EVALUATING LAND MANAGEMENT SYSTEMS WITH A DECISION SUPPORT SYSTEM: AN APPLICATION TO THE MSEA SITE NEAR TREYNOR, IOWA

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INTRODUCTION

The long term data records of the watersheds in the Deep Loess Soil Major Land Resource Area near Treynor, Iowa make these watersheds ideal candidates for testing and evaluating the prototype decision support system (PDSS) for water quality modeling developed at the USDA-ARS Southwest Watershed Research Center. We present the results of evaluating several proposed alternative management systems on one of the watersheds with the PDSS. The management systems considered are those which are currently being tested at the Walnut Creek Management Systems Evaluation Area (MSEA) site in Iowa, as well as the current system on Watershed #1 at the Deep Loess Research Station MSEA site near Treynor, Iowa.

The PDSS simulation module, which includes a user-friendly input file generator, simulates hydrology, erosion, pesticides, nutrients, crop growth and economics on a field scale (see (5) for a description of the components and references). To consider simultaneously the economic, ground water, and surface water impacts of alternative management systems, a multi-objective decision model was designed which utilizes the information provided by the simulation model or historical data to recommend a management system from among a set of feasible alternatives for the given watershed. The method combines graphically based scoring functions and simple, yet powerful, linear programs to rank the alternative systems (4,5). This ranking is achieved in an objective manner under the guidelines of the decision maker. The PDSS decision module requires little interaction from the user if default values based on the conventional (current) system are used but allows the user to modify the importance given to different decision criteria.

A BRIEF DESCRIPTION OF THE DECISION COMPONENT OF THE PDSS

To compare noncommensurable decision criteria such as runoff volume, nitrogen in sediment, net income, and sediment yield, the PDSS converts the predicted data from the simulation model to values on a 0 to 1 scale using scoring functions which are either set by default in the PDSS or designed by the user of the system (5). The conventional or baseline system scores 0.5 for each decision variable by definition. Thus, a system that performs better than the conventional based on a certain criterion will score > 0.5 for that criterion and one that performs worse will score < 0.5.

The next step is to rank the decision criteria in order of importance. The PDSS allows the importance or priority order to be specified explicitly by the decision maker. In the absence of a preferred order of importance of the decision criteria, for example when policy or specific environmental problems are unknown, a default importance order is determined using the absolute value of the normalized slopes of the scoring functions at the baseline values. Based on the established importance order of the decision criteria, best and worst composite scores are determined for each of the alternatives by solving two linear programs (LPs) whose solutions are available in closed form (4). The objective values of these LPs are the most optimistic and pessimistic composite scores (weighted averages) which are consistent with the given importance order. The full range of possible scores for each alternative is then displayed and the alternatives ranked in descending order of the average of the best and worst composite scores.

DESCRIPTION OF THE SITE AND THE ALTERNATIVE SYSTEMS

Located near Treynor, Iowa, Watershed #1 is a 74.5 acre field, which has been planted annually with corn on the contour since research on the watershed was initiated in 1964 . The tillage practice currently used is deep disking (2). This system will constitute the conventional management system in our analysis. Twenty-four years of data from this watershed were used to calibrate the simulation model component of the PDSS.

Computer simulations of seven other management systems, defined similarly to those in (3), were performed in the simulation mode of the PDSS to predict the impact of these systems on the factors that effect water quality and farm income. The alternative systems considered are those which are currently being tested at the Walnut Creek MSEA site in Iowa. Together with the current system on Watershed #1, the management systems considered include four tillage practices, deep disking (DD), chisel plow (CP), ridge till (RT), and no till (NT), and two crop rotations, continuous corn (CC) and corn soybean rotation (CS). We will use the notation [RT, CS] to indicate the system which considers ridge till with a corn-soybean rotation. No costs or time lags for conversion of the watershed to an alternative system or changes in capital equipment were considered. In addition, all management systems were assummed to be equally affected by weed and insect pests. Each corn crop in the continuous corn rotation received (in the simulation) 168 kilograms of nitrogen per hectare per year (kg N/ha/yr) , while corn crops in the corn-soybean rotation received 140 kg N/ha/yr. At planting, a 28 kg N/ha application is simulated and the remaining N was added after planting as anhydrous ammonia in split application, except the no till system which received a single application. Nitrogen was not applied on any of the soybean crops.

Pesticide applications varied according to tillage practice and rotation. All continuous corn systems received simulated treatments with atrazine, metolachlor and terbufos. Corn-soybean rotations received simulated treatments of atrazine, alachlor and metolachlor. The corn-soybean ridge-till and no-till system also included treatment with paraquat. No-till systems also included simulated treatments with bromoxynil octan. ester and 2,4-D. The no-till corn-soybean system also included an application of metribuzin.

The prices of corn and soybeans were assumed to be the average of the 1988-1990 prices, $2.31/bushel and $6.23/bushel respectively (1).

RESULTS

Based on the results of the simulations, the decision criteria we consider are: sediment yield, N and phosphorus (P) surface losses (in runoff and with sediment), pesticide surface losses, N and pesticide losses in percolation and net income. The decision criteria considered and the scores for all alternatives appear in Table 1. Pesticides which did not show up in appreciable amounts in either runoff, percolation or with sediment over all systems and those that exhibited equal behavior over all systems were not included as decision variables. The scores were obtained by accepting the defaults of the PDSS. Note that the conventional system scores 0.5 for all criteria and that the CP systems dominate (score at least as high in all criteria and score better in at least one) the DD systems with respect to the same rotation.

