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Review Article

Theoretical and practical propositions for more sustainable livestock production

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Abstract

A brief review is made of theoretical and practical propositions for more sustainable livestock production (meat and milk). An Organic Livestock Conversion Index (OLCI) was developed to evaluate the level of approximation of Livestock Production Units (LPU) to the organic model. Organic practices such as crop rotation, use of cover crops, mechanical and manual weed control, and recycling of manure reduce soil erosion and pest problems and generally allow for avoiding the use of chemical fertilizers and pesticides, which - along with the substitution of nitrogen fertilizer with legumes and/or manure – reduces energy use in organic systems. Furthermore, practices by LPU contribute to sustainable livestock production by means of minimal use of chemical fertilizers in pastures; adding nutrients to the soil solely by cattle depositing manure during grazing, manual weed control, use of silvopastoral systems, and energy efficiency by the farmers. The approximation of the LPU to organic production, the use of organic practices, Silvopastoral Systems and more energy efficiency demonstrate the potential of organic livestock farms for contributing to more sustainable production as compared to conventional livestock production.

Introduction

Sustainable livestock production has been defined in various ways and includes prevention of emissions and other sources of contamination, environmental management, efficient resource use, and sustainability, among other issues.

The products offered to consumers by sustainable livestock production must be healthy and of high quality, without harmful effects on animal welfare, human health, or the environment, and that is acceptable to society [1].

It has also been considered that sustainable livestock production represents an alternative to improve livestock productivity and competitiveness, with less impact on natural resources, and the use of good socially accepted practices to strengthen the conservation of resources in communities or production units [2]. In addition, sustainable livestock production is developed according to guidelines for the conservation of water, soil, and plant and animal genetic resources, without degrading the environment and with economic viability and social acceptance. Based on the above, there is greater competitiveness, maintained without causing environmental damage [3].

This review is important because most conventional livestock production systems have been questioned due to their negative impacts on the environment, such as deforestation and greenhouse gas emissions, as well as other aspects such as animal welfare, productivity, and public health. To reverse these impacts, animal production based on the sustainability paradigm has been proposed, in addition to knowing its level of sustainability, or the tendency towards its reduction or increase.

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The approximation of conventional livestock production to the more sustainable organic model is also important in economic aspects. Valdivieso, et al. [4] evaluated the approximation of conventional dual-purpose cattle production units to the organic model in the humid tropical region of Chiapas, Mexico, and demonstrated that the closer they are to the organic production model, the greater the economic sustainability given the net margin per cow. This is mainly due to the fact that organic livestock products are sold in specialized fair markets and short marketing chains, thereby avoiding intermediaries and favoring the income of producers organized through Rural Production Societies.

Furthermore, sustainable livestock production provides environmental services [5], including hydrological services, which contribute to the capture and infiltration of water and the reduction of surface runoff, contributing to the recharge and sustenance of aquifers, as well as the mitigation of the effects of climate change, oxygen generation and pollutants assimilation, biodiversity protection, soil retention, refuge for wildlife and scenic beauty, among others [6].

From the perspective of sustainable livestock production, this review aimed to evaluate the potential for organic conversion of livestock production, and evaluate its energy efficiency. This is critical given global energy and environmental crises and the persistence of malnutrition worldwide, which are alarming indicators of poor natural resource use, lack of production, and poor distribution of healthy food. In 1975, Nicolas Georgescus-Roegen described free energy as that which is available and useful for carrying out work, and pointed out that for all practical purposes, we may not control solar radiation, nor use future solar radiation in the present; however, we are currently consuming free energy from underground mineral reserves. While terrestrial energy provides us with low entropy matter with which to produce manufactured goods, solar radiation is the primary source of all life on earth and allows for greater photosynthetic efficiency of fodder and other crops. In order to make food available to more people, society has generally supported increased mechanization of agriculture, replacing low entropy solar energy with terrestrial inputs. Draft animals such as oxen and buffalo that derive their mechanical power from photosynthesis through solar radiation have largely been replaced by machinery produced and operated using terrestrial low entropy in order to farm a large quantity of land to produce food (including fodder necessary for supplying animal products). Similarly, organic fertilizers and traditional cultivation methods are being replaced by chemical fertilizers and pesticides. Mechanization of agriculture eventually will provoke economic and social disaster as humans´ biological existence increasingly depends on scarce low entropy energy sources [7]. On a global level, there is a need to replace fossil fuel consumption with efficient use of renewable energy [8], for example through certified organic livestock production (meat and milk) [9].

