The Role of Livestock in Developing Communities: Enhancing Multifunctionality

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8 Sustainable Livestock Intensification

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Abstract

Livestock intensification is a response to increased demand for livestock products, especially milk and meat. Although intensification offers opportunities for better income, it may deny smallholders the benefits of the multifunctionality of livestock, particularly the intangible benefits derived when products become increasingly commoditised. The increase in livestock populations has meant consequent impacts on the environment due to management changes such as increased use of commercial feeds and poor waste management practices. Although traditional livestock systems have provided a livelihood mainstay, particularly for farmers in developing countries, they now face challenges from a degraded natural resource base, negative impacts of climate change such as prolonged droughts, and an unresponsive policy environment. Livestock intensification is bringing about structural changes in livestock systems, particularly within the poultry and swine subsectors which provide huge returns per unit input and offer farmers economies of scale. This practice is edging closer to urban centres where there are large markets supported by better infrastructure. However, there are also current environmental, disease and welfare concerns when animal rearing occurs in small spaces with little waste-absorptive capacity. The right pathway for intensification in these situations seems dependent on sound policy and legislative frameworks aimed to mitigate impacts on the environment and welfare, while ensuring enterprise profitability. This chapter follows the livestock intensification theme and evaluates various practices influencing its sustainability and multifunctionality from the perspective of practitioners in both the developing and developed worlds.

Keywords: livestock intensification, livestock revolution, environmental impact, animal protein consumption, driving forces

1. Introduction

The 1992 United Nations Earth Summit held in Rio de Janeiro sought to lay a foundation for sustainable development in the world economy. The esteemed Brundtland Report credited with raising the debate five years earlier, defined sustainability in simple terms as the ability to meet the needs of the present generation without compromising the ability of future generations to meet their own needs (WCED, 1987). Two decades after the Brundtland Report was issued, sustainability had proven a hard concept to pin down, vague as a guide to the future, and interpreted to mean "all things to all people" (Tietenberg, 2005). However, sustainability has become more clearly assessed and understood in terms of environmental, economic and social dimensions with quantitative indicators acceptable to the stakeholders (Mollenhorst, 2005).

Intensification of livestock systems is the process of modifying production practices to increase output per animal, per unit of land and per unit of labour (Nicholson *et al.*, 1995). For instance, in ruminant livestock production, production output is measured in terms of the amount of milk or beef per unit of land. In its broadest sense, intensification can range from minor modifications to the complete restructuring of existing systems. It therefore identifies more closely with the objectives of productivity in a given system.

This chapter assesses the status of livestock intensification in developing countries, especially with regard to smallholder farmers who experience resource constraints such as decreasing land sizes, low financial inputs, low access to information and markets, and insufficient infrastructure to develop their animal enterprises. In spite of these challenges, improved productivity, profitability and sustainability of smallholder livestock farming is viewed as the main pathway out of poverty and for stimulating agricultural development (World Bank, 2007).

Furthermore, this chapter evaluates the multifunctionality of livestock systems and the role of intensification in the developing world, namely Africa, Latin America and Asia. The concept of multifunctionality recognizes agriculture as a multi-output activity producing not only commodities (food, feed, fibres, agro fuels, medicinal products and ornamentals), but also non-commodity outputs such as environmental services, landscape amenities and cultural heritages (IAASTD, 2008). To understand underlying issues better, the chapter introduces key intertwined themes:

- changes to the existing livestock systems and what intensification may imply;
- management of the transition to livestock intensification and related system dynamics; and
- analysis of agricultural economic systems to ascertain if they will automatically produce sustainable livestock intensification systems or if policy changes will be required and, if this is the case, what policy changes will be needed.

Structural changes in global agriculture will cause the livestock sector to change from a multifunctional to a commodity subsector. In this light, the following sections detail an overview of trends in livestock development in the quest for sustainable intensification.

2. Role of livestock in developing countries

The livestock sector is projected to become the world's most important agricultural subsector in terms of value-added products and land use. Livestock products account for about one-fifth of the global trade of agricultural products (Ali, 2007). In developing countries, demand for livestock products such as beef, milk and hides continues to expand due to increased household income, urbanisation and population increase. Each year in developing countries, the human population grows by 72 million, which adds to the demand for food products. There are, however, wide differences in population growth between East Asia, which has reported a decreased rate of 1.6 percent in population growth per annum, while sub-Saharan Africa has had increases of 2.8 percent per annum. In addition, the changing population structure has seen a fast increase in urbanisation and, as has been shown, urban dwellers adopt new eating habits, consuming higher amounts of animal proteins and eating a higher proportion of food away from home (Steinfeld *et al.*, 2006).

Animal-protein consumption

According to Delgado (2003), consumption of meat in developing countries increased by a factor of five from the early 1970s to mid-1990s. In East and Southeast Asia, where population, income and urbanisation grew rapidly from the early 1980s to the late 1990s, meat consumption grew between 4 and 8 percent per year. In India, which is the world's largest milk producer, milk consumption doubled from the early 1980s to the late 1990s, now accounting for over 13 percent of the world's total milk produced and over 30 percent of the milk consumed in developing countries (Ali, 2007).

Rapid urbanisation in Latin America has led to a higher average level of milk consumption at 112 kg per capita, compared to 43 kg per capita in the developing world as a whole (Delgado, 2003). This compares well with per capita meat consumption of 80 kg for developing countries and 130 kg per year in high income countries (Steinfeld *et al.,* 2006). The increasingly urban and more affluent population in the developing world will demand a richer, more diverse diet, with more meat and milk products. As a result, global meat demand is projected to grow from 209 million tonnes in 1997 to 327 million tonnes in 2020, and global milk consumption from 422 million tonnes to 648 million tonnes over the same period. This has appropriately been called the "livestock revolution" (Delgado *et al.,* 1999). Table 1 provides an overview of the important dietary transition that has occurred in the average diet in different parts of the world.

