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PROTECTION OF THE ENVIRONMENTIN ANIMAL PRODUCTION: BIOSYSTEMS, ECOLOGY AND WASTE TREATMENT

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SUMMARY

In this paper, the environmental sustainability of animal agriculture is examined from a systems-engineering perspective. The boundary between the system and its environment is defined so that all inputs and outputs can be identified. Regardless of how difficult it may be to do so, ultimately animal production systems have the authority and responsibility to exercise control over all outputs, whether market or non-market (leakage). Current attempts to regulate animal production systems based on prescribing allowable technologies and management practices, or based on monitoring the environment, are failing. Despite the inherent difficulties associated with monitoring leakage, especially from extensive animal production systems, it is this approach to regulation and management that has the greatest potential to ensure the long-term environmental sustainability and social responsibility of animal agriculture.

Keywords: environmental sustainability, leakage, ecosystems

INTRODUCTION

It is generally well accepted today that successful agricultural production systems will be those that are globally competitive (i.e., economically viable), environmentally sustainable, and socially responsible. The research connecting these three measures of success has been relatively recent and the examples of systems documented to meet all three criteria are sparse.

When animal enterprises were small, it was generally assumed that the enterprise could live in perpetual harmony with its environment so long as we used common sense. For example, animals might be allowed to drink from a lake in one situation but would not be allowed to wade in a watercourse within a municipal watershed. Manure might be routinely spread on frozen ground but only where there was no chance of runoff to a public watercourse. Traditionally, dead animals were left out for scavenger animals but not if one lived in close proximity to an urban area or to another livestock enterprise of the same animal species. Today, animal enterprises have become larger and look less like traditional farms. The rural landscape has become more and more viewed as a resource to be shared with a multiplicity of users, often users with differing objectives. In wealthy countries, the public has increasingly been able to direct its attentions beyond security of the food supply to issues of the environment and to the details of not just the safety of food but also how that food was produced. Today we are less able to apply common sense and traditional ethics to communicate what we are doing in animal agriculture, and society is demanding new rules and controls.

In the developed world, agriculture has become very sophisticated and, despite its continuing definition in world dictionaries as being synonymous with farming the land, has come to be something quite different. Included within the modern definition of agriculture are the production of plants and animals for food and non-food uses, and the first-stage processing of those products on and off-farm, regardless of the extent to which the enterprise depends upon use of the soil. Thus, a greenhouse enterprise may still be called farming even though from a production standpoint it does not depend upon a land base. A livestock enterprise may purchase all its feed inputs and may have no need for a land base except as a foundation for buildings, and yet may defend its practices by claiming itself to be a farm. Classification of some plant and animal production enterprises that do not require a land base as rural industries may lead to a more realistic analysis of these enterprises in terms of their environmental impacts.

As scientists, we have an obligation to assist the animal industry and the public to understand animal enterprises and the environment as a system. Too often, the debate about animal agriculture is polarized and politicized, environmental issues are confused with social issues, and insufficient attention is paid to the many complex interactions within the animal enterprise and between the enterprise and its environment. Animal agriculture has sometimes unnecessarily defended its practices on the basis of "right to farm" principles rather than principles of sustainable environments. In this paper, the environmental sustainability of animal agriculture is examined from a systems-engineering perspective. The systems approach is examined for its applicability to the problem of identifying, monitoring and regulating leakage from animal enterprises.

THE ANIMAL PRODUCTION ENTERPRISE AS A SYSTEM

The systems approach requires us to define a system boundary and to identify all inputs and outputs. The system itself is made up of many entities (buildings, pastures, equipment, animals) that are described by attributes (size, age, quality). The system is governed by the rules that define how the entities interact with each other and with the environment (everything outside the system boundary) via the system inputs and outputs.

It is not entirely easy to define the system boundary, and the way the boundary is defined will depend to some extent on the purpose of the analysis. For an environmental analysis, it is logical to identify the side boundaries of the system coincident with the legal property boundary. The lower system boundary may be defined as the bottom of the root zone if not covered by buildings or other permanent features, and by the building-soil interface otherwise. The upper boundary is the most difficult to define. One possibility is to define this boundary as the lower extreme of the undisturbed atmosphere with which there is no exchange of material with the air that affects, or is in any way affected by, the animal enterprise. With this definition, we can assume there is no transfer of airborne contaminants across the upper boundary.

