Sustainable Dairy Farming Initiatives and Systemization

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Abstract

The pollution of closed bodies of water by excess nitrogen in runoff from overfertilization and improper treatment of manure has become a significant environmental problem. Our objectives are to assess the environmental impact of farming and assist local governments in formulating policies that promote good farming practices. We hope to achieve these objectives by monitoring water quality with remote sensors, constructing a water quality database, and developing an environmental assessment system for dairy farming.

1. Effects of farming on the environment

The degradation of Japan's water and air quality caused by the vast quantities of untreated effluent produced and the smoke and soot spewed from factories during its period of rapid economic growth became a major environmental problem as manifested in pollution-related diseases and other adverse effects. At that time, whether or not agriculture was contributing to the degradation was of little concern. However, this is not true today as is apparent from the many issues continually being raised in the press and other media concerning the impact of farming on the environment. Indeed, the soil and water contamination resulting from overuse of chemical fertilizers, the fouling of air and water due to inappropriate processing of animal wastes, and the spread of toxins from the overuse of pesticides have become serious problems.

The government white paper on the environment shows that in 1998 Japan imported some 700 million tons of materials while it exported only 100 million tons for a net difference of 600 million tons left in Japan. The biogenic material balance for nitrogen associated with food, feed, and fertilizer is similar: in 1994 Japan imported the equivalent of 660,000 tons of nitrogen and exported 180,000 tons, for a net 480,000 tons left in country. This excess nitrogen finds its way into food residue, excreta of farm animals, and, if it is not properly processed, has an adverse impact on the environment as it accumulates in soil, flows into rivers, and is released into the atmosphere. In addition, the shift toward intensified and large-scale farming in recent years has led to excessive amounts of nitrogen in localized areas, which is responsible for the accelerated eutrophication (nutrient pollution) of closed bodies of water in some areas of Japan. On a national level, some legislation has already been passed or revised to address these issues. It includes the Environment Basic Law (encompassing the Water Quality Pollution Law, the Offensive Odor Control Law, and the Air Pollution Law), as well as the Three Laws Pertaining to Farms and the Environment (including legislation promoting the rationalization and introduction of better control methods for dealing with excreta). As public concern rises, a good deal of interest has come to focus on technologies for assessing the environmental impact of farming.

2. Analysis of material cycles at Hokkaido University's Shizunai Livestock Farm

Quantitatively analyzing material cycles and identi-

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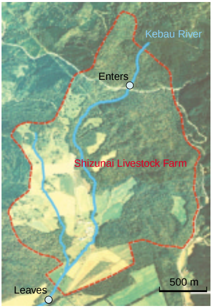

Fig. 1. Aerial view of Shizunai Livestock Farm.

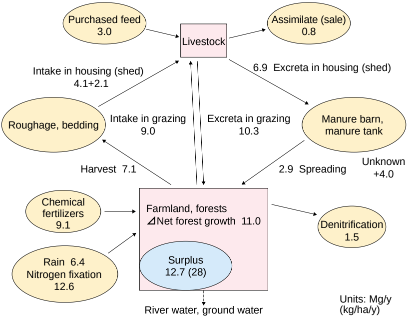

Fig. 2. Nitrogen flow on Shizunai farm and estimated nitrogen runoff into river.

fying the factors involved and their degree of contribution are essential in assessing the environmental impact of farming. In a collaborative research project with Hokkaido University, we have been investigating the nitrogen flow balance at the Shizunai Livestock Farm in Shizunai, Hokkaido. The farm is affiliated with Hokkaido University's Field Science Center for the Northern Biosphere [1]. The Shizunai Farm is divided in half by the Kebau River. As this flows through the farm, it picks up spring water from the forested areas of the property, runoff from the cultivated fields, drainage from culverts, and water from open ditches. In this work, we analyzed the various material runoff mechanisms by determining the amount of nitrogen runoff entering the river as it crosses the Shizunai Farm by measuring the difference in the river's nitrogen load near where it enters and leaves the property (Fig. 1).

The Shizunai Farm supports 90 horses and 140 cows and has a total area of 457 hectares, 67 percent of which is forested and the rest pastureland and cultivated fields. The measured flow of nitrogen in this environment is illustrated in Fig. 2. We found that some 12.7 tons of excess nitrogen produced by the farm finds its way into the Kebau River every year. The various processes contributing to the flow can be identified in the figure.

This study revealed that a major portion of the nitrogen runoff is a result of rainfall and snow melt. We used this nitrogen balance analysis as the basis for analyzing environmental degradation factors and for suggesting remedial actions to reduce the amount of nitrogen runoff.

3. Sustainable dairy farm environmental assessment system

A sustainable dairy farm environmental assessment system is being developed by NTT Energy and Environment Systems Laboratories on the basis of research results from the Shizunai Livestock Farm. Besides its somewhat common capabilities—remote sensing, sampling, water-quality analysis, and database building—the system features a number of more technical ones, including factor analysis, environmental enhancement simulation, and policy-drafting support.

