

# **Livestock and Food Security**

## **The Relevance of Animal Science to the Hungry Poor**

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### **Abstract**

*Livestock play a major role in basic food-security, which in turn is the first principle of national security and international security. Food-insecure populations emigrate and undermine precarious States. Even at the level of more luxurious food-security expressed in UN ideals, livestock products are critical. Outside single product industrial farms, livestock provide multiple outputs, including: high-quality protein; income; draught and traction power; nutrient recycling; various edible and non-edible by-products, and they reproduce themselves. Children and reproductive-age women, whose diets are deficient in amino acids not readily accessible from plant foods or in micronutrients, benefit significantly from even small amounts of animal protein, which globally makes up perhaps 28 percent of protein intake. In Asia, livestock production has increased markedly in recent decades, particularly from intensive systems in China as part of its planned food-security – an approach that provides lessons for smaller food-insecure countries. Future animal scientists and development planners will learn to balance such innovations with those of the West and move beyond routine European breeds and production systems to consider the livestock 3Rs – ruminants, rabbits and rodents that thrive on waste products and lands not suited to other forms of food production. They will make such contributions to food security as: animal production within city limits; periurban farms; industrial and home-based aquaculture; home-based rodent/rabbit hutches; contract-growers supplying cities; insect-protein units; huge capital-intensive operations with integrated market chains; non-agricultural foods, and more. For now, extensive ruminant grazing systems and small mixed farms seem likely to remain the most efficient production systems, although the majority of animal products that can be delivered to cities, where most of the world will live, will probably be from specialized intensive production, particularly of poultry and pigs. As animal scientists we do well to reflect on our ethical and technical roles, especially with respect to food security.*

### **Introduction**

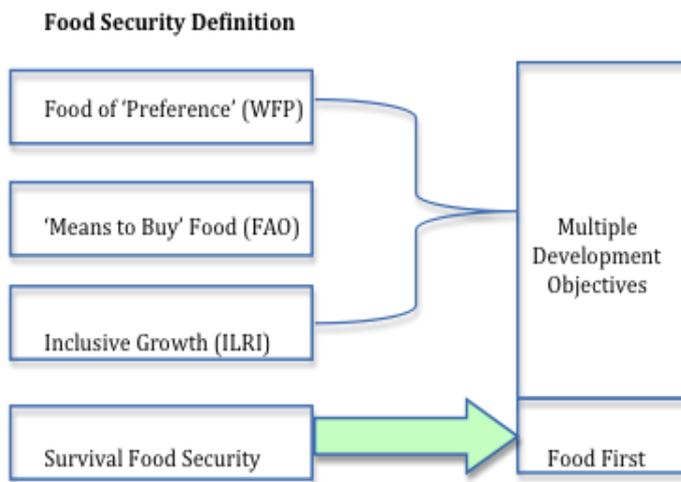
Food security is probably the major global issue. Where food is scarce, governance is weak at best and all security is compromised. This has been the case since Empires and States began, and may be traced back into prehistory as the basis of a tribe's or nation's security. Today, we think we are more sophisticated than that. But we are not – and with a burgeoning population, instant international communication and means of fleeing from disastrous events more available than ever before, food security is not only the first principle of national security, but also of international security. Emigration can undo the best intentions of precarious States and massive immigration can undermine the lifestyles of protected economies that are in decline. It is thus a

primary responsibility of government and international development to ensure that conflicts and disasters do not threaten access to the most basic forms of food that a population needs to survive until circumstances improve. Livestock form a key part of such food and national security.

It has become fashionable to refer to the ability of a food system to maintain security as 'resilience', which so far as it extends to livestock requires acknowledgement of different types of production systems for different consumers. Such resilience refers, in this paper, to ensuring the food needed to survive through natural disasters, epidemics and conflicts. It does not refer to luxury foods such as juicy T-Bone steaks with pepper sauce, or even hamburgers.

So we are not discussing the food security of the 1996 World Food Summit, which stated that *'food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary*

**Livestock Contribute Through all Definitions of Food Security**



*needs and food preferences for an active and healthy life.'* We are being much more realistic – we are discussing food for survival. When food is really scarce food preferences mean little, and the world has recently increased that risk where international agencies' promotion of free trade in food has directed poor country policies away from

survival food security planning.<sup>i</sup> And we are also concerned with something more real than food security in the sense propounded by FAO, which claims that *'one of the hardest challenges for food security is ensuring that all who need food have the means to buy it'*;<sup>ii</sup> that is part of food security, but another critical part is the two billion small farmers who feed themselves and their families and are not in the 'buying' economy. In addition, we do well to conceive food security as a psychological state of safety as much as a physical state of eating, and thereby to take the viewpoint of those who are in need of food, not some national average or international benchmark.<sup>iii</sup> These are all aspects of real food security.

