horizontal lenght of terrace.
Rainfall index (R) is given the value 95 in this study.
Since conservation cost of terracing is given in per ft. (45.34/1000 ft), this should be converted to per acre cost since all computations are in this unit. This is done by assuming a fixed lenght and width (L=217.8' W=200'). The W(idth) is then divided by the recommended horizontal terrace lenght (TLENGHT) to get the number of terraces in one acre field. The resulting value is multiplied by L to get the total length of the terrace in the one acre plot. This is again multiplied by 0.04534 ($45.34/1000ft) to get the conversion cost from per 1000ft to per acre.

REFERENCE:
K-Value: Michigan Soil Erosion Sediment Control Guidebook, page 60.
P-Value: Agriculture Handbook, Table 15, page 37. R-value = 95: Agriculture Handbook #537. Figure 1, for Sycamore Creek, Ingham County, MI location. $45.34 for terracing - Flat Rate Schedule-Costs of conservation Practices, Section V. 1988. USDA-SCS-MI Technical Guide.

RULE NUMBER: 147
RULE: Conspracl
IF:
> Retain present tillage system (Conventional)- Conf. = 1

THEN:
[CONSPRAC] IS GIVEN THE VALUE 0

NOTE:
Retain present tillage system refers to conventional tillage. The cost of conventional tillage is built-in on the costs of crop production.

RULE NUMBER: 148
RULE: Consprac2
IF:
> Conservation Tillage- Conf. = 1

THEN:
[CONSPRAC] IS GIVEN THE VALUE 0

NOTE:
The cost of conservation practice for conservation tillage is already built-in on the costs of crop production.

RULE NUMBER: 149
RULE: Consprac3
IF:
> Contouring- Conf. = 1

THEN:
[CONSPRAC] IS GIVEN THE VALUE [CONTOURH38]

REFERENCE:
Cost of contouring one acre land - Flat Rate Schedule-Costs of Conservation Practices, Section V. 1988. USDA-SCS-Michigan Technical Guide.

RULE NUMBER: 150
RULE: Consprac4
IF:
> Contouring with Terracing- Conf. = 1

THEN:
[CONSPRAC] IS GIVEN THE VALUE ([CONTOURH38]+[ACTER])

NOTE:
Since conservation cost of terracing is given in per ft.($45.34/1000 ft), this should be converted to per acre cost since all computations are in this unit. This is done by assuming a fixed lenght and width (L=217.8" W=200'). The W(idth) is then divided by the recommended horizontal length of terrace (l) to get the number of terraces in one acre field. The resulting value is multiplied by L to get the total length of terrace in the one acre plot. This is again multiplied by 0.04534 ($45.34/1000ft) to get the conversion cost from per 1000ft to per acre.

REFERENCE:
$45.34 for terracing - Flat Rate schedule-Cost of Conservation Practices, Section V.1988. USDA-SCS-Michigan Technical Guide.

RULE NUMBER: 151
RULE: ssyscost1
IF:
[TNN] >= 1
and: [S] <= 25.9
and: the rotation is {1}

THEN:
[YESYSCOST] IS GIVEN THE VALUE ([CPCR1]-[CONSPRAC])*[CPI]
and: [CONSPRACCPI] IS GIVEN THE VALUE [CONSPRAC]*[CPI]
and: [SSYSCOST] IS GIVEN THE VALUE ([TAA]-[TN])*3.89*[CPI]
and: [FB] IS GIVEN THE VALUE ([YESYSCOST]-[NOSYSCOST])*500
and: [SB] IS GIVEN THE VALUE ([SSYSCOST]-[SYSCOST])*500
and: [FAC] IS GIVEN THE VALUE [CONSPRACCPI]*500
and: [FACFB] IS GIVEN THE VALUE [FAC]+[FB]

RULE NUMBER: 152
RULE: ssyscost2
IF:
[TNN] >= 1
and: [S] <= 25.9
and: the rotation is {2}

