Independent Science and Partnership Council

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Urbanization and farm size changes in Africa and Asia:

Implications for livestock research

A Foresight Study of the Independent Science and Partnership Council

Cees de Haan

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February 12, 2013

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Executive Summary

(i) *Overview.* This background paper identifies issues for livestock research emerging from urbanization and changing farm size in sub-Saharan Africa and Asia. It highlights the strong past and the expected, although somewhat slower, continuing demand for livestock source food (LSF) in the developing world, resulting in a significant growth in the livestock population and feed grain demand. It is expected that in in 2030 in the developing world more that half the grain production will be fed to livestock. *Research on increasing the efficiency of feed grain use deserves therefore a high priority.*

(ii) *Urbanization and LSF consumption.* LSF consumption is higher in more urbanized countries, as could be expected, although it is not clear whether urbanites consume more LSF independent of income levels. With rising income levels there seem initially an increase in the consumption of poultry (and sometimes pork) whereas in a later phase of economic development there is a shift to beef although regional and cultural differences exist. For livestock products, urban consumers still rely heavily on traditional markets with limited processing and intermediation. This has important trade-offs between food safety, affordability and employment generation. Animal welfare might standards might gain importance in the future. *Research on the effect of urbanization on future demand, type of preferred meat, food safety, quality and ethical standards is therefore recommended to better understand the main characteristic of future demand.*

(iii) *Urbanization and livestock geography.* The spatial distribution of livestock, and in particular that of pigs and poultry, is heavily dependent on relative prices of transport, land and labor. As soon as smallholder farming emerges from subsistence, proximity to urban consumers to easily supply urban consumers with the perishable livestock products becomes important. With increasing employment opportunities outside the smallholder farm, larger enterprises emerges, initially still near the urban centers, but, as transport costs decline and processing technology improves, increasingly located in the

feed producing areas. From a public/animal health and environmental viewpoint, such a more even spatial distribution is preferable. The alternative would be locating large intensive farms at industrial parks. *Research on the type of and the associated incentives for an optimal spatial distribution of intensive mostly large farms is recommended to inform planners.*

(iv) *Peri-urban livestock farming.* Peri-urban and urban livestock systems are important in poverty reduction and food security, not only in low-, but also in middle-income countries. While unpopular with urban policy makers, they are so important and flexible, that it is unlikely that this system will disappear in coming decades. *Research on technologies and institutional arrangement to improve the environmental and health effects of these systems is therefore recommended.*

(v) *Livestock production system dynamics.* Changing herd/flock size is taken in this paper as the more appropriate criteria for livestock production systems dynamics than changing farm size. Unlike the crop-sector, there is a strong tendency for increasing herd/flock size, in particular in the mono-gastric (pigs and poultry) sectors of Asia and, to a lesser extent in SSA. In the cattle sector increases in herd size and scale occur only in East Asia and in the high potential areas of SSA and South Asia. In the lower potential areas, in particular in areas where livestock grazing relies on communal resource access, herd size is generally declining. In the pastoral areas there is an accumulation of livestock by outsiders. Key drivers for this change are:

- Efficiency of resource use. While at an early stage of development, household and crop-residues result in high “tradable” resource use efficiency, once a commercial scale is reached large farms generally have a more favorable feed conversion than smallholders. The impact of the less favorable feed conversion of smallholders will be exacerbated by the projected increase in feed grains prices;
- Economies of scale in labor use. The literature quoted in this report shows that for pigs and poultry smallholders are only competitive if family labor is not included. For the dairy subsector smallholders are competitive;
- Economies of scale in equipment. There are clear economies of scale in the use of food safety (milk cooling equipment, livestock housing) and environmental abatement. There is evidence that smallholders face a higher abatement costs than large operators;
- Comparative advantage in meeting quality (food safety and other quality characteristics and regularity of supply; and
- Environmental emissions. Smallholder farms generally have a higher emission of GHG per kg product (although this doesn’t take into account the additional functions of livestock) and higher BOD in water pollution.

(vi) However, smallholder livestock farming will most likely remain for some time to come the main supplier of meat and milk in South Asia and sub-Saharan Africa. In the context of the 2030 horizon of this foresight study, this report therefore recommends a research program facilitating the entire pathway from subsistence/transition farming to either intensification or diversification and continuing to large farms. The proposed research program is detailed in this report, but will include as **main crosscutting** issues:

- *Increasing the feed use efficiency through a combination of plant breeding (both grain and biomass), animal genetics, animal physiology (rumen manipulation and feed additives) and animal feed production and conservation. This will also reduce the environmental print of the livestock sector; and*

- *Enhancing inter-institutional and public-private cooperation, and collective action on removing the barriers for smallholders to increasing scale.*

The main herd/farm size research specific issues cover the disease, genetics, feeds, NRM/soil food safety and quality and institutional subjects. They are detailed in paragraphs 31 to 36 of this report. It includes an involvement in research on the negative externalities of large farms, and it is recommended that the CGIAR, within a 2030 horizon, should be involved in large farm operations.

Urbanization and farm size changes in Africa and Asia

Implications for livestock research

1. This background paper[1] identifies issues for livestock research emerging from urbanization and changing farm size in sub-Saharan Africa and Asia. In particular, the paper seeks to identify the researchable questions resulting from the effects of urbanization and changing farm size on the (a) volume and main characteristics (quality, safety, and composition) of the demand for livestock source foods (LSF); (b) livestock geography (trends, the special case of urban and peri-urban livestock); and (c) production system dynamics (trends, smallholder pathways, constraints and opportunities).

I. **Setting the scene: the global demand and supply picture**

2. Driven by a growing population, rising per capita income growth and high rates of urbanization, with income and expenditure elasticities[2] often higher than 1, the demand for LSF in developing countries has grown rapidly over the last decades. For example, according to Alexandratos and Bruinsma (2012), demand for meat and of milk and dairy products in developing countries has grown between 1970 to 2007 at average annual rates of 5.1 percent and 3.6 percent respectively. Till 2030, these authors foresee an almost stagnating growth in the developing world (with the exception of the countries of the former Soviet Union) and somewhat slower growth in the developing world, i.e. annually 2.2 percent for meat and 2.1 percent for dairy products. This could be the result of two trends. First, as shown in figure 1, at higher consumption levels (about 80 kg and 200 kg meat and milk per capita/year respectively) the rate of growth slows down, and consumption eventually even shrinks. This slow down in per capita LSF consumption is expected to occur over the next decade in the two main drivers of consumer demand from the last two decades (Brazil and China), as they are respectively already at and near those levels. Second, this trend could be reinforced by the expected price increases in feed grain (see below) and the resulting more expensive LSF. Both trends are supported by the decrease in the expenditure elasticities reported by Narrod et al (2011)[3].

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[1] Paper prepared for the International Science Partnership Council (ISPC) workshop on January 26-27, 2013. It is based on the ISPC Concept Note: Agriculture towards 2030- Changes in Urbanization and Farm Size, their implications for CGIAR Research. This paper is based on a literature review and the author's experience in livestock development in Asia and sub-Saharan Africa.

