Sustainable Animal Agriculture

OVERVIEW:

Agricultural practices are often defined as either sustainable or unsustainable. This categorization is subject to how one defines "sustainability". Sustainable agriculture may mean, for example, to lower inputs (chemicals, fossil fuel energy), to promote a certain scale or pattern of farming, to maximize production (conventional agriculture; Thompson, 2007) or to minimize release of environmentally harmful byproducts of agriculture. Thompson (2007) argued, however, that each individual practice in agriculture is neither sustainable nor unsustainable in itself. The true meaning of agricultural sustainability may be reached only from a holistic view of a system that encompasses a wide variety of farming practices by both small and large operations. A broad and dynamic definition of sustainability for animal agriculture describes a system of sufficient and profitable food production that is independent of scale and includes complex interactions between agriculture and society.

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Animal agriculture within society

Animal production has been a vital part of human civilization for millennia. Animal products include foods such as milk, meat and eggs that are rich in important nutrients. Furthermore, animal agriculture provides organic fertilizer, labor, hides and hair to clothe, horns and bones for tools, and energy, and serves for education, entertainment and spirituality.

Animal agriculture also has contributed to the rise and fall of several cultures. For example, the collapse of the once-blossoming cultures in Mesopotamia around 3000 B.C. was due, at least in part, to deforestation and overgrazing of the once fertile soil and subsequent soil erosion and desertification. Since that time, prospering societies have emerged and vanished, and strong societies have been established predominantly around centers of productive agriculture.

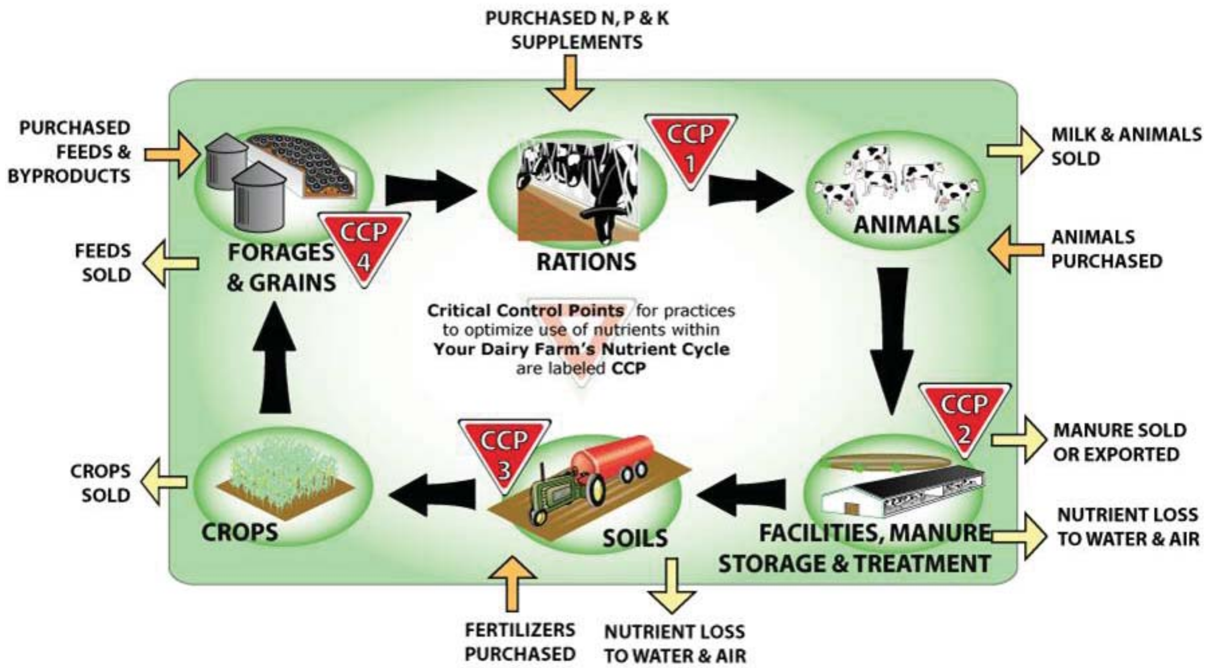
Positive contributions of animal agriculture to local societies are often overlooked. Family-owned and independently operated animal production operations add to the wealth of the local community. Honeyman (1996) listed increased income, community services and participation in democratic processes, as well as a more balanced class structure, in communities with family-owned and -operated animal farms. In addition, rearing of domestic animals increases overall joyous feeling in society and serves as a learning tool to educate people, especially children; or, as Aldo Leopold once stated: "There are two spiritual dangers in not owning a farm. One is the danger of supposing that breakfast comes from the grocery and the other that heat comes from the furnace." Society with little animal agriculture augments those dangers. Unfortunately, it seems impossible to assign a concrete value to animal agriculture's intrinsic contributions to society.

