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A Decision Support System for Sustainable Farming

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U.S. farmers are faced with growing environmental concerns and rising costs associated with highly specialized farming operations. They are searching for farming systems that are both ecologically sound and economically viable. They are searching for sustainable systems of farming.

Many farmers are motivated by perceived risks that inputs upon which they depend today may not be available, may not be effective, or may cost much more in the future. Some are motivated by a desire to conserve and protect the long-run productivity of their resource base. Others realize the ultimate necessity of responding to social concerns regarding potential negative impacts of agriculture on the environment.

The current search for sustainability is centered on helping farmers develop more ecologically sound and economically viable farming systems with existing technology while searching for even more sustainable and profitable alternatives for the future. The emphasis is on substituting reliance on management of internal farm resources, particularly land and labor, for reliance on external inputs, particularly chemical pesticides and commercial fertilizers.

More efficient use of inputs may improve both the economic and ecologic aspects of conventional farming systems. However, more diversified systems of farming may be required for long-run sustainability. Diversified farmers traditionally have utilized crop rotations to control pests, conserve soil, and maintain productivity. Integrated cropping and livestock systems have been used to reduce feed costs, recycle waste, and stabilize farm incomes.

Diversified systems are less input-dependent and thus tend to be more ecologically sound than specialized systems of farming. However, diversified

farms are generally considered to be less productive and thus may be less profitable than more specialized systems.

Over time, increased emphasis on systems research and redirection of component technology development may enhance the productivity and economic sustainability of diversified farming systems. Ultimately, government programs that support specialized farming may have to instead be redirected to support diversification if ecological sustainability is to be achieved. However, many farmers may be able to improve the overall sustainability of their farming operations with existing technologies and existing farm programs through a systems approach to farm planning and management.

Farm Decision Support System

Lower-input, diversified farming systems are more complex and thus require more intensive "hands on" resource management than do higher-input, specialized systems. However, the potential synergistic gains from effective integration of enterprises and activities within diversified farming systems may more than offset the alternative gains from specialization.

A systems approach to farm planning and management may represent the best hope for achieving long-run sustainability with existing technologies and policies. Success in achieving this goal may depend at least in part on finding ways to combine new technologies, including microcomputers and biotechnology, with the tried-and-proven principles of objective-based management and diversification—old principles with new technologies.

Many microcomputer-based decision support systems have been developed to help farmers plan and manage various aspects of their farming operation. A whole range of systems address such tasks as nutrient management, pest management, soil conservation, energy conservation, financial management, and water quality protection. Some of these systems address more than one dimension

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of the management task. Few, if any, of these systems allow simultaneous consideration of resource conservation, environmental protection, productivity, and profitability, all of which are equally important in developing sustainable systems of farming.

A microcomputer-based farm decision support system has been developed under a project funded jointly by the Extension Service and Cooperative State Research Service of the U.S. Department of Agriculture to integrate all of these critical dimensions of sustainability into a single farm-planning process. This system, the Sustaining and Managing Resources for Tomorrow-Farm Resource Management System (SMART-FRMS), is the primary focus of the remainder of this paper.

Sustaining and Managing Resources for Tomorrow

The two basic components of the SMART-FRMS program are BUDGETOR, a module for resource management strategy (RMS) budgeting, and PLANETOR, the whole-farm planning module. PLANETOR utilizes databases made up of (1) RMS budgets (created by agricultural specialists using BUDGETOR), (2) local soil types and characteristics (developed by the Soil Conservation Service), and (3) pesticide characteristics (developed by the Agricultural Research Service (ARS) and Soil Conservation Service).

RMS Budgeting

The resource management strategy (RMS) associated with a cropping system consists of a crop sequence or rotation, an irrigation system (if any), a tillage system, a fertility system, and a pest management system. An RMS budget reflects the expected resource requirements, input requirements, input costs, production or output, gross and net returns, production and market risks, soil conservation impacts, and environmental impacts of the individual crop enterprises as components of a cropping system. An RMS budget contains all non-site-specific information needed to calculate expected soil loss, water quality risks, pesticide contact risks, gross returns, gross margin over purchased inputs, and net-return risks.

