A Review of the Impact of Different Types of Livestock Production Systems on Economic Sustainability and Environmental Management

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Abstracts

Different feedstuffs and feeding systems may affect the sustainability of livestock production. In this review, two aspects of sustainability have been taken into consideration namely, ecological and economic sustainability. Comparisons between the two aspects of sustainability (ecological and economic) have been made for pasture-based systems and indoor feeding system. This has been done for developing countries as well as for developed countries. While the impact of intensive farming system on economic sustainability in developed countries is relatively stable, their environmental and ecological sustainability in these countries is questionable. In less developed countries, poor economic and environmental sustainability have been associated with bureaucratic procedures for accessing and using land resources, poor availability of feed resources, lack of capital, and pastoral mobility. It is recommended that profitable livestock production should focus on integrated crop-livestock production systems to achieve food security and environmental sustainability. Integrated crop-livestock systems can provide opportunities to capture ecological interactions among different land use systems and improve nation economic well-being.

Keywords: *Ecological sustainability, Environment, Economic sustainability, Livestock, Systems*

Introduction

Agricultural sustainability has recently become a hot debate all over the world. While the concept of sustainability has difference meaning to different scholars, it appears to offer the potential focus for future development plans (Gibon 1999). In the context of livestock production, sustainability is defined as the production system that attempt to meets the needs of the present population without compromising the ability of future generation (Thompson and Nardone1999). However, the interpretation of the sustainability concept is very complex and subjective, depending on society's perceptions. Moreover, sustainability is not static, what is acceptable today may not be acceptable in future.

According to Thompson & Nardone, (1999) a livestock production system is considered to be sustainable if the resources required for production are perceived to be available in the foreseeable future. The rate at which resources are produced and the time frame within which production takes place are key aspect in this definition. For example in most developed countries, technological advance offers sustainable feed production sufficient for livestock consumption such as silage, hay and various concentrates within short time span. However the use of heavy machinery and chemicals in making these feeds may affect environmental sustainability on the long run. For that matter, the following discussion highlights the effect of intensive and extensive livestock production systems on environmental and economic sustainability. In the discussion, comparison has been made between less developed countries in Africa and developed countries particularly in Europe in terms of livestock production systems and the ecological and economic sustainability.

Environmental Sustainability

Intensive livestock production system

Intensive livestock production systems in well developed countries particularly in the European countries involve the use of external (purchased) inputs for feed production. These inputs include industrial fertilizers, pesticides and herbicides in order to increase feed production and improve livestock performance. However, application of such inputs impairs the environmental and ecological sustainability of livestock production. Wauchope (1978) pointed out that, despite the important role played by application of pesticides in the improvement of pasture yield, they are potential source of adverse impact in the environment. Most of these agricultural inputs have long term residues effect in the soil. Horrigan *et al.* (2002) highlighted that many of the pesticides and industrial fertilizers generate waste that is harmful to the environment and to public health. According to the above authors, these chemicals have long term effects on biodiversity among plants and animals, eroding soil much faster than it can be replenished. Use of such chemical more often increase water and air pollution through contamination, evaporation and volatilization (Horrigan *et al.*, 2002).

Intensification of production systems in developed countries by using high-yielding agricultural inputs such as fertilizer, irrigation water, and pesticides has contributed substantially to significant increase in production over the past 50 years. However, this intensification has altered the biotic interactions and patterns of resource availability in ecosystems leading to serious environmental consequences (Matson *et al* 1997). In such countries, livestock feeds have become richer in grains than grasses. Most of these grains are obtained from monoculture production systems which depend on the use of chemicals to increase yield per unit of land. As a consequence use of such chemicals have impacts that affect a wide range of ecosystem services, including water quality, environmental pollination, nutrient cycling, soil retention, carbon sequestration, and biodiversity conservation (Dale and Polasky 2007). In additional to application of industrial agro-inputs to increase forage yield for livestock production, use of growth-promoting hormones is one of the factors contributing to environmental and public health consequences. According to Horrigan *et al.* (2002), an increase in pesticides resistances and prevalent food-borne pathogens are overwhelmingly associated with animal products, most of which come from factory farms and high-speed processing facilities. Matson *et al.* (1997) cautioned on the long term environmental consequences of applying the industrial agricultural inputs. According to these authors, production systems that rely heavily on agro-inputs such as inorganic fertilizers, pesticides and herbicides are not sustainable, because these chemicals increased soil erosion, reduce biodiversity, increased pollution of ground and surface water and have impact on atmospheric constitutes and climate.