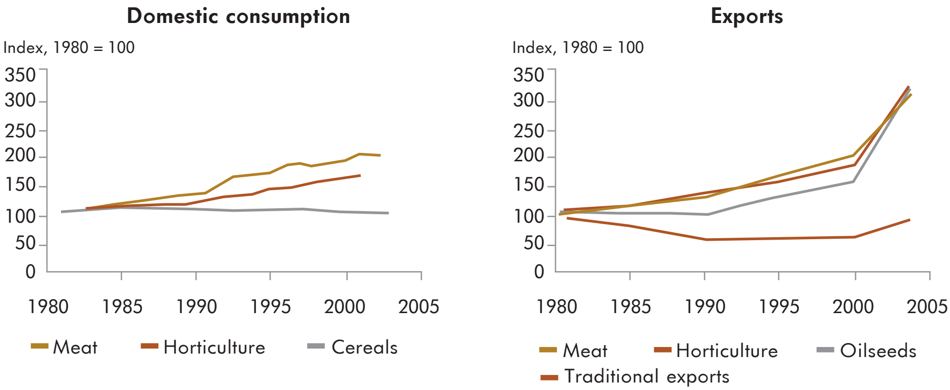
Table 1: *Protein supply from livestock & all sources in 1980 and 2002 (FAO, 2003)*

Region	Total protein from livestock		Total protein	
	1980	2002	1980	2002
Sub- Saharan Africa	10.4	9.3	53.9	55.1
Near East	18.2	18.1	76.3	80.5
Latin America	27.5	34.1	69.8	77.0
Developing Asia	7.0	16.2	53.4	68.9
Industrialised countries	50.8	56.1	95.8	106.4
World	20.0	24.3	66.9	75.3

Industrialised countries derive over 40 percent of dietary protein from livestock, excluding fish and seafood, and saw little change in these amounts between 1980 and 2002. However, in developing countries, changes were quite evident in those same years. They were most dramatic in Asia where protein supply from livestock increased by 131 percent followed by Latin America where per capita animal protein intake rose by nearly a third. In contrast, livestock consumption in sub-Saharan Africa declined, perhaps reflecting economic stagnation and a decline in available incomes (Steinfeld *et al.*, 2006).

Developing countries realised an average annual growth of 3.8 percent (1.8 percent per capita) from 1991 to 2001, up from 2.9 percent in the preceding ten years, while developing countries in East Asia experienced a very strong annual economic growth of 7.4 percent (6.2 percent per capita between 1991 to 2001) with China leading as the world's fastest growing economy (Steinfeld *et al.*, 2006). Consumption of livestock products is closely related to per capita income. According to the World Development Report (World Bank, 2008), domestic consumption and exports of high value products such as meat, horticulture and cereals are growing rapidly (World Bank, 2007). Figure 1 depicts the trends in the last two-and-a-half decades.

It is apparent that the developing world will be the most important supplier to this growing market. Production of meat and milk is expected to increase by about 3 percent per year in the developing world, compared to about 0.5 percent in industrial countries (de Haan *et al.*, 2001). For instance, India reported an increased annual milk production of 88.1 million tonnes from 2003–2004. In value terms, Indian exports of livestock products increased from US$90.8 million in 1980–1982 to US$469.6 million in 2002–2004.



Source: http://faostat.fao.org, accessed June 2007, and http://comtrade.un.org.

Figure 1: *Domestic consumption and exports of high value products in developing countries are growing rapidly.*

The exports of meat and meat products, dairy products and eggs registered a remarkable increase during this period. These accounted for 72.8 percent, 13.4 percent and 10.4 percent respectively of total livestock exports from 2002–2004 (Ali, 2007).

It is anticipated that industrial poultry production will be the fastest growing sector with an expected increase in output of about 80 percent until 2020, while other livestock commodities are anticipated to grow at about 50 percent in the same period compared to the production recorded in 1997 (de Haan *et al.*, 2001). Poultry, an inexpensive meat in times of economic recession, has a more efficient conversion than either pigs or beef cattle, and remains relatively cheap when feed prices are high. Consumption is therefore increasing compared to a decrease in other, more expensive meats. Within poultry, consumers in the developing world prefer less expensive cuts, therefore there is a tendency to replace breast meat with wings (Rabobank, 2008).

3. Livestock production systems

Livestock agricultural systems are categorised according to agro-ecological circumstances and the demand for livestock commodities. Steinfeld et al. (2006) observed that these systems are largely shaped by biophysical and socio-cultural factors. The livestock element is often interwoven with crop production, such as in the rice/buffalo and cereal/cattle systems of Asia. In other cases, livestock uses semi-nomadic pastoral systems.

Extensive pastoral production utilises up to 25 percent of the world's land area and produces 10 percent of the meat used for human consumption, while supporting some 20 million pastoral households. Pastoral production is split between the extensive, enclosed systems typical of North America, Australia and parts of South America, and the traditional production, open-access systems of Africa, the Andes, Asia and Siberia (Blench, 2001).

Many livestock systems are under pressure to adjust, due to socio-economic conditions as witnessed by the emergence of large poultry and pig production units. In Latin America, alternative cattle systems range from specialised intensive technologies (e.g. dairying) from affluent countries in temperate regions to traditional dual-purpose (milk and beef) technologies from resource-poor countries in subtropical regions. These options represent extremes in a continuum of intensification alternatives. The diversity of climatic zones – ranging from cool highlands to warm lowlands, with substantial variation in rainfall – adds to the complexity. Intensive systems are better suited to highland agro-ecozones and dual purpose is typically suited to lowland areas (Nicholson *et al.*, 1995).

Types of livestock systems

Steinfeld et al. (2006) identified five classification criteria to define key livestock systems, namely:

- integration with crops (includes traction, manure and residual feed);
- relation to land;
- agro-ecological zone;
- intensity of production; and
- type of product.

Based on these criteria, Seré and Steinfeld (1996) defined a widely used global livestock production classification system. In referring to a livestock production system as a subset of farming systems, they identified 11 broad categories of systems based on the first three classification criteria. Two main groups of livestock production systems were identified from all the categories – those based solely on animal production and those that mix cropping and livestock.

