The Global Livestock Research Agenda: Opportunities and challenges[1]

Jimmy Smith with Delia Grace, Mario Herrero and Keith Sones

International Livestock Research Institute (ILRI), PO Box 30709, 00100 Nairobi, Kenya

ABSTRACT

The global livestock sector is diverse, undergoing rapid change and frequently misunderstood. Livestock impact issues of major global concern, including food security, poverty alleviation and environmental and human health. But these impacts differ greatly across the globe, depending on factors such as the levels of wealth or poverty in a country/region, the livestock commodity, consumer demands, the policy environment and the livestock production system. This paper explores global trends in the livestock sector in relation to the production and consumption of meat, milk and eggs; livestock impacts on the environment; the critical role livestock play in livelihoods of the poor; and the close links between animal and human health. Demand for livestock products continues to rise in developing countries, notably in Asia, presenting the livestock sector with both challenges and opportunities in meeting this demand. Supplying demand requires overcoming feed, breed and animal health constraints and the potential adverse impacts of increased livestock production on greenhouse gas emissions, water resources and land use require renewed research attention to ensure that opportunities to mitigate environmental harm are maximized as production systems transition. At the same time, livestock keepers in developing countries need to cope with climate change and multiple disease risks while functioning efficiently in dynamic resource-scarce environments. Global concerns about the impacts of livestock-associated diseases on people are justified and recent data show that poor and developing countries carry the largest burden of 'zoonotic' diseases, with South Asia a hotspot for zoonosis impacts and intensification a driver for disease emergence. The health problems associated with over-consumption of livestock products, especially fatty red meat, are well documented but need to be balanced by awareness of the positive, life-changing impacts these dense and nourishing foods have on millions of poor people; even small amounts of animal protein in the diet of the poor can, for example, improve the cognitive development of children and maternal health. Farm animals remain essential to small-scale agriculture across most of the developing world and provide livelihoods for some one billion poor smallholders, many of them women. Enabling poor households to help supply the rising demands for meat, milk, fish and eggs, and to escape poverty in doing so, will require addressing issues such as the roles of small farms compared to industrial production systems, the links between informal and formal livestock markets, opportunities for people to exit from the livestock sector, and ways to ensure greater equity in livestock development. Livestock research has a critical role to play in understanding and providing solutions for such issues spanning the biophysical and socioeconomic trade-offs in livestock development at multiple scales and the new organizational models needed to facilitate a positive transition of developing-country livestock sectors.

Keywords: Global livestock trends, livelihoods, environment, nutrition, zoonoses, livestock research-for-development

[1] Plenary paper presented at the 15th Asian-Australasian Association of Animal Production Societies Animal Science Congress, Bangkok, Thailand, 26-30 November 2012.

INTRODUCTION

The global livestock sector is diverse, is undergoing rapid change and is frequently misunderstood. It is also huge: the total asset value of livestock is at least US$1.4 trillion; the world's 17 billion livestock (Herrero et al., 2009a, 2012) account for one-fifth of total terrestrial animal biomass (FAO 2006); the global livestock industry, through its long value chains, employs 1.6 billion people, directly supporting the livelihoods of 600 million poor smallholder farmers in the developing world; grazing land occupies one-third of the earth's ice-free surface area and a third of cropland is devoted to production of feed for animals (Reid et al 2004; Steinfeld et al., 2006); and livestock provide one-sixth of the energy and a third of all protein in global diets.

Livestock diversity embraces a couple of dozen species of domesticated mammals and birds[2]. This diversity includes not only the near ubiquitous cattle, sheep, goats, pigs and poultry, but less familiar species which are highly adapted and largely confined largely to specific local environments, such as dromedaries in African and Asian drylands, yaks in the Himalayas and llamas in the High Andes. The world's livestock species are thought to comprise more than 7000 distinct breeds and ecotypes that, over the past 11,000 years, have evolved either through selective breeding to accentuate desirable traits or through natural selection, or through a combination of the two, and thus have become adapted to harsh local conditions where they remain productive (FAO, 2007).

The range of the world's livestock production systems and scales is also enormous. One end of this continuum is exemplified by women in Asian and African villages who keep small flocks of free-ranging local hens in the hope that a few chicks will escape disease, predation and theft and, after several months, they can be sold for the equivalent of a couple of US dollars. At the other extreme are large-scale intensively managed enterprises comprising many large buildings, each of which houses tens of thousands of highly productive hybrid chickens in a single building, with large numbers of similar buildings on one site where all aspects of the environments are carefully monitored and controlled, from each of which several tonnes of uniform broilers are harvested after just six weeks or less, processed and sold in a wide variety of added-value products.

In stark contrast to developed countries, where most livestock are raised solely for production purposes, in emerging and developing economies, people keep livestock to serve many purposes. And while meat, milk and eggs, or the income that can derived from their sale, are often a primary motivation for keeping livestock, this is not always the case and is rarely the only motivation. In some regions, cattle are valued primarily for their draught power or for the prestige associated with owning cattle; in others, cow manure is valued more highly than cow milk. And for most smallholder farmers in poor countries, a few farm animals provide some protection against ruin in the event of a crop failure; this insurance role is becoming increasingly important role as climate variability increases with global warming (Jones et al., 2008).

Even when livestock are kept primarily for their meat, milk or eggs, the way these products are used varies enormously: whilst Ethiopians relish *kitfo*, a dish based on raw beef, Indians

[2]Here the term livestock is taken to mean domesticated mammals and birds reared primarily for their meat, milk, eggs, draft power or manure. Fish, insects and other invertebrates and vertebrate species are not included for the purpose of this paper.

in Nagaland usually boil their pork for an hour before eating. The French alone enjoy over 400 types of cheese, with another 500 types found throughout the rest of the world.

The way livestock are reared, slaughtered and consumed are subjects which polarize public opinion: in parts of the developing world, especially Asia, per capita consumption of meat, milk and eggs has increased dramatically over recent decades, yet in India an estimated 340 million people are vegetarian and a further 99 million consume eggs in addition to vegetarian foods (Yadav and Kumar 2006). Between 2000 and 2025, the same nation is anticipated to experience a 176% increase in demand for meat, a 70% increase in demand for milk and vegetables and a 27% increase in demand for grains (Parthasarathy Rao and Birthal, 2008).