Chemical inputs such as application of industrial fertilizers in pasture production systems, leads to environmental degradation as a result of Nitrogen leaching. Nitrogen leaching from livestock intensive production systems has been blamed for raising the concentration of nitrate in ground and surface water worldwide (Di and Cameron, 2002). High concentration of nitrate in water has consequent effects on the environment and subsequently to animals and human health. According to Baso and Ritchie (2005), nitrate concentration in excess of 10mg/L in drinking water, may pose risks to both animals and human beings. Nitrogen has high affinity to hemoglobin, and thus presence of high concentration of nitrogen in drinking water can oxidize ion in hemoglobin and form *methemoglobin* in the red blood cells (Baso and Ritchie 2005). Such chemical reaction lowers the capacity of hemoglobin to carry sufficient oxygen and as a consequences lead to respiratory problems for those animals drinking water with high level of nitrates. In addition potential cancer risk has been reported from areas with high concentration of N contents (Jasa *et al.* 1999).

Intensive livestock production systems in developed countries do not only affect soil ecosystems but also contribute significantly to the atmospheric greenhouse emission. Although use of high quality forage and alternative feeds such as concentrates can decrease emission of Green House Gasses (GHG), but use of fossil fuel and machinery in pasture production offsets such gains, contributing significantly to emission of these harmful gasses. The use of fossil fuel in manufacturing fertilizer in highly industrialized countries emits up to 41 tons of carbon dioxide per year (Table 1). In fact more than 60 % of Nitrogen fertilizers produced in developed countries uses electricity from coal (Steinfeld *et al.* 2006). Indeed, on-farm use of fossil fuel by intensive system produces almost two times higher Co_2 emission than those from Nitrogen fertilizers.

Table 1: Carbon dioxide emission from burning fossil fuel to produce Nitrogenous fertilizer in selected countries

	Amount of N fertilizer produced 1000 x tons	**Emitted Co_2 1000 tons/year**
Argentina	126	314
Brazil	678	1,690
Mexico	263	656
Turkey	262	653
China	2,998	14,290
Span	491	1,224
UK	887	2,212
France	1,371	3,284
Germany	1,247	3,109
Canada	897	2,237
USA	4,697	11,711
Total	**14 million tons**	**41 million tons**

Source: Steinfeld *et al.* 2006

Globally, there has been concern about environmental sustainability with respect to intensive livestock production system. As a way of combating environmental consequences related to intensive farming, organic farming has recently been taken as an alternative way of halting environmental degradation. Organic farming through integrated crop–livestock systems could provide opportunities to capture ecological interactions among different land use systems and thus preserving natural resources and the environment, improving soil quality, and enhancing biodiversity (Lemaire *et al.*, 2013). Organic farming is directed towards biologically based fertilizers (bio-fertilizers) and bio-control of diseases (Sinha *et al.*, 2011). Organic farming is considered an effective way of reducing environmental degradation compared to more intensive conventional farming systems (Baso and Ritchie 2005). Organic farming systems are believed to eliminate agrochemicals and reduce other external inputs which subsequently improve the environment while also sustaining economic profitability. According to Pimental *et al.* (2005), the aim of organic farming is to augment ecological processes that foster plant nutrition and yet conserve soil and water resources. For environmental and ecological sustainability in developed countries, organic livestock production systems can be adopted instead of the conventional intensive production systems, which have been blamed for having serious negative impacts on the environment.

Disappearance of forage crops and grass-land interaction reduces the potential attainment of ecosystem services traditionally obtained from diversified crop livestock systems. Increased intensification and specialization of agricultural system, has come with increasingly negative impact on environment (Schils 2007). Production has been largely driven by use of non-renewable resources which impair environmental sustainability through emission of considerable amounts of greenhouse gasses, which have long term residues effects in the soil. Poor management of animal manure also contributes significantly to emission of Methane, Nitrous Oxide, Ammonia and Carbon Dioxide (Steinfeld *et al.*, 2006). Hence, one of the most promising approaches for improving livestock production and subsequently reducing negative impact on the environment is to adopt integrated farming systems. According to Lemaire *et al.* (2013), integrated farming system, improves soil structure, water infiltration, nutrient cycling, soil organic Carbon sequestration, soil biological diversity; and controlling weed communities, insects, and disease populations.

