## 4.1 Agricultural Production Management Overview

*Production management deals with how farmers combine land, water, commercial inputs, labor, and their management skills into practices and systems that produce food and fiber. On most acres, U.S. farmers follow a high-synthetic-input system, but increasingly some are trying reduced-synthetic-input and organic systems, or practices associated with these systems. A desire to reduce cost, environmental pressures and programs, and increasing market demand for organic food are some of the factors causing farmers to alter production management practices.*

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To sustain production over time, full-time farmers must make a profit and preserve their resource and financial assets. Society wants a wide variety of food and fiber products that are low cost, safe to consume, nutritious, and appetizing. Also, many persons want agricultural output to be produced using systems that preserve or even enhance the environment. These potentially competing goals are reflected not only in the inputs made available for production, but also in how the inputs are combined and managed at the farm level. Increasingly, U.S. farmers face economic incentives and environmental pressures to change from conventional systems to alternative ways of managing production.

Agricultural production management involves the combination of land, water, labor, and other inputs such as seeds, nutrients, pesticides, and machinery in the production of food and fiber. Farmers' objectives influence and complicate the process. These objectives include profit, income adequacy and stability, risk reduction, production sustainability, peer group acceptability, lifestyle maintenance, and environmental preservation or improvement.

### Production Management Categories

Production management can be divided into various categories of decisions that farmers make to produce food and fiber. The major ones are:

- **Soil and crop management—**deciding what crops and varieties to grow and in what sequence to utilize the soil's productive capacity, and what tillage, cultivation, and soil conservation measures to undertake to physically till and preserve the soil and conserve moisture.

- **Pest management—**determining weed, insect, disease, and other threats to crop growth, yield, and quality and what preventive or remedial actions to take against those pests (including whether to plant genetically modified varieties with pest management qualities), mindful of food and worker safety and environmental impacts.

- **Nutrient management—**determining the additional nutrients the soil needs for crop growth, and applying animal manure, compost, or commercial fertilizer in forms, amounts, and ways that foster crop yields and farm profitability, while reducing nutrient loss to the environment.

- **Water management—**determining the water needed for crop growth and applying that water efficiently, considering water availability, drainage, and offsite water quantity/quality impacts.

These categories of production management are each examined more fully in chapters 2.2, "Irrigation Water Management," 4.2, "Soil Management and Conservation," 4.3, "Pest Management," and 4.4, "Nutrient Management." The balance of this introductory chapter provides an overview of how specific management practices from these categories are combined into conventional (high-synthetic-input) and alternative farming systems, and of the multiple factors entering into farmers' production management decisions.

## Types of Farming Systems

A farming system is a combination of production management practices employed to achieve production, profit, and, increasingly, environmental and sustainability (maintaining longrun production capability) objectives (table 4.1.1). Thus, technically, there are as many farming systems as there are combinations of management practices. When deciding on a farming system to apply, farmers consider the interaction among the components and options. For example, use of a crop rotation may change the amounts and types of nutrients and pesticides needed. Use of no-till will generally reduce soil loss and conserve soil moisture, but may also change weed management needs, increase water infiltration, and reduce surface flows. Use of sprinkler irrigation generally increases yields and the need for application of nutrients.

One way of grouping farming systems is by the extent to which synthetic inputs are used and the precision with which they are applied (figure 4.1.1). Farming systems grouped this way range from conventional high-synthetic-input systems to organic systems that avoid synthetic inputs. In between are many systems and subsystems that reflect local resource situations, producer preferences, available technology, and business and economic decisions. (For some specific examples of farming systems combining various management options, see table 4.1.2.)

### *Conventional, High-Synthetic-Input Systems*

Farmers using high-synthetic-input systems produce the bulk of most U.S. field and specialty crops. These systems usually involve high reliance on synthetic pesticides and commercial fertilizers, and can be divided into three groups according to the general precision with which these inputs are applied.

*Low Precision*. Farmers in this group usually apply synthetic pesticides and fertilizers at traditional rates for the crop, even though these rates may exceed rates recommended for the area by the State University or Extension Service, just for extra "insurance of good yields." Application rates are usually constant across all areas of the field. Limited or no systematic soil testing or pest scouting occurs on the field. Fertilizer may be applied in the fall, increasing opportunity for loss to the environment. Pesticides are often applied on a set schedule whether or not pests are present. Use of crop rotations may also be limited. Much acreage is tilled by multiple implements to prepare a fairly clean seedbed, which may leave the field more vulnerable to soil and moisture loss. Among the three groups of conventional systems, low-precision farming is potentially the least friendly (most costly) to the environment (more likely to result in soil, pesticide, and nutrient loss to the environment).