Within Europe, the UK is thought to have the largest proportion of vegetarians (5–6%), with an estimated 10% of the population categorized as 'meat avoiders' (Mintel, 2006). Animal welfare issues are widely tipped to be the next big issue to feature on the global livestock agenda, even in developing countries. There is an increasing debate about how much animal protein the world needs, and the major differences between regions of the world (Stehfest et al., 2009; Westhoek et al., 2011).

Livestock generate up to a fifth of anthropogenic greenhouse gas production and cause around 60% of all human diseases (O'Mara, 2011; Taylor et al., 2001). People in the West, as well as the rapidly emerging African and Asian middle classes, are making themselves ill by consuming too much livestock food, particularly fatty red meat, whereas in developing countries livestock foods can be life enhancing when added, even in very modest amounts, to the diets of the poor, especially children and women of child-bearing age (Neumann et al., 2002).

It can be seen from the above that global livestock production and consumption trends and issues bear acutely upon several major global concerns, including food security, poverty alleviation, animal welfare and environmental and human health. What is less widely appreciated are the great, sometimes extreme, differences in the costs and benefits of livestock production and consumption across the globe depending on a given community's wealth or poverty, livestock commodity, production system and policy environment.

The remainder of this paper explores these differences and looks at global trends in the production and consumption of meat, milk and eggs; livestock's impacts on the environment; the critical role livestock play in the livelihoods of the poor; and the close links between animal and human health. We then explore how livestock research for development is helping to provide solutions to the constraints and problems faced by livestock keepers in different regions. We examine biophysical and socio-economic trade-offs in livestock production at several scales and new organizational models that may best facilitate positive transitions of developing-country livestock sectors.

TRENDS IN PRODUCTION AND CONSUMPTION

Over recent decades, global consumption and production of meat, milk and eggs has increased dramatically and this trend is expected to continue for the foreseeable future (Table 1). Most of this increase has occurred and will continue to occur in developing countries: total meat production in developing countries tripled between 1980 and 2002 (Steinfeld et al., 2006). The primary driver of these increases is growth—growth in the human population, in urbanization and in incomes.

Table 1: Past and projected trends in consumption of meat and milk in developing and developed countries

		Total consumption	
		Meat Mt	**Milk Mt**
Developing countries	1980	47	114
	2002	137	222
	2050	326	585
Developed countries	1980	86	228
	2002	102	265
	2050	126	295

Data for 1980-2002 from Steinfeld et al. (2006) and for 2050 from FAO (2006).

Rising population. The global population is estimated to peak at a little over 9 billion in 2050; compared to the year 2000, Asia will have 1.4 billion more people and Africa, 1 billion more (United Nations, 2011). Even at low levels of per capita consumption, the extra 2 billion mouths to feed represents a huge incremental demand for livestock products—a doubling, for example, of annual chicken production and consumption from 50 billion today to 100 billion birds at mid-century.

Rising incomes. There is a clear relationship between people's incomes and their consumption of livestock products: as incomes grow, expenditure on livestock products increases sharply. The countries that experienced the highest rates of GDP growth from 1990 to 2005, such as China, India and Vietnam, also experienced the greatest increases in demand for livestock products (McDermott et al., 2010). Demand for livestock products increases rapidly as people move from poverty (less than $2 per day) to become middle class ($2–20 per day). One in three Africans, 313 million people, are now middle class, close to triple the number in 1980 (African Development Bank, 2011). Globally, the middle class is expected to rise from about 8% to over 28% of the global population by 2050 (FAO, 2012). Current rates of economic growth are highest in developing countries and this trend is expected to continue.

Rising urbanization. The world's increasing urbanization is having big impacts on food consumption patterns. For the first time, most of the world's population became urban dwellers in 2008, although the proportions vary markedly between regions—from less than 30% in South Asia to 80% in developed countries and Latin America. The United Nations Food and Agriculture Organization (FAO, 2012) predicts that two-thirds of the world population will be in urban areas by 2050, with unprecedented increases in the rate of urbanization in Africa and Asia, which, in turn, will drive increased demand for livestock

products. Studies conducted in countries as diverse as Uganda, Vietnam and Peru have shown that, on average, people who live in towns and cities tend to consume more livestock products than their rural counterparts (Maltsoglou, 2007). More and more people are also increasingly relying on foods prepared outside the home. This is due to increasingly long travel times to work, lack of cooking facilities in many shanty towns, more people living alone or apart from their extended families, more women in employment, and the increasing availability of ready-to-eat foods, with animal-source foods being among the most commonly sold street foods (which are almost invariably prepared and sold by women) (Delisle, 1990).

Supermarket revolution. A 'supermarket revolution' occurring in parts of Asia and Africa since the early 1990s, driven by liberalization of retail direct foreign investment in addition to urbanization (Reardon et al., 2007) and with an initial upper- and middle-class clientele, is now attracting the mass market. The share of the market taken by supermarkets varies across the world, from 80% in the USA, to 30% in China, to 20% in Kenya (Reardon et al., 2007). The growing role played by supermarkets in the developing world's food supply represents a potential threat to smallholder producers. Supermarkets demand adherence to stringent quality standards and also usually require commitments to supply large quantities of uniform products. Smallholders struggle to meet these conditions, so many are missing out on this large, growing and increasingly dominant market segment. On the other hand, despite such trends, informal markets continue to dominate certain sectors in many countries, such as India, the world's largest milk producer, which sells almost 80% of its milk through the informal sector (Intercooperation, 2006).