Extensive Livestock Production System

This part of the discussion focuses on environmental and ecological sustainability in relation to extensive livestock production system, which is dominant in Africa. Most African pastoralists inhabit arid and semi-arid areas are dominated by variable and unpredictable rainfall. The biophysical environment (climate, topography, drainage, vegetation and fauna) determines livestock production in pastoral societies (Homewood, 2008). Most pastoralists' strategies involve movement and patchy use of forage resources ranging from very mobile to relatively sedentary production systems. Transhumance: the seasonal movement of livestock herds between spatially distant sites is a common grazing system in African countries that enable pastoralists to make use of the best pasture, water and mineral resources. This system optimizes the quantity and quality of forages which varies from one place to another. Although, the pastoral ecosystem has been perceived as unproductive and environmentally damaging (Vetter, 2005), currently there is evidence that transhumance system may lead to significant better health and productive animals compared to sedentary livestock systems (Homewood 2008). In line with the negative perception against pastoralism, different countries in Africa have attempted to develop some policies against pastoral mobility as a way of halting environmental degradation. For example, Mattee and Shem (2006) highlighted that, in African countries, negative perception pervade pastoral policies especially in regard to pastoral mobility.

Since extensive grazing systems involve free ranging of large livestock herds have detrimental effects on vegetation and soil through mechanical soil compaction and nutrients removal. Although it is possible that plants may increase their growth rate following defoliation and thus compensate for the total amount of biomass removed, but heavy grazing normally exposes the soil cover to erosion and thus affects soil structure. Chronic intensive grazing in one area is detrimental to vegetation because it removes the leaf area that is responsible for converting active radiation to chemical energy through photosynthesis (Briske *et al.* 2008). Reduction of photosynthetic leaves by grazing animals normally lead to poor root mass development which subsequently affects the plant's ability to access soil water and nutrients. According to Valentine (2001), trampling plant and soil by livestock leads to loss of forages and soil compaction in arid and semi-arid regions and thus reducing environmental sustainability.

Negative views regarding the effect of extensive livestock production system on ecological and environmental degradation in African have received critical criticisms from many scholars (Scoone 1995; Vetter 2005). Some of them arguing that, in arid and semi-arid regions, with high climatic variation, intervention focused only on manipulation of livestock population may not be appropriate, since rangeland productivity and livestock performance in these regions are neither driven by livestock number, nor affected by production systems. Rather, stochastic abiotic factors are considered primary driver of vegetation dynamic and livestock performance (Vetter 2005). Several factors may affect environmental or ecological sustainability of African rangelands, namely drought, overgrazing, fire and poor soil fertility. Prolonged drought in arid and semi-arid environments has detrimental effect on plant communities. Although, pastoral communities living in arid and semi-arid areas they have the ability to cope with drought related challenge. Nonetheless, prolonged droughts stretch their coping mechanisms beyond their limit.

During prolonged drought, fire is prevalent in African rangeland ecosystem, which accelerates environmental deterioration, thereby affecting the sustainability of livestock production in these marginal areas. Although fire is used as a management tool in African rangeland (controlled fire has positive influences on the rangeland ecosystems such as plant germination, rapid growth, nutrients recycling and pest control), but uncontrolled fire may have adverse effects on the sustainability of rangeland ecosystem. Depending on the fire's severity, intensity, plant response and seasonality, fire can destroy and degrade favourable rangeland ecosystem (Glennis 1988).