Livestock form a critical part of such real food security. They provide multiple outputs, including: high-quality protein; income; draught and traction power; nutrient recycling; various edible and non-edible by-products, and can reproduce themselves. Particularly critical are the livestock 3Rs – ruminants, rabbits and rodents, which thrive on waste products and lands not suited to other forms of food production. Of course, poultry in its varied forms also has a role, particularly in converting waste products into edible protein. However,

livestock are not as important in overall food security as cereals, which are the major human foodstuff. Nevertheless, livestock has been neglected in discussions, perhaps because their products are seen as luxury foods. Thus as FAO has noted *'although much has been said about livestock's role in achieving food security, in reality, the subject has been only partially addressed and no current document fully covers the topic'* – their 2011 report *'is an attempt to fill the gap'*.<sup>iv</sup>

It appears that the gap may also be being addressed by the principal livestock research centre oriented to development, the International Livestock Research Institute (ILRI). Previously focused on poverty as a function of its donors' worldviews, it seems poised to add food security in combination with such objectives of poverty alleviation, environmental care and health issues.<sup>v</sup> In making this change, ILRI is consulting people such as animal scientists about which of three livestock sector scenarios, derived in conjunction with the World Bank,<sup>vi</sup> might be of greatest developmental value. The three scenarios are: 1) Systems that support inclusive growth, agricultural transition, well-being of people now and in the future, supply gap reduction, and environmental and human health challenges. 2) Low growth systems in which livestock may benefit from targeted research not conducted by others. 3) Growth where livestock's negative effects on environmental services or human health might be mollified. While it is encouraging to see food security mentioned, it is unlikely to be the primary focus given the economic paradigm of free trade that forms the worldview of most of ILRI's donors. Perhaps there is another way to see livestock.

### **Seeing Livestock Correctly**

It is reasonable to ask why livestock has been largely omitted from the most important subject in international development. One response is that a Western bias in development approaches has caused livestock to be viewed from that perspective rather than as integral to the farming systems of smallholders in poor countries. A further expression of this may well be an assumption that herder-lifestyles and small mixed farmers are inferior and will inevitably disappear and therefore should be encouraged in their demise. Such biases, if they exist, would be a disservice to science as much as they would be to development.

In an external review of ILRI that I was privileged to lead, we prefaced our report by noting that while *'global figures indicate that livestock are important in providing some 20 percent of food energy and 30 percent of protein ... these figures mask their relatively higher value to the poor, in terms of geographical distribution, the excess consumption of animal products in some diets and nutrient deficiencies in others, as well as cultural dietary differences'*.<sup>vii</sup> Livestock associated with the poor are not usually those that are criticized among new global concerns; they do not consume much grain, are not the major source of risk of animal-to-human disease transmission, environmental damage or even the largest greenhouse gas emissions. These common criticisms of animal

production are less relevant to the low-intensity systems of the poor than to the industrial systems created to feed cities. And in fact, nomadic or mixed small farming systems are highly evolved efficient systems within the worldview of the nomads and farmers as distinct from narrow Western conceptions. Similarly, fixed conceptions of animal production commonly overlook the role of rabbits, rodents, poultry, native pigs, native goats, native sheep, native cattle, buffalo, yak, camels, horses and other animals providing meat, milk, blood and other food products in areas remote from affluent markets.

If we separate animal production into; rangeland, integrated farming, intensive production and landless systems, we find that each contributes to food security across Asia. From the extensive pastoral systems of Mongolia and Tibetan China, to the mixed crop-and-livestock systems that involve billions across most poor countries, to the intensive production systems that provide low value byproducts to the urban poor especially in China, to the landless dairy herders and milkers of India that ensure their neighbours have regular animal protein in their diets, each system contributes to the food security of the vulnerable poor though not necessarily in market forms recognizable to the global middle classes.