We consider two importance orders of the decision criteria. The first is: 1. N in percolation; 2. N surface losses; 3. sediment yield; 4. net income; 5. alachlor surface losses; 6. terbufos surface losses; 7. atrazine surface losses; 8. metolachlor surface losses; 9. P surface losses; 10. 2,4-D loss in percolation; 11. paraquat surface losses; 12. 2,4-D surface losses. The second importance ordering we consider moves net income to first place and maintains the relative order of the other criteria.

The resulting range of scores for the alternatives under consideration given the score values and the first importance order above is displayed in Figure 1. Note that the best and worst composite scores for the conventional system, [DD,CC], are both 0.5 by design. Based on the average of the best and worst scores the systems are ranked: 1. [RT,CS]; 2. [CP,CS]; 3. [NT,CS]; 4. [CP,CC]; 5. [RT,CC]; 6. [DD,CS]; 7. [NT,CC]; 8. [DD,CC]. When net income is given the highest priority [NT,CS] switches places with [CP,CS] in the ordering above. Thus, in both cases the top three systems with respect to this analysis include the corn-soybean rotation.

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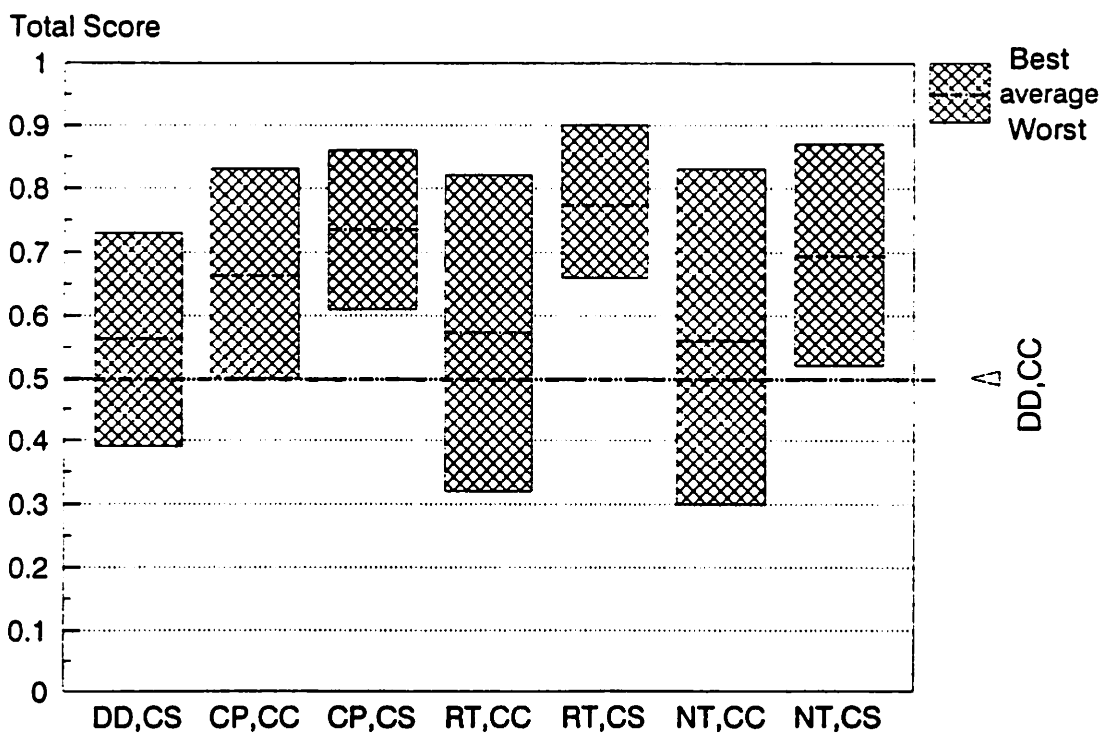
Figure 1. Range of scores for the eight systems



	DD,CC	DD,CS	CP,CC	CP,CS	RT,CC	RT,CS	NT,CC	NT,CS
net income	0.5	0.67	0.51	0.71	0.61	0.82	0.66	0.82
sediment	0.5	0.34	0.97	0.91	0.99	0.97	1.00	0.99
N (p)	0.5	0.74	0.50	0.73	0.32	0.66	0.30	0.52
N (s)	0.5	0.51	0.93	0.91	0.98	0.98	1.00	0.99
P (s)	0.5	0.38	0.88	0.81	0.93	0.93	0.96	0.95
alachlor (s)	0.5	0.00	0.50	0.06	0.50	0.22	0.50	0.47
terbufos (s)	0.5	1.00	0.86	1.00	0.98	1.00	0.98	1.00
atrazine (s)	0.5	0.92	0.88	0.97	0.45	0.81	0.44	0.85
metolachlor (s)	0.5	0.94	0.89	0.98	0.42	0.79	0.44	0.86
paraquat (s)	0.5	0.50	0.50	0.50	0.50	0.17	0.50	0.21
2,4-D (s)	0.5	0.50	0.50	0.50	0.50	0.50	0.40	0.46
2,4-D (p)	0.5	0.50	0.50	0.50	0.50	0.50	0.41	0.48

(s) = surface losses, (p) = losses in percolation

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