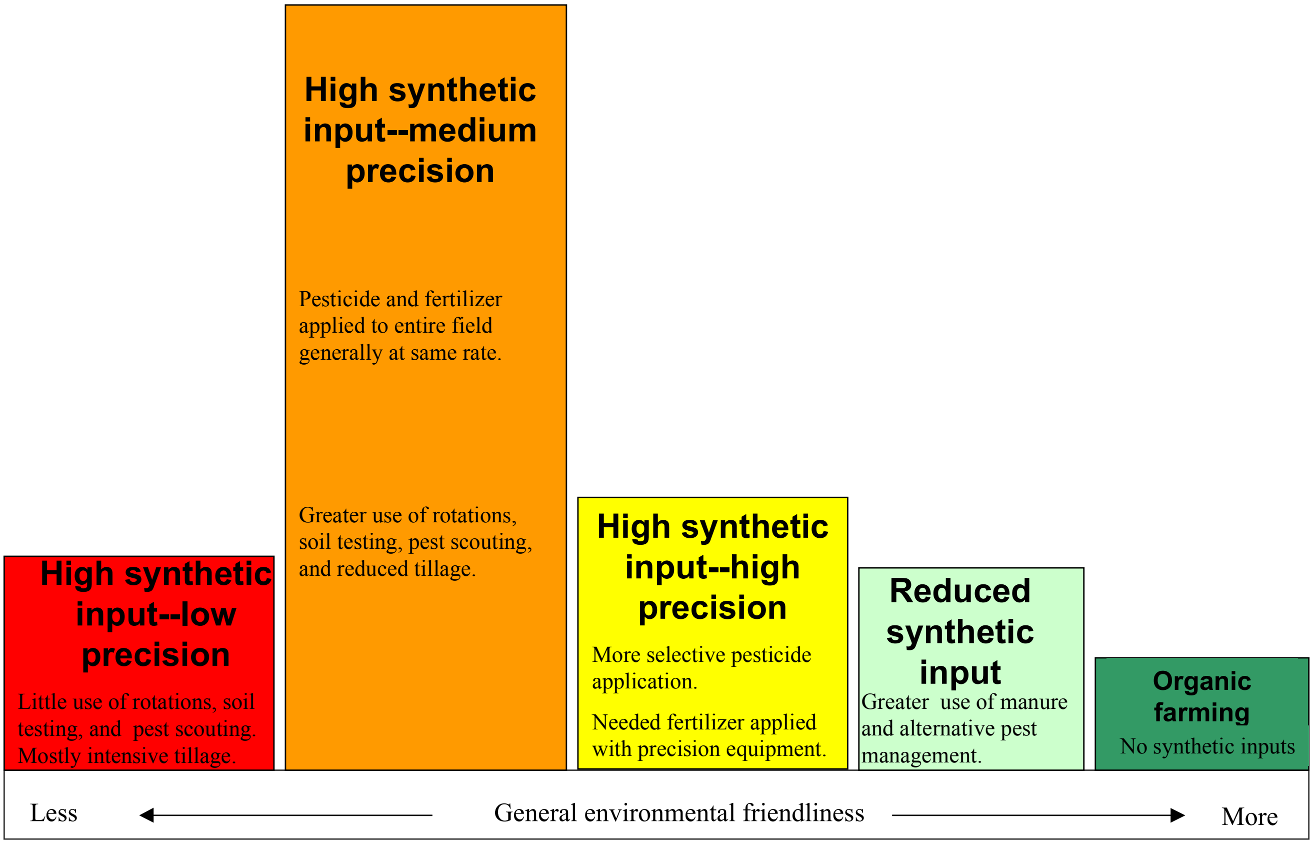
**Table 4.1.1--Production management options that farmers combine into farming systems**
(for examples of typical farming systems combining these practices, see table 4.1.2)