THEN:
[YESYSCOST] IS GIVEN THE VALUE ([CPCR2]-[CONSPRAC])*[CPI]
and: [CONSPRACCPI] IS GIVEN THE VALUE [CONSPRAC]*[CPI]
and: [SSYSCOST] IS GIVEN THE VALUE ([TAA]-[TN])*3.89*[CPI]
and: [FB] IS GIVEN THE VALUE ([YESYSCOST]-[NOSYSCOST])*500
and: [SB] IS GIVEN THE VALUE ([SSYSCOST]-[SYSCOST])*500
and: [FAC] IS GIVEN THE VALUE [CONSPRACCPI]*500
and: [FACFB] IS GIVEN THE VALUE [FAC]+[FB]

RULE NUMBER: 153
RULE: ssyscost3
IF:
    [TNN] >= 1
and: [S] <= 25.9
and: the rotation is {3}

THEN:
    [YESYSCOST] IS GIVEN THE VALUE ([CPCR3]-[CONSPRAC])*[CPI]
and: [CONSPRACCPI] IS GIVEN THE VALUE [CONSPRAC]*[CPI]
and: [SSYSCOST] IS GIVEN THE VALUE ([TAA]-[TN])*3.89*[CPI]
and: [FB] IS GIVEN THE VALUE ([YESYSCOST]-[NOSYSCOST])*500
and: [SB] IS GIVEN THE VALUE ([SSYSCOST]-[SYSCOST])*500
and: [FAC] IS GIVEN THE VALUE [CONSPRACCPI]*500
and: [FACFB] IS GIVEN THE VALUE [FAC]+[FB]

RULE NUMBER: 154
RULE: ssyscost4
IF:
    [TNN] >= 1
and: [S] <= 25.9
and: the rotation is {4}

THEN:
    [YESYSCOST] IS GIVEN THE VALUE ([CPCR4]-[CONSPRAC])*[CPI]
and: [CONSPRACCPI] IS GIVEN THE VALUE [CONSPRAC]*[CPI]
and: [SSYSCOST] IS GIVEN THE VALUE ([TAA]-[TN])*3.89*[CPI]
and: [FB] IS GIVEN THE VALUE ([YESYSCOST]-[NOSYSCOST])*500
and: [SB] IS GIVEN THE VALUE ([SSYSCOST]-[SYSCOST])*500
and: [FAC] IS GIVEN THE VALUE [CONSPRACCPI]*500
and: [FACFB] IS GIVEN THE VALUE [FAC]+[FB]

RULE NUMBER: 155
RULE: ssyscost5
IF:
    [TNN] >= 1
and: [S] <= 25.9
and: the rotation is {5}

THEN:
    [YESYSCOST] IS GIVEN THE VALUE ([CPCR5]-[CONSPRAC])*[CPI]
and: [CONSPRACCPI] IS GIVEN THE VALUE [CONSPRAC]*[CPI]
and: [SSYSCOST] IS GIVEN THE VALUE ([TAA]-[TN])*3.89*[CPI]
and: [FB] IS GIVEN THE VALUE ([YESYSCOST]-[NOSYSCOST])*500
and: [SB] IS GIVEN THE VALUE ([SSYSCOST]-[SYSCOST])*500
and: [FAC] IS GIVEN THE VALUE [CONSPRACCPI]*500
and: [FACFB] IS GIVEN THE VALUE [FAC]+[FB]

RULE NUMBER: 156
RULE: ssyscost6
IF:
    [TNN] >= 1

and: [S] <= 25.9
and: the rotation is {6}

THEN:
[YESYSCOST] IS GIVEN THE VALUE ([CPCR6]-[CONSPRAC])*[CPI]
and: [CONSPRACCPI] IS GIVEN THE VALUE [CONSPRAC]*[CPI]
and: [SSYSCOST] IS GIVEN THE VALUE ([TAA]-[TN])*3.89*[CPI]
and: [FB] IS GIVEN THE VALUE ([YESYSCOST]-[NOSYSCOST])*500
and: [SB] IS GIVEN THE VALUE ([SSYSCOST]-[SYSCOST])*500
and: [FAC] IS GIVEN THE VALUE [CONSPRACCPI]*500
and: [FACFB] IS GIVEN THE VALUE [FAC]+[FB]

RULE NUMBER: 157
RULE: ssyscost7
IF:
[TNN] >= 1
and: [S] <= 25.9
and: the rotation is {7}