Nutrient flow within agricultural production systems

Consumption of products derived from plants or animals by humans or animals completes the flow of nutrients and energy in nature. Currently, humans in developed and developing countries acquire roughly 27 percent and 13 percent of calories, respectively, from animal products (Gilland, 2002). Conceptually, agricultural production can be viewed as controlled management of the flow of nutrients and energy. Nutrients flow within a cycle in the whole farm as a system. This cycle is by no means perpetual -- there are nutrient inflows and outflows from the whole farm (Figure 1). For example, nitrogen volatilizes inevitably during agricultural production and has to be reintroduced into the cycle by means of addition of organic or inorganic fertilizers, fixation via legumes (N-fixing plants) or atmospheric deposition.

Furthermore, the cyclic flow of nutrients is dynamic. Raising animals in times of excess crop production will provide nutrition for following "lean" years. In the cradles of civilization, Mesopotamia and Egypt, animal husbandry was originally introduced to utilize fibrous plants in dry hills distant to the flood plains as a food reserve for years of excess or missing floods. Today, human consumption of grains remains rather stable in times of crop failures, whereas intake of animal products decreases

Figure 1. Example of a farm nutrient cycle. Courtesy of Michigan State University Extension Dairy Team (2006).



drastically (Gilland, 2002). This suggests a shift from grain usage from animal to human consumption and may contribute to the malnutrition during famine.

Historically, the flow of nutrients was largely confined within individual, multipurpose farms. Yet, the modernization of agriculture in the past century has spread nutrient flow over a larger area as farms often concentrated solely on either crop or animal production, and, subsequently, crop (feed) products were transferred to animal farms. Eventually, designated regions of crop and animal production emerged, and the once cyclic flow of nutrients between crop and animal enterprises on a single farm became a one-way street with nutrients (e.g., phosphorus) moved from crop-producing farms and regions to farms in animal-dense regions and not recycled. Consequently, nutrients have been accumulating in regions with an emphasis on animal production while being depleted in crop-producing regions. Recently established regulations require larger animal farms to account for their manure nutrients and avoid overapplication of nutrients. This leads to the export of manure nutrients and/or to the depopulation of animals in livestock-dense regions. Both impose exorbitant cost in the short and midterm, not only to animal agriculture but also to rural communities of the affected regions.

Animal agriculture and the industrial paradigm

Animal production has increasingly followed the paradigm of traditional manufacturing industries rather than one primarily focused on cyclic nutrient flow. Improvements of labor and land productivity, technological advances and increased value of products have occurred over the same time period in animal farms to increase economic efficiency and farm income (Hoshiba, 2002). However, the manufacturing process is not cyclic but straight-line -- products are efficiently manufactured from raw materials, with the goal of generating very little waste.

Animal agriculture is relatively inefficient in transforming dietary nutrients into meat, milk and eggs (Hoshiba, 2002). Huge volumes of waste accumulate during the transformation of feed to milk. For example, efficiency of dietary N recaptured in milk on dairy farms rarely exceeds 30 percent with the remaining 70 percent excreted as manure (Hollmann et al., 2008). Often, animal production is based on large imports of feed grains and, in many cases, forages from local farms or even distant regions as discussed above. Under these circumstances, manure may not have been valued as a resource but as a waste product that farmers had to dispose of. The once cyclic nutrient flow in agriculture gave way in some cases to a straight-line industrial waste-disposal system. The subsequent contributions of animal agriculture to past and current environmental problems were thus in part an artifact of enhancing economics without attention to the overall sustainability of the food production system (Hoshiba, 2002).