| General environmental friendliness | Soil management options: Cropping pattern | Soil management options: Tillage type | Soil management options: Cover crop | Pest management options | Nutrient management options | Water management options |
|---|---|---|---|---|---|---|
| Less ↑ | Monoculture or continuous same crop<br><br>Row crop rotation<br><br>Row crop/legume rotation<br><br>Row crop/small grain rotation<br><br>Small grain rotation<br><br>Small grain/fallow rotation<br><br>Rotation with pasture | Intensive tillage<br><br>Reduced-till<br><br>Mulch-till<br><br>Ridge-till<br><br>No-till | No cover crop<br><br>Cover crop | No pest scouting, synthetic pesticide application to whole field<br><br>Synthetic pesticide application to selective parts of field based on scouting and economic thresholds<br><br>Combination of cultural and biological practices and synthetic pesticides<br><br>Only biological and cultural pest control methods used | No soil testing for nutrients<br>Fall application of nutrients<br><br>Synthetic fertilizer applied generally to entire field<br><br>Nutrient management plan<br><br>Synthetic fertilizer applied as supplement to legume, manure, or other organic sources<br><br>Synthetic fertilizer applied in variable amounts using precision equipment<br><br>Only legume, manure, or other organic fertilizer used<br><br>Intensive testing of soil and manure, with corresponding nutrient application<br><br>Split application, nutrients applied during plant growth | Gravity irrigation with tile drainage<br><br>Gravity irrigation without tailwater recovery<br><br>Gravity irrigation with tailwater recovery<br><br>Sprinkler irrigation<br><br>Drip irrigation |
| ↓ More | | | | | | |

Not all options are listed. For definition of terms and additional information, see chapters 2.2 and 4.2-4.5.
Environmental friendliness is defined as the reduced likelihood of soil, pesticide, or nutrient loss to the environment. Indications are approximate.
Source: USDA, ERS

# Figure 4.1.1--Major farming systems in U.S. agriculture

**(Height of bar grossly indicates the relative acreage in that system)**




Source: USDA, ERS

*Medium Precision.* This group is characterized by generally higher levels of input management compared with the low-precision group. Soil testing and pest scouting occur more frequently. Some farmers may use economic threshold models to determine when pesticide applications are economical (yield benefits exceed cost).

Commercial fertilizer application takes into account soil test results and recommended rates for the crop and soil, but still tends to be constant over the entire field. Fertilizer application more frequently occurs in the spring before or at planting, rather than during fall or winter, and is more often injected or placed near plants to reduce loss. Split application of fertilizer is more frequent, which increases efficiency of nutrient uptake.

Farmers using medium-precision systems may rotate cash crops, such as corn with soybeans, which helps to control pests. Where legumes are part of the rotation, commercial fertilizer use may be lower. However, some farmers dedicate acreage to a continuous single crop (61 percent of the cotton and 38 percent of winter wheat in 1998-99 were so produced). While intensive tillage may be used on acreage in this group, many farmers have adopted reduced forms of tillage and no-till that leave additional residue on the soil surface to reduce soil and moisture loss.

*High precision*. Farmers in this group apply new technology and even greater management to tune input use to the needs of the crop. Innovations in the computer, telecommunications, and satellite industries during the last decade have made spatial and temporal management of nutrients and other inputs technically feasible. The application of these information technologies, known as precision farming or site-specific farming, enables producers to monitor and differentially manage small areas of a field that have similar soil or plant characteristics. Components of a precision farming system typically include:

- Intensive testing of soils or plant tissues within a field;
- Equipment for locating a position within a field via the Global Positioning System (GPS);
- A yield monitor;
- A computer to store and manipulate spatial data using some form of Geographic Information System (GIS) software; and
- Variable-rate applicators for seed, fertilizer, animal manure, pesticides, and/or irrigation water that are continually computer adjusted for various parts of the field.

More involved systems may also use remote sensing from satellite, aerial, or near-ground imaging platforms during the growing season to detect and treat areas of a field that may be experiencing nutrient or pest stress.