THEN:
[YESYSCOST] IS GIVEN THE VALUE ([CPCR7]-[CONSPRAC])*[CPI]
and: [CONSPRACCPI] IS GIVEN THE VALUE [CONSPRAC]*[CPI]
and: [SSYSCOST] IS GIVEN THE VALUE ([TAA]-[TN])*3.89*[CPI]
and: [FB] IS GIVEN THE VALUE ([YESYSCOST]-[NOSYSCOST])*500
and: [SB] IS GIVEN THE VALUE ([SSYSCOST]-[SYSCOST])*500
and: [FAC] IS GIVEN THE VALUE [CONSPRACCPI]*500
and: [FACFB] IS GIVEN THE VALUE [FAC]+[FB]

RULE NUMBER: 158
RULE: ssyscost8
IF:
[TNN] >= 1
and: [S] <= 25.9
and: the rotation is {8}

THEN:
[YESYSCOST] IS GIVEN THE VALUE ([CPCR8]-[CONSPRAC])*[CPI]
and: [CONSPRACCPI] IS GIVEN THE VALUE [CONSPRAC]*[CPI]
and: [SSYSCOST] IS GIVEN THE VALUE ([TAA]-[TN])*3.89*[CPI]
and: [FB] IS GIVEN THE VALUE ([YESYSCOST]-[NOSYSCOST])*500
and: [SB] IS GIVEN THE VALUE ([SSYSCOST]-[SYSCOST])*500
and: [FAC] IS GIVEN THE VALUE [CONSPRACCPI]*500
and: [FACFB] IS GIVEN THE VALUE [FAC]+[FB]

C.3 Sample EXSYSP RULE-BASE Output

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                    EXPERT SYSTEM ON SOIL CONSERVATION PRACTICES
                                        by
                                  VIVIAN A. GO


A. INPUT/OUTPUT DATA
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Allowable soil loss based on the major soil type (tons/acre/yr) = 1
The present tillage system is Conventional
The present crop yield range per acre is High or >= 126 bushels
The year of study is 1995
The major soil type in the area is Aurelius muck
The desired rotation is C/C/Sb/W seeded to red clover.
S = 4.7
P = 1
K = .26
C = .5
COR1Q13 = .05502
COR2Q20 = .11932
SOYQ27 = .10051
VCLO = -6.5
VCORH34 = 21.91
VSOYH173 = 125.779999
VWHEH105 = 41.400002
VALBH297 = -134.860001
VALSH330 = 242.800003
SCORH72 = 29.870001
SSOYH204 = 136.449997
SWHEH139 = 46.43
SALBH359 = -129.669998
SALSH392 = 242.800003
SCLO = -6.5
CONTOURH38 = 3.27
PN = .5
CN = .091617
TN = .52
ST = 2
TAA = 5.77
TNN = 1.04

Where:
  K   - Soil erodability factor     CN   - Recommended C-value
  S   - Land slope (%)              PN   - Recommended P-value
  ST  - Soil texture                TNN  - Soil loss with crop
  C   - Original C-value                   rotation recommendation only
  P   - Original P-value            TN   - Soil loss with crop rotation
  TAA - Soil loss before                   and conservation practice (OR
        recommendation (tons/acre)         soil loss for seeding to
                                           perrennial grass (SPG) if the
                                           recommendation is SPG.)
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B. RECOMMENDATION (Practice)

Conservation Tillage
(A minimum of 30% spring residue is required. No-till or minimum tillage using chisel should be used for this practice.)
Contouring

C. ECONOMIC ANALYSIS

Farmer's income with rotation only ($/Ac/Yr) =	69.02
Offsite benefit per ton of soil saved ($/Ac/Yr) =	3.89
Society's benefit from rotation only ($/Ac/Yr) =	24.84
Farmer's income w/ rotation and practice ($/Ac/Yr) =	75.28
Cost of conservation practice ($/Ac/Yr) =	4.41
Society's benefit from rotation and practice ($/Ac/Yr) =	27.57

NOTE: If a farmer applies the recommended practice, a 500 acre farm will result to:

Farmer's Additional Cost for practice ($/500 Acres) =	2,207.25
Farmer's Gross Benefit for the year ($/500 Acres) =	5,335.87
Farmer's Net Benefit for the year ($/500 Acres) =	3,128.62
Society's Benefit for the year ($/500 Acres) =	1,365.39