[2] For example, Schroeder et al (1995) quoted in Delgado et al (1999) found that for annual per capita incomes of about US$ 1,000 (1985 prices) each percent increase in per capita income would increase consumption of pork by 1 percent, poultry by nearly 2 percent and beef by more than 2 percent. At a per capita income of about US$ 10,000, a 1 percent increase in income would increase per capita consumption of these commodities by about 1 percent

[3] Based on IMPACT projections from November 2006, comparing 2005 with 2025 figures in developing countries, beef would drop from 0.69 to 0.50, pork from 0.46 to 0.35, poultry from 0.77 to 0.66 and milk from 0.48 to 0.66.

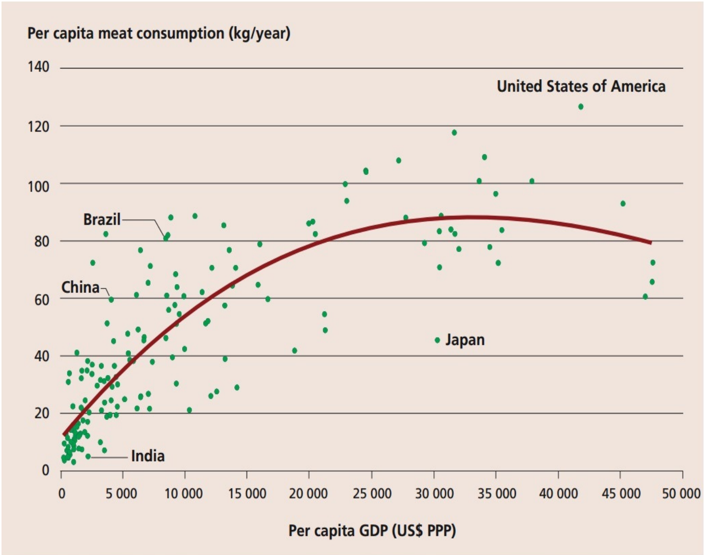


Figure 1 Per capita GDP (PPP)[4] and meat consumption by country (2005) Source FAO 2009.

3. However, the growth of the demand in Africa and Asia, the focus areas for this study, is still robust with an expected annual growth of demand for meat in sub-Saharan Africa and South Asia till 2030 of 3.2 and 4.5 percent respectively. In East Asia the growth in demand for meat is expected to slow down to an annual rate of only 1.9 percent. However, in spite of this slow down, the increase in demand for LSF will still be substantial in sheer volume. Alexandratos and Bruinsma (2012) project that over period 2007-2030 total annual demand for meat in the developing world will increase by 60 percent from about 140 million to 240 million ton, in Africa by 100 percent to 15 million ton and in South Asia by 160 percent to 20 million ton. As in meat, annual growth in the demand for dairy products would slow down to about 58 percent in the period to 2030 to a total of 510 million ton.

4. According to Alexandratos and Bruinsma (2012), this growth in demand will lead the global cattle population to increase from 1.7 billion in 2010 to 2.4 billion in 2030. Over that same period, the number of sheep and goats would increase from 1.8 to 2.6 billion and the poultry population from about 20 to 28 billion; the number of pigs would remain at the 2007 level at 1 billion. Also, it is expected that the annual global feed demand will grow from 720 million tons in 2007 to an estimated 1220 million tons (Alexandratos and Bruinsma, 2012) or 1300 tons (Lyons 2007) in 2050 or an increase of about 65 percent. The share of feed grain in the total grain consumption is now globally 36 percent and in the developing world 42 percent. The latter is expected according to Alexandratos and Bruinsma (2012) to go up to 56 percent in 2050. Meeting these projections constitutes a major challenge for the international agricultural research community, not only in physical terms, but also to do this on a sustainable fashion addressing the effects on the environment in terms of land use and bio-diversity (conversion into crop land and grazing pressure), greenhouse gas emission, pollution, health (zoonotic diseases) and food safety. The increased demand will also have important implications for the

[4] Based on Purchasing Power Parity and constant 2005 US$, using data from FAOStat 2009 for meat consumption and the World Bank for GDP data.

characteristics (species, intensity, efficiency) of the evolving production systems in SSA and Asia, as is explained later.

II. **Urbanization and LSF consumption**

(a) Per capita consumption levels

5. Assessing the effects of urbanization on LSF per capita consumption is difficult, as income growth and urbanization are highly correlated and the effect of urbanization can't be easily separated out. Logically, one would expect that urbanization would lead to higher LSF consumption by urban dwellers independent of income growth, as urban consumers have:

- More sedentary jobs, with a lower requirement for energy rich starchy foods; urbanites have thus more financial means and physiological space for LSF;
- Better access to shopping opportunities, with a greater variety of LSF products, supported by a more concerted advertising effort;
- Better access to power and hence refrigeration, allowing larger volumes of LSF to be purchased and conserved (Rae and Nayga 2010);
- Generally smaller households, resulting in a higher per capita disposable income; and
- Increased demand for a larger variety of foods, for which LSFs are particular suitable.

6. This is confirmed by a small number of studies. For example, Rae (1998) found consumption of LSF in six Asian countries to be related to urbanization, independent of income. Thornton (2010) also argues that urbanization is a driving force for increased consumption. Similarly, Betra and Kawashima (2009) found that, for a given level of income, urban households consumed more meat than rural households. For example, at the annual income level of ETB 1500, rural households consumed in 2004 about 3 kg meat per capita per year, whereas their urban income counterparts were at the annual level of about 7 kg per capita. However, these findings are not universally confirmed. For example, Stage et al (2010) citing evidence from China, India, Sri-Lanka and Vietnam argue that increased consumption of LSF is not caused by

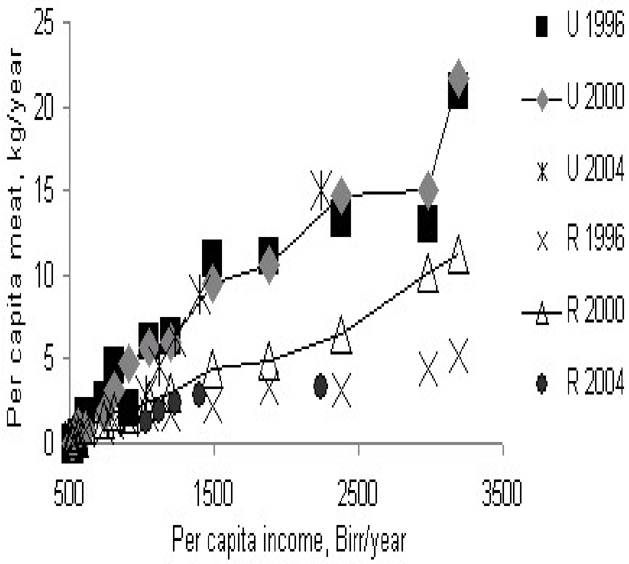


Fig 1. Relationship Income and meat consumption in Ethiopia (U=Urban, R=Rural Source: Betra and Kawashima (2009)

urbanization and cultural change, but is only the result of income differences. *Research on the effect of urbanization on per capita consumption, independent of income levels, is therefore recommended.*

(b) Urbanization and preferred LSF characteristics

7. Urbanization has significant effects on the source/species (beef, poultry, pork, etc.), quality (mostly organoleptic characteristics) and safety (microbial hygiene and contaminants), but these effects might also be related to income differences. Consumer preferences are largely defined by culture and ethnic origin, but other factors, such as urbanization and income also play an important role, and can be expected to become even more important in the future, as shown by a summary of the findings of recent consumer surveys.