Nonetheless, it is noteworthy that farm scale does not categorically affect farm sustainability. Large animal operations are not unsustainable per se. They are sustainable if they are part of an intact cycle of nutrient, or energy flow. And small farms are unsustainable if they, for example, have a low efficiency of nutrient and energy use or cause environmental pollution.

Dimensions of agricultural sustainability

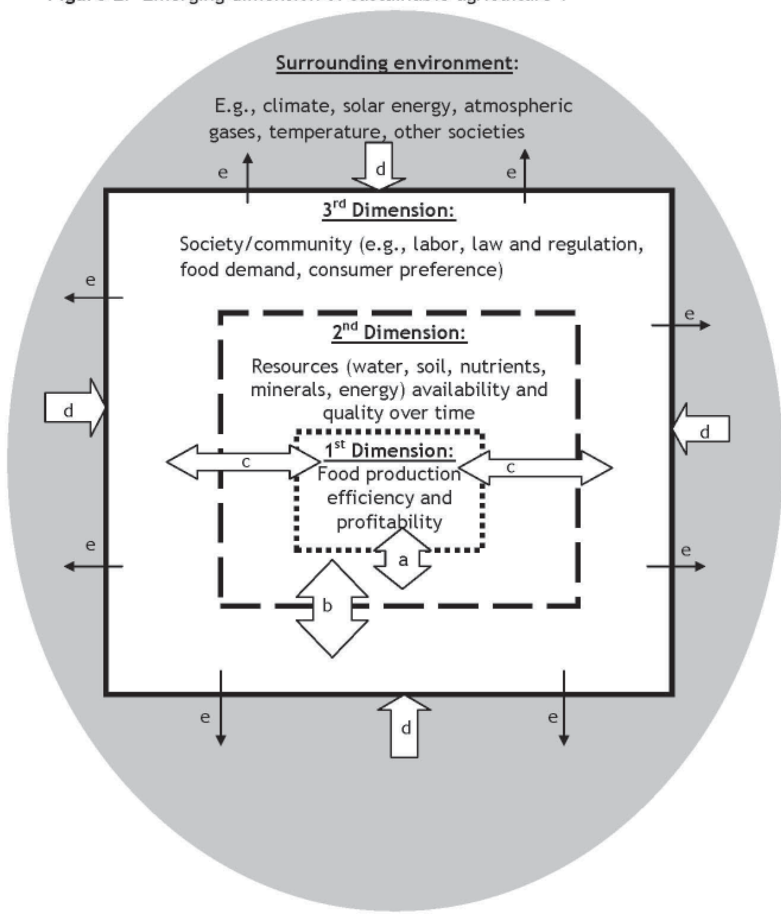
The definition of sustainability is often ambiguous or poorly stated, and depends on personal experience, intellect and worldview. In addition, "sustainability", or exactly what is to be sustained, can change with time. This is true for animal agricultural sustainability. Douglass (1984) proposed that there are three emerging dimensions to sustainable agriculture, and each dimension is founded on a different school of thought or view.

The first dimension encompasses food security and profitability, in that agriculture is obligated to produce sufficient amounts of healthy food that are acceptable for consumption by people while providing sufficient income to farmers, farm workers, and processers up- and downstream from the farm. This dimension describes a sustainability based mainly on the market regulations of supply and demand, on profitability and on technological progress to ensure ever-increasing yields (e.g., grain yield per acre or milk yield per cow). Mathematically, this can be equated as maximization of outputs divided by inputs. Proponents of this school of thought trust in conventional agriculture and its regulation by the free market and are skeptical about the need for sustainable agriculture programs (Thompson, 2007). This view implies unlimited resources such as energy, fresh water, a fertile land base and minerals, and an indestructible environment.