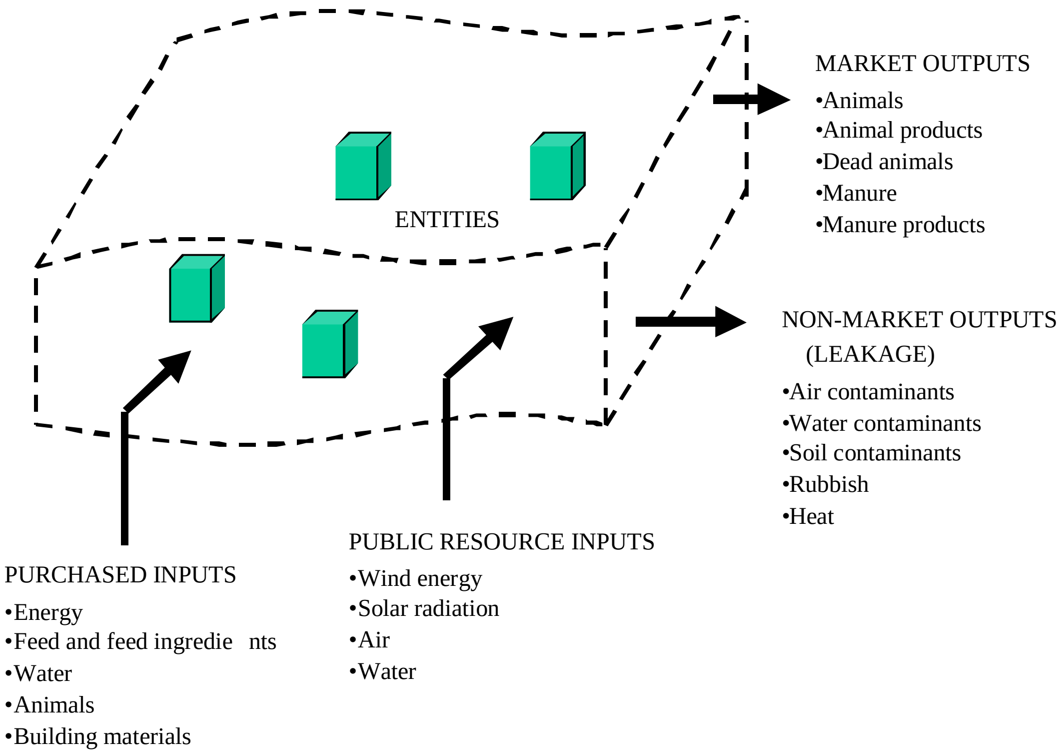

Figure 1. The animal enterprise system

For purposes of this paper, the analysis is limited to material entities, inputs and outputs. Animal enterprises may influence their environment in non-material ways, for example by blocking site lines of neighbors, casting shadows on neighboring properties, or imparting psychological impacts on neighbors, but these effects are not considered here.

To understand the environmental impact of an enterprise, we need to identify and describe all inputs and outputs through any portion of the system boundary. The animal enterprise has varying levels of authority and responsibility over inputs and outputs. The enterprise will generally be able to control purchased inputs and market outputs, and has authority over both the quantity and quality of these material fluxes. There may be only limited ability to control the non-market, public resource inputs, although control may be exercised over the extent to which these inputs interact with the system entities. For example, the enterprise will not be able to stop the flow of air that enters the system but may be able to exercise control over the attributes of the air (eg, quality, temperature) as a process within the system. This analysis also does not account for unusual crossings of the system boundary such as by unauthorized persons or animals.

Regardless of how difficult it may be to do so, the enterprise always has authority and responsibility to exercise control over all outputs, whether market or non-market (leakage). It is this responsibility for leakage from the system that characterizes the modern livestock enterprise and causes us to think in terms of rural industry.

Having accepted responsibility for all inputs and outputs, we likely will decide that there are some that we do not need to keep track of. For example, on the input side, we may conclude that the capture of wind energy by the animal enterprise does not need to be paid for. Similarly, we are likely to conclude that the heat released to the environment from animal enterprises is not a deleterious leakage. Note, however, that some animal enterprises might decide to turn waste heat into a resource to be sold to another enterprise, for example, to a greenhouse operator, in which case a leakage output may be turned into a market output. There are some examples where inputs of public resources may become purchased inputs, for example when water for livestock or irrigation becomes scarce or rationed. Careful identification of all inputs and outputs will demonstrate accountability and may lead to innovative new market opportunities.