Livestock Production Systems versus Economic Sustainability

Intensive livestock production system and economic sustainability

Intensive systems are high input - high output in nature, with animals spending their lifetime in stalls, receiving improved feeds or partly spending time on pasture and get finished in feedlot. This system is very common in developed countries. For example feedlot production with high milk yield (more than 10,000kg/year) is a common practice in modern dairy production in developed countries (Rodriguez-Martinez 2009). High yield is a combination of improved genetics, good feeding system and management. For example, in Sweden, the average milk yield production per cow almost doubled between 1957 and 2002 (Figure 1). However, the main concern here is whether such yield is economically sustainable over time. Rodriguez-Martinez, (2009) established a negative relationship between milk yield and cow fertility over time. The argument here is that, despite high livestock productivity in developed countries, reproductive performance in terms of calving rate is likely to decrease in many animals with improved genetic potential because of fertility and health impairment. For example, improved genetic potential for high milk yield can lead to poor fertility as well as poor animal health and thus affect economic sustainability of the production system in the long run. Oltenacu and Broom (2010) commented that, livestock production in well developed countries should be viewed with great concern because the increase in milk yield has been accompanied by declining fertility, increasing leg disorder and other metabolic problems which subsequently lead to declining longevity of animals.

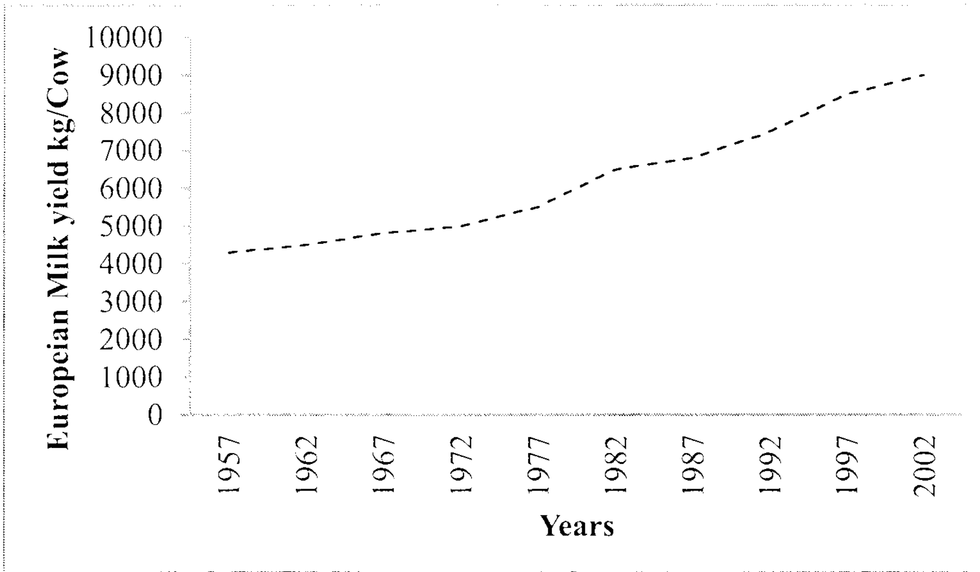

Figure 1. The trend of milk production in Sweden from 1957 to 2002
Source modified from: Oltenacu and Broom, 2010

Apart from genetic potential, the type and amount of feeds and the entire cost of production are important factors determining the economic sustainability of livestock production in developed countries. In European countries for example, feeding animals with silage has advanced considerably since the 1960s. Within pastures, most of the silage is made from grass, followed by legumes (such as Lucerne), whole crop cereals (such as maize) and beetroots (Cherney, *et al.*, 1998). Improved crop husbandry practices that result in high yield nutritious ensiled forage have reduced the cost of silage production making silage an economically attractive feedstuff. Availability of important materials used to make silage, such as polythene covers, big round balers, additives and their applications as well as high technological innovations related to mechanization and storage have contributed to adopting silage making in developed countries. To ensure sufficient silage is produced, high use of industrial fertilizers and use of heavy machinery for silage harvest is common in developed countries. For that matter, the economic evaluation of livestock production through silage feeding is complicated as sustainability depends among other things on operating cost in relation to the total revenue. In most cases intensive livestock farming in developed counties has always been encouraged by financial incentives (subsidies) from governments (Drennan, 2009).