Default RMS databases will contain budgets for cropping and livestock systems deemed appropriate for the geographic region of application. These databases will be constructed by agricultural specialists using a basic financial budget format (FINPACK) augmented by additional resource and

environmental (R&E) components. The BUDGETOR program facilitates development of the R&E components of RMS budgets.

Default databases should include budgets for a wide range of cropping systems deemed appropriate for the geographic region where the SMART-FRMS program is to be used. A cropping system may include from one to twelve different crops. A monocrop system would have the same budget for each year. A given crop following different crops in different rotations may have a different budget for each rotation position. Different crops, of course, will have different budgets.

Each cropping "system" may be budgeted for several alternative input systems. An input system will reflect a specific fertility and pest management system. It is anticipated that most systems will be budgeted with unrestricted-input, reduced-input, and low-input RMS alternatives.

Unrestricted RMS budgets will reflect use of typical fertilizer and pesticide inputs for a particular cropping system on fields with no significant fertilizer or pesticide leaching, or runoff potential. Reduced-input RMS budgets will reflect some lower level of inputs suggested for fields with significant nutrient or pesticide risk potential. Low-input systems should reflect minimum levels of external inputs that specialists deem feasible for commercial production on fields with high nutrient or pesticide leaching, or runoff risks.

Each cropping system may be budgeted also for alternative tillage levels. Tillage options will range from unrestricted tillage to minimum tillage. Unrestricted tillage would be a suggested system for fields without erosion problems, while minimum tillage would be suggested for highly erodible fields. Each tillage system should be matched with an appropriate complement of inputs. Consequently, some systems may have no low-input, minimum-tillage RMS if such a combination of tillage and inputs is not considered feasible for a given cropping system.

In general, the alternative input systems will be designed to reduce water quality risks and other environmental risks by moving to lower-input alternatives. In general, alternative tillage systems will be designed to reduce soil erosion risks by moving to lower tillage levels. Irrigation systems, if any, will be specified as a part of each input system.

Farmers using an unrestricted system for one crop would likely use an unrestricted system for another in the same rotation, although unrestricted might imply different tillage and input regimens for different crops in the same rotation. Likewise, a farmer interested in a low-input alternative for

one crop likely would be interested in a similar system for other crops in the same rotation. Thus, the levels of inputs and tillage are identified for whole cropping systems rather than individual crops within a rotation.

Whole-Farm Planning

PLANETOR is a microcomputer-based decision support system that allows farmers to evaluate the potential impact of using various cropping systems or RMS's on their specific farms. PLANETOR is a field-based system. It allows the farmer to plan his or her farm field by field, year by year, and to assess the RMS implications for each field and each year for the whole farming system, including livestock and crops.

A typical SMART-FRMS user would begin with the PLANETOR component of the system. An agricultural specialist working with the farmer should have determined the basic rotations used by the farmer and have those RMS's available in the PLANETOR database at the time of the first planning session. Otherwise, the farmer and agent would have to add those budgets to the database before the planning process could begin. Most farmers will want to begin with an assessment of their current system before they begin to evaluate alternatives.

All site-specific information and associated yield and environmental-impact estimates are calculated within the PLANETOR program. Thus, the whole-farm planning process begins with a field-by-field inventory of the land or soil resources of the farm. Much of the information related to soil erosion and environmental vulnerability can be derived from the Soil Conservation Service (SCS) database of soil types. Soil texture (*K*), average slope (*S*), pesticide leachability, and pesticide surface-loss potential are identified in SCS databases of U.S. soils. Slope length (*SL*) must be added at the state level.

The specialist may need to enter slope lengths and should add the appropriate rainfall factor (*R*) for a specific farm location. The farmer will be asked to identify predominant soil types by field, indicate any planned conservation practices (*P*), and verify soil characteristics and environmental-impact estimates during the planning process.

Environmental and conservation impacts will be evaluated field by field over a planning period of up to twelve years. Estimates of soil loss, water quality risks from pesticides and fertilizers, and pesticide toxicity will be evaluated for cropping systems rather than for individual crops.

Financial and resource implications of alternative systems will be evaluated for the whole farm

for each year in the planning period. The acreage of each crop, pasture, and set-aside or conservation reserve is totaled and can be viewed for each year in the planning horizon. Expected revenues, input costs, gross margins, revenue risks, corn equivalents produced and needed, hay equivalents produced and needed, nitrogen balance, and non-renewable energy use also are summarized for each year.