8. *Species/Source of meat* As people move into towns, their preferred meat (beef, pork, poultry, etc) type changes, but regional differences occur. Delgado and Courbois (1998) found, on the basis of urbanization elasticities[5] from household surveys in 64 developing countries covering the 1970-1995 period, that as the percentage of urban dwellers increased in a country, the consumption of pork, poultry and lamb got more important in the LSF basket, whereas the share of beef and dairy products in that basket declined. This might be also a price effect, as the urbanization stage of development often coincides with the emergence of large pig and poultry farms and lower prices for white meat. But there are regional differences. Per capita consumption data (FAOstat 2012) over the period 2000-2009 (although on a national basis and not differentiated between rural and urban consumers) show growth in pig meat consumption slowing down in Asia and that of poultry in South Asia. Growth in poultry consumption was still strong in Eastern Asia and particular strong in Africa. Beef consumption was accelerating in Asia but not in Africa. As economic growth continues, and Western fast food chains come in, consumer preference seems to shift to beef. This is also demonstrated by the continued strong growth in the demand for beef in China, in particular by urban consumers (KSU, 2012). In summary, in an early stage of development, preference goes probably to poultry (and to some extent to pork), because of its lower price. At a later stage of development, the preference might shift to beef. *Researchable question would include on how these consumer preferences will play out in the future, to be able to better define future meat, feed grain and grazing area demands.*

9. *Food Safety.* The above-mentioned study of Jabbar et al (2010) shows also that consumers attach a high priority to food safety. Recent food safety scares (melamine in milk in China, formaldehyde in Indonesia and Vietnam) and outbreaks of zoonoses (Highly Pathogenic Avian Influenza, BSE) have heightened concerns, in particular of the urban consumer. Still the majority of LSF in developing countries still passes through traditional market channels. For example, it is estimated that in India, the traditional market share of milk is a high as 85 percent, in Kenya 88 percent, and even in middle-income countries such as Costa Rica still 44 percent[6]. Figures on the share of meat procured through traditional markets (called wet markets) are not available, but, for example for poultry are still substantial as experienced with the campaigns to control HPAI. The food safety and animal health implications of these informal market channels are unclear. For example, ILRI's work on the East African milk market

[5] They reported urbanization elasticity of –0.20 for beef, 0.46 for pork, 0.38 for poultry meat, and –0.17 for milk.
[6] http://globalfoodchainpartnerships.org/india/Presentations/Anjani.pdf

shows that milk procured through traditional channels is, at household level, not necessarily less safe in microbial or anti-microbial residue contamination than the products supplied through the official channels (Kaitibi et al 2008, Omore et al 2000). Jabbar et al (2010) makes the same point for meat products. The informal market channels generate also more employment per unit of output. For example, Staal et al (2006) finds in four countries that per 1000 liters output employment in the traditional chain was between 20 and 150 percent higher[7]. The appropriateness of modern food safety (Codex Alimentarius) and animal health (OIE terrestrial code) standards to these traditional channels is an issue of debate. The application of these standards will increase the price of LSF and reduce their affordability for the urban poor, and has often led to rent seeking by standard control authorities. *Researchable items would include: (a) trade-offs between the application of modern and traditional standards (cost, affordability for the urban poor, health risk) i.e., cost of compliance studies; (b) intermediate technologies that will reduce health risks, without major cost implications; (c) the identification of appropriate food safety pathways (including capacity building) with a gradual evolution to the "golden" OIE and Codex standards.*

10. *Quality*. Jabbar et al (2010) found from household surveys in seven countries[8] that urban consumers, also those who bought their LSF in the traditional "wet" markets, gave priority in milk to cleanliness and origin and for meat to breed, age and leanness. The latter characteristics are, of course, highly correlated. For both groups of commodities, price was one of the most important criteria. Urban/rural differences related to urban preference for lean meat and absence of residues, whereas rural consumers preferred meat with more fat and attached less importance to residues.

11. *Animal welfare*. Consumers in the developed world, and increasingly also in the developing world, want to be assured that LSF is humanely produced. Animal welfare standards might also become a non-tariff trade barrier for developing to developed country trade. OIE has established a set of animal welfare standards, but they deal only with transport, slaughter and commercial beef production. Developing country issues, such as animal traction and reducing animal suffering because of drought have not (yet) been covered. *Research questions would include an assessment of current and to be expected future developing country consumer demand for animal welfare standards, the identification of animal welfare parameters for typical developing country animal welfare issues, and an assessment of the effect of current livestock husbandry if these standards would be introduced.*