Livestock trade. Perhaps surprisingly, global trade in livestock products from surplus to deficit regions represents a relatively small part of overall supply. The perishable nature of livestock products means that most livestock production is consumed locally and most livestock trade occurs within rather than between countries. Dairy and eggs dominate international trade in livestock products, with the global meat trade being dominated by a just a handful of countries, including Brazil and Thailand. While imports of livestock products from low-cost producers, such as Brazil for meat and New Zealand for dairy products, can provide affordable animal-source foods, this comes at the cost of disadvantaging local producers who cannot compete on price alone. Production and export subsidies provided by rich-world countries to their livestock industries continue to harm developing-country producers and processors. And the increasing number of urban dwellers in developing countries demanding low-cost food, including meat, milk and eggs, could result in a shift in policies that favour local producers to those that favour consumers.

Livestock systems. Much of the increasing demand for livestock foods will be met by three major livestock production systems: confined intensive, mixed crop-livestock and open grazing systems (Robinson et al., 2011). The following information on trends in these systems draws heavily on modelling work undertaken by Herrero et al. (2009b, 2010) using an IMPACT model developed by the International Food Policy Research Institute (IFPRI).

Confined intensive monogastric systems. Much of the increased consumption of meat over recent decades has been supplied by poultry and pigs produced in intensive confined systems: currently, 55% of the world's pork and 71% of poultry are produced in intensive systems; it is projected that they will account for three-quarters of the increase in meat production to 2030, growing at rates of around 7% a year, especially in Latin America and Asia (Bruinsma, 2003). In the 50 years since 1960, while beef production has doubled,

production of chicken meat has increased by close to a factor of 10 (Thornton, 2010). Over recent decades, these intensive monogastric systems, which originated in industrialized countries, have spread to developing countries, especially Asia. Steinfeld et al. (2006) describes a two-stage process for the establishment and maturing of these systems in developing countries. Initially, intensive pig and poultry production units spring up close to towns and cities to meet rapidly growing demand and minimize problems associated with transporting and storing the live animals or perishable commodities. As infrastructure improvements occur, these production facilities tend to be relocated further from urban centres, facilitated by improved roads and distribution networks and sometimes encouraged by deliberate policies. This shift allows the owners to benefit from cheaper land and labour costs, and also overcomes environmental and public health threats associated with large concentrations of pigs and poultry being kept close to large concentrations of people. A major requirement for these systems is a reliable source of feed, especially grains and soya beans, whether locally produced or imported. FAO projects that three-quarters of the production growth to 2030 will come from such intensive systems, especially in Asia. Globally, between 2000 and 2050, although pig numbers are projected to increase only slightly, poultry numbers are set to double: by 2050 the global flock will number 34.6 billion birds, approximately four for every man, woman and child on the planet (FAO, 2012).

Mixed crop-livestock systems. Regions characterized by mixed crop-livestock systems, where crop growing and livestock raising are integrated on the same farms, and the cities that occur within these regions, are home to two-thirds of the world's population and produce 50% of the world's meat and cereals and 90% of its milk (Herrero et al., 2009b; 2010). It is projected that, in line with historic trends, increased production of crops in these mixed systems will be achieved largely through productivity gains, largely because little additional land is available to transform into farm land. However, increased production of livestock, and ruminant animals in particular, will occur largely through increases in numbers of animals. In half a century, between 2000 and 2050, the global cattle herd is projected to increase from 1.5 billion to 2.6 billion, while the sheep and goat flock is expected to grow from 1.7 billion to 2.7 billion, with almost all the increases in the developing countries. These increases will exert great pressure on these systems, especially the need for greater amounts of feed and water. While increases in stover production in sub-Saharan Africa are expected to be significant, due to gains in the productivity of maize, millet and sorghum, stover production may stagnate in South Asia, which has the largest numbers of ruminants in any system globally (Herrero et al., 2009b). The decreasing land and water resources available to farmers will limit options for their production of alternative feeds for ruminants. One response to this situation has been the emergence of 'fodder markets', with fodder traded between surplus and deficit areas. This trend is likely to grow as fodder prices increase, especially if road networks improve. Another option in the mixed systems in higher potential areas is to encourage the production of pigs and poultry, where productivity gains can be achieved without using more land and water. However, while smallholders enjoy competitive advantages in the production of milk and ruminant meat due to their ability to use family labour and otherwise low-value feed, they are usually, though not always, less competitive when it comes to monogastrics, for which economies of scale at production level are more significant than those in dairy and ruminant production (Tarawali et al., 2011).

Open grazing systems. Open grazing lands, including savannas, grasslands, prairies, steppes and shrublands, occupy 30% of the earth's ice-free surface and provide up to 30% of global beef and mutton (Herrero et al., 2009b). Until now, increased production from extensive rangelands in developing countries has occurred largely due to an increased number of animals. In the future, with the potential to continue increasing numbers of animals limited or capped in many regions, intensification is likely to occur in some humid-subhumid zones, where pasture improvements and other improved management options are viable. The arid and semi-arid zones, however, present few viable options for intensification. Effective use of these drylands depends on the mobility of pastoralists, who need periodically to move their herds and flocks to find new forage. But pastoral mobility has been progressively constrained over the past 50 years or more, even though the greater climate variability and long-term trends towards hotter climates are making this mobility more and more critical for pastoral systems (Reid et al., 2004). Dry rangelands are increasingly being valued for their biodiversity and their role as storehouses of carbon. Future development of these areas may therefore be driven as much, if not more, by recognition of the custodial role of pastoralists and the value of the environmental services they provide as by the potential of pastoralists to produce ruminant meat (Conant and Paustian, 2002; Silvestri et al., 2012).

The burgeoning and changing demographics of the global population places significant demands on the provision of wholesome foods. Livestock commodities and their under pinning production systems have a crucial role to play but there is a diversity of solutions. In addition to enhancing technical and institutional aspects of production systems to produce more food more efficiently, research is also needed to understand the on-going evolutionary pathways of diverse systems and the implications for environment, health, economics and livelihoods. The ability to disaggregate such diversity at an appropriate level is needed to guide research and development targets and investment decisions in the sector without over-generalising.

LIVESTOCK IMPACTS ON THE ENVIRONMENT – AND VICE VERSA

In the process of providing humanity with a wide range of benefits, including food, income, livelihoods, employment, insurance and savings, draft power, manure, clothing, prestige and pleasure, livestock use significant amounts of land, water, feed and food and other resources, are a major source of anthropogenic global greenhouse gases and can pollute surface and underground water sources. Especially in developing countries however, there are significant opportunities to mitigate environmental impacts from livestock systems.