Extensive livestock production system and economic sustainability

Throughout the African continent, most of the rangelands are managed on the basis of complex and negotiable land use system. Unlike western countries, the system of access and use of land in Africa is not clear-cut, land is generally held by groups (common pool resources) rather than individuals. In most African countries land ownership for grazing is largely owned communally, where its acquisition relies on birth-rights and close family relationship (Selemani, 2014). Meanwhile, the feeding regime for livestock in Africa involves extensive livestock production system, which is characterized by free ranging on natural pasture whose quality and quantity vary with season. Despite seasonal variability in the quality and availability of forage in African semi-arid regions, a body of literatures indicates that, extensive production system gives higher economic return per unit area compared to other intensive feeding regimes (Campbell *et al.*, 2000; Selemani 2017). Breman and de wit (1983) shows that, production of protein per ha of nomadic pastoralists in Mali and Botswana is two to three times higher than production from sedentary systems with similar climatic conditions.

While pastoral mobility is claimed to offer high economic return in Africa due to opportunistic utilization of rangeland resources (Selemani, 2014), little effort has been made to analyze the cost-effectiveness pastoralists' mobility (Nkedianye *et al.*, 2011). Such mobility may have economic implication for African pastoralists in terms of animals' performance, which subsequently affects livestock marketing. For example, Nkedianye *et al.* (2011), found a significant high mortality rate of livestock in the Maasailand (at Kitengela in Kenya and Simanjiro in Tanzania) due to immigration of large herds of livestock from drought stressed areas. A Very high loss of livestock was also noted in Tanzania in 2011 where more than 50% of pastoralists from the Usangu plains in Mbarali district, Mbeya region were forcibly reallocated to avert further environmental damage of the great Ruaha watershed. Subsequently, many pastoral families suffered from food insecurity due to livestock losses following pastoral mobility (Ngailo 2011). The loss of livestock could was attributed to migration of large herds over a long distance to new allocations, which increased competition for forage and water resources en-route, thereby lowering the body condition of migrating animals, sometimes leading to their death. Moreover, interaction of livestock herds from different areas increases the risk of contracting diseases, which affected the body condition of resident and immigrant livestock (Nkedianye *et al.*, 2011).

In general there is a contradiction or a difference regarding how the profitability of extensive livestock production systems is perceived and computed among researchers. In Africa valuation of economic profitability of

extensive livestock production should incorporate various variables including; such as livestock population dynamic, forage production, climatic condition, production cost and opportunity cost, which are often difficult to model (Kobayashi *et al.*, 2003). For example the temporal and spatial variability of rainfall coupled with vegetation heterogeneity seriously limits the economic evaluation of extensive livestock production system due to seasonal fluctuation in the quality and availability of forage resources. The multiple uses of livestock (as capital investment, social value and saving for risk management) also complicate economic analysis of African pastoralists. Livestock are themselves considered a productive input that is set aside and used to generate more productive output (Homewood, (2008). For example, livestock directly contributes to modification of Carbon and Nitrogen cycles (Steinfeld *et al.* 2006). Livestock is used as a source of food in terms of milk and meat, while also contributing to crop production (manure and draught power). However, the integration between livestock products and cultivated crops is a fundamental determinant of pastoral economy. In most African countries where the main economic activity is agriculture, increased economic profitability gained from cultivated crops determines the purchasing power of livestock products. In these countries, where the prices of commodities are relatively unstable, marketing system depend on the negotiation power between the owners of commodities and buyers, thus making it difficult to predict economic stability.

Conclusion

Sustainability is a complex concept involving several aspects such as resources availability, environment, ecological integrity, social support and economic aspect. Achieving sustainable system depends on achieving among other things, environmental integrity and economic efficiency. Livestock production systems vary across the African continents and across the world. Although intensive production with specialized high-input systems appear to be a goal for modern farming in developed countries because of high economic return, this system has a high level of environmental degradation, reflecting the low sustainability of non-diverse farming systems. Integrated crop livestock production systems, therefore, could be a key form of ecological intensification needed for achieving future food security and environmental sustainability. Unlike most developed countries, African pastoralists are characterized by mobility, searching for forage and water for their livestock. Due to the multiple functions of livestock in Africa and among pastoralists in particular, (a source of life saving, production of organic fertilizers and social status), increasing the number of livestock is a normal trend in pastoral communities. High livestock population may generate highly specialized and uniform pastoral land use systems, which may subsequently lead to environmental degradation. Hence, for both economic and environmental sustainability, integrated crop–livestock systems could provide opportunities to capture ecological interactions among different land use systems and improve economic well-being with minimal production cost.

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