The ecological vulnerability of each field is identified by color-highlighted codes for high, medium, and low levels of erodibility, pesticide leaching, and pesticide runoff potential. Each cropping system or RMS is color-coded with respect to its potential for soil loss, water quality, and pesticide toxicity risks. These two sets of codes, one for the field and the other for the RMS used on the field, are combined to generate a similar color-coded set of implications of using a given RMS on a given field.

Soil losses, estimated using the Universal Soil Loss Equation, are compared with soil-loss tolerance or *T* levels for predominant soil types. Pesticide water quality risks are assessed using soils-pesticide interaction values developed by SCS and ARS. Nitrogen water quality risks are derived by comparing estimates of nitrogen applied with estimates of nitrogen used at optimistic yield levels. Pesticide toxicity values are based on pesticide-warning-label information.

Each combination of field and RMS will have a color-coded indicator of soil loss, pesticide or nitrogen water quality risk, and input toxicity. A set of "red R's" for a given RMS on a given field, for example, would indicate severe ecological problems. Such problems would be associated with using a particular RMS on a particular field. The same RMS might be all right on another field, but a different RMS might be indicated for this particular field.

There will be relatively few alternatives for correcting the ecological vulnerability of a given field. Exceptions would be the use of contour tillage, terracing, strip cropping, or ridge tillage to reduce soil-loss potential. In most cases, farmers will have to change RMS's to correct ecological problems.

Each RMS will be identified as unrestricted, restricted, or low with respect to tillage and input levels. These identifications should be helpful to farmers in selecting alternative RMS's to address a particular problem. For example, a farmer with an erosion problem on a particular field might consider an RMS with less tillage. If, instead, the farmer is faced with a water quality problem, he or she might select a lower-input RMS. If the farmer has an erosion and water quality problem, he or

she may need to choose a longer crop rotation that includes meadow or some other soil-conserving crop.

A similar approach is used in the financial, risk, and resource sections of the program. An unacceptable income level for a given year might be addressed by shifting crops within rotations to get more high-income crops in a given year if the problem occurred only for one or two years. However, if the problem occurs for several years, the farmer might need to consider some more intensive RMS's that will generate more income in more years.

Inconsistencies between labor needed and labor availability are identified by month of the year. Season-labor deficits may be addressed by mixing spring-fall with winter-summer labor-demanding crops or by shifting rotations to mix high and low labor-demanding crops. If shifting rotations doesn't work, the farmer may consider changing to a lower-labor RMS or hiring labor during peak periods. Feed needs and production can be handled in a manner similar to labor.

Income or economic risks are indicated by probabilities that returns will fall below budgeted cost levels. The probability of failing to cover total costs of purchased inputs is calculated automatically. If the farmer enters off-farm income, family living expenses, debt payments, and overhead costs, these will be included in calculating a whole-farm net return. Unacceptable levels of expected net returns may suggest adding more intensive RMS's to the farm plan.

Acceptable expected returns with unacceptable risk levels may suggest a change in RMS's to add diversity through selection of alternative cropping systems, adding livestock to the system, or possibly considering off-farm employment for income stability. A diversification factor is calculated to indicate risk-reducing impacts of diversifying the farming system.

Changes in RMS's to solve financial, risk, or resource problems may generate ecological problems. However, no attempt is made to calculate an optimum system for a given farm. Farmers simply attempt to solve their ecological and economic problems by matching alternative resource management strategies (cropping systems with alternative tillage, input levels, and livestock enterprises) with their internal resources (land and labor).

Information describing each RMS, including any specialized machinery requirements, is included with RMS budgets and is available within the PLANETOR program. For example, a farmer may want to know what type of fertility program, tillage system, pest-control system, or labor requirements are assumed for a low-input soybean alternative in a corn-soybean rotation in field #3 in year 4 of the

plan currently on the screen. He would indicate with a key stroke that he wanted to review the basic data for this particular alternative.