A comparison between conventional livestock production and sustainable livestock production

Table 1 presents the average percentages of approximation to the organic model of ten indicators and the OLCI of LPUs grouped as conventional and close to the organic production model, based on data from Valdivieso, et al. [4]. It is observed that the values of all the indicators are significantly higher or tend to be higher in the organic LPUs compared to the organic ones. With the exception of the ecological management indicator, which presents values with very low viability of organic conversion, the other indicators have values of intermediate to very high viability of organic conversion in the organic LPUs. In summary, the OLCI values of the organic LPUs are higher, so it has the highest viability of organic conversion as observed in the highest OLCI value. These values are similar to those reported by Nahed, et al. 2013 [10], who after intense training work for ranchers to overcome the limitations of the LPU, achieved organic certification, which has allowed ranchers to increase their productivity through quality and in general they are more sustainable.

From the sustainability perspective, Table 2 shows that the five attributes or properties that agroecosystems must have to be sustainable are relatively higher in organic LPUs compared to conventional ones, according to data reported by Nahed, et al. [11]. The attributes of self-management and stability, reliability, and resilience stand out. The behavior of the attributes allows the sustainability index to be relatively higher in organic LPUs.

Table 1: Indicators and OLCI average value (%) of conventional livestock production units with high viability of organic conversion and sustainable in the Zoque region of Chiapas, Mexico.

Indicator	Conventional	Organic HCV
N=	17	19
1. Feed management	67.5	96.1
2. Sustainable grassland management	36.5	53.7
3. Soil fertilization	44.1	55.3
4. Weed control in pastures and crops	47.1	94.7
5. Pest and disease control in pastures and crops	64.7	94.7
6. Prophylaxis and veterinary medical care	27.3	49.8
7. Breeds and reproduction	97.1	100
8. Animal welfare	67.1	68.4
9. Food safety	40.4	66.7
10. Ecological management	8.2	18.9
OLCI	42.6	61.5

Based on data from Valdivieso et al. (2019). HCV= High conversion viability. OLCI= Organic Livestock Conversion Index.

Table 2: Average values (%) of sustainability attributes in conventional and organic livestock production units in the Zoque region of Chiapas, Mexico.

Sustainability attribute	Conventional	Organic
N=	21	21
Equity	30.45	36.05
Self-management	78.9	82.95
Stability, reliability, and resilience	66.45	67.45
Adaptability	45.8	51.25
Productivity	34.4	38.3
Sustainability index	51.2	55.3

Based on data from Nahed et al. (2018).

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The concept and importance of sustainable livestock production

Currently, there is no unique definition of the concept of sustainable livestock production or sustainable livestock farming, and an approximation can be made with the contribution of the different dimensions of current reality and disciplines related to animal, human, and environmental health. In this sense, in order to embark on the path towards sustainability, ethics in the production of animal-origin foods is imperative [12]. According to the above, different definitions and aspects have been proposed for the concept of sustainable livestock production or sustainable livestock farming. Varijakshapanicker, et al. [13], for example, consider that this concept must be economically viable for farmers, respectful of the environment, or at least neutral and socially acceptable; Sustainable livestock production contributes to sustainability in a number of ways, such as using non-arable land for food production, converting non-human-usable energy and protein sources into highly nutritious animal-based foods, and reducing environmental pollution from agro-industrial by-products, while generating income and supporting the livelihoods of millions of people around the world. Furthermore, it has been noted that in addition to being more economically efficient, sustainable livestock production must strike a balance between meeting the growing demand for animal products while minimizing negative side effects and externalities in the livestock sector [14].