**Table 4.1.2--Four examples of farming systems combining production management options**

| Farming system | Soil management | Pest management | Nutrient management | Water management |
|---|---|---|---|---|
| High synthetic input, low precision, specialized | Continuous corn using intensive tillage and no cover | Synthetic pesticides applied to entire field at the same rate | Synthetic fertilizer applied to entire field at the same rate, no soil testing | Sprinkler irrigation |
| High synthetic input, low precision, diversified | Corn/wheat/soybean rotation using no-till, rye as a cover crop | Same as row 1 above except potentially less insecticide because of the rotation | Same as 1 above except less nitrogen used because of fixation by the soybeans | Same as row 1 above |
| High synthetic input, high precision, diversified | Same as row 2 above | Synthetic pesticides applied where needed as determined by scouting | Synthetic fertilizer nutrients applied in specific amounts using precision equipment | Same as row 1 above |
| Organic farming | Same as row 2 above | Only biological and cultural pest management practices used | Only legume, manure, or other organic fertilizer used | Same as row 1 above |

Based in part on systems being evaluated as part of the Farming Systems Project at the Beltsville Research Center, USDA, ARS.
Source: USDA, ERS

USDA surveys indicate that about 10 percent of corn farms in the United States in 1996 were using some aspect of precision farming, primarily for nutrient management. (See chapter 4.4, "Nutrient Management," for more detail and references.) Precision farming has the potential to improve net farm income by: (1) identifying places in a field where additional nutrient use will increase yield, and thus farm income, by more than the added nutrient cost; and (2) identifying places where reduced input use will reduce costs while maintaining yield. Precision farming also has the potential to reduce surface runoff, subsurface drainage, and leaching of agricultural chemicals, if profit or appropriate incentives motivate farmers to utilize the technology in more carefully managing inputs.

Most precision farming has addressed nutrient management, but research on pest management using this technology is also emerging. Recordkeeping features are also being added to precision-farming equipment to facilitate organic and other identity-preserved crop production. Recent industry surveys indicate that only a small number of corn growers are experimenting with precision application of pesticides. The yield monitors and precision equipment necessary for many other crops, especially vegetables, are not commercially available yet. USDA, the chemical industry, and other organizations are examining the potential for this technology to increase yields or reduce pesticide use. Drip irrigation is also considered a precision technology.

***Reduced-Synthetic-Input Systems***

These systems are characterized by greater use of organic fertilizers (manure, compost, or other organic waste) and alternative pest management practices. Before synthetic pesticides were generally available, farmers relied on cultural practices such as crop rotations to reduce crop losses to pests. Today, environmental and health concerns prompt some farmers to use farming systems that utilize cultural and biological practices to reduce use of synthetic pesticides.

***Cultural practices*** for managing crop pests include crop rotation, tillage, alterations in planting and harvesting dates, trap crops, sanitation procedures, irrigation scheduling, fertilization, physical barriers, border sprays, cold air treatments, and providing habitat for natural enemies of crop pests. Cultural controls work by preventing pest colonization of the crop, thereby reducing pest populations, reducing crop injury, and increasing the number of natural enemies in the cropping system. They also seek to improve plant health and vitality to reduce susceptibility to pest damage. New cultural techniques, such as solarization (heating the soil to kill crop pests), continue to emerge.

***Biological practices*** include the use of pheromones, plant regulators, and microbial organisms such as *Bacillus thuringiensis* (Bt), as well as pest predators, parasites, and other beneficial organisms. The Environmental Protection Agency currently regulates biochemicals and microbial organisms and classifies them as biorational pesticides. Another major biological tactic has been to breed and plant crop varieties with host plant resistance to insects and disease.

***Organic Farming Systems***

Organic farming systems foster the cycling of resources; rely on practices such as crop rotations, cover crops, and biological pest management; and virtually prohibit synthetic chemicals in crop production and antibiotics or hormones in livestock production. More and more U.S. producers are considering organic farming systems in order to lower input costs and conserve nonrenewable resources, as well as capture high-value markets for organically produced products and improve farm income. Farmers have been developing organic farming systems in the United States for decades. State and private institutions have also emerged to set organic farming standards and provide third-party verification of label claims to support organic farming and thwart fraud directed at consumers. Legislation requiring national standards was passed in the 1990s and the final rule implementing the legislation was published in December 2000. The new standards are expected to become effective in October 2002.

Certified organic farming systems were used on about 1.4 million acres of cropland and pasture in 49 States in 1997, or less than one-half of one percent of the harvested cropland. However, the systems have been growing rapidly, with certified cropland more than doubling between 1992 and 1997. Two organic livestock sectors—eggs and dairy—grew even faster.