The second dimension to sustainable agriculture accounts for the finite nature of most resources in agriculture and environmental degradation. In this dimension, sustainability is regarded as "stewardship" (Douglass, 1984). Where the previous dimension of food security and profitability relies on maximization of output over input, the stewardship dimension adds a time-variable and views sustainable agriculture as "resource management" (Berkes and Folke, 1998): food must be secured for an ever-growing population indefinitely. According to the stewardship school, production has an environmental cost, and neither resources nor the environment can be depleted to attain food security. Resource management seeks to optimize yield (output) and efficiency of resource use (input) over an infinite time period, which implies an intact environment. One may think of the combination of use of finite resources and environmental cost as destructive units. Under the assumption that there is an ethical obligation to assure sufficient food (nutrients) for all humans now and in the future, agriculture must produce the necessary amounts of nutrients while minimizing the destructive units generated. The emergence of a second dimension from the first dimension of food security exemplifies general systems theory --. i.e., combining several lower level dimensions (subsystems) leads to the emergence of a broader system. Food production is the system of the first dimension, surrounded by an environment that supplies resources such as air, water, soil fertility, biodiversity and energy. However, food production actively interacts with these resources and changes the availability or quality of these resources -- e.g., extensive soil erosion may affect soil fertility and quality, water quality and biodiversity. Thus, the system of food production ought additionally to include its resources as subsystems (Figure 2). This ensures that food production effectively can alter the resources. Conversely, narrowing food production to just production efficiency within a surrounding environment that supplies resources, as in the first dimension, neglects the complexity of dynamics between food production and the resources. This emphasizes the need to examine food production, including animal agriculture, from a more holistic view than simply production efficiency.

The third proposed dimension of sustainability incorporates "society" and its expectations of what is sustainable food production or agriculture. In this philosophy, agriculture no more is its own

Figure 2. Emerging dimension of sustainable agriculture[1].



[1] Arrows indicate interactions among dimensions. Note that conceptually the surrounding environment affects the lower level dimension (system, arrows '***d***'); whereas, the system affects the surrounding environment rather little and, most importantly, in non-controllable ways (arrows '***e***'). Emerging systems combine lower level systems (now subsystems) with parts of their surrounding environment. As a result, subsystems interact and influence one another actively and directly (arrows '***a***', '***b***', and '***c***').

entity but is embedded in a larger system with other subsystems, all relying on the same limited resources.

Abstractly, the three dimensions symbolize an increasing hierarchy (Figure 1). At the lowest dimension of hierarchy, the farmer's responsibility revolves around sufficient and profitable production of food. Subsequently, ecological and environmental responsibilities emerge in the second dimension of agricultural sustainability. Part of the environment is no longer viewed as a surrounding of food production but is itself an important and dynamic factor in the production of sufficient nutrients and energy. At the third dimension, the most integrated and sophisticated, sustainable agriculture is seen interactive with society and vice versa -- members of society have an active role as stakeholders in agricultural production. Society obtains the responsibility of providing the infrastructures (roads and transport, governmental support, industries upstream and downstream of agricultural production, etc.) and political assurances (monetary system, banks, insurances, enforcement of laws and regulations, etc.). In return, farmers not only provide nutrients for the people in return for income but support the local community by provision of leadership, jobs and public services. Sustainable agriculture in this scenario obtains a role in the larger system of a sustainable rural community or, on an even greater scale, a rural-urban community.

Dynamic changes affecting animal agriculture in a sustainable rural community

As a result of the ever-changing nature of the balance of subsystems within and the environment surrounding the sustainable community, the exact meaning of "sustainability" is dynamic, and thus changing over time, because of three variables: the demands for the amount, type, prize and quality of products (output) and availability and price of inputs vary; the changes in the environments surrounding the rural or rural-urban community; and the sociopolitical changes in society.

Demand of products and availability of resources

Estimations by the United Nations Population Division (2008) revealed that world population will have surpassed the 9 billion mark by 2050. Sustaining 6.8 billion people in 2010 differs greatly from sustaining 9-plus billion people in 2050 -- additional food demands will put additional strain on resource management. Certainly, given the current state of agricultural production, securing food for 9 billion people shifts the pendulum further from maximizing resource efficiency and closer to yield maximization. The challenge is not only to achieve sustainable resource management in the current world, a monumental task in itself, but to do even more in the world of 2050 and beyond. Therefore, two related aspects of paramount importance in agricultural science, including animal science, are to improve drastically the efficiency of agricultural production, and to increase the units of production per destructive unit generated in the production process. Meanwhile, food production must remain profitable for the farmers and food must be affordable for the consumers.