In the production systems based solely on animal production, 90 percent of dry matter fed to animals comes from rangelands, pastures, annual forages and purchased feeds, with less than 10 percent coming from non-livestock farming activities. In mixed-farming systems, or where 10 percent of the total value of production comes from non-livestock farming activities more than 10 percent of the dry matter fed to animals comes from crop by-products such as stubble. Mixed systems are mostly rainfed and are widespread in semi-arid and subhumid areas of the tropic and temperate zones. Other systems include the following.

- **Landless livestock systems (LLs)** are a subset of the pure livestock systems in which less than 10 percent of the dry matter fed to animals is farm produced and in which annual average stocking rates are above ten livestock units per hectare of land.
- **Grassland-based systems (LGs)** have more than 10 percent of the dry matter fed to animals produced from farm and average stocking rates are less than ten livestock units per hectare of agricultural land. A distinction is made between temperate zones and tropical highland, humid/sub-humid tropics and subtropics, and arid/semi-arid tropics and subtropics.
- **Rainfed mixed-farming systems (MRs)** are a subset of the mixed systems in which more than 90 percent of the value of non-livestock farm production comes from rainfed land use. These systems can be subdivided into the same agro-ecological sub classes as given above.
- **Irrigated mixed-farming systems (MI)** are a subset of the mixed systems in which more than 10 percent of the value of non-livestock farm production comes from irrigated land use. It also includes the same subclasses. The systems are found throughout the world in relatively small size. Exceptions are the eastern parts of China, northern India and Pakistan where they extend over large areas.

The worlds 1.5 billion bovine and 1.7 billion ovine are well distributed across the land-based systems, but average densities increase sharply from grazing systems to mixed-irrigated systems. Mixed-irrigated systems have greater livestock supporting capacities per unit area. Some 70 percent of ruminants are found in grazing systems and over 80 percent of large ruminants in grazing systems are located in developing regions (Steinfeld *et al.,* 2006). Table 2 shows the ruminant populations and animal production in the different production system groups, both globally and for the developing regions.

Table 2: *Global livestock population in different production systems (Averages 2001 to 2003) (Steinfeld et al.2006)*

Type of animal/ animal product	Livestock population (10^6 heads) and production (10^6 tonnes)			
	Grazing	Rainfed mixed	Irrigated mixed	Industrial
Animal				
Cattle and buffaloes	406	641	450	29
Sheep and goats	590	632	546	9
Animal product				
Total beef	14.6	29.3	12.9	3.9
Total mutton	3.8	4.0	4.0	0.1
Total pork	0.8	12.5	29.1	52.8
Total poultry meat	1.2	8.0	11.7	52.8
Total milk	71.5	319.2	203.7	-
Total eggs	0.5	5.6	17.1	35.7

(Based on FAOSTAT data and calculations by J Groenewold classification and characterisation of animal systems; unpublished FAO report, 2005)

As population density increases and less land becomes available, there is a general trend for crop and livestock activities to integrate. For instance in Asia, both ruminants and non-ruminants are integrated into the systems where annual crops and perennial tree crops are grown. More than 90 percent of the total population of large and small ruminants are kept on mixed farms in the region. Some 69 percent of cattle, 64 percent of goats and 46 percent of sheep are raised on farms of 5 ha or less (Devendra and Thomas, 2002). Box 1 provides levels of production for both ruminants and monogastrics under different systems and by region. It is noteworthy that the most economically important livestock systems in Asia, Latin America and West Asia–North Africa are mixed systems, which provide for 75 percent of all livestock reared in these regions.

Livestock production systems in marginal lands that were previously pastoralist areas are increasingly changing to focus on sedentary farming and as reserves of biodiversity. Their very inaccessibility has permitted the survival of species eliminated in high-density agricultural areas (Blench, 2001). Consequently, there is pressure on governments to declare large regions as protected areas, both because of pressure from the conservation lobby and the potential income from tourism (Wilke, personal communication 2010). Uncertainties about pastoral tenure and common property rights have made it difficult for pastoralists to lodge effective land claims.

Box 1: Ruminant and monogastric production in different livestock systems

Ruminant productivity varies considerably within each livestock production system. It is lower in grazing and mixed systems of developing countries than in developed countries. Worldwide, average annual beef production averages 36 kg/head, but the average for developing countries is only 29 kg/head. The difference between developed and developing regions is even more marked in mixed rainfed systems which have the largest variation of production intensity and are the largest producers of ruminant products. Even though developing regions host the vast majority of the mixed rainfed ruminant population, they account for far less than half of the systems' production worldwide. Beef productivity of mixed rainfed systems is, on average, 26 kg/head per year as opposed to 46 kg/head at world level, and their milk production represents 22 percent of the world total. Across all systems, developing regions account for half of the worlds beef production, some 70 percent of mutton production and about 40 percent of milk production.

In the monogastric sector, more than half of the world's pork and over 70 percent of poultry production originates from industrial systems. About half of this production originates from developing countries. There is substantial monogastric production from irrigated mixed systems in developing regions accounting for the majority of the world's pork, poultry and egg production. Huge differences are found among the developing regions. Although production is substantial in Latin America, its total production is less than one tenth that of Asia, and the production in Africa and the Near East is almost non-existent. The industrial countries, together with Asia, account for 95 percent of the world's industrial production.(Steinfeld et al., 2006)

Mixed-farming systems provide farmers with opportunities to diversify risk from single crop production systems, to use labour more efficiently, to have a source of cash for purchasing farm inputs, and to add value to crops or their by-products (Devendra and Thomas, 2002). Combining crops and livestock also has many environmental benefits, including maintaining soil fertility by recycling nutrients, and providing entry points for practices that promote sustainability, such as the introduction of improved forage legumes. In intensive mixed farming systems around the central highlands of Kenya, Franzel and Wambugu (2007) report the benefits of incorporating high protein agroforestry fodder species such as *Calliandra calothyrsus* and *Luceana trichandra* into smallholder entities. These species help substitute farmer spending on commercial feeds while substantially boosting milk production in zero-grazing systems. Using 6 kg of fresh *Calliandra* per day substitutes 2 kg of purchased dairy meal, resulting in savings of about US$130 per cow per year. A smallholder with about one ha requires about 500 *Calliandra* shrubs to sustain one dairy cow per year. Mekoya et al. (2008) reported similar potential of multipurpose fodder trees for sheep production in Ethiopia.