Land and water resources. Livestock raising represents the largest use of land on Earth: around one-third of the planet's land surface is used for pastoral livestock production, with additional land taken up to grow plants for livestock feed (one-third of arable land) and other livestock-related uses (Reid et al., 2008; Steinfeld et al., 2008). Livestock already impact water resources in three main ways: through the water used to grow plants to feed animals, through the direct consumption of water by livestock (but note that the amount of water consumed by livestock is 25–50 times less than the amount used to produce their feed [Peden et al., 2007]), and through the pollution of water sources with manure and the physical damage livestock cause vegetation and soil around water sources. Heavy grazing can have detrimental impacts on water: removal of vegetative cover can result in soil erosion, down-slope sedimentation and reduced infiltration. Localized problems associated with livestock drinking points in extensive systems are a particular problem. The anticipated increase in livestock numbers, especially through the proliferation of intensive systems, will likely lead to more water pollution. Slaughterhouses, tanneries and other livestock processing industries can contaminate water sources with nutrients, heavy metals and pathogens. Intensification of feed and fodder production supported by the use of fertilizers and pesticides can pollute soils as well as water (Steinfeld et al., 2006). But significant opportunities also exist to improve livestock use of water, especially in the intensifying crop-livestock systems in the developing world (e.g. Descheemaeker et al., 2010).

Climate change. Estimates of livestock's current contribution to anthropogenic (human-caused) climate change, expressed in carbon dioxide equivalents, range from 8.5% to 18% (O'Mara, 2011). Carbon dioxide emissions are generated mainly by changes in land use, methane through eructation by ruminants, and nitrous oxide mostly from manure handling practices. Total emissions of all three greenhouse gases are likely to increase in the coming decades: it has been estimated that emissions of methane due to livestock and nitrogen dioxide emissions due to agriculture will increase by up to 60% by 2030. There are, however, significant regional variations; greenhouse gas emissions from western Europe are expected to decrease to 2020, while there will be steep increases in East Asia and sub-Saharan Africa, the latter driven by increasing numbers of ruminants (Thornton and Herrero, 2010).

In turn livestock keepers will need to cope with the impacts of climate change, including increasing temperatures, changing precipitation patterns, and more frequent and intense extreme weather events. The changing climate will present new challenges in terms of emerging and re-emerging diseases and changes in disease distribution and dynamics (especially of diseases transmitted by vectors such as ticks, mosquitoes and biting flies), insufficient quality and quantity of feeds and reduced carrying capacity of rangelands, increasing pressure on water resources, and increasing need to switch to livestock species and breeds that can cope with the emerging, often harsher, environmental conditions. Projected impacts of climate change in Africa to the end of the present century include large increases in number of people exposed to water stress, reduced yields of rainfed crops and

increases in food insecurity and malnutrition, sea-level changes affecting densely populated coastal areas and an increase in arid and semi-arid lands. During the same period Asia is projected to be impacted through decreased freshwater availability, increased risk of flooding of river deltas, increased pressure on natural resources and increased mortality and morbidity from diarrheal diseases (FAO, 2012).

An increase in the frequency of droughts, floods, storms and other extreme weather events will threaten livestock directly (Thornton et al., 2009). More frequent droughts, such as that which devastated people in the Horn of Africa in 2010–2011, also means that pastoralists have insufficient time to rebuild their herds during the 'good years'. Thornton and Herrero (2009) found that while Kenya pastoralists can maintain their herd sizes when droughts occur once every 5 years or more, droughts occurring every 3 years can be ruinous for them. And as mentioned, whereas pastoralists in arid and semi-arid areas have in the past survived by deploying a range of coping strategies underpinned by the freedom to move their herds and flocks long distances, such mobility is now increasingly restricted. Indeed, in some regions, conflicts between settled agriculturalists and nomadic herders are also increasing in frequency and severity. Population growth often exacerbates these pastoral problems. The result is an increasing number of people from traditionally pastoralist communities are dropping out of pastoralism and are unlikely ever to return: many now rely on perpetual food aid or have migrated to urban areas in search of scarce jobs or other opportunities – the future of pastoralism is a subject of debate (Catley et al., 2012).

On the positive side of the environmental equation, livestock play a pivotal role in sustaining mixed crop-livestock systems, especially in sub-Saharan Africa, where a large proportion of soils are depleted of nutrients and use of chemical fertilizers is very low. Globally, livestock manure supplies up to 12% of gross nitrogen input for cropping and up to 23% in mixed crop-livestock systems in developing countries (Liu et al., 2010). A risk associated with intensification of livestock systems is that crop-and-livestock systems become less interconnected and manure becomes less used as a soil nutrient: in these situations, what was previously an asset can become a liability and can result in pollution, such as excessive levels of phosphates in soils and water—even as the world faces severe phosphorus shortages in the future (van Vuuren et al., 2010). According to a recent report by FAO (2010)[3], use of draught animals is increasing in Africa and persisting in Asia and even in parts of Latin America.

The intersection of livestock with the environment again provides multiple opportunities for research to inform and provide robust solutions for key challenges. Included here are issues such as increasing efficiency of production in smallholder systems, leading to reductions in animal numbers, targeting where such strategies make sense and where a more rapid shift to larger scale production is more appropriate; proof at scale of feasible options for payment for ecosystem services is another dimension requiring both technical and institutional solutions.

[3] http://www.fao.org/fileadmin/user_upload/ags/publications/draugth_ap_overview.pdf

THE CRITICAL ROLE LIVESTOCK PLAY IN LIVELIHOODS OF THE POOR

There are two contrasting views of the role of livestock in the lives of the poor. One school of thought emphasizes the role of livestock as a *pathway* out of poverty for the world's poorest inhabitants (Kristjanson et al., 2005); the other regards livestock production as an *expression* of poverty practiced by people, especially those from Africa and Asia, who have no other options (Perry and Grace, 2009).