Before considering approaches to regulating and managing leakage from animal enterprises, it is worth noting again that the definition of the system boundary and of inputs and outputs depends upon the purpose of the analysis. Most often, farm animal enterprises are analyzed from a business perspective. In this case, there are inputs and outputs in addition to those identified previously, most obviously labor, financing and profit. There is a tendency in business analyses to take for granted non-market (public resource) inputs and to ignore non-market (leakage) outputs. A responsible animal industry will include all of these environmental inputs and outputs in its economic models.

REGULATING LEAKAGE FROM ANIMAL ENTERPRISES

When animal enterprises become very large, there is a growing pressure to classify them as industrial land uses, just as a pulp mill or a manufacturing enterprise. Regulatory control of livestock enterprises is inevitable, but the livestock industry can still influence how regulations are framed and applied.

Environmental regulations typically all require some level of monitoring but are distinguished by differences in what is monitored. Using the language of systems as described in the previous section, monitoring to regulate animal enterprises may be applied to the environment (i.e., what is happening outside the system), to the entities or processes within the system, or to the leakage outputs.

The traditional approach to regulation of farms has been to concentrate on the impact of the system on its environment, to be aware of changes in the environment and to alter the agricultural enterprise in response to excessive contamination. Even as cropping systems have become more intensive and the use of specialized inputs, mostly fertilizer and pesticides, has increased, the agricultural industry has defended its practices on the basis that impact on the environment has not yet been proven to be excessive. In animal agriculture, any kind of manure storage might be defended as acceptable so long as no one can document unacceptable contamination of surface or ground water. Animals may have free access to surface water courses so long as no other user of the water course objects. This approach to regulation is reactive as opposed to proactive. There is a sense that the first users of an environment may use that environment as a sink for contaminants until prescribed contamination levels are reached (eg, 10 ppm nitrate in groundwater beneath a manure spreading site) but then subsequent users have no ability to discharge leakage. Those who contributed to contamination eventually found to be in excess of acceptable standards usually argue against accepting responsibility for clean-up. In general, future generations must pay for the environmental abuses of the past. The agricultural industry as a whole should reconsider its traditional dependence on this form of regulation.

As livestock enterprises have become larger, it has become more common to formulate environmental regulations in terms of prescriptions for how the enterprise itself is to be constructed and managed. Regulations might prescribe covers on manure storages to mitigate odor release, low-permeability liners for effluent ponds to minimize groundwater contamination, injection of land-applied manure to reduce odor and contamination of surface water, minimum land-base requirements for a given number of animal units, and use of particular technologies for dead animal disposal. Minimum separation distances between intensive livestock enterprises and particular adjacent land uses are another form of prescriptive standard. Prescriptive standards such as these may make monitoring relatively easy (the prescriptive technology either is or is not used) but they discourage innovation and they deprive managers from deriving advantage through excellent management.

In many jurisdictions in the developed world, industrial enterprises require a permit to discharge waste products into the environment, whether the discharge is into the air, water, or soil, or in the form of solid wastes delivered to stockpiles or landfills. The regulatory approach is not to prohibit leakage but to monitor the leakage and control it to levels that are predicted to be absorbed on a sustainable basis by the environment. The regulated enterprise has the ability, and often the incentive, to be creative about how it achieves the performance levels specified by the discharge permit.

The livestock industry and the public will be best served in the long run by regulations based on independent monitoring of leakage at the system boundary rather than by applying prescriptive standards for how animal facilities are to be constructed and managed, or relying on detection of excessive contamination already in the environment. The public will work with the livestock industry to decide what levels of leakage are acceptable on a case-by-case basis, recognizing that the environment of any particular livestock enterprise has some capacity to absorb contaminants.

A performance based regulatory approach will be equally applicable regardless of the size of the enterprise or the circumstances of the enterprise. Consider, for example, a livestock enterprise that is operated in close association with a cropping enterprise. So long as we adopt the attitude that whatever is contained within the system boundary is the business of the enterprise and not of the public, then any movement of manure from the animal facilities would not need to be regulated. Instead, the regulatory authority would be exercised at the system boundary of the animal-crop enterprise and would apply to leakage at that boundary (eg, runoff from fields across public boundaries, odours escaping the property boundary, movement of contaminants beyond the root zone, etc).