III. Urbanization and livestock geography

(a) General trends

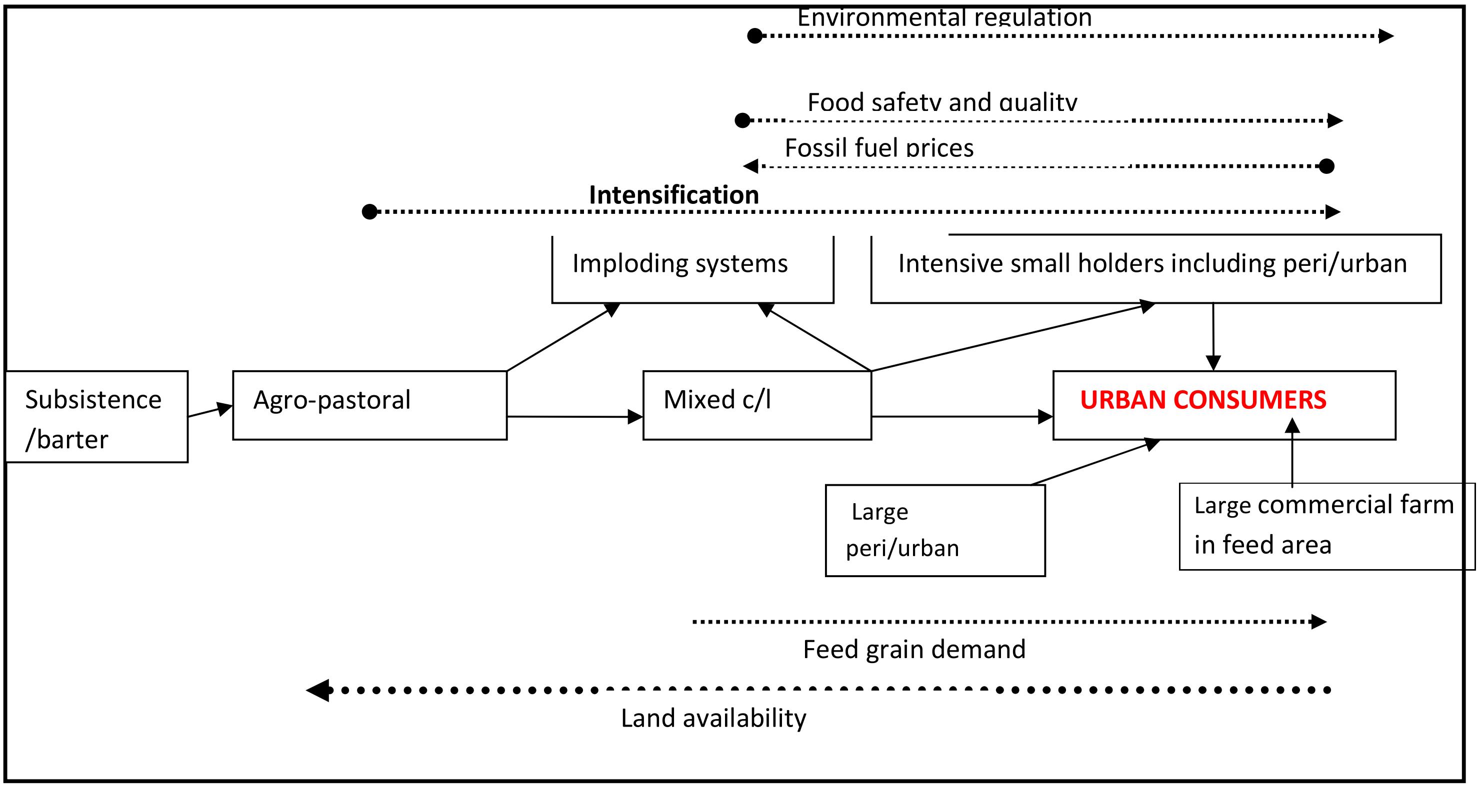
12. The geographical transition of livestock production and marketing follows a rather universal pathway, dependent on relative labor, land and transport costs, and the stringency of environmental and food safety regulations. In a very early stage of development, production and consumption are at the household level, in spatially widely dispersed units. As incomes rise and extra-household demand emerges, local subsistence production will start to get bartered and later exchanged on a monetary basis. Livestock production will move closer to markets and denser populated areas. There is little

[7] Ethiopia, India, Kenya and Pakistan

[8] Bangladesh, Cambodia, Ethiopia, India, Kenya, Tunisia and Vietnam

intermediation, as products are directly sold, or passed through a single middleman. As urban centers grow, small-scale rural and peri-urban/urban production systems for urban consumers emerge, and the chain gets more complex. Smallholder rural production systems still form the backbone of the livestock sector, in Africa for all LSF and for red meat and milk in Asia. For these systems, proximity to markets and consumers and access to inputs, in particular to maintain soil fertility, is important. Farms become mixed crop-livestock farms, using their crop-residues for livestock feed and the manure for maintaining soil fertility. As land prices increase and farms further intensify, for example through the establishment of cultivated forages and higher yielding crossbred cows, manure availability increases as well, but important trade-offs between nutrients for feed or food emerge (Giller et al, 2011). Quality of the crop-residues and manure management then become very important.

Figure 2: Schematic diagram of livestock systems dynamics and its drivers. Source: Author



13. As, in parallel with income, land and labor costs increase, systems intensify and larger industrial farms emerge, in particular in Asia, but also, to a more limited degree in sub-Saharan Africa. Initially, and still in most Asian and exclusively in African countries, these larger, more intensive production units are still located near the urban centers. For example, it is estimated that about 80 percent of the large intensive livestock Chinese operations are located around Beijing and Shanghai (Xiaoyan, 2005). Similarly, almost all Kenyan intensive pig farms are located around Nairobi (FAO, 2012). This large concentration, with generally weak enforcement of environmental regulations, is a major source of

water and air pollution, although their point-source pollution character makes it easier to regulate and control than non-point source smallholder induced pollution. The geographically close mix of small scale and large farms near densely populated areas is also a major source of emerging and "traditional" zoonotic diseases. A further trend might be the emergence of more intensive smallholder pigs and poultry production, with their low land-dependency, to areas with high land pressure. For example in the Netherlands in the early twentieth century, pig and poultry production developed in particular in areas with a small and shrinking farm size. During all stages of these developments, urban/peri-urban production systems continued to operate in the urban areas with a special role and dynamics (see below).

14. As a final transition, with further improvements in road and sea/river transport and stricter environmental regulations, intensive large livestock production systems tend to move to away from urban areas to the feed growing areas or feed importing locations. This has happened in Europe (Brittany in France, the Netherlands) and in the US (East Coast) and is now occurring in Brazil (the shift from Southern Brazil to Mato Grosso and Western Bahia, FAS 2012), and in China at the Eastern seaboard (although the latter remains thus also near the areas with a high population density) for pigs and poultry production. A similar trend occurred with the dairy industry in China, where intensive, larger dairy operations in China initially were established around the urban centers. However, with greatly improved transport infrastructure and the introduction of ultra-high-temperature (UHT) processing technology, increasing labor costs and tightening of the environmental regulations around the major cities, the production and processing moved to the northern grassland areas of Inner Mongolia and Heilongjiang. In Brazil and China dairy, this move towards the feed producing areas goes together with most of the processing industry.

15. From an environmental viewpoint such a geographical transition can have a positive impact, as it brings livestock waste production more in line with the absorptive capacity of the surrounding areas. Manure can then be transported to other farms, as for example happens in the Netherlands, where only half (53 percent) of the manure produced is applied on the farm where the manure was produced; the rest is transported to other farms or exported (Hoogeveen et al., 2008). Such a move to feed production areas away from urban centers also removes other environmental nuisances such as noise and odors away from urban dwellers. However, this geographical concentration in feed producing or easily accessible port facilities can also have negative impacts as in those areas livestock density get out of balance with the nutrient absorptive capacity of the surrounding areas. For example in Brazil, in 1992 five percent of the country hosted 78 percent of the chicken population, while in 2001 the same area contained 85 percent of the population (Gerber et al, 2007). A similar major risk is developing at the Chinese eastern seaboard, where intensive poultry farms are established near the soybean cake and maize importing ports. There is a wide array on technologies available, to both reduce the amount of waste produced (through increasing feed conversion efficiency), store manure and apply it to the land to minimize leakage to surface and ground water (World Bank 2005). The main issue is the identification of the appropriate incentives for adoption of these technologies.

16. From a public health viewpoint, such a broader spatial distribution would also beneficial, as it would reduce the inter-farm transmission. Another factor, which might affect the livestock geography is the zoning/compartmentalization (establishment of disease free zones) concept, recently introduced by

the World Animal Health Organization (OIE), where rather than on a country basis, the freedom from trans-boundary diseases such as Foot and Mouth Disease can certified for a more restricted area (or even one farm). The implication of zoning and compartmentalization on smallholders still an issue of debate.