Changes of the surrounding environment

This variable encompasses changes within or outside the rural community that are not easily controlled. Examples include long-term changes in temperature, solar energy, concentrations of atmospheric gases, natural disasters, outbreaks of diseases and pests, and loss of availability of resources or market outlets due to war or trade embargos from other societies.

Sociopolitical transformation

Governments and societies impose ever-changing demands on agriculture, especially on animal agriculture. Governments decide on and oversee compliance with laws and regulations, secure and regulate the monetary and taxation systems, may supply incentives or subsidies, and negotiate bi- and multilateral trade agreements on agricultural products and resources. Societies have various beliefs about agricultural practices, such as animal welfare and animal rights; the extent by which technologies, especially biotechnologies such as cloning or hormonal treatments, should be utilized in animal production; or scale and patterns of farming. These beliefs transform and evolve over time. Society enforces its beliefs by exercising consumer preference for certain food types and tastes, and foods of a specific origin; by lobbying for laws and regulations; and by voting during democratic elections.

These three variables impose a strong dynamism on agricultural production of food. However, "sustainability" is based on specific values reflecting a snapshot in time; therefore, these dynamics make it rather impossible to concretely define "sustainability". It is, however, naïve to assume that feeding 6 billion people in the year 2000 and more than 9 billion people by 2050 worldwide can ever be based on a perpetual system. In addition, it may be illusionary that any agricultural practice will be sustainable indefinitely. Any type of agriculture and utilizations of other food resources such as hunting and fishing will dissipate resources and environment. A reasonable goal should be to extend sustainability as far into the future as possible. The following sections will examine ways to limit the destructive units originating from animal agriculture.

Sustainable animal agriculture

In 2002, Tilman and co-workers reported that food production worldwide exceeded food consumption by roughly 8 percent. However, per capita cereal harvest worldwide had peaked in the early 1980s and declined from there on while meat production increased linearly from 23 kg/person in 1960 to 37 kg/person in 1997, despite an exponential growth in global human population. Some researchers project a continuous increase in grain yields per acre (Borlaug, 2009), while others forecast diminishing increases and stagnation in grain yields (Tilman et al., 2002). In the near future, scarce resources such as water, fertile soil and arable grounds, as well as energy from fossil fuel and, subsequently, synthetic nitrogen fertilizers, will become limiting. Therefore, the need to utilize human food and animal feed sources more efficiently constantly rises.

Conversion of humanly inedible foodstuffs

Animals have the ability to convert feed sources of little value to human nutrition (e.g., fibrous plants, byproducts, food waste) into nutrient-rich foods for human consumption (e.g., meat, milk and eggs) or to increase the protein quality of human-edible foods. Perennial fibrous feeds such as grasses can be grown and utilized from poor soil that is unsuitable or only marginally suitable for cultivation. Compared with annual row crops, perennials require less fossil fuel energy, reduce soil erosion, enhance biodiversity and regenerate destructed soil, and ought to be included in crop rotations. In addition, animals transform byproducts and food waste such as distiller's grains from grain ethanol production or kitchen waste, respectively, which otherwise would have to be disposed of as waste, into proteins for human consumption.

Efficiency of feed conversion into humanly edible foodstuffs

Animals do not convert all nutrients consumed, mainly protein and energy, directly into foods for human consumption; protein and energy are inevitably lost during the conversion. More importantly, however, protein of animal origin has a higher nutritive value than protein in animal feed. In nutritive value, protein efficiency in milk from dairy cows is 96 percent to 276 percent, and in meat from beef cattle, 52 percent to 104 percent, using moderate conversion rates (Oltjen and Beckett, 1996).

Generation of environmentally destructive units (e.g., greenhouse gases, phosphorus in surface waters) and usage of fossil fuel energy and energy-derived fertilizer must be minimized while usage of photosynthetic energy is maximized. Indeed, maximization of efficiency in animal production may reduce the overall generation of destructive units (Capper et al., 2008). In practical terms, greater production yields in animal agriculture, and in crop production as an upstream unit of animal production, should be achieved with less resources and lower environmental cost. This includes less dependence of intensive crop and animal production on water availability and on the use of inorganic fertilizers for crop production.