Box 2: Integration of oil palm-ruminant systems

Devendra (2009) identified the opportunities of integrating oil palm into ruminant systems for intensification. Oil palm plantations offer feed sources such as oil palm fronds, oil palm trunks, oil palm kernel cake and palm oil mill effluent. These feeds, combined with leguminous trees, provide a balanced diet at relatively low cost. Vast areas in Southeast Asia are available for mixed production of palm oil and milk and meat. There is evidence of increased productivity, increased yield of fresh fruit, increased income, saving of weeding costs and an internal rate of return of approximately 19 percent. However, feeding strategies may require using oil palm kernel cake in ruminant feeding in local production systems instead of exporting the oil palm kernel cake, and paying more attention to growing multi-purpose trees as an additional protein rich feed. Little information is available about the carbon sequestration of integrated systems and greenhouse gas production. The plantation management needs to interact with local communities, representing the livestock owners, to create a win-win situation. Institutional arrangements can be made through participatory programmes and government policies that support credit availability, encourage joint use of oil palm plantation land with ruminants, create awareness of the advantages on both sides, and support research and training.

Mixed-farming systems are known to maintain soil biodiversity, minimize soil erosion, conserve water, provide suitable habitats for birds, and make the best use of crop residues that might otherwise be burnt and lead to carbon dioxide emissions (de Haan *et al*., 1997). The closed and intensive nature of mixed-farming systems makes them less damaging and more beneficial to the natural resource base. Devendra and Thomas (2002) suggest that mixed-farming systems provide the best opportunities for exploitation of the multipurpose role of livestock. Key among these is improved nutrient cycling from fodder, feed inputs for animals, and obtaining animal manure for supporting intensive cropping systems. Cattle manure application is reportedly high in intensive livestock systems of central and western Kenya, Tanga and Kilimanjaro in Tanzania, Gokwe, Chiota and Chiduku in Zimbabwe, while there is limited use of both fertiliser and manure in extensive systems of Ntonda and Chisepo in Malawi (Thorne *et al*., 2003 and Waithaka *et al*., 2007). However, there are concerns about farmers' manure management, as ineffective collection, composting and application have negative effects. Labour shortages, taboos, work discomforts and long-term efforts to improve soil fertility pose further bottlenecks (Batz *et al,* 1999).

It is clear that smallholder mixed farming systems are more productive and competitive than market returns, based on tangible production, as suggested by policy makers. Indeed, in the event of a fall in milk and beef prices, smallholders continue to engage in production due to in kind income and the intangible benefits derived from livestock keeping (Moll *et al.,* 2007).

Animal production dynamics can be determined by one or a combination of forces, depending on the livestock production system and production site. This interplay of constraints and opportunities can lead to their intensification or even to extensification, insofar as the appropriate technologies are both available and cost effective. According to Fearnside (1999) before 2000, Brazilian policy efforts to encourage livestock – as a means of discouraging deforestation in Amazonia – focused on pasture fertilisation, use of improved pasture, genetic improvement of cattle herds and better regulation of stocking densities. However, this actually resulted in extensification as farmers speculated on the value of land, livestock and tenure securities given the high rate of inflation. Siegmund-Schultze et al. (2007) showed that livestock in the eastern Amazon was attractive as a low input system and that farmers would only change to more sustainable practices if stable credit programmes replaced the financing function of cattle. After 2000, increased soybean and maize prices also made it attractive to use virgin *cerrado* (tropical savannah ecological region of Brazil) and tropical forest for these crops.

Nicholson et al. (1995) observed that extensive cattle systems pervade Latin America because extensive production systems serve the objectives of individual investors and farmers, despite their lower rates of outputs as compared with intensive specialised systems. Cattle production, though viewed as a stable store of wealth, is also a means for farmers to gain other resources accompanied with land ownership, such as government subsidies, subsurface mineral rights and speculative increases in land value. For small producers, extensive cattle systems require relatively lower amounts of capital and labour to provide highly marketable products, improve the cash flow of the farm household and serve as a store of wealth that protects against inflation (Schelhas, 1994). Since extensive systems fulfil many roles other than meeting demand for livestock products, it is important that strategies to intensify cattle systems recognise these roles and work to enhance productivity as well as social security through improved policies.

Livestock production is expected to shift from temperate and dry regions to more humid and warmer regions (de Haan *et al.*, 2001). A clear, worldwide shift from the temperate regions has already occurred. For example, in the USA, production has moved from the northern states to the southern states and, in the South American tropics, from temperate highlands to subhumid savannas. In Brazil, the share of cattle in the subhumid *cerrados* has risen from 14 percent of the national population in the 1940s to 29 percent in the 1990s. A similar trend is occurring in Africa, with strong increases of livestock numbers in the subhumid savannas. Delgado et al. (2008) predict that poultry will be the main source of growth, with other sectors growing at a lower level. Poultry have a better feed conversion ratio than pigs and ruminant animals, and their production technology is more universal. For these and other reasons, worldwide poultry production will increase by almost 80 percent over the period 1997–2020, whereas dairy, beef, and pork production are projected to increase by 40–50 percent over the same period.

4. Transitions in livestock systems

Globally, the livestock subsector is undergoing enormous structural changes to meet the increasing world animal product demands. In developed countries, the rate of growth of commercial systems has outstripped smallholder farming. Similarly, a shift to large-scale commercial and away from smallholder farming in developing countries is now imminent. Indeed, livestock production in Asia and Latin America has been transiting away from a multipurpose activity of producing food, savings, traction power, hides and manure, observed over the last 25 years. With this transition, family labour and farm-produced feed on smallholder crop farms is moving towards a more specialised enterprise that uses hired labour, borrowed capital, western technology and purchased inputs in systems producing more uniform quality food items, similar to industrial modes of organisation (Seré and Steinfeld, 1996 and Delgado *et al.*, 1999).