Irrespective of these polarized views, it is estimated that currently livestock production and marketing are essential to the livelihoods of more than one billion poor people in Africa and Asia—one-seventh of humanity. Almost two-thirds of the world's billion poor livestock keepers are rural women (Staal et al., 2009). Earlier estimates indicted around 70% of the rural poor depended on livestock (LID, 1999). Others have estimated that 40–50% of those living in poverty ($1.25 threshold) are at least partially dependent on livestock (Robinson et al., 2011) A more recent 12-country study found around 68% of poor rural households and around 25% of poor urban households kept livestock (Pica-Ciamarra et al., 2005).

Herrero et al. (2012) recently summarized the roles of livestock as an income source. Their review found that, for example, beef production and marketing in West Africa supports 70 million people; dairy supports 124 million people in South Asia and 24 million in East Africa; while small ruminants support 81 million people in West Africa and 28 million in southern Africa (Staal et al., 2009). More than 80% of poor Africans and up to 66% of poor people in India and Bangladesh are estimated to keep livestock (FAO, 2009).

In a study undertaken mainly in mixed crop-livestock systems in 15 countries, more than two-thirds of households earned income from livestock, with the actual amount ranging widely from less than 2% to more than 33% of total household income (Davis et al., 2007). The 12-country study of Pica-Ciamarra et al. (2011) found that livestock contribute on average 12% to household income, with no statistical differences between their contributions in rich and poor countries. Another study, based on 92 case studies across the developing world, found that on average livestock contribute one-third of the income in mixed crop-livestock systems; the proportion was higher where income was associated with dairy or poultry production (Staal et al., 2009). Although livestock ownership, particularly of 'prestigious' species such as cattle, is sometimes regarded as a sign of wealth, livestock have been shown to contribute a greater share of income in the poorest households (Davis et al., 2007).

Livestock are often one of the major assets that rural households possess. Access to and control and ownership of assets are regarded as being critical aspects of well-being (Sherraden, 1991). Accumulation of livestock has been identified in some studies as the tipping point that allows poor households to invest in land or small businesses, thereby diversifying their incomes and becoming less poor and vulnerable (Ellis and Freeman, 2004). Livestock assets are generally more equitably distributed between men and women than are other assets, such as land (Flintan, 2008). Widely held beliefs that women tend to own mainly small ruminants and poultry are not always supported by the evidence: in some cultures women also own oxen, bulls and other large animals (Rubin et al., 2010).

The massive increase in demand for livestock products over the past few decades has created equally significant opportunities to meet that demand. The role that smallholder

livestock keepers play, however, has been shown to vary depending on the stage of development in different countries—which can be classified as agriculture-based, transforming or urbanized. In economies that are agricultural, where agriculture contributes 30–50% to GDP, smallholders will tend to remain competitive and informal markets will predominate. As economies develop to the transforming stage, agriculture's share of GDP drops to 15–25%; some smallholders will find opportunities in increasingly formal markets, some will transit to larger and more intensive farms, and others will exit the sector to take advantage of new opportunities in construction, manufacturing and service industries. Finally, as economies mature into urbanized ones, value chains become complex, there is increasingly vertical integration in production systems and, although there may still be roles for small-scale entrepreneurs, smallholders will rarely be competitive (Tarawali et al., 2011). In China, for example, it has been reported that 70 million small-scale farmers ceased to keep poultry between 1990 and 2005 (Bingsheng and Han Yijun, 2007).

An emerging trend in developing-country agriculture appears to be the aging of farmers and the reluctance of young people to follow their parents into agriculturally based livelihoods (Homewood et al., 2007). When interviewed, poor livestock keepers often say their motivation for keeping livestock is to be able to secure a better future for their children. In this scenario, livestock may provide them with the cash and nutrient-rich foodstuffs that help ensure that their children are able to realize their full potential, including normal cognitive development and a good education, and thus are later able to take advantage of new opportunities that arise and lead healthy and productive lives.

Research to support enhancing the role of livestock in livelihoods is multidimensional and includes aspects of market engagement, development sustainable institutions and service provision mechanisms (which may include new business models), and new public and private sector roles. Understanding and addressing issues around the transition of smallholder livestock farms to be part of future food systems that are beneficial to livelihoods, and the environment is a key aspect.

LINKS BETWEEN ANIMAL AND HUMAN HEALTH

During the past decade the world's attention was for a time focused on the threat of emerging zoonotic disease: estimates suggested that a global pandemic of avian influenza could cost the world economy up to $2 trillion and the 'worried well' in industrialized countries demanded action. This resulted in 2006 in donors pledging $1.87 billion to fund global preventative and preparedness measures, not all of which delivered on their promises. In hindsight, many observers now believe this to have been an overreaction, although the threat of a global pandemic remains.

However, a recent study (Grace et al., 2012) has shown that the real burden of zoonotic diseases falls on the world's billion poorest people: 13 zoonotic diseases, including Rift Valley fever and tuberculosis, were found to cause 2.4 billion cases of human illness and 2.2 million deaths per year, with the vast majority of cases occurring in low- and middle-income countries. Around 60% of all human diseases and 75% of all emerging infectious diseases are zoonotic (Taylor et al., 2001) and 12% of the infectious disease burden in least-developed countries is due to zoonoses, with most of the diseases transmitted to people from livestock hosts through consumption of animal-source foods, the vectors of pathogens or direct contact (Grace et al., 2012). The study's authors found high levels of infection with these zoonoses among livestock in poor countries; for example 27% of livestock in developing countries showed signs of current or past infection with bacterial food-borne disease—a source of food contamination and widespread illness. The researchers attribute at least one-third of global diarrheal disease to zoonotic causes and find this disease to be the biggest zoonotic threat to public health. The true impact of zoonotic diseases is likely to be even higher due to massive under-reporting of zoonoses and animal diseases in general in poor countries: in sub-Saharan Africa, for example, it was estimated that 99.9% of livestock losses do not appear in official disease reports (Grace et al., 2012). A major finding of the study was that most of the burden of zoonoses and most of the opportunities for alleviating zoonoses lie in just a few countries: Ethiopia, Nigeria and India have the highest number of poor livestock keepers, the highest number of malnourished people, and are in the top five countries for both absolute numbers affected with zoonoses and the relative intensity of zoonoses infection. The shift to more intensive livestock systems, especially those in which high densities of pigs and poultry are kept close to urban populations, is considered to represent a significantly increased risk of disease spread. The report identifies Burkina Faso and Ghana in Africa and India, Myanmar and Pakistan in Asia as countries where the most rapid changes in pig and poultry production systems are likely to occur in the near future.