The structure of the organic sector differs substantially from the agricultural industry as a whole, with fruits, vegetables, and other high-value specialty crops making up a much larger proportion of the organic sector. About 2 percent of top specialty crops--lettuce, carrots, grapes, and apples--were grown under certified organic systems in 1997, compared with only 0.1 percent of the top U.S. field crops--corn and soybeans. Also, organic field crop producers generally grow a greater diversity of crops than their conventional counterparts because of the key role that crop rotation plays in organic pest and nutrient management. While some large-scale organic farms emerged during the 1990s, small farms producing mixed vegetable or fruit crops for marketing direct to consumers and restaurants still made up a large segment of the organic sector in 1997.

***Other Ways of Grouping Systems***

Farming systems can be grouped in ways other than on the basis of synthetic input use and management by emphasizing other production management aspects, such as cropping pattern, tillage type, and form of irrigation.

*Cropping systems*. Farmers may use a specialized system such as continuous corn, cotton, or wheat, a two-crop system such as corn/soybeans, or a more diversified system such as corn/soybeans/wheat or corn/soybeans/wheat/hay. Many other cropping systems exist.

*Tillage systems*. Groupings emphasizing tillage range on one extreme from intensive or clean-till, where little or no crop residue is left on the soil surface, to no-till where the soil surface is left undisturbed from harvest to planting except possibly for nutrient injection. Many farmers are finding they can gain soil and water conservation, environmental, and economic benefits by reducing or eliminating tillage and leaving previous crop residue on the soil surface. No-till is accomplished by planting or drilling in a narrow seedbed or slot using special equipment such as a no-till drill. Pest and nutrient management under reduced- and no-till systems may be similar to that under intensive systems, except in some cases for a different mix of pesticides, particularly herbicides. No-till may reduce use of available animal manure since the manure cannot be incorporated into the soil as easily as in more intensive tillage systems. No-till use has been increasing, reaching 17 percent of the planted crop acreage in 2000. Other conservation tillage systems that leave at least 30 percent of the soil surface covered with residue after planting (mulch-till and ridge-till) accounted for 19 percent of planted acreage.

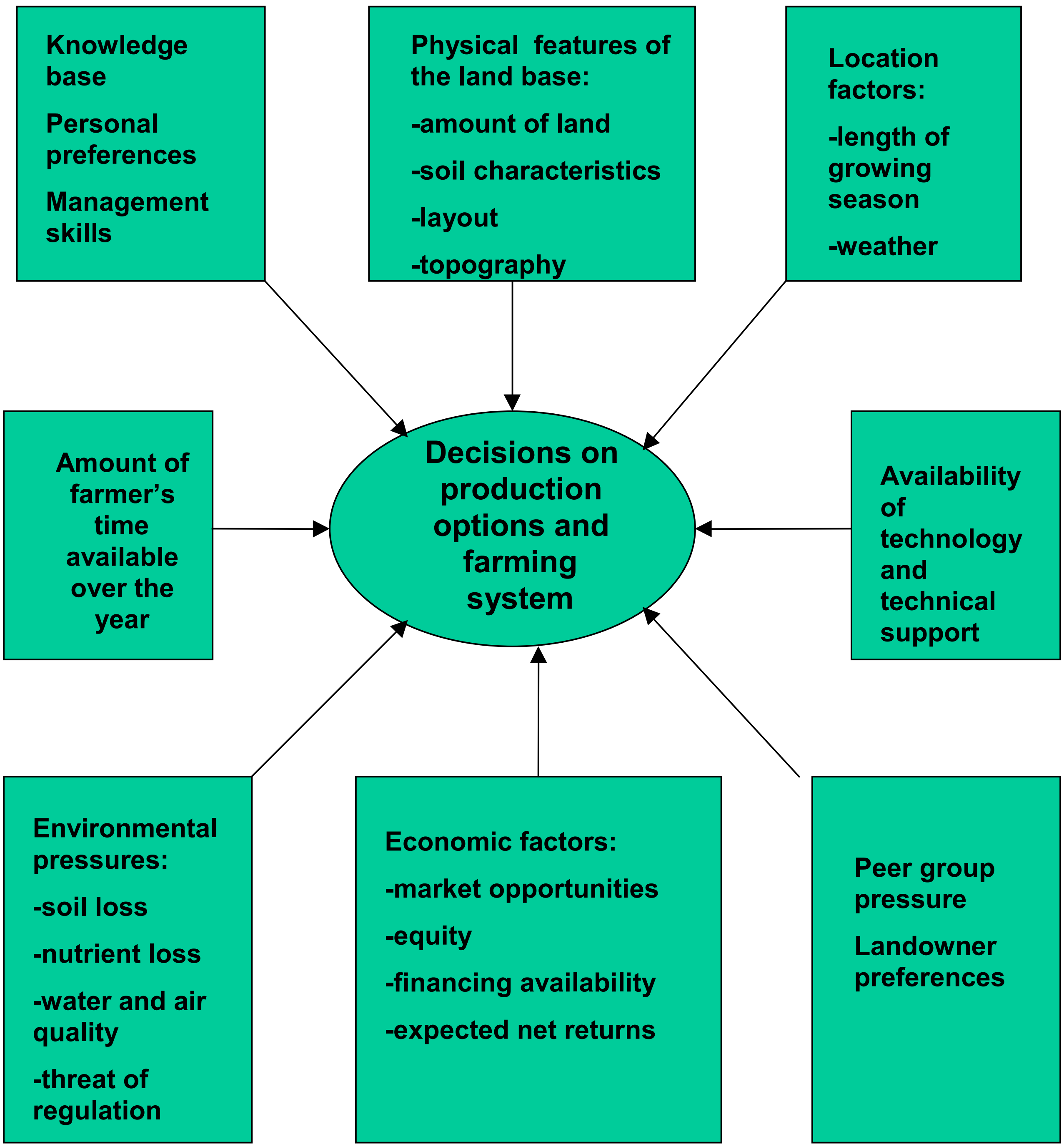
*Irrigation systems*. Less than 15 percent of cropland used for crops is irrigated, but on this land, the type of irrigation can substantially alter other production management choices. Major irrigation types are gravity irrigation, sprinkler irrigation, and drip irrigation. A farm using drip irrigation, or in some cases sprinkler irrigation, often applies highly managed amounts of pesticides and nutrients in the irrigation water. Such a system differs significantly from that of a farmer using gravity irrigation and applying nutrients and pesticides by other means.