MEASURING AND MONITORING LEAKAGE FROM ANIMAL ENTERPRISES

Animal production enterprises, as they become larger and more specialized, will need to adopt similar engineering environmental programs to those that have been applied previously to many other industrial enterprises. Environmental assessment will precede building permits, and outputs will be monitored. Intensive animal industries will have to produce scientific evidence for claims about environmental sustainability.

One challenge associated with measuring leakage from an individual animal enterprise is to distinguish the outputs of one system from the outputs of adjoining systems. Likewise, the leakage from a newly established animal enterprise needs to be distinguished from any accumulated leakage from prior land use activities. Perhaps the biggest challenge is to monitor leakage from extensive animal enterprises, such as pasture-based systems.

In a recently completed project in Saskatchewan, the environment at and surrounding a new intensive pig production facility was monitored for one year before construction began and continued for an additional year while construction was completed and during the start-up phase. There had been no recent animal agriculture at the site. Odour monitoring and dust collection stations were established at radiuses of 600, 1,200 and 2,400 meters from the barns. Every 3 months, multiple air samples were taken upwind and downwind from the barn site along the same radiuses to account for seasonal variations in weather and wind speeds. Odour monitoring sites were also established in neighbouring farm yards and were sampled on the same frequency. In the later sampling events, air samples were also analysed for total dust, endotoxin and microbial DNA. At the barn site and manure application sites, soil samples were analyzed for chemical composition. Groundwater piezometers were installed in a grid beside and beneath the earthen manure storage ponds. Sampling ports were installed in drains located beneath the barn itself to monitor for leakage from the in-barn manure gutters. Water samples from all wells and all surface water bodies within 2 km of the barn site were analyzed for chemical and microbiological constituents. The intention is to resume monitoring after two to five years of operation of the pig enterprise to document leakage levels.

This experience, along with a great body of published literature, suggests that monitoring leakage from intensive livestock production systems is feasible, although more research is needed to develop some aspects of measurement technologies, especially for airborne contamination. Monitoring for contamination from animal enterprises confined within buildings is easiest. Monitoring leakage from field application of manure presents exactly the same difficulty as does monitoring leakage from all field crop systems and is an area for which research is much needed.

APPROACHES TO REDUCING OR ELIMINATING LEAKAGE

Opportunities to control and manage leakage can be exercised at several key locations within the animal enterprise system. It is convenient to categorize the interventions in terms of where the intervention takes place: (a) modify or control the outputs such that they do not become leakage; (b) modify entities or processes within the system to minimize leakage; (c) modify the inputs to minimize leakage.

Modify outputs

Traditionally, livestock enterprises have been operated as part of a joint cropping-livestock system. In this case, manure is utilized as a soil amendment and plant fertilizer. In a properly balanced system, there are no leaks from the system associated with manure utilization. As livestock enterprises have become increasingly separated from crop production, manure has often become a leakage term in the systems analysis.

The literature is rife with thousands of approaches to minimizing manure as leakage from the stand-alone animal enterprise. In a few cases, the approach has been to treat the manure physically, chemically and biologically to reduce it to its basic elements (water, carbon dioxide, nitrogen, phosphorus etc.), which are then discharged to the environment as innocuous compounds. This approach is analogous to many municipal sewage treatment systems. While it is theoretically possible in this way to create a system in balance with its environment, the costs are very high because of a lack of recovery of components that, in another form, would have value as input to another system. Further, as with municipal sewage treatment systems, it has usually been the case to only partially treat the manure and to change or reduce but not eliminate the leakage as a pollutant.

A more conservation-based approach has been to convert manure to a form that makes it valuable as an input to another system and often to improve it handling characteristics. The technologies are varied but the goals have been few, usually to convert manure into a soil amendment, plant fertilizer, energy, animal feed, or substrate for growth of other organisms such as worms. There remains considerable scope for optimization of these technologies, and for their uptake by entrepreneurs.

For intensive livestock producers, the greatest impediments to adoption of appropriate technology for converting manure from leakage into a marketable output may be lack of incentive and lack of knowledge. It is likely that much manure will be wasted as leakage from animal enterprises until society attaches a cost to such leakage and passes that cost back to the livestock enterprise. Unrealized opportunities to reap financial returns through manure treatment and utilization are enough to keep the interest level high among researchers and entrepreneurs.