To achieve the sustainability of livestock production, it is necessary to improve the efficiency in the use of resources, reduce the advance of its surface towards natural ecosystems, mitigate its negative impacts, and improve natural resources such as soil, water, and air, in addition to the reduction of the intensive use of agricultural inputs. Producers must also have a fair economic income, in an economic, safe, and healthy environment, in addition to increasing the recovery and adaptation capacities of individuals, communities, ecosystems, and the livestock system as a whole, in cases of environmental and economic risks [15].

In Europe, the sustainable development objectives of livestock production include the reduction of emissions, mainly of GHGs throughout the entire process chain; the conservation of resources, their sustainable management and new methods for their conservation; the maintenance and improvement of biodiversity; the reduction of the use of antibiotics and the increase of animal health and welfare [16].

To achieve its objectives, sustainable livestock farming is based on carrying out good practices that improve productivity and economic profitability with the conservation of ecosystems and the care of the natural resources used, which favors an increase in productivity and food security, in addition to contributing to mitigating and adapting to climate change through the generation of ecosystem services [17].

Sustainable livestock farming is also a response to the demand for differentiated livestock products (meat and/or milk and their derivatives), obtained according to a set of good production practices that, with their integration, diversify and improve production, maintain or increase economic benefits, improve the well-being of producers and their families and consumers, in addition to the rational use of natural resources available on and off the farm [18]. Among the practices for sustainable livestock production, Cabezas, et al. [19] recognize other actions such as zoning and organization of livestock production units, improvement of the grazing system, use of manure to fertilize farm soils, capture and use of water, establishment of silvopastoral systems, a hydrological plan for the farm and animal welfare. In relation to grazing, sustainable livestock systems must implement adequate management of the number of animals that the land supports without overgrazing them, rotation of pastures that allows for the recovery of pastures, and alternation with other forage crops of legumes or grasses [20].

In a broader context, it is considered that for animal production to be sustainable, the efficient use of energy and nutrients must be maximized. In the context of sustainable communities, social sustainability requires that agriculture provide leadership and invest money in rural communities. Holistically, sustainable livestock production is best described as regionally diverse, integrated with crop production within the nutrient and energy cycle; considering the efficient conversion of nutrients into products for human consumption and the preservation of food security; financially secure and profitable for farmers, farm workers, and industries at all levels of the farm; family owned and operated; and integrated within its local community [21].

It is also considered that for animal production to be more sustainable, it is imperative that the proximity, interrelationships, cycles, and balances between soil, water, plants, and animals be emphasized, revitalized, and developed. This builds and maintains healthy soils and a continuum of sustainable holistic animal production systems. Among the different variations on the concept of sustainable agriculture and livestock, virtually all encompass manageable, viable, and equitable interrelationships among the three main pillars of sustainability: social, environmental, and economic [22].

Definitions of sustainable agriculture also include references to financial, environmental, ethical, social, and product quality issues. In addition to such considerations, sustainable animal production must also address issues related to animal welfare [23].

A broad and dynamic definition of sustainability for animal production considers a sufficient and profitable food production system, independent of scale that includes complex interactions between agriculture and society [21].

Finally, sustainable livestock should be considered a crucial component of sustainable agriculture, because animals are an irreplaceable component in the interaction between water, other nutrients, and energy recycling in mixed plant-animal systems. Furthermore, sustainable agriculture and livestock are indispensable for achieving sustainable development, particularly social sustainability, at regional, national, and global levels [22].