Aside from infectious diseases, the world is struggling to cope with malnutrition at both ends of the scale: the latest estimates suggest that while close to one billion people go hungry every day and another billion suffer from hidden hunger due to lack of essential vitamins and minerals in their diets, even more are overweight. And an increasing number of countries is having to deal with both problems simultaneously: a recent study found that while 17% of South African children are overweight or obese, 19% are stunted as a result of malnutrition (Pettifor, 2006). Similar situations occur in other developing countries with rapidly emerging middle classes, such as India, China and Brazil.

In 2008 it was reported that worldwide 1.46 billion people were overweight (body-mass index [BMI]>25 kg/m^2), 502 million adults were obese (BMI >30 kg/m^2), and 170 million children (aged <18 years) globally were classified as overweight or obese. Although prior to the 1980s problems associated with being overweight were confined largely to rich

countries, since then middle-income and many low-income countries have become affected. It has been demonstrated that elevated BMI is a risk factor for diseases such as type 2 diabetes, cardiovascular diseases and many cancers. The disability attributable to obesity was calculated in 2004 at more than 36 million disability-adjusted life-years, accounting for up to 6% of total health-care costs in many countries (WHO, 2010). Over consumption of livestock foods, which are energy-dense and often high in saturated fats, is undoubtedly a contributory factor to the global obesity epidemic.

Under-nutrition, however, remains widespread amongst the poor in developing countries. It is implicated in the deaths of a third of all children under five (Black et al., 2008); an estimated 195 million children are too short for their age (stunted) and 129 million children are underweight (UNICEF, 2008). The prevalence of stunting and underweight children is highest in Africa and Asia, but also prevails amongst the poor in other regions, such as Latin America and the Caribbean. Consumption of even small amounts of milk, meat, eggs and fish is an effective way of preventing under-nutrition and achieving nutritional security, thereby enabling children to develop normally, reaching their full potential as healthy, productive adults. Animal-source foods are dense and palatable sources of energy and high-quality protein but, equally important, provide various essential micronutrients, some of which, such as vitamin A, vitamin B_{12}, riboflavin, calcium, iron, zinc and various essential fatty acids, are difficult to obtain in adequate amounts from plant-based foods alone (Murphy and Allen, 2003).

Longitudinal studies in Egypt, Kenya and Mexico (Neumann et al., 2002) have shown strong associations between intake of animal source foods and better growth, cognitive function and physical activity of children, better pregnancy outcomes and reduced morbidity from illness. Consumption of adequate amounts of micronutrients, such as those that can be found in animal-source foods, is associated with more competent immune systems and better immune responses (Keusch and Farthing, 1986; Neumann et al., 1991). But the availability and affordability of meat, milk and eggs in poor countries lag behind the rest of the world and consumption rates remain low, exacerbated by recent upward pressure on food prices. Even poor households that rear livestock often sell surplus animals or any milk or eggs produced to provide much needed cash.

Research on the intersection of livestock with human health focuses on a number of key dimensions including appropriate diet and nutrition, infectious diseases (including zoonoses) and strategic approaches to identify at risk populations and entry points.

ROLE OF LIVESTOCK RESEARCH IN UNDERSTANDING AND PROVIDING SOLUTIONS TO THESE ISSUES

Clearly there are both opportunities and challenges associated with the global livestock sector. Livestock research-for-development has a critical role to play in enabling greater understanding of these and in providing solutions. These will span both biophysical and socio-economic trade-offs in livestock production at multiple scales and the new organizational models needed to facilitate a positive transition of developing country livestock sectors.

Biophysical research includes productivity dimensions (notably feeds, breeds, health) to enhance the efficient production of animal source foods and mitigate environmental impacts, addressing livestock-human nutrition and disease challenges and practical options for environmental management. Institutional aspects where research can contribute span solutions for PES schemes, market and service provision models and the provision of evidence to guide public and private sector roles and investments in livestock.

Today's livestock systems, on which many millions of poor people depend are dynamic and will need to transition in the coming decades to respond to future food needs in ways that are environmentally, socially and economically equitable and sustainable. There will be no one-size-fits all solutions, nor panacea-type answers, and research is needed to better target options and solutions in relation to the diverse situations that are today's starting points systems in order to result in a positive transition.

Research that enhances understanding, targeting and provides biophysical and institutional solutions must combine to enhance the transition of today's smallholder livestock farms through inclusive growth to be a vibrant part of the food, poverty alleviation, environmental and health solutions of the future.

REFERENCES

African Development Bank. 2011. The middle of the pyramid: Dynamics of the middle class in Africa. Market Brief, 20 April 2011. www.afdb.org

Bingsheng K and H Yijun. 2007. Poultry sector in China: Structural changes during the past decade and future trends. In: *Poultry in the 21st Century: Avian Influenza and Beyond.* Bangkok, November 2007. Rome: Food and Agriculture Organization of the United Nations.

Black RE, LH Allen, ZA Bhutta, LE Caulfield, M de Onis, M Ezzati, C Mathers, J Rivera, for the Maternaland Child Undernutrition Study Group. 2008. Maternal and child undernutrition: Global and regional exposures and health consequences. *Lancet* 371: 243–60.

Bruinsma J. 2003. *World Agriculture: Towards 2015/2030, An FAO Perspective*. London: Earthscan Publications.