In Brazil, it has become the norm for large commercial dairy farms to buy out smallholders who, in turn, are forced to operate in difficult environments (Nicholson *et al*, 1995 and Fearnside, 1999). In India, where land holding is more skewed towards medium- and large-scale farmers, rearing of small ruminants, pigs and poultry is emerging as an option for poor households to earn their livelihood on a sustainable basis (Ali, 2007). Within India's value chain, the introduction of the *Kuroiler* – a dual-purpose hardy bird suited for poor rural people – has proven a remarkable development (Ahuja *et al.*, 2008). It has been developed as part of a system that supports the value chain from the parent farm to village markets. Evaluations have found that the government could improve the *Kuroiler's* impact by providing appropriate health and extension services for the *Kuroiler* value chain. The result of these evaluations could be applied to many situations in developing countries, where a large number of smallholders are livestock producers who need appropriate technologies and often lack alternative employment and livelihood options.

Livestock industrialisation

The more commercial and intensive livestock systems based on commercial feeds taking root in the developing world prefer poultry and swine, which are increasingly being produced in landless systems. This so called "livestock industrialisation" (Delgado *et al.*, 2008), with its shift to more grain-based production, has raised concerns over its effect on global and national food security. For instance, Steinfeld et al. (2006) indicate that the total global production of 54 million tonnes of human edible animal protein requires an estimated 74 million tonnes of human edible plant protein, at a conversion of 1:1.4. The Council for Agricultural Science and Technology (CAST, 1999) calculated that the average grain consumption per 1 kg of beef in the OECD countries is 2.6 kg of edible plant food per 1 kg of live weight gain. In developing countries, only 0.3 kg of edible plant food is used to produce 1 kg of live weight gain.

Though using human edible food for animal production has been of concern to mostly industrial world production systems, the livestock revolution is now causing these models to expand rapidly in the developing world. This means that choice of animal species and systems will be important because different systems have different feed and energy efficiencies, with an increasing efficiency from milk, via broilers, eggs, pork to feedlot cattle. Table 3 provides some ranges of total feed conversions and amount of edible grain used per kilogram of animal product produced.

Table 3 *Feed conversion for main species and world regions (CAST 1999; de Haan et al., 2001)*

Species	Feed conversion		Edible grain per kg of product	
	Kilograms feed per kg live weight gain	Kilograms feed per kg product	Industrial world	Developing world
Aquaculture	1.2-1.6	1.5-2.0	n.a.	n.a.
Poultry meat	1.8-2.4	2.1-3.0	2.2	1.6
Pork	3.2-4.0	4.0-5.5	3.7	1.8
Beef	7	10	2.6	0.3

n.a. – not applicable

A steady shift to grain-based pig and poultry production could increase grain prices and thus reverse the balance from grain feeding to grass-based systems, or lower consumption levels. The eventual resource constraints such as water and land, and significant increases in energy costs are not clear. Additionally, intensive systems require more energy per kilogram of meat than the more extensive land-based systems, mainly because of the high energy and water requirements for feed production.

Increases in the price of energy would tend to shift the balance back to grass-based systems. A major breakthrough in the production of high-quality fodder in the tropics or improved digestibility of the current high-fibre tropical forages could radically shift the balance from pigs and poultry to cattle and small ruminants and from industrial production to grazing systems. It would also shift production to subhumid tropical areas, as they have the potential for high levels of biomass production. From a global perspective, it would appear that increases in poultry production would put the least pressure on global food security, but part of the feed used in these systems competes directly with human cereal consumption.

The large number of cattle worldwide (estimated at almost 1.5 billion) is responsible for about 45 percent of agricultural land use, with each animal requiring between 0.5 and 5 ha of land to feed on. This large livestock population has a huge impact on natural resource use and the environment (Devendra and Thomas, 2002 and World Bank, 2005). For instance, the rapid deforestation of large expanses of the tropical rainforest, such as in Amazonia, due to the extension of large-scale ranches (Nicholson *et al.*, 1995 and Fearnside, 1999). The desertification and land degradation of sub-arid tropical regions, particularly in the Sahel, both north and south of the Sahara, has also become problematic. Sanchez et al. (1997) estimated annual losses of 4.4 million tonnes of nitrogen (N), 0.5 million tonnes of phosphorous (P) and 3 million tonnes of potassium (K) in 37 countries in sub-Saharan Africa. This is exacerbated because smallholders have shortages of land and capital to adopt economically sustainable land management practices.

The more intensive livestock systems are increasingly edging closer to urban centres where markets are large and there are economies of scale, a trend that has raised environmental and health concerns in developing countries. It is feared that increased concentration of livestock might lead to an increase in the emergence of new disease patterns and more incidences of food-borne diseases. Environmental pollution could worsen, as has happened in France, the Netherlands, the USA and the eastern seaboard of China where surface water and aquifers have been polluted due to the excessive intensification in densely populated areas (Devendra and Thomas, 2002). Furthermore, it has been suggested that over-consumption of animal products by the middle-income class in the developing world might lead to diet-related chronic disease patterns similar to those in the industrial world (de Haan *et al.*, 2001).

In summary, rapid industrialisation of livestock systems is driven by factors such as consumer demand, declining real prices for feed grains (which are now linked to energy prices through the biofuel expansion), improved feed-to-meat conversion efficiencies, better animal health and reproduction rates, relatively cheap transportation costs and trade liberalisation (World Bank, 2005). Another economic perspective suggests that stricter environmental regulations, consumer concerns about health and animal welfare, increases in the price of grain, water, energy, and transport, land scarcities and major breakthroughs in the use of tropical fodder will shift the balance back to red meat production. What is clear from available evidence is that the livestock sector is undergoing dramatic structural and geographic changes in the way livestock products are produced, marketed and consumed (de Haan *et al.,* 2001; World Bank, 2005 and Delgado, *et al.*, 2008).

5. Sustainable livestock intensification

Intensification of agriculture is a process which decreases production costs per unit of agricultural product produced. Production costs are the function of costs of labour, land and capital. Capital-intensive agriculture develops where availability of cheap labour and, most of all, land, is limited, as in, for example, Belgium and the Netherlands. While countries with limited capital and land, such as India and China, have developed labour-intensive agriculture, countries with limited capital and labour, such as Argentina, have developed agricultural systems that require extensive tracts of land.