In summary, different farming systems are evolving over time toward greater precision in applying inputs and greater friendliness to (i.e., reduced negative impacts on) the environment.

## Factors Affecting Farmers' Decisions

Many factors enter into farmers' production management decisions (figure 4.1.2). A farmer begins with a knowledge base, personal interests and preferences (including propensity for risk aversion), and management skills. For example, farmers with interest in organic and low-synthetic-input agriculture may investigate market opportunities for organically produced products.

## Figure 4.1.2--Many factors enter into farmers' production management decisions




Source: USDA, ERS.

Constraints on what farmers can do come from the physical (agronomic) and location (growing season and weather) aspects of the land they operate, and from the amount of time they have to devote to the farming operation. Farmers considering system and practice changes must take into account the availability of the required technology and technical support. For example, availability of new technology (such as precision applicators, no-till drills, and genetically engineered seeds) is influencing some farmers to change production practices.

In making production decisions, today's farmers are increasingly subject to pressures to reduce soil and nutrient loss to surface and groundwater. They may also perceive or actually experience pressure from peers to farm in certain ways. The landowner, if different from the operator, may have specific views on how the land is to be farmed.

In addition, the farmer wants to make a profit and to continue farming. Thus, the farmer must consider market opportunities for his output, financing availability, input costs including government cost-sharing for environmental practices, expected net returns, and the additional risk that may be involved in adopting new practices. A farming system that achieves the highest yield and total production may incur costs that make it less profitable than an alternative system. In managing nutrients, a farmer would not want to apply fertilizer to achieve a higher yield if the additional cost would exceed the value of the additional output. Likewise, a farmer would not want to apply insecticide to control a pest infestation if the value of the yield saved would be less than the cost of pesticide application. Predictive tools, such as yield-growth models and economic thresholds for pests, are becoming available to help farmers make better economic decisions when faced with imperfect knowledge of the cost and yield effects of applying additional fertilizer or pesticide.

These factors affecting production management decisions are discussed further in chapters 2.2, "Irrigation Water Management," 4.2, "Soil Management and Conservation," 4.3, "Pest Management," and 4.4, "Nutrient Management."

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