17. Active government zoning policies to regulate livestock density is therefore required. For the environment, such policies can consist of maximum N-application or stocking rate limits (Nitrate Directive EU 1991 and Integrated Pollution Prevention and Control Directive EU 1996 with 2012 modifications). The Government of Thailand has sought to move the urban and peri-urban intensive poultry units away from Bangkok through tax incentives, which resulted in a rapid decrease in poultry density near Bangkok between 1992 and 2000 (Steinfeld et al 2006). Finally, in this context, the Government of Vietnam, based on both sanitary and environmental reasons, has introduced a spatial concentration policy for pigs and poultry operators through a strict zoning policy.

18. The influence of sourcing policies of supermarkets on the livestock geography is estimated as important, but not overriding, to the extent that developing countries supermarket sourcing policies are unlikely to replace domestic production in the developing countries in a major fashion. First, as shown in a number of consumer surveys, African and Asian consumers prefer fresh meat, as shown by the high share of meat still sold through the wet markets (e.g. Jabbar et al, 2010). Second, the total global trade in beef, pig meat and poultry at 25 million ton in 2011 (USDA 2012) is only about 10 percent of total production of these commodities. While it has grown somewhat faster than global consumption, the perishable characteristics of most LSF will probably cause local production to remain the main source. On the other hand, a number of recent food scares in East and South East Asia with locally produced LSF (residues, bacterial contamination) are increasing the demand for safer, i.e., supermarket procured food. *Researchable questions would cover (a) a more precise identification of the positive and negative incentives needed to get the available technologies adopted and livestock production and processing in balance with the absorptive capacity of the land area within the radius of economically feasible transport distance of its waste; and (b) identifying required incentives and the implications of the commodity and zoning approaches (OIE 2010).*

b) The special case of urban and peri-urban livestock

19. Urban and peri-urban livestock systems have a special role in poverty reduction and food security. Thys (2006), who carried out a major review on peri-urban and urban livestock, estimated that worldwide about 800 million urban residents practice peri-urban and urban agriculture. These urban and peri-urban farmers reportedly keep in majority livestock, and in particular dairy animals, because of the advantage of proximity to the buyer with such a perishable product. Indeed, there seems a trend that as urban land prices rise, urban and peri-urban farmers shift from crops to livestock, which is less land dependent and more flexible. There are a good number of urban center specific surveys, demonstrating its importance. For example, 79 percent of the dairy demand was met by urban dairy farms in Addis Ababa (Tegegne et al 2001) in the late nineties. Lee-Smith and Menon (1994) reported that 51 percent of the households in six major cities of Kenya kept livestock. In Dar-es-Salaam urban farming was the second largest employer and 75 percent of the urban farmers keep livestock there.

More than 20,000 households keep livestock in Bamako, and also in East Asia and urban centers such as Lima, livestock keeping is widespread. (Schiere and van der Hoek, 2001).

20. The future of these urban and peri-urban systems is not clear, as there are few historical data series available on livestock densities in urban areas. Surveys show that, because of health and pollution hazards and insect and odor nuisances, urban and peri-urban livestock systems are quite unpopular with urban policy makers and administrators. On the other hand urban livestock producers in Mexico City easily adapted their production system (housing, breeding, feeding practices) as urbanization progressed and land-prices rose, showing that also in a metropolis of a mid-income country, such as Mexico, urban livestock production still has a place (Losada et al, 1998). Thys (2006) therefore postulated that there are no indications that peri-urban and urban livestock farming is decreasing, and that it might be there for some time to stay. *Researchable questions would therefore include: (a) a better understanding of the future importance of peri-urban and urban livestock production; and (b) if these systems can be expected to remain an important component of the livelihoods of urban poor, research on waste management (biogas) and disease control (and in particular of the zoonotic diseases) technologies and appropriate regulatory and institutional frameworks are required.*

IV Changing farm/herd size and production systems dynamics

(a) Recent trends

21. Within the overall context of the ISPC foresight study on changing farm size, this paper will focus on changing herd/flock size and not on farm (land) size as the major change indicator. Major structural changes are currently taking place, in terms of scale, ownership and scope in particular in the mono-gastric sub-sector, and to a lesser degree in the ruminant sub-sector. These changes, in particular regarding scale increases, are probably much stronger than in the crop-sector

22. In the ***pig sub-sector***, tightening sanitation and environmental requirements and volatile prices in *East and Southeast Asia* have caused the backyard system to decline sharply over the last decade. For example, whilst the Chinese backyard system (less than 50 animal output per year) still provided 74 percent of the production in 2005, this has declined to 37 percent in 2012, and is expected to decline further to 27 percent in 2015 (Rabobank 2012). Similarly, farms with more than 30 sows now constitute 60 percent of the Chinese pig population (McOrist et al, 2011). The strongest growth is taking place in the intermediate systems with 50-3000 animals output per year, to such an extent that the production of these intermediate systems basically caters for the growth in demand by Chinese urban consumers. The same development is taken place in the rest of Southeastern Asia, where medium-sized operators produce already around 25 percent of the pigs[9] (Huynh et al 2006). Looking to the trends in the European Union (Eurostat 2012), where the fastest increase is in the large units (more than 200 sows or 4000 pigs per year) a further increase in size can be expected also in East and Southeast Asia. *In sub-Saharan Africa,* pig production is still mostly smallholder based. For example, an estimated 80 percent of the pigs in Uganda are kept by smallholders (ILRI, 2012) and in Kenya about 60 percent of the sector is

[9] Cambodia, Lao PDR, Philippines and Vietnam

smallholder based (FAO 2012). As in Asia, intensification and increasing in scale can also be expected in sub-Saharan Africa.

23. Developments in the *Asian* ***poultry*** **sub-sector** are similar to those in the pig sub-sector; the growth in farm/flock size might be even stronger in poultry. Worldwide about 69 percent of the poultry was raised in 2005 under intensive conditions (Robinson et al 2011). This is the result of a strong commercialization trend in important producing countries. For example, in Thailand over the period 1993 to 2003 the number of backyard poultries (1-20 birds) declined by 78 percent, smallholder operations (20-99 birds) by 33 percent, whereas small sized commercial operators (100-999 birds) increased by 20 percent, medium sized operation (1000-9999 birds) by 9 percent and large-scale operators (over 10,000 birds) by 72 percent (NaRanong 2007). Also in Vietnam, the small-scale commercial poultry sector is growing fast and provided in 2006 28 percent of the broiler meat, up from 20 percent in 2005 (Burgos et al, 2007). Finally, the number of poultry farms in China dropped from over 100 million in 1996 to 35 million in 2005 (Bingshen and Yijun 2007). The recent wave of HPAI will have further accelerated these trends. With the exception of South Africa, poultry production in *sub-Saharan Africa* is still largely a household activity. For example, in 2003 in Tanzania, 87 percent of the national flock was still kept in flocks of 1 –49 birds, with an average of 9.7 birds per household (Msami, 2007).