The whole-farm-planner program assumes that a farmer has multiple objectives that include both ecological and economic factors. The ecological factors are soil loss, water quality, input toxicity, and nonrenewable energy use. Standards for the ecological factors will be predetermined. The economic factors include net returns or income, income risks, and utilization of land and labor. Farmers will need to develop their own income objectives from overall farm financial information.

Some farmers may be willing to settle for a whole-farm plan with a large number of red or warning indicators on the ecological factors to achieve acceptable expected results in the financial and resource areas. Others may be willing to tolerate lower economic returns or higher financial risks to achieve green lights or reduced risks in the ecological areas. Others will continue to explore alternatives until they have all ecological and economic indicators showing relatively safe outcomes or they will not farm. These choices are to be made by the individual farmer.

Customizing Budgets

Each farmer will need to work with his or her agent or specialist in customizing RMS budgets to reflect inputs and resources for tillage and cropping systems that the farmer actually expects to use. Using the PLANETOR program with default budgets allows the farmer to greatly narrow the range of RMS's to be considered for a given farming operation. However, the budgets ultimately must be customized to fit the individual farmer's production practices and expectations.

Changes from default values to customized values may significantly change the estimated outcome of an overall farm plan. For example, substituting one pesticide for another can change a given RMS from a high to a low pesticide-leaching or runoff potential. Changing a tillage method can affect soil loss. Changing yield levels can have major impacts on financial results.

In some cases, budget changes may be made to address specific environmental or economic problems. The PLANETOR program indicates the specific pesticides, by trade name, associated with potential water quality or pesticide toxicity problems. The farmer can easily evaluate the potential impact of using alternative pesticides on any particular field. Information of similar detail is provided for soil loss, resource use, or financial problems associated with any given RMS on a given field.

The farmer, however, should consider secondary implications of any change in budgets from default levels. For example, changing herbicides may also require changes in tillage, yield risk, and other factors. Changes in tillage likewise may require changes in herbicides, energy use, labor, and other elements of the RMS budget. RMS budgets represent systems of production. A change in any component of a system may require changes in other components.

Objectives of SMART-FRMS

The resource management strategy budgeting process allows agricultural specialists to reflect the full range of existing and future research results and information in a form that is readily usable by farmers. For example, ecologic and economic impacts of cover crops, intercropping, relay cropping, etc. in various rotations can be reflected in alternative RMS budgets. Uses of legumes and livestock manure for fertilizers, as well as alternative systems of fertilizer application, can be included among the RMS alternatives to be considered.

Impacts of alternative tillage systems and residue management programs on potential soil loss are an integral part of the budgeting process. Alternative weed-, insect-, and other pest-control systems, including specific pesticides uses and their potential human and water quality risks, will be reflected directly in the environmental components of each RMS budget.

The whole-farm planning process allows farmers to synthesize profitable and sustainable farming systems by integrating relevant RMS's with their particular set of land, labor, and management resources. They can select RMS's that are well suited for their soils, climate, and specific pest problems.

They can integrate systems of livestock and crop RMS's that tighten or complete nutrient cycles, facilitate energy flows, and enhance the ecologic and economic viability of their farming systems.

Farmers using PLANETOR can evaluate potential impacts of using various levels of nitrogen fertilizer and various pesticides on specific fields. They can match tillage systems and soil-conserving practices with specific slope and soil characteristics of fields to reduce erosion. They can assess risks through evaluation of diversification effects of alternative farming systems and develop systems that are resistant, resilient, and regenerative.

The SMART-FRMS program will not result in a recipe for success. SMART-FRMS is only a tool to facilitate farm planning and management. Farmers who choose an alternative to their current system will be advised to gather as much additional information as is available before adopting a new farming enterprise or practice. They will be strongly encouraged to talk with other farmers who have experience with the practice under consideration. They will be encouraged to visit other farms where the practice is used before they change their own operation. They will also be advised to work into any new system slowly so they can learn as they go.

The SMART-FRMS system will not ensure a more profitable or sustainable farming system. However, it will allow farmers to evaluate the potential impact of alternative technologies and strategies within the context of their particular farming situation without doing the necessary research and testing on their own. Using the SMART-FRMS program will not ensure success. However, it can be a valuable and important aid in taking the first step toward the goals of economic and ecologic sustainability.