In extensive systems, increasing the number of animals reared without improving system performance places pressure on the available resources, often resulting in land and pasture degradation. For example, in southern Africa, poor range management involving overgrazing practices are to blame for increased soil erosion and increased amount of poor pasture and invasive plant species on the natural pasture. Often, degraded cropland is converted into pastures. Pasture productivity has lagged far behind that of cultivated areas, although detailed estimates are difficult to make. These trends demand new policy and well-defined roles for public and private institutions to manage system dynamics and ensure equitable use of available resources without compromising the needs for future generations. Obviously, different forms of production will have different impacts on the environment, and social structure of rural areas. When population density increases and less land becomes available, the general trend is for crop and livestock activities to integrate and later to specialise in separate intensive and large-scale crop and livestock farms.

Intensification of livestock production is taking place mostly with regard to inputs. There is a shift towards more grain-based production and away from traditional livestock production systems based on locally available feed resources, such as natural pasture, local fodder, crop residues and unconsumed household food (FAO, 2005). Pressure to intensify livestock production systems has resulted in direct competition between crops for human and animal feed and biofuels (see Table 2). For instance in 2004, 690 million tonnes of cereals (34 percent of the global cereal harvest) and another 18 million tonnes of oilseeds (mainly soya) were fed to livestock. In addition, 295 million tonnes of protein-rich processing by-products were used as feed (mainly bran, oilcakes and fish meal). In this context, intensification draws on technological improvements – in areas such as genetics, health, feed and farm management – that contribute to increased natural resource use efficiency and output per animal.

A dramatic shift towards the production of monogastric animals, such as chickens and pigs, which use concentrated feeds more efficiently than cattle or sheep, has occurred in the last decade. Chickens and pigs also have short life cycles that accelerate genetic improvements. For instance, between 1980 and 2004, pig meat, chicken meat and milk offtake per unit of stock increased by 61 percent, 32 percent and 21 percent respectively (FAO, 2005). According to Naylor et al. (2005), the average time needed to produce a broiler in the USA was cut from 72 days in 1960 to 48 days in 1995, and the slaughter weight rose from 1.8 to 2.2 kg. Meanwhile, feed conversion ratios (FCRs) of kilogram of feed per kilogram of meat produced were reduced by 15 percent for broilers and by over 30 percent for layers.

Overall, annual growth in pig and poultry production in developing countries was twice the world average in the 1990s. By 2001, three countries – China, Thailand, and Vietnam – accounted for more than half of the pigs and a third of the chickens produced worldwide (Delgado *et al.*, 2008). Brazil is also a major producer of chickens and pigs and is expected to become the world's leading meat exporter (FAO, 2005).

Determining the most appropriate ways to increase production is critical in intensive systems. Feed accounts for about 50–60 percent of total production costs in ruminant-feeding systems, and 65–80 percent in industrial or intensive systems. Smallholder farmers are more wary of large production costs, especially feed costs, and industrial production systems depend heavily on external inputs (Devendra and Sevilla, 2002). The increased cereal requirements needed to meet increased feed demand of the pig and poultry population over the next two decades will require an additional 65 million hectares to be placed under cultivation, an area more than the size of France (World Bank, 2005).

Rudimentary indicators that define livestock systems' levels of intensification and specialisation or diversification will need to estimate the share and trend of agricultural land engaged in livestock breeding or cereal (wheat and maize) production. This means assessing the number of livestock units (stocking density) per hectare of utilised agricultural land and milk or cereal production trends per hectare.

The intensification and concentration of the livestock industry over the last decades is threatening to crowd out the poor. Successfully protecting the smallholders therefore, depends to a large extent on the level and success of pro-poor policies, institutions and technologies focused on poverty alleviation (de Haan *et al.*, 2001). Mitigating the negative effects and enhancing the positive effects of livestock intensification, and to enhance sustainability, the following factors have become crucial: environmental impact, markets, food safety and institutional arrangements.

Environmental impact

Agriculture currently contributes 60 and 50 percent of global anthropogenic emissions of methane gas and nitrogen oxide, respectively. Since the 1960's the natural resource base on which agriculture depends has declined faster than at any time in history due to increased global demand for agricultural products and degradation of the natural resource base. Additionally, 75 percent of the genetic base of agricultural crops has been lost. Increases in population and changes in diet are projected to increase water consumption in food and fibre production by 70–90 percent. If demands for biomass energy increase, this may aggravate the problem and further exacerbate the stress on developing country producers. Degradation of ecosystem functions, such as nutrient and water cycling, constrains production and may limit the ability of agricultural systems to adapt to climatic and other changes in many regions. Sustainable agricultural practices are part of the solution to current environmental changes. Examples include improved carbon storage in soil and biomass, reduced emissions of methane gas and nitrous oxide from rice paddies and livestock systems, and decreased use of inorganic fertilisers (IAASTD, 2008).

Livestock activities emit considerable amounts of carbon, methane and nitrous oxide gases from respiratory and digestion processes and manure, although totals vary depending on how the activities are managed. Carbon balances for land used for pasture or feed crops are also affected, especially if forests are cleared for pasture (FAO, 2006). Excessive nitrogen, phosphate and heavy metal levels in the effluent of intensive livestock farms cause environmental pollution and loss of biodiversity. While exact data on the total global environmental impact are not available, some illustrative facts estimate that more than 130,000 km^2 of arable land in China and 30,000 km^2 in Thailand (together an area about four times the size of the Netherlands) have an annual livestock nutrient waste production of phosphate of at least 20 kg per hectare per year. This is in excess of the absorptive capacity of the surrounding ecosystem. The extent of nitrate-nutrient loading is probably even more severe

(World Bank, 2005). Box 3 provides key sources of environmental pressure and some recommendations on policy.

On the other hand, because intensive production systems produce less carbon dioxide per kilogram product than low-production systems, industrial systems might also have a positive effect by reducing the pressure on fragile ecosystems and their unique biodiversity, and reducing greenhouse gas emissions (de Haan *et al.*, 1997). However, the comparative advantages of economies of scale of industrial pig and poultry production might disappear if the "polluter pays" principle is invoked in the developing world and the environmental costs of excess nutrient emissions are made inclusive.

