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Computer Models for a Farm Eco-System

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Today's dairy farmer must be a superb livestock and business manager, an agronomist, economist, soil, water, and waste management expert. Awareness of the long-term impact of agricultural run-of on streams, rivers and ground water has led to legislation governing the number of animals a farmer can keep on a given piece of land and how the disposal of animal waste is handled. The farmer has the formidable task of maintaining a profitable dairy herd with minimal impact on the land.

This complex task is only possible with the aid of computer models. Researchers at Penn's Center for Animal Health and Productivity at the New Bolton Center campus, who earlier developed a feeding strategy model for dairy herds, are now looking to create a more complex model to integrate not only feeding strategies but also cropping and planting strategies to keep the production and health of a herd at a maximum while reducing its environmental impact.

"We are looking at the entire dairy farm, its soil composition, and the feed crops that can be grown economically utilizing the animal wastes," said Dr. James Ferguson, assistant professor of nutrition. "At first we looked mainly at feeding strategies for production and health, and we didn't worry too much about the waste products and their composition. However, manure and urine contribute to nitrate pollution of soil and water and we began to develop feeding formulas to reduce the level of nitrates in dairy cow wastes."

Cows have a complex digestion system where food is broken down with the aid of bacteria and bacterial products are absorbed by the cow in it intestines. When feeding a cow, the bacteria must be kept in mind, in essence cow and bacteria must be fed. "We must look at what happens to the feed in the cow's rumen," said Dr. Ferguson. "The bacteria need protein for the fermentation process that breaks down the cellulose into volatile fatty acids and starch to provide energy sources. Bacteria break down protein into ammonia which is then converted to microbial protein that is absorbed by the cow in the intestine. But if there is too much protein excess ammonia is produced and is excreted in urine and manure, where, over time it is converted into nitrate by another set of bacteria. This nitrate then is discharged into the soil to enter the ground water."

The issue is further complicated by the fact that microbial protein alone is not enough to keep a cow in good health and high milk production. The feed must be balanced in such a way to provide carbohydrates that supply energy, just enough protein to be utilized by the bacteria, and additional protein that can be absorbed by the cow in the intestines. To

add to the complexity, it must be taken into account what kind of feed crops can be raised economically by the farmer.

"We look at the composition of the soil and the plantings it will support," said Dr. Ferguson. "Then we build a feeding and a cropping program. The cropping program is not just for one year but for three to five years, considering crop rotation and fertilizing with manure. The land may be ideal for alfalfa, but alfalfa fixes nitrogen in the soil from the air and when fed as silage, contains too much protein. We may recommend that the alfalfa be fed as hay and that a rye cover crop follow the alfalfa to take up the nitrogen in the soil."

The model also has to take into account the requirement of other feed plants, such as corn, beets or grass and the nutrient properties of the manure that will be applied to the fields. "If you use reasonably fresh manure the urea in it has not been converted to nitrates. Such fresh manure is best for rapidly growing plants because they can easily convert urea to nitrogen. On the down side, urea in a lagon or on the ground is converted by bacteria to ammonia that evaporates. If you use aged and solidified manure as fertilizer, you add nitrates which are available more slowly to the plants and can leach into ground. In planning cropping strategies one must take into consideration the nature of the soil and the farming methods." Today fields are not plowed but disced and fertilized by manure injection to reduce the exposure of manure to air.

"We are examining many different models," said Dr. Ferguson. "Our aim is to build integrated models that utilize information on soil, agronomy, water, and feeding efficiency so that a program can be tailored to the individual farm. We also need to integrate into this the lactation cycle of the various groups in the herd because nutrition requirements vary depending on the stage in the cycle of lactation. Such a model must do its calculations rapidly, it can't take all day." Modern computers and advanced software make this a feasibility.

The New Bolton Center researchers have developed a reduced protein feeding program that increased milk production and decreased nitrate output. It also reduced the feed costs for a 400-head herd by $100,000 annually. This is just the first step. By developing a computer model that encompasses the entire cycle from growing feed crops to milk production to fertilizing of croplands to planting, the New Bolton Center researchers hope to develop a strategy that will enable the farmer to have maximum milk production with minimal environmental consequences while making a profit.

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