24. In the **ruminant sub-sector** the structural changes have been less pronounced, but are still significant. Until recently, ***dairy production*** has been almost exclusively smallholder/family farm activity in Asia and Africa, although *in Asia* important structural changes are taking place. In China in 2006, smallholder (1-20 cows) reportedly produced 52.5 percent of the total milk production down from 55 percent on 2002, whereas the number of farms with more than 1000 cows increased by about 50 percent (Hu D. 2009). Similarly, the share of dairy stock on farms between 1-20 cows decreased from 62 percent in 2003 to 57 percent in 2009 (Dobson et al, 2011). No statistics on the trends in herd size are available for the South Asian subcontinent, but herd size seems to grow in the high potential areas (in particular in irrigated areas, such as the Punjab, and for buffalos) and to decline, because of competition for grazing resources, in the poorer rain fed areas. *In sub-Saharan Africa*, in the arid and semi-arid pastoral systems, the average cattle and small ruminant herd/flock sizes are falling below the critical levels needed to sustain pastoral peoples. Besides, there is a strong concentration of livestock ownership in the hands of urban traders and civil servants, and herding is increasingly carried out by hired labor. In contrary to popular belief, these systems are already highly efficient, for example, the transhumant system in Mali produces twice to three times more protein/ha than ranches in the US or Australia under similar conditions (Breman and de Wit, 1983). Diversification, such as developing incentive frameworks for environmental conservation and carbon sequestration by pastoralists could be an interesting alternative livelihood approach. In the higher potential, densely population areas with a more moderate climate (i.e. the highlands) the average number of dairy animals per farm seems to be on the increase in Kenya and Tanzania, but declining in the rest of the region. In particular in Rwanda and Burundi, where land pressure is so strong that systems are “imploding” (de Haan et al 1997, Steinfeld et al, 2006) i.e. evolving in a vicious downward circle of declining livestock numbers, a shift towards smaller livestock (goats, pigs, hens), and hence declining soil fertility.

25. ***Beef production*** is *in sub-Saharan Africa and in most of East and Southeast Asia* still a by-product of the dairy industry or the end product of animal traction, although dairy-beef from young

bulls is still rare in China (Wang et al, 2008) and, of course for cultural reasons, also in India. Beef systems are emerging in China, and as in the other livestock sub-sectors there, are experiencing a strong growth in scale. For example, cattle from farms with more than 10 heads only accounted for 14 percent of the total inventory in 1996, but constituted more than 30 percent in 2004 (Wang et al 2008). Most cattle are also still fattened in small feedlots, although large operations, including international enterprises, are starting in China. Indonesia and Malaysia have established large commercial intensive feedlots, often depending on imported young feeder stock from Australia, although recently imports are being reduced, as the Indonesian Government seeks to promote their own cattle feeder sector. In sub-Saharan Africa beef feedlots have a checkered history, as consumers were not willing to pay the differential price for the higher quality beef, which is necessary for the financial viability of feedlot operations. This might be changing with the current emergence of a more discerning sub-Saharan consumer.

(b) Smallholder competitiveness

26. Some important differences between smallholders and larger farms are:

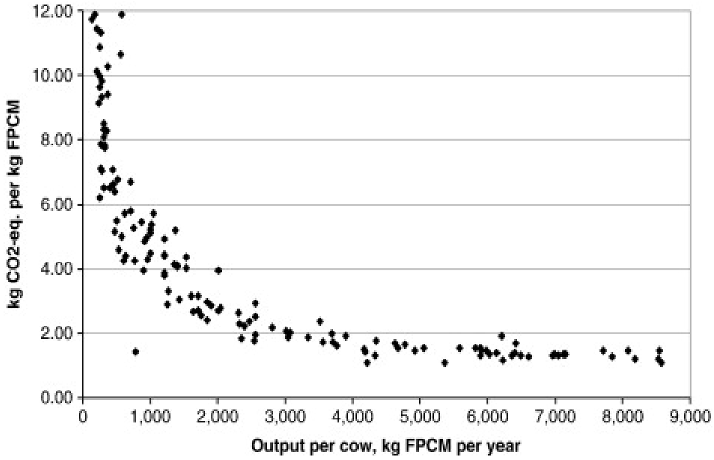
- *Lower cost efficiency in resource use and less economies of scale.* For example, Delgado et al (2008), based on household surveys in four rapid growing economies[10], found that larger farms were more cost efficient than smallholder livestock farming if the cost of family labor is included. Only if household labor was excluded smallholders produced at a lower price. Smallholders also expended a higher amount of investment per unit product in environmental abatement. Gale et al[11] (2012) found also lower cost of pig production of the commercial sector than in the backyard sector in China. The direct reasons are (a) the higher feed conversion ratio (more feed per kg product) and longer life-cycle of pigs and poultry under the traditional system, although normally the ingredients used by traditional farmers are less expensive (household scraps and crop-residues); and (b) the higher capital and labor costs per unit product. For example the obligatory installation of on-farm dairy cooling equipment in Brazil reduced the number of smallholders over the period 1997-1999 from 175,000 to 133,000, eliminating basically those with less than ten cows from the modern dairy market (Farina, 2002). Qualitatively, the larger, intensive production units produce LSFs more hygienically and, using improved breeds, of a better quality, can guarantee a more regular supply and, as shown already, have the flexibility to meet the growing urban demand.

- *Higher greenhouse gas emission per kg product.* The entire global livestock value chain emits about 18 percent of the total anthropogenic GHG emissions (Steinfeld et al, 2006), broken down by 9 percent of the global CO_2 emission, 35 percent of the global CH_4 emission and 65 percent of the global N_2O emission. Per kg product, specialized beef generates about 60 kg CO_2 equivalent (CO_2e), dairy beef about 18 kg, milk 2.7 kg and pig meat about 8 kg (Gerber et al 2011). The level of emission per unit of product is strongly related to the level of production, as shown in Figure 3 for dairy production.

[10] Pig production in the Philippines, Thailand Brazil, broiler production in Brazil, India, the Philippines and Thailand, layer production in Brazil, India and Thailand and dairy production in Brazil, India and Thailand.

[11] http://www.ers.usda.gov/media/262067/ldpm21101_1_.pdf

Figure 3 Relation between level of production (kg Fat Correct Milk, FCM per year) and CO2e emission per kg FCM



This implies that products from smallholder systems, with generally lower levels of production, have a larger carbon print than LSF from larger commercial production systems. It implies also that the GHG emission per unit product in the two focus regions of this paper (sub-Saharan Africa and Asia) is high. For example, Gerber et al (2011) calculated that per kg fat corrected milk (FCM), in sub-Saharan Africa 6.8 kg CO2e, in South Asia about 4.2 kg CO2e and in East Asia about 2 kg CO2e was generated, compared with a global average on 2.7 kg CO2e per kg FCM. This comparison doesn't take account of the multiple functions of livestock in those countries (de Boer 2012) and the large geographical variation (Udo, personal communication), but the main message remains that intensification of production will reduce the GHG emission per kg product. The main drivers are feed digestibility, growth and fertility rates, and land use changes, and in these areas research can make a difference.