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Sustainable production and conversion of conventional livestock production to organics

Organic agriculture - also known as ecological or biological agriculture - is based on the principles of health, agroecology, equity, precaution, responsibility, and sustainability [24]. Organic regulations of all nations are based on principles stated by IFOAM. Organic livestock production emphasizes preventative measures over veterinary treatment [25,26]. Hygienic-sanitary livestock management favors animal well-being and adequate nutrition so that animals maintain a high immunity. Furthermore, creole animals and their crosses are recommended as they are better adapted to local environmental conditions and therefore have greater resistance to predominant diseases and parasites [27-29]. Organic livestock production makes use of natural medicine, such as homeopathy, herbalism, and acupuncture [25,26]. Artificial insemination is permitted, although the use of hormones to synchronize oestrus, bovine embryo transfer techniques, and the use of genetically modified animals are prohibited [28,29].

Based on regulations by [24] and the Council of the European Union [30], an Organic Livestock Conversion Index (OLCI) was developed to evaluate the level of approximation of livestock production units to the organic model and identify limitations, potential, and opportunities for organic transition [31]. This methodology was used to successfully transition farmers from two small peasant organizations in Chiapas, México, to organic certification of milk and live cattle and become certified by the Mexican Certifier of Ecological Products and Processes (CERTIMEX). In this case, the steps to obtaining organic certification [32] were: i) evaluation based on the OLCI methodology [29,33,34]); ii) training to strengthen farmers´ and technical advisors´ organic farming capabilities; iii) fundraising with government agencies; iv) implementing and following up on the transition process; and v) inspection and certification. Even after beginning to market their products as organic, these farmers were motivated to continue to evaluate their farms´ level of approximation to the organic model due to their perceived need (as expressed in meetings and participatory workshops) to implement sustainable organic production and management techniques. They were further motivated by learning of other cases in which organic farming was shown to be more sustainable than conventional farming.

Farms that produce milk and meat from grazed cows using low levels of external inputs may more easily convert to organics [35], achieve sustainability status [36,37], and furthermore contribute to a variety of products and environmental services [38-40], especially when cows graze in innovative Silvopastoral Systems (SPS) with high levels of biodiversity. In such systems, cows may produce twice the milk as those grazed in grasslands in monoculture - aside from meat, fiber, manure, work animals, timber, and firewood - with minimal use of external inputs [35]. SPS allows for sustainable livestock production as well as adaptation to - and mitigation of - climate change, as they increase tree and shrub cover, provide shade, and regulate climate stress [13]. SPS also mitigate emissions of carbon dioxide, nitrous oxide, and methane; recycle nutrients and restore degraded soils; conserve biodiversity; protect watersheds; reduce runoff; improve air and water quality; and increase wildlife connectivity and scenic beauty [41,42]. Therefore, as compared to conventional paddocks in monoculture, SPS greatly benefit society from the farm and local levels to the landscape and global levels [43]. As SPS involve intensive management - consisting of a high density of woody fodder plants - and high use of manual labor to compensate for reduced use or absence of external inputs, they preserve small farmers´ livelihoods by creating employment [44,45], thereby contributing more to farmers´ economic well-being than conventional treeless grazing systems due to their greater biodiversity, as well as productivity of fodder and animal products [38]. The animals´ diet which is based on grazing on herbaceous and woody species in SPS – which are often integrated with agricultural crops, use of local breeds, and veterinary prevention and care and reproductive techniques that meet organic regulations - contributes to animal well-being, food safety, and sustainability in general given that they are based on low use of external inputs and fossil energy [9].