Figure 3 shows a conceptual overview of the system. Fixed-point observation systems are set up at target sites to collect data. These systems use a variety of different sensors to measure pH, electrical conductivity, oxidation-reduction potential, water level, precipitation, and so on. They remotely monitor conditions at their sites and transmit the data over a network to a water quality monitoring system installed in the system manager's control room. The water quality monitoring system is connected to the dairy farm environment assessment database, where data

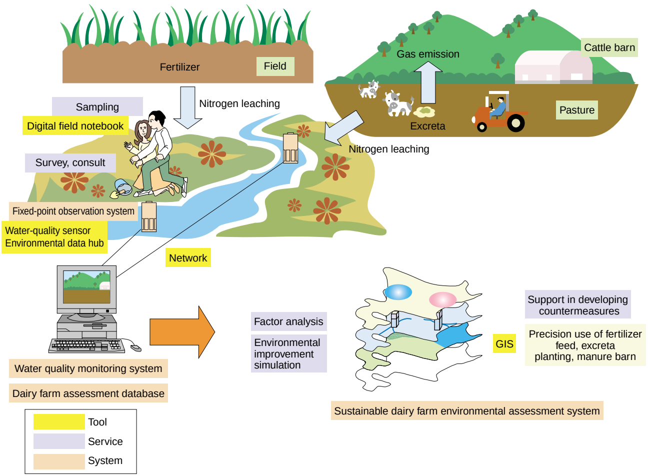

Fig. 3. System overview.

from all measurement sites are stored. Water samples are chemically analyzed mainly to determine the concentrations of total-nitrogen, total-phosphorous, and nitrate-nitrogen, and this water-quality data is added to the database. These sets of data are then mapped onto a geographic information system (GIS), which is a subsystem containing location information about the area, detailed topography-based data covering land use, and statistical farm-related data, which can be used for GIS-based environmental impact analyses from various perspectives.

Figure 4 shows a detailed overview of the fixed-point observation system. Water is steadily drawn from the river by a pump, and water is continuously expelled from the top and bottom of the reservoir so that fresh river water is always temporarily stored in the system. Water-quality sensors in the reservoir measure the pH, electrical conductivity (EC), oxidation-reduction potential (ORP) and dissolved oxygen (DO) of the water. In addition, a turbidity meter and water-level gauge are installed directly in the river. A shed at the site houses an automatic water sampler hooked up to a rain gauge. If the amount of rain exceeds a certain level, then the water sampler is automatically activated. All of the data, including the water-quality data, turbidity and water-level data, amount of precipitation, and water sample log data, are automatically sent over the network via the environmental data hub to a server in the control room.

3.1 Future enhancements

The system gives even non-experts in the environmental sciences an immediate grasp of the environmental circumstances of a place and suggests appropriate measures to address any problems. We are now working on a more advanced system that integrates the fixed-point observation system, the water quality monitoring system, and the dairy farm environment database; incorporates factor analysis and environmental enhancement simulation; and uses a GIS-

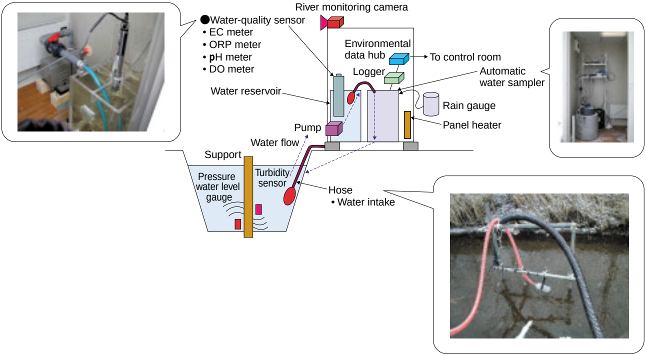

Fig. 4. Fixed point observation system.

based user interface to create a more full-featured and intuitive system that is easy for anyone to use.

Factor analysis is a powerful tool for identifying factors having an impact on the environment, and environmental enhancement simulation is a useful technique for predicting how the environment might be enhanced by planting trees or spreading some sort of absorbent while factoring in such parameters as time, season, and temperature.

3.2 Advantages of the system

The establishment of environmentally friendly farming practices is being driven by the need to comply with legal sanctions and the pressure of public opinion (negative inducements) and voluntary efforts to enhance brand images and differentiate one's product from those from other localities (positive inducements). In light of public awareness of environmental issues, it is important for farmers to understand these positive inducements in particular. Making it known to consumers that a product was made with regard for the environment can be a very powerful marketing strategy. A number of significant advantages will be gained by deploying the sustainable dairy farm environmental assessment system:

- Good public relations in letting people know that their dairy products come from a clean farm environment (marketing strategy).
- Curtailment of overfertilization (cost-saving effect).
- Preservation of the local environment.
- Greater environmental awareness (optimization of feed purchases, *etc.*).
- Promotion of environmental education.

4. Challenges ahead

Assessment of the agriculture environment has been a central concern of the Ministry of Agriculture, Forestry and Fisheries research institutes, agricultural experimental stations, and universities for some time. Indeed, what is needed now is to channel this considerable research into easy-to-understand systems, obtain feedback on actual farms, collect and analyze large quantities of data using remote techniques as much as possible, focus the analysis on the overall picture, and devise comprehensive measures and guidelines that will promote good sustainable farming practices. And considering the fluidity of these substances and how easily they circulate, it is apparent that the concerns addressed in this article are not limited to local regions, but extend to local governments, urban and rural prefectures, and to the nation at large. We can already envision the need for more far-reaching assessment technologies based on remote sensing that can be applied to these wider geographic domains and even applied nationwide.

Reference

[1] http://ecodb.agr.hokudai.ac.jp/www/(in Japanese)

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