Catley A. J Lind and I Scoones (Eds). 2012. Pastoralism and Development in Africa: Dynamic Change at the Margins. Earthscan / Routledge, July 2012

Conant RT, K Paustian. 2002. Potential soil carbon sequestration in overgrazed grassland ecosystems. *Global Biogeochemical Cycles* 16: 1143–1152

Davis B, P Winters, G Carletto, K Covarrubias, E Quinones, A Zezza, K Stamoulis, G Bonomi and S DiGiuseppe. 2007. Rural income-generating activities: A cross-country comparison. *ESA Working Paper 07–16*, Rome: Food and Agriculture Organization of the United Nations.

Delisle H. 1990. Patterns of urban food consumption in developing countries: Perspective from the 1980s. Rome: Food and Agriculture Organization of the United Nations.

Descheemaeker K, Amede T and Haileselassie A. 2011. Improving water productivity in mixed crop livestock farming systems of sub-Saharan Africa. *Agricultural Water Management* 47, 21-38.

Ellis F and HA Freeman. 2004. Rural livelihoods and poverty reduction strategies in four African countries. *The Journal of Development Studies* 40 (4), 1–30.

FAO. 2006. Livestock impacts on the environment. Spotlight, November 2006. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2007. *The State of the World's Animal Genetic Resources for Food and Agriculture*, ed. by B Rischkowsky and Pilling D. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2009. *The State of Food and Agriculture: Livestock in the Balance.* Rome: Food and Agriculture Organization of the United Nations.

FAO. 2011. The state of food and agriculture: Women in agriculture-closing the gender gap for development. FAO, Rome and http://www.fao.org/gender/en/

FAO. 2012. Committee on Agriculture 23rd Session. Rome, 21-25 May 2012 Web Annex 2012/2: http://www.fao.org/docrep/meeting/025/md883E.pdf

Flintan F. 2008. Women's Empowerment in Pastoral Societies. World Initiative for Sustainable Pastoralism, Global Environment Facility, IUCN, and UNDP.

Gerber P, P Chilonda, G Franceschini and H Menzi. 2005. Geographical determinants and environmental implications of livestock production intensification in Asia. *Bioresource Technology* 96: 263–276.

Grace, D.; Mutua, F.; Ochungo, P.; Kruska, R.; Jones, K.; Brierley, L.; Lapar, L.; Said, M.; Herrero, M.; Pham Duc Phuc; Nguyen Bich Thao; Akuku, I.; Ogutu, F. 2012. Mapping of poverty and likely zoonoses hotspots: Report to the Department for International Development. Nairobi, Kenya: ILRI

Herrero, M, PK Thornton, P Gerber and RS Reid. 2009a. Livestock, livelihoods and the environment: Understanding the trade-offs. *Current Opinion in Environmental Sustainability* 1, 111–120.

Herrero M, PK Thornton, A Notenbaert, S Msangi, S Wood, R Kruska, J Dixon, D Bossio, J van de Steeg, HA Freeman, X Li and P Parthasarathy Rao. 2009b. *Drivers of Change in Crop-livestock Systems and Their Impacts on Agro-ecosystems Services and Human Well-being to 2030.* CGIAR Systemwide Livestock Programme. Nairobi: International Livestock Research Institute.

Herrero M, PK Thornton, AM Notenbaert, S Wood, S Msangi, HA Freeman, D Bossio, J Dixon, M Peters, J van de Steeg, J Lynam, P Parthasarathy Rao, S MacMillan, B Gerard, J McDermott, C Seré, M Rosegrant. 2010. Smart investments in sustainable food production: Revisiting mixed crop-livestock systems. *Science* 327, 822–825.

Herrero M, D Grace, J Njuki, N Johnson and M Rufino. 2012.The roles of livestock in developing countries. *Animal* (in press).

Intercooperation, 2006. Towards accelerated growth in dairying: An action research to improve the traditional milk sector. Summary Report, CALPI Programme Series 2. Intercooperation, Hyderabad, India.

Jones, P.G.; Thornton, P.K. 2008. Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. *Environmental Science & Policy*. 12, 427-437

Keusch GT, MJ Farthing. 1986. Nutrition and infection. *Annual Review of Nutrition* 6: 131–154

Kristjanson P, A Krishna, M Radeny, J Kuan, G Quilca and A Sanchez-Urrelo. 2005. *Dynamic Poverty Processes and the Role of Livestock in Peru.* Pro-Poor Livestock Policy Initiative Working Paper. Rome: Food and Agriculture Organization of the United Nations.

LID. 1999. Livestock In Poverty-Focused Development. Crewkerne: Livestock In Development. 95pp

Liu J, L You, M Amini, M Obersteiner, M Herrero, AJB Zehnder, H Yang. 2010. A high-resolution assessment of nitrogen flows in cropland. *Proceedings of the National Academy of Sciences* 107, 835–840.

Maltsoglou I. 2007. *Household Expenditure on Food of Animal Origin: A Comparison of Uganda, Vietnam and Peru.* Pro-Poor Livestock Policy Initiative Working Paper No. 43. Rome: Food and Agriculture Organization of the United Nations.

McDermott, J., Staal, S.J., Freeman, H.A., Herrero, M., van de Steeg, J., 2010 Sustaining intensification in smallholder livestock systems in the tropics. *Livestock Science* 130,95-109.

Mintel. 2006. *Attitudes towards Vegetarianism UK*. September 2006. Mintel Group Ltd, London, UK.

Murphy SP, LH Allen. 2003. Nutritional importance of animal source foods. *Journal of Nutrition* 133: 3932S–3935S.

Neumann CG, GJ Jr Lawlor, ER Stiehm, M Swendseid, C Newton, J Herbert, AJ Ammann and M Jacob. 1975. Immunologic responses in malnourished children. *American Journal of Clinical Nutrition* 28: 89–104.

Neumann CG, LS Stephenson. 1991. Interaction of nutrition and infection. In: Strickland GT, ed. *Hunter's Tropical Medicine*, 7th ed. Philadelphia: WB Saunders Co.

Neumann C, DM Harris and LM Rogers. 2002. Contribution of animal source foods in improving diet quality and function in children in the developing world. *Nutritional Research* 22 (1–2): 193–220.