Recent outbreaks of pandemics such as classical swine fever, avian influenza and foot-and-mouth disease have focused consumer attention on the negative side effects of intensive production. The widespread use of antibiotics has lead to antibiotic resistance to methicillin-resistant Staphylococcus aureus (MRSA) for example, and *E.coli* and Campylobacter have become the source of frequent intestinal infections in humans.

Box 3: Sources of livestock system pressure on the environment and recommended remedial policies

According to the World Bank (2001), pressure on the environment is manifested in several ways.

- **Waste production.** Nutrient surpluses from production using feed concentrates, seen earlier mostly in the eastern USA and northwestern Europe, are now also common in areas of East Asia and Latin America. Extremely high (more than 800 kg per hectare) nitrogen surpluses around urban areas of eastern China have been reported. A rough estimate indicates that about 100,000 km^2 in the developing world are already threatened by severe nutrient loading, which would cause eutrophication of waterways and subsequent damage to aquatic ecosystems.
- **Gas emission**. Animal waste produces methane and nitrous oxide gases – one of the most aggressive greenhouse gases – and ammonia, which in turn cause acid rain and the destruction of marginal landscapes and habitats.

- **Feed grain demand**. Significant demand for feed grains increases the need for cultivation. More cultivation causes additional erosion, loss of plant and animal biodiversity, and puts an additional strain on the world's scarce water resources. Delgado et al. (1999) estimate that under the normal demand scenario, the additional feed grain requirements are about 240 million tonnes, which, with an average yield of 6 tonnes per hectare, would require 40 million hectares of additional arable land to be placed under cultivation.
- **Requirement for genetically uniform stock.** The industrial system and the consumer require uniformity, which contributes to an erosion of domestic animal diversity as local breeds are crowded out by industrially popular breeds. The consequent narrowing of the genetic base also increases vulnerability to epidemics.

Several current technologies could mitigate these negative effects. A policy framework to induce those technologies should contain the following.

- **Internalise environmental costs in the price of the product**. Although more information needs to be collected on the environmental costs of industrial production units, some figures from Australia and Singapore point to a 10–15 percent direct surcharge to mitigate water and soil pollution and abate gaseous emissions (de Haan *et al.*, 1997). The key issue will be governments' willingness to impose these surcharges on predominantly urban consumers.
- **Search for the tools (e.g. zoning, taxation) that will provide a better geographic distribution of intensive production.** The key challenge of intensive production is to bring waste production in line with the absorptive capacity of the surrounding land. In particular, pig manure has high water content, and neither drying nor transporting it over long distances is economically attractive. A combination of zoning regulations and fiscal incentives, now being tested successfully in East Asia could be a solution.
- **Promote the use of technologies that increase the efficiency of feed conversion, reducing inputs and nutrient emissions.** A large number of technologies currently exist that could improve the digestibility of key nutrients, thereby reducing nitrogen and phosphates emissions. The adoption of such technologies should be encouraged.
- ***Support ecological farming practices.*** Mainstream sound ecological farming practices, such as integration of crops and livestock and development of markets for organic products, has potential where it is ecologically efficient on the relevant environmental parameters.

(de Haan et al., 2001)

Finally, it is evident that most environmental damage by livestock is a consequence of how livestock are managed. With good management, livestock can enhance sustainable agriculture and with bad management, it can harm the environment. Policies should define emergent livestock production practices and their impact on the environment.

Markets

The ongoing livestock revolution is market driven, unlike the green revolution which was supply driven. Market drivers include increasing human population, rising incomes, urbanisation and increased consumer consumption of animal products and proteins. To a certain extent, liberalised markets have meant that livestock producers and other industry actors have been increasingly able to respond to consumer demands (Waldron *et al.*, 2007). Most food is being consumed locally and, with higher energy prices, local consumption will be preferred wherever possible.

Most of the growth in livestock product demand will be in the developing world because meat and milk have high income elasticity for those with lower incomes. For example, Schroeder et al. (1995) found that in countries with per capita annual incomes of between US$1000 and US$10,000, income elasticity for meat varied between 1 and 3 depending on the type of meat. Above US$10,000, income elasticity levels are up to 1. For these reasons, per capita meat consumption in the developing world has been projected to increase from 25 kg to 35 kg from 1997 to 2020, compared with an increase of 75 kg to 84 kg in the industrial world (World Bank, 2001).

Consequently, increased livestock product demand can offer opportunities for the poor, as livestock production is among the few commodities that smallholder farmers produce widely (Moll *et al.*, 2007). The production of meat in the developing world was projected to increase from 110 million tonnes in 1997 to 206 million tonnes in 2020, and milk from about 208 million tonnes in 1997 to 386 million tonnes in 2020 (Delgado *et al.,* 2008).

Though globalisation might increase trade, infrastructure (port facilities, road networks and communication technology) constraints, and higher transportation costs in the developing world pose serious challenges. On the other hand, stricter animal welfare and environmental regulations in the industrial world may support a shift toward increased production in the developing world. Recently, it has been observed that smallholders in developed countries have been forced to exit livestock farming, mainly because smallholder operations cannot compete with the larger operations that benefit from both technical and allocative economies of scale embodied in genetic improvement of animals and feeds or improved organisation. This is especially true for the poultry and pig industries, where profitable adoption simply requires larger farm sizes (Delgado *et al.*, 2008). Furthermore, industrial poultry and pork operations seem uniformly characterised by a rapid transfer of breeding and feeding innovations. There is also a tendency for large firms to control production and marketing as they are increasingly linked to major retail chains. They tend to be concentrated in geographical areas where input costs are relatively low, infrastructure and access to markets are well developed and, in many cases, environmental regulations are lenient.

Therefore, strategies to support developing countries production should consider subsidies wherever effective, and renew efforts to reduce trade-distorting subsidies in developed countries and regional barriers such as (informal) tax levies at road checkpoints or borders, so that fair competition is established in the global and regional markets. There is also a need to streamline and reinforce legitimate anti-dumping measures and provide temporary protection and improved international market access through equitable contractual arrangements. Proven policy interventions that benefit smallholders include: expanding access to microfinance, keeping inflation rates low, identifying reliable banks, financing value chains, developing local markets, supporting farmer associations and cooperatives, and supporting fair trade and product diversification. The trade policy environment should be supported by reducing or eliminating escalating tariffs on agricultural products in developed and developing countries, along with strengthening of national institutions and infrastructure, including improved local and regional market linkages. These factors will be the key determinants of whether policy approaches will produce pro-poor results at grassroots level.