Sustainable livestock production and energy efficiency

According to systems theory, livestock systems constantly exchange matter and energy with the exterior [46]. Energy entering the system is processed and circulated by interacting with the system´s components. However, the quantity of energy entering the system is not always proportional to that leaving the system. Understanding energy flows is necessary for achieving energy sustainability, for economic, ecological, and social reasons. Quantification of energy efficiency of productive systems is fundamental to designing sustainable agriculture that produces both food and energy, as well as to political decision-making regarding agriculture [47-50]. Three principal methods have been developed to measure the efficiency of energy use of productive systems: ecological footprint, energy analysis, and energy analysis [51]. Energy analysis is one of the first methods developed [47,52] to estimate the direct and indirect use of fossil fuel to produce a given good or service; this approach has been applied to study the impact of changes in energy use and management and compare organic and conventional agricultural systems. This method not only considers fossil fuels but also energy in relation to the number of people that the system may feed, taking into account inputs and yields [48]. Thus, evaluating energy efficiency allows for analyzing energy dynamics within a farm, which may contribute to making farmers´ decisions regarding productive practices that allow for reducing dependence, vulnerability, and lack of resilience of production systems.

Organic practices such as crop rotation, use of cover crops, mechanical and manual weed control, and recycling of manure reduce soil erosion and pest problems and generally allow for avoiding the use of chemical fertilizers and pesticides, which - along with the substitution of nitrogen fertilizer with legumes and/or manure – reduces energy use in organic systems [53]. Many studies have demonstrated that the elimination of

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synthetic fertilizers, pesticides, and herbicides leads to less fossil fuel use, and thus greater energy efficiency [54]. For example, mechanical weed control with machinery uses less than half the energy of weed control with herbicides [36]. Practices by Livestock Production Units (LPU) recommended in the present study include minimal use of chemical fertilizers in pastures; adding nutrients to the soil solely by cattle depositing manure during grazing; and manual weed control by the majority of farmers. Rather than completely eradicating weeds, ecological weed control is based on maintaining populations of spontaneously growing plant species in pastures and crops at levels by which interspecies competition does not reduce the productivity of grasses [55]. With respect to insect pests, instead of using pesticides in pastures, ecological control is principally manual, and to a lesser extent mechanical through grazing, use of botanical insecticides and repellents [56], and/or integrated pest management, which includes ecological soil and biodiversity management [28].

Transportation and supply of concentrates and other feed for conventional livestock greatly contributes to energy use, responsible for up to 90% of total energy input [57]. In the Netherlands, the transportation of feed concentrates from factory to farm was responsible for 83% of the total indirect energy use of conventional farms, and only 67% of that of organic farms [58]. In Chiapas, México, the approximation of the LPU to organic production, their use of SPS, and their energy efficiency demonstrate the potential of livestock farms for contributing to more sustainable production as compared to conventional livestock production.

In order to recommend the adaptation of the organic and sustainable production model mainly in arid and semi-arid agroecosystems or in areas with temperate climates, it is recommended to consider [59,60]: i) The foundations for organic conversion [61,11]; ii) the knowledge, experience, knowledge and forms of organization of the producers of each region for the appropriate use of natural resources. iii) The location of the livestock units in the best physiographic conditions where humidity tends to accumulate, for example in low areas. iv) preparation of areas surrounding the livestock units to harvest rainwater, directing it appropriately so as not to cause erosion and infiltration into vegetation areas, as well as establishing water storage areas. v) Making the most of the scarce local rainfall, to prevent water from running off and staying on the ground.

In relation to sustainable pasture management, rotational grazing with the use of native grasses adapted to the soil conditions is recommended, in association with protein-rich forage trees and shrubs and other species, especially in the dry season [62]. The establishment and care of local forage trees and shrubs provide forage and shade for livestock as they allow the browsing of local species that subsequently favor the natural dispersal of seeds of favorable species adapted to the areas to improve grazing lands. Maintenance of soil organic matter is required to have a better soil structure that allows better infiltration and conservation of moisture, together with plant roots adapted to local environments. The variability of extreme temperature and drought conditions, aggravated by climate change, requires the implementation of all possible mechanisms such as risk prevention and adaptation mechanisms [59].

Conclusion

This work suggests that the LPU approximation to organic production allows for the conservation and promotion of biodiversity, the provision of agroecosystem services, and the promotion of energy efficiency and sustainable livestock production, compared to conventional extensive and intensive livestock production.

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