O'Mara FP. The significance of livestock as a contributor to global 21 greenhouse gas emissions today and in the near future. *Animal Feed Science and Technology* (in press).

Parthasarathy Rao, P. and Birthal, P.S. 2008. Livestock in mixed farming systems in South Asia. National Center for Agricultural Economics and Policy Research, New Delhi, India; International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India, p.156.

Peden D, G Tadesse, AK Misra, F AwadAmed, A Astatke, W Ayalneh, M Herrero, G Kiwuwa, T Kumsa, B Mati, D Mpairwe, T Wassenaar and A Yimegnuhal. 2007. Chapter 13: Livestock and Water for Human Development. In: Molden D et al. (eds). *Water for Food, Water for Life: Comprehensive Assessment of Water Management in Agriculture.* Oxford: Oxford University Press, p. 485–514.

Perry B, D Grace. 2009. The impacts of livestock diseases and their control on growth and development processes that are pro-poor. Philosophical Transactions of the Royal Society B 364, 2643–2655.

Pettifor, JM. 2006. Combined stunting and overweight in young children—a paradox? *The South African Journal of Clinical Nutrition.*Volume 19 No. 3.

Pica-Ciamarra U. 2005. *Livestock Policies for Poverty Alleviation: Theory and Practical Evidence from Africa, Asia and Latin America.* Pro-Poor Livestock Policy Initiative Working Paper No. 27. Rome: Food and Agriculture Organization of the United Nations.

Reardon, T., Henson, S. and Berdegué, J. 2007. Proactive fast-tracking diffusion of supermarkets in developing countries: implications for market institutions and trade. Journal of Economic Geography, 7: 399-432.

Reid RS, PK Thornton, GJ McCrabb, RL Kruska, F Atieno and PG Jones. 2004. Is it possible to mitigate greenhouse gas emissions in pastoral ecosystems of the tropics? *Environment, Development and Sustainability* 6: 91–109.

Robinson TP, PK Thornton, T Franceschini, RL Kruska, F Chiozza, A Notenbaert, G Checchi, M Herrero, M Epprecht, S Fritz, L You, G Conchedda and L See. 2011. *Global Livestock Production Systems.* Rome, Food and Agriculture Organization of the United Nations and the International Livestock Research Institute. 153 pp.

Rubin D, S Tezera, L Caldwell. 2010. *A Calf, a House, a Business of One's Own: Microcredit, Asset Accumulation, and Economic Empowerment in GL CRSP Projects in Ethiopia and Ghana.* Global Livestock Collaborative Research Support Program.

Staal S, J Poole, I Baltenweck, J Mwacharo, A Notenbaert, T Randolph, W Thorpe, J Nzuma and M Herrero. 2009. Strategic investment in livestock development as a vehicle for rural livelihoods. Bill and Melinda Gates Foundation—ILRI Knowledge Generation Project Report. Nairobi: International Livestock Research Institute. 78 p.

Stehfest E, L Bouwman, DP van Vuuren, MGJ den Elzen, B Eickhout, P Kabat. 2009. Climate benefits of changing diet. *Climatic Change*, Volume 95, Numbers 1–2.

Sherraden, M. 1991. Assets and the poor. A new American welfare policy. Armonk, NY: M.E. Sharpe.

Silvestri, S., Osano, P., Leeuw, J. de, Herrero, M., Ericksen, P., Kariuki, J., Njuki, J., Bedelian, C. and Notenbaert, A. 2012. Greening livestock: Assessing the potential of payment for environmental services in livestock inclusive agricultural production systems in developing countries. ILRI Position Paper. Nairobi, Kenya: ILRI

Steinfeld H, P Gerber, T Wassenaar, V Castel, M Rosales and C de Haas. 2006. *Livestock's Long Shadow: Environmental Issues and Options.* Livestock Environment and Development. Rome: Food and Agriculture Organization of the United Nations. 390 p.

Tarawali S, M Herrero, K Descheemaeker, E Grings and M Blümmel. 2011. Pathways for sustainable development of mixed crop livestock systems: Taking a livestock and pro-poor approach. *Livestock Science* 139: 11–21.

Taylor, L.H., Latham, S.M., and Woolhouse, M.E.J. 2001. Risk factors for human disease emergence., *Philos Trans R Soc Lond B Biol Sci.,* 356:983-989.

Thornton PK, M Herrero. 2009. *The Inter-linkages between Rapid Growth in Livestock Production, Climate Change, and the Impacts on Water Resources, Land Use, and Deforestation.* World Bank Policy Research Working Paper, WPS 5178. Washington, DC: World Bank.

Thornton, PK, J Van de Steeg, A Notenbaert and M Herrero. 2009. The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural Systems* 101: 113–200.

Thornton, P.K. 2010. Livestock production: recent trends, future prospects. Philosophical 1161 Transactions of the Royal Society B. 365, 2853-2867

Turner MD, AA Ayantunde, KP Patterson and ED Patterson. 2012. Conflict Management, Decentralization and Agropastoralism in Dryland West Africa World Development 40(4), 745–757.

United Nations. 2011. World Population Prospects: The 2010 Revision, Highlights and Advance Tables. Working Paper No. ESA/P/WP.220. United Nations, Department of Economic and Social Affairs, Population Division.

UNICEF. 2008. *State of the World's Children 2009: Maternal and Newborn Health*. New York: UNICEF.

Van Vuuren, DP, AF Bouwman, AHW Beusen. 2010. Phosphorus demand for the 1970–2100 period: A scenario analysis of resource depletion. *Global Environmental Change* 20: 428–439.

Westhoek, H, T Rood, M van den Berg, J Janse, D Nijdam, M Reudink, E Stehfest. 2011. The Protein Puzzle, The consumption and production of meat, dairy and fish in the European Union. The Hague: PBL Netherlands Environmental Assessment Agency. www.pbl.nl/en.

WHO. 2010. *Global Status Report on Noncommunicable Diseases*. Geneva: World Health Organisation.

Yadav Y and S Kumar. 2006. The food habits of a nation. *The Hindu*, 14 August 2006 (online edition), New Delhi, India.