Food Safety

Food safety is emerging as the most prominent source of conflict in international markets. Developing countries are required to upgrade their food quality control capacities if they want to maintain access to international markets. Fears that increased intensification is leading to the emergence of new diseases is worsening the situation. For instance, *bovine spongiform encephalopathy*, caused by recycling animal slaughter waste, is a direct result of the increasing scarcity of feed resources and the cost of waste treatment. The re-emergence of classical swine fever and foot-and-mouth disease, which has led to massive destruction of animals, is directly related to animal densities that increase the effects of infection. Another example is the *Nipah* virus, which caused a new form of viral *encephalitis* in Malaysia and led to the destruction of more than 1 million pigs (World Bank, 2005). Emphasis is on export development demands, good sanitary practices, standards and compliance with health and food safety obligations. It is, however, often forgotten that food production is largely for local use and has to be acceptable for local/domestic consumers. For instance, Kenyans like fresh milk to be boiled for their *chai* (tea), so there is no need to pasteurise milk and raise costs. It is clear that driving up cost of production for small export markets is not fair to local consumers and may drive small farmers out of business. Through research by Kurwijila et al. (2006) in Tanzania, local functioning of milk markets in East Africa was improved by training raw milk sellers. Rather than pushing them out of business with unwanted pasteurised milk, they contribute to a growing market of raw milk buyers.

Control measures of zoonotic diseases require rapid identification and communication of disease outbreaks, financial compensation, and training and strengthening of coordination between veterinary and public health infrastructure. Identifying emerging infectious diseases and responding effectively to them requires enhancing epidemiologic and laboratory capacity and providing training opportunities (IAASTD, 2008). Focusing on interventions at a single point along the food chain may not provide the most efficient and effective control. Therefore, for a stronger focus on food safety and health issues, programmes must at least concentrate on the following areas;

- **policies and institutions** related to the level of involvement in food safety for domestic consumption and export, control of diseases during trade, emerging diseases and their effect on human health and, consequently, strengthening links with the health sector;
- **appropriate legislation** is needed, that factors in local food preparation practices and trends, the role of the public sector in food safety, and partnerships with the private sector and consumers; and
- **infrastructure, human and institutional capacity building** in general, but particularly in sustainable animal health and production, best practices in managing the food chain from farm to fork, and informed participation in organisations for setting international standards, so that the voices of the developing countries are heard.

Institutional Arrangements

The role of livestock as an income generating activity depends on the success of markets, policies, institutions and technologies that are available. In the absence of strong local and national institutions that support development and sustainability goals, the transfer of productivity-enhancing technologies does not significantly benefit resource-poor, risk-exposed producers. The global linear transfer of research and technology results in imbalanced competition among farming systems that have been supported by public economic investments for decades over systems that have never received comparable public investments. On the other hand, natural resource management policies are needed to address how access and ownership is shared among the communities from which these resources originate.

To ensure that technology supports livestock development and sustainability goals, strong policy and institutional arrangements are required to balance private and communal rights with regards to knowledge and resources. The individual small farmer will only achieve these goals if strong farmer associations and cooperatives can succeed in the newly emerging livestock value chains. Hazell et al. (2007) and Delgado et al. (2008) provide ample evidence of the institutional needs for a future of relatively small but productive and sustainable livestock farms.

6. Conclusion

Livestock farming in the developing world is undergoing tremendous structural change attributed to increased global demand for animal products. The role of livestock is quickly changing from multifunctional systems to a commodity-driven sector. Developing parts of the world will be the suppliers of livestock products for their own markets due their own steadily increasing domestic demand, rapid urbanisation, improved incomes and diet changes.

Intensification of livestock systems, also known as *livestock industrialisation*, is primarily taking root in the poultry and swine industries, although it is also taking place in dairy, followed by beef. Poultry and swine are particularly appealing to farmers due to their economies of scale. They are more efficient feed converters than cattle, have a short reproductive cycle that accelerates genetic improvements, and thus, productivity and returns can be realised within a short time. The trend in developing countries is to set these enterprises near urban centres where there is a ready market for inputs and outputs and accessible transport, and operational costs are generally low. There are, however, environmental and health concerns over these industrial systems similar to those in developed countries, especially where uniform products are demanded, particularly for the export market. The shift to monogastric intensification in developing countries has been attributed to lenient environmental regulations.

Cattle, swine and poultry production systems are changing and in many cases, this means intensification which is most often based on external input systems involving feed grains. This trend has raised concerns that it could compromise national and global food security as more crop protein is fed to animals. Smallholder operations in developed countries are already facing challenges to remain competitive with their large-scale counterparts who wield economies of scale owing to the size of their operations and their better access to capital. Livestock intensification is a result of technology advances and greater use of crop inputs in crop production in the areas of plant breeding, irrigation and water management, application of fertilisers and mechanisation.

As a result, smallholder farmers are wary of large production costs, especially for feed, and industrial production systems that depend heavily on external inputs. Although globalisation might increase trade, infrastructure (port facilities, road and communication networks) constraints and higher transportation costs in the developing world pose serious challenges. Traditional production systems based on pasture and local forages are experiencing challenges due to degradation of the natural resource base and declining land sizes. As population density increases and less land becomes available, there is a general trend for crop and livestock activities to integrate.

The livestock sector is undergoing dramatic changes in the way livestock products are produced, marketed and consumed. Establishing sustainable intensification will depend largely on the level and success of pro-poor policies, institutions and technologies for poverty alleviation. It is critical to determine the most appropriate ways to increase production at local, regional and international levels. In order to mitigate the negative and enhance the positive effects of livestock intensification on the environment, livestock development emphasis needs to be product driven, but it also needs to give more recognition to its multifunctional roles. Intensification as a response to increasing consumer demand has to address three major issues, environment which includes climate change and water productivity, energy needs and poverty alleviation.

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