The animal raisers that service such ‘markets’ differ from those in commercially-linked systems. They view dung not only as manure, but also as a construction material and a cooking fuel, and animal power as not only for ploughing but also for traction, packing and working mills while providing a regular small income and nutritional contributions from milk, eggs, hair and blood. They prefer small breeds over large ones to mitigate the risk of losing an animal and may view a product such as meat as an end-of-working-life by-product; they see milk as more than a liquid drink, butter or cheese and more as a storable and transportable product. And they know that the financial value of an animal set by an urban market can as a consequence grossly undervalue its economic value.

**Why Livestock Owners Persist with Low Financial Returns**  
(value exceeds financial (monetized) return)

Sources of Financial Returns	Value of Livestock to Owners
Sales of meat	Sales of meat
Sales of milk	Sales of milk
Sales of hides	Sales of hides
Sale of wool/hair	Sale of wool/hair
Sales of byproducts	Sales of byproducts
	Traction/transport
	Draught power
	Dung: fuel/manure
	Savings
	Risk mitigation
	Status
	Religion/Tradition

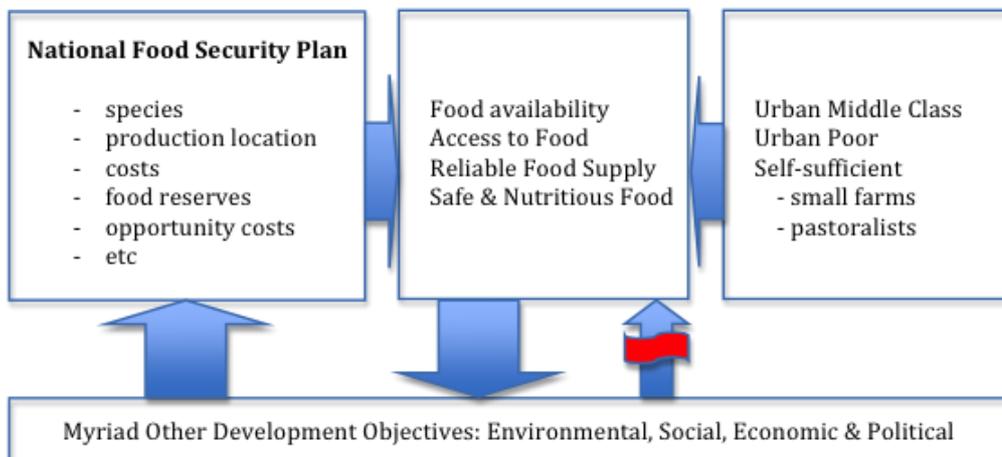
So rather than assume that nomadic and pastoral systems will tend toward sedentary mixed crop-livestock systems or that all systems will move towards commercial agriculture, it is more realistic to address the needs and contributions of each animal production system. We have seen the negative environmental effects of such thinking, for example after 70 years of enforced settlement of Mongolian pastoralists under Russia’s governance.<sup>viii</sup> And rather than assume commercial production is the end game, we may do well to see that small subsistence farmers and their animals are providing a great service by

feeding up to two billion small farming families around the world. If those families were to migrate to cities, the consequent increase in food demand would not be met from current levels of production of broadacre agriculture even if it used all the land once tilled by small farmers.

### Who is Food Insecure?

FAO has collated the various UN approaches to food security into the four aspects of: food availability; access to food (during conflicts and crises also); reliability of supply, and sound food safety and nutrition.<sup>ix</sup> A food system that meets all four aspects simultaneously is considered to be '*sustainable and resilient*'.<sup>x</sup> It is an ideal, for it seeks production of adequate food, its transportation with minimum waste and sale at affordable prices, and then adds other ideals such as monetized environmental and public nutritional education costs. It assumes free movement of food across the world and that it is possible to plan systems that are resilient to wars, economic crashes, disease and natural disasters. Despite its impracticality, we can use the approach to define in gross terms who is food insecure. And like most ideals, it is a worthy goal to strive towards – but to believe that such a golden age will be reached is unrealistic.

#### National Food Security Planning for Sustainability and Resilience in a Food Insecure Nation



And since it is unrealistic, we cannot be ethically responsible and at the same time impose idealistic approaches on food-vulnerable persons unless we guarantee to improve their food security. It remains more responsible to approach food security on a local rather than a global basis, which when matched with the need for legislative and sometimes military power, usually means at a national level. Hence this advocacy for realistic national food security planning based on the needs of each country.<sup>xi</sup> However, since most international work uses averages, it is easier to start the discussion with a simple overview of some average protein intakes and energy deficiencies, as presented in Table 1.