Efficient use of food

Agricultural sustainability neither starts nor ends at the farm gate. Further destructive units may accumulate upstream and downstream of the farm during production of farm facilities and equipment, and transport, storage and preparation of foods. Within the community, food should, therefore, be produced close to centers of consumption to reduce transportation. Animal products have less seasonality than plant products and thus require less storage time and cost. Additionally, spoilage and waste of food products must be minimized. Destructive units generated for production of later wasted food reduce sustainability. These include foods lost, spoiled and prepared but not consumed, and nutrients consumed above one's requirement.

Economics of sustainable agriculture

A community has two major requirements if it is to retain sustainable food production: foods for a well-balanced diet must be affordable for every member of the community, and farmers, as well as upstream and downstream agricultural markets, must receive enough money to sustain themselves financially. For decades, food in industrialized countries has been kept inexpensive and affordable. The current trend in agriculture to increase size to remain economically secure is in part a consequence of that policy. However, keeping food prices low has other types of costs (Corson, 2002). Costs are reallocated and paid indirectly in farm and energy subsidies and other governmental programs; environmental destruction and cleanup of environmental problems; loss of biodiversity; increased risk with monocultures, such as a great dependence on very few crops – e.g., corn and soybeans; infrastructures (e.g., for transport and processing); and decreased standards of living locally. Currently, the fundamental question is whether we want to continue with the current system of inexpensive food prices and have greater social and environmental cost accumulate elsewhere. If food prices are kept inexpensive, society will need to provide incentives to communities including farmers to increase their sustainability. Alternatively, increased food prices need to provide income for farmers to cover short- and mid-term cost related to an evolving sustainability.

Sustainable animal agriculture is inseparably connected with sustainable crop production (Figure 1). Both need to be interconnected within a cyclic flow of nutrients and energy. Inclusion of perennial fibrous crops and legumes may improve sustainability of a crop rotation. Manure generated in animal farms represents a valuable fertilizer for crop production. The utilization of this organic fertilizer for crop production must be maximized to make resources such as fertile soil, clean waters and mineral deposits last longer, and to reduce reliance on fossil fuel. Moreover, animal agriculture needs to maximally use feed sources provided by the cropping entities, either directly or indirectly via by products from other sectors.

Lastly, to ensure optimization of the nutrient cycle and the well-being of society, animal agriculture must be integrated with other agricultural production units within a community. Currently, food production in the United States relies heavily on transportation of inputs and products. Likewise, the regionalization of agriculture into areas of crop production and areas of animal production is detrimental to soil fertility and exacerbates use of inorganic fertilizers and chemicals to sustain production while enhancing environmental destruction. In addition, profit gained in animal operations ought to be reinvested locally, leading to increased wealth of rural communities (Honeyman, 1996).

Sustainability, as discussed previously, can be vaguely defined as providing the population with sufficient nutrients for a balanced diet while conserving finite resources and the environment and furthering the overall well-being of societies. Animal agriculture is a vital part not to but in society, not only with regard to food sufficiency but also as a provider of social capital as an employer, provider of leadership, conservationist of nature and educator. Sustainable animal agriculture is a main cornerstone of a sustainable society.

Conclusion

Sustainability of animal agriculture cannot be evaluated on the basis of individual practices but must be viewed on a holistic basis. Animal agriculture is a vital part of society in the United States and worldwide. Sustainability of societies depends largely on the sustainability of their agriculture. Agricultural sustainability is based on a concept of three emerging dimensions. The responsibility of animal agriculture is to provide food security in concert with crop production. On a broader scheme, animal agriculture must maximize efficient use of energy and nutrients to be sustainable. Within the context of sustainable communities, social sustainability demands that agriculture provide leadership and invest money in its rural communities. In return, society establishes the infrastructures and regulations for profitable agriculture, and provides inputs, markets and labor. Holistically, sustainable animal agriculture is best described as regionally diverse; integrated with crop production within the nutrient and energy cycle; efficiently converting nutrients into products for human consumption; preserving food security; financially secure and profitable for farmers, farm workers, and industries up- and downstream of the farm; family-owned and -operated; and embedded within its local community.

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