• *Higher water and air pollution.* Livestock is already a major, if not one of the most important environmental polluters in East Asia. For example, all livestock, including poultry, would produce in 2010 about 95 percent of agricultural and 45 percent of total emissions as measured by the Chemical Oxygen Demand (COD). In addition, the livestock sector emitted 25 percent of national total ammonia or 79 percent of agricultural emission (People's Daily, 5 January 2013)[12]. The share of total discharges from smallholders is difficult to estimate, although environmental regulations for these operations, by their non-point source discharge, are difficult to enforce. There are a wide variety of technologies available covering zoning and location of farms, feeding restrictions, waste-storage and processing (biogas) and application (injecting manure, etc.), but they lack appropriate incentive frameworks for their application (World Bank 2005).

27. However, the differences are quite small, and Delgado et al (2008) foresees a continuing strong role for smallholder livestock farming, if supported by adequate institutional backup in the form of micro-credit and advisory services and under conditions of limited alternative employment opportunities. In any case, all sub-sector smallholder systems will most likely supply the lower end of

[12] http://english.peopledaily.com.cn/90778/8078762.html

domestic markets, as meeting export and top-end domestic safety standards is often not economical for them (Mc Dermott. et al (2010). *For these reasons, a broadening of the CGIAR current almost inclusive focus on smallholders to a more diverse set of scales and intensities, including those of large operators is recommended.* This might be more relevant in the livestock sector, as increases in scope and scale are probably occurring faster than in the crop-sector. It will require also a focus for the public R&D sector on a different set of issues, as private/public responsibilities change, and the attention will have to shift to the mitigation of negative externalities of large operations in health and the environment.

c) Pathways for smallholder livestock farming

28. Future development paths from subsistence to commercial farmer depend to a large extent on the economic situation (employment outside the sector, resource endowment, etc.) in the target area. In line with Hazell's background paper for this foresight study, the development stages for the livestock sector are:

- **Transition from subsistence to market,** normally with increase in the number of animals, but without major genetic or feed improvement, and with limited intermediation in the market;
- **Fully commercial smallholder livestock farming** with increased factor productivity, in particular through genetic improvement and increase of feed production, and already a more complex intermediation, eventually through collective action or vertical integration;
- **Diversification of smallholder systems** producing (a) niche products (organic, traditional local, etc.) and/or expanding to other livestock species, normally without major intensification and with a rather short value chain; and
- **Scaling up to large commercial enterprises,** either as vertically integrated systems or as independent operations.

Key researchable questions concern (a) decision tools and key indicators to inform policy makers on desirable pathway(s); (b) desirable farm manager profiles for the different stages, realizing that different management skills are required for these different livestock enterprise development stages.

d) Future production system dynamics.

29. The picture that emerges from this review shows in both regions important smallholder based production systems, but for Asia rapidly emerging small to medium sized commercial systems. For the ruminant sector, smallholder dairy production is still the mainstay of milk production in both regions, and can be expected to stay that way for some time to come, but increase in herd size is also occurring. These trends are most likely to continue. In particular in the mono-gastric sector, economies of scale will continue to lead to increased herd/flock sizes. Specific drivers will be:

- *Future feed prices*. As described in paragraph 4, feed grain demand will rise rapidly, and most likely cause also higher feed prices. Under a baseline scenario, IFPRI's COMPACT predicts till 2030 an increase of about 33 percent in the price of all coarse grains (Msangi and Rosengrant, 2011). Such a price increase would also be reflected in the price of meat, and could have the following consequences:

- A drop in meat consumption, as already predicted in several projections, such as by Alexandros and Bruinsma (2012);
- Greater attention to technologies that optimize feed use, in terms of feeding systems, feed composition etc., which will favor larger farms;
- A shift towards LSF from species with a low feed conversion, such as aquaculture and poultry products;
- A shift back from feed lots to grass-fed beef and mutton, which would also meet consumer demand for leaner meat; and
- Intensification on smallholder (and also larger farms) in pasture management (fertilizer levels, grazing intensity).

e) Research requirements

30. Pathways from traditional smallholder systems to more diversified or more intensive and larger commercial operated systems require technology packages of improved disease and hygiene management (food safety) and better genetics and nutrition. In addition, it requires a policy framework that supports smallholder development. The priority research requirements in these areas include crosscutting issues, and more farm/herd size specific ones.

The **main crosscutting** issues are:

- **Improving the quantity and nutritive value of livestock feeds.** With the expected rise in feed grain demand and prices improving the Feed Conversion Ratio (FCR) and other digestibility factors will be critical for the future sustainability of the sector. The major approaches to lower the amount of feed per unit product, and at the same time reduce the amount of waste and greenhouse gasses emitted, are listed below.
  - *Plant breeding:* Current plant breeding objectives focus mostly on human food needs. More attention to reducing the high lignin content of coarse grains, correcting the unbalanced amino-acid composition (lysine, tryptophan and methionine) and in the urban areas with a high non-ruminant (pigs and poultry) density, increasing the low phosphate digestibility (low phytate) are major factors affecting feed conversion and production of waste. *More attention of plant breeders to enhancing the nutritive value of coarse grain, and the residues of all cereals is therefore recommended;*
  - *Animal breeding:* Major progress has been made in the past on pigs and poultry, for example in the OECD countries for pigs from an average of 3.3 in 1975 to 2.7 in 2010 (Knap and Wang, 2012). Genetic marker based selection for feed efficiency (and hence methane emission) has shown to have interesting potential to accelerate genetic progress in enhancing efficiency of resource use and reducing methane emission (de Haas et al 2011). *More research, using new genetic tools to lower feed conversion is therefore recommended;*

- *Animal physiology:* Manipulating the rumen flora and fauna or identifying feed additives (lipids, identification of anti-methanogenic plants) to increase the digestibility of crude fiber and reduce methane emission would be of particular importance for the tropical ruminant livestock systems, as tropical fodders have very high crude fiber/ lignin content. *Research on new means of enhancing rumen digestion of fodders with high levels of crude fiber, although a high risk, but also high reward area, is therefore recommended*; and
- *Animal feeds*: Better storage techniques/usage of conventional feed stuffs, such as ILRI successfully developed and applied with sweet potato in Southern China (Lapar et al 2011). *Research to reduce waste in feed resources could have fast and important pay-offs and is recommended.*

The Global Research Alliance[13], a voluntary network of 30 member countries has several programs focusing on greenhouse gas emission through animal breeding and animal physiology, and the Global Agenda for Sustainable Livestock Development[14], managed by FAO, under their program on the efficiency gap would be natural partners for collaboration in this topic.