In many cases, there is excellent technology available (for example, methane production) and the technology may be profitable, but the livestock enterprise generally lacks the knowledge and skill required to operate a biological treatment facility. Whereas some success has been achieved with community treatment facilities that gather manure from several enterprises, for modern large-scale livestock enterprises there is sufficient manure at one production site to operate an efficient treatment facility and thus save the costs of transporting raw manure. Opportunities exist for entrepreneurs to place manure treatment plants near individual intensive livestock enterprises. The livestock enterprise would sell manure (as a market output rather than leakage) to the manure treatment enterprise.

Specialists in biological treatment could operate a series of such treatment plants if several were located in one geographic area. The outputs of the manure treatment plants would be sold to buyers, which could include the livestock enterprises from which the manure derived.

Modify entities and processes within the system

Livestock production systems are diverse – there has been little or no standardization of the process of livestock production. Opportunities abound to design, modify, and manage the livestock production process to reduce or contain leakage.

Whereas it is most common to modify the engineered entities (buildings and equipment) of the system to accommodate the biological process (in this case the animal), it is also possible to modify the biological process to make it easier for the engineered components to work. Animals could be modified genetically to achieve the goal of less or different excreta, or to otherwise make them more efficient. For example, experiments are underway to alter the genetic makeup of the pig so as to increase the efficiency with which it uses dietary phosphorus. In addition to the potential to decrease feed costs, less phosphorous would be contained within the excreta. When pig manure is utilized within a closely coupled animal-cropping system, phosphorus tends to accumulate in the soil and can ultimately become a leakage element, hence there is expected to be an environmental benefit from use of the modified pigs.

By far the most effective way to minimize leakage from animal production would be to design systems that more effectively separate the animal from its excreta, and prevent the excreta from escaping the system in an uncontrolled manner. For most livestock species reared in intensive confinement facilities, the animal remains in physical contact with its excreta to some extent, and the excreta remains within the same space as the animal and the human workers. Humans live in cleaner environments than farm animals primarily because of the use of the common toilet to completely and rapidly separate excreta and move it into containment for further processing. We should never cease to strive to emulate this engineering accomplishment in livestock production.

Modify the inputs

The outputs (and leakage) from a system can be affected by the quality of the inputs. Continuing with the example of reducing phosphorus excretion by modifying the pig, it also is possible to accomplish the same objective by modifying the feed. Researchers have been able to genetically modify cereal grains, for example, to reduce the concentration of phytic acid and to increase the efficiency of total feed phosphorus by the animal and in this way reduce excretion of phosphorus. There are more opportunities to systematically examine inputs to animal agriculture and to maximize the efficiency with which all these inputs are used so as to reduce leakage and environmental contamination.

INFLUENCE OF SCALE OF ANIMAL ENTERPRISE ON ECOSYTEM HEALTH

The desire of animal agriculture to be globally competitive from an economic perspective will continue to drive the industry toward larger enterprises. There is a general hypothesis among the public that large intensive animal rearing systems pose greater environmental risks than smaller extensive systems.

Smaller animal enterprises, and enterprises with fewer animals per unit of land area, generate non-market outputs (leakage) just as larger ones do, but there will generally be more capacity of the ecosystem within which they operate to absorb the leakage without creating problems for other users of the ecosystem. On the other hand, larger, more intensive enterprises, while generating more concentrated sources of leakage, also have greater ability to control or manage the leakage. In a recent well-publicized water quality incident in Ontario, several persons in a small community died as a result of bacterial contamination caused by a low-density animal enterprise. It is technically more feasible to capture leakage from livestock enterprises that are contained entirely within a building than it is for a pasture-livestock system.

Experience has indicated that some livestock enterprises have operated in harmony with their environment, while others have been a source of pollution and nuisance. There are examples of both small and large, extensive and intensive, animal operations within both groups. For some time now, it has been technically possible to operate a large intensive animal production system within a heavily populated area without creating any adverse effects on the environment other than competition for space and traffic associated with movement of inputs and outputs. Such production systems do not currently meet the criterion of economic competitiveness. It may not be technically possible to operate a pollution-free range-based animal enterprise in the same urban-like setting.

RECOMMENDATION

The key to environmentally sustainable animal enterprises is the ability and willingness to eliminate leakage. Some leakage will be acceptable in most cases, where the leakage rate is matched to the capacity of a particular environment to absorb that leakage on a sustainable basis. More generally, all materials that could become leakage need to be contained within the animal enterprise system boundary, modified to become innocuous when discharged to the environment, or converted to market outputs (i.e., inputs to another system). These should be the goals of animal agriculture.

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