- **Enhancing inter-institutional and public-private cooperation and collective action and removing barriers to transition.** There are several institutional aspects, which will affect the success of the different transition stages. They are:
  - **Underpinning the benefits of Inter-institutional cooperation in disease control**, and in particular in the area zoonotic diseases. Pigs and poultry often act as an intermediate host for influenza type viruses, as shown by the recent potential pandemics of HPAI and H1N1. By their nature, for these zoonotic diseases the interaction of biologists, veterinarians and physicians is of major importance. The “One Health” approach, which seeks to formalize such interaction (World Bank 2010 and 2012), has some traction in the scientific community. *More convincing evidence about the effectiveness and efficiency of this approach needs to be collected, to inform policy makers on further implementation*
  - **Clarifying the distribution of responsibilities between public and private agents.** Unclear public and private roles in the provision of services, for example of animal breeding, veterinary health and advisory services (World Bank 2009), has led sometimes to the crowding out of private suppliers, and inadequate services at the farm/herd level. *Identifying good practice would help to inform policy makers on the most appropriate strategies;*
  - **Understanding the factors of success and failure in livestock related institutions for collective action.** Collective action is particular important for livestock products because of the perishable nature of LSF, and cooperatives are of major significance in the OECD countries, with good institutional performance. However, they have had limited impact in India (Staal et al, 2006) and a generally poor performance in sub-Saharan Africa. Similarly,

[13] http://www.globalresearchalliance.org

[14] http://www.fao.org/ag/againfo/programmes/en/global_agenda.html

vertical integration has increased the cost efficiency of smallholders in Asia, as they generally received a higher price than independent smallholders (Catelo and Costales, 2008). However, the integrators often discriminate against the smallest producers, and contracts are often not adequately enforced. *Research to identify good practice in these areas would facilitate the transitions.*

31. *The main herd/farm size specific research topics are provided and briefly described below.*

Farm/herd typology	*Approximate characteristics*	*Disease*	*Genetics*	*Feeds*	*NRM/ soil*	*Food safety*	*Institutions /policy*
Subsistence	*1-5 cattle (more in pastoral system), 1-5 pigs, 1-20 birds*	*African Swine Fever (ASF) New Castle disease (NCD), Highly Pathogenic Avian Influenza (HPAI)*	*None*	*Low quality crop residues*	*Overgrazing communal areas, competition with wild-life*	*None*	*Access to water and dry-season grazing (pastoral)*
Transition	*5-10 cattle (draft oxen), 5 - 20 pigs, and 20-100 birds*	*ASF, NCD, HPAI, cysticercosis*	*Poor access to superior genetics*	*Feed quality*	*Poor manure management, lack of efficient crop-livestock integration*	*Lack of inter-mediate technology*	*Access to micro-credit, Level playing field, tenure security*
Diversification	*5-15 cattle (draft oxen), 5 - 50 pigs, and 20-200 birds*	*ASF, NCD, HPAI, cysticercosis*	*Erosion domestic animal genetics*	*Appropriate feeds*		*Lack of inter-mediate technology*	*Access to micro-credit, certification tenure security*
Fully commercial smallholder	*10-100 dairy cattle, 10-200 beef cattle, 100-2000 birds, 50-200 pigs/year*	*ASF, NCD East Coast Fever (SSA) and Hemorrhagic Septicemia (SA)*	*Poorly functioning delivery systems for AI;*	*Feed availability and quality*	*Poor manure management, pollution*	*Lack of inter-mediate technology and cost of compliance on standards Applicability of commodity approach.*	*Access to veterinary services Level playing field, functioning institutions of collective action.*
Large commercial farm	*> 100 dairy cattle, >200 beef cattle, > 50 sows and > 2000 birds*	*Diseases of trade (FMD, including ASF)*	*None, easily available, tech*	*Feed availability and quality*	*Pollution*	*Applicability of zoning or compartmentalization*	

Source: Authors views

(f) Detailed descriptions

32. **Diseases:** *African Swine Fever* (ASF) is a highly contagious virus disease in pigs without proper prevention or control technologies, except normal bio-security measures. This disease is now spreading through Central Asia, and might develop into a global disease risk. Immunological approaches need to be investigated, in cooperation with private vaccine research organizations. *Cysticercosis* is a zoonotic disease (i.e. transmittable between animals and humans), in particular important in SSA, and work on the epidemiology of this disease under a "One Health" framework would be required. *Highly Pathogenic Avian Influenza* (HPAI) in poultry has major production and human health risks and trade implications in particular in Southeast Asia. The overall approach to the control/eradicate this disease is well known; the main issues are organizational and financial (Swayne 2012). *New Castle Disease (NCD*) as probably economically the most serious disease challenge in Asia and sub-Saharan Africa, where the main issue is delivery and application of vaccines at smallholder level; and *Foot and Mouth Disease (FMD) and Hemorrhagic Septicemia (HS) in Asian and Contagious Bovine Pleuro-pneumonia (CBPP) in sub-Saharan cattle* have proven control technologies. For intensifying African smallholders control of vector-borne diseases, such as *East Coast Fever* is critical. Further research on ECF is needed to improve the thermo-stability and reduce its unit costs. Regarding Trypanosomiasis, newer molecular biology tools might improve the prospects of a break through, and open-up large areas of SSA's sub-humid zones

33. **Genetics:** *Artificial Insemination delivery systems*, providing the appropriate genotypes needed to enable smallholders to compete with commercial operators in productivity, quality (meat leanness) and feed conversion ratio (FCR). For dairy smallholders, a regular and reliable supply of Liquid Nitrogen remains a major constraint. Room temperature semen as practiced extensively in New Zealand, could be an interesting option. To capture the meat now lost because of the young age male dairy calves being slaughtered in Asia, more research on reproductive approaches to increase the female/male rate of calves born. *Domestic Animal Diversity*, as smallholders change to exotic breeds to be able to compete with larger operations. However, maintaining farm animal bio-diversity is essential for future selection purposes and the smallholder option of diversification.

34. **NRM**: In the *pastoral communal areas*, the focus will have to be on access rights to water and dry-season grazing areas to enable pastoralists to maintain the migratory mode, which is the most appropriate system for the highly variable (inter-annual and spatial) rainfall of these areas. The development of Payment for Environmental Services schemes, which would incentivize pastoralist to conserve the arid flora and fauna, enhance carbon sequestration, although difficult, would be an important long-term solution. In *crop-livestock integration*, the emphasis needs to be on land tenure security, to ensure that investment in soil fertility improvement are captured by the farmer involved, in plant breeding for better quality crop-residues (leaves and stems). To *mitigate pollution* from smallholder farms, intermediate technology for waste management needs to be further developed. For the large farms, the technology to mitigate is widely available, but more emphasis on the political economy of enforcement is needed.

35 **Food safety and quality standards:** A major issue on the institutional side is the appropriateness of the OIE Terrestrial Animal Health Code and Codex Alimentarius *standards* for transition and smallholder farmers, as traditional cooking practices of LSF often reduces the microbial risk from these

products. A better understanding of the social, public health and economic cost of compliance of the different alternatives i.e., application of OIE and Codex standards, zoning/ compartmentalization (disease free zones) and the commodity approach (shifting from area related health risks to product related health risks i.e., FMD free de-boned beef) would be useful for policy makers. The identification of "food safety pathways" for local LSF consumed products, that sets standards that give due account of local food preparation practices, are cost efficient, and would gradually lead to the international standards would be the outcome. For the transition and commercial smallholder farmers more work on intermediate technology is needed.

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