Some take heart that figures quoted for undernourishment indicate an absolute decrease of about five percent in the actual numbers of persons, which with rising world population represents a decrease in the percentage of undernourishment in the world from the 1980 figure of 28 percent to 13 percent

in 2007 (16 percent for developing countries).<sup>xii</sup> Such arithmetic is based on food calorific intake, which omits consideration of nutritional quality – defined as malnourishment. Malnourishment includes diets deficient in minerals and vitamins, or otherwise grossly imbalanced, and extends to some two billion persons, most of whom as a consequence are exposed to increased health risks. This leads to such estimates as 146 million children being underweight, of which 31 percent are stunted.<sup>xiii</sup> It is in these areas that animal products make a specific contribution.

**Table 1. Dietary Protein and Energy, and Undernourishment per Region<sup>xiv</sup>**

<b>Region</b>	<b>Protein</b> gday <sup>-1</sup> 2003-05	<b>Energy</b> kcalday <sup>-1</sup> 2005-07	<b>Insufficient Calories</b> (%) 2005-07
World	76	2,780	13
Developed countries	102	3,420	<5
Developing countries	70	2,630	16
Asia (incl. Oceania)	70	2,610	16

### **Animal Products in Food Security**

Average world consumption of food products derived from livestock totals about 13 percent in calorific terms and 28 percent in terms of protein in meat, milk, eggs and offal. Table 2 presents the change in average output of selected global animal products per person over 40 years. Increased availability on a global basis does not mean that the diet of marginalized persons has improved. Where they can access these products, nutrients deficient in many diets may be reduced, particularly protein (including amino acids not readily accessible from plant foods) and micronutrients (such as iron, zinc, vitamin A, vitamin B12 and calcium) in diets of children and reproducing women. While there are no nutritional scales that recommend the amounts of livestock products for different categories of persons, it is suggested that gross protein consumption levels exceed the minimums except in sub-Saharan Africa.

**Table 2. Increases in Average Global Animal Product Output per Person<sup>xv</sup>**

<b>Product</b>	<b>1967 (kg)</b>	<b>2007 (kg)</b>	<b>Increase (%)</b>
Milk	110	102	-8
Beef (incl. buffalo)	11	10	-7
Pork	10	15	52
Eggs	5	10	83
Poultry	4	13	269
Sheep/goat meat	2	2	5

We all know that a healthy diet need not rely on animal products. In rich economies this leads some advocates to erroneously suggest that animals should not be considered in development planning. However, in poor countries with significant parts of the population existing on marginal diets, means of augmenting amino acid and micronutrient deficiencies may be accomplished most easily through the incorporation of animal products. Benefits accrue from small amounts of animal products, for example from meat that provides zinc and

iron as well as increasing absorption of iron from plants,<sup>xvi</sup> and both meat and milk that provide vitamin B12, riboflavin and vitamin A, and milk that provides calcium. With iron deficiency affecting some 1.6 billion people,<sup>xvii</sup> impairing mental development of 40–60 percent of children in developing countries and implicated in 20 percent of maternal deaths each year,<sup>xviii</sup> ensuring reliable access to small amounts of animal products remains key to food security. And with meat consumption projected to rise more in developing than developed countries (Table 3) it is impossible to ignore the potential role of animal food products in the diets of even the urban poor.

**Table 3. Projected Rise in Meat and Dairy Product Consumption<sup>xix</sup>**

Product	World Consumption (t x10 <sup>6</sup> )			Developing Countries (t x10 <sup>6</sup> )		
	2010	2050	% Rise	2010	2050	% Rise
All meat	269	464	173	158	330	209
Dairy (not butter)	657	1,038	158	296	641	216

Average national food consumption figures suggest an increase in animal food products in diets with rises in income.<sup>xx</sup> However, national figures hide within-country variations, and simple correlations of income and animal product consumption can miss cultural taboos such as pig meat consumption in Muslim communities or social changes such as in Thailand where a traditionally non-milk drinking society changed to one with school milk representing 25 percent of national milk consumption compared to between one and nine percent elsewhere in the country.<sup>xxi</sup>

Supplying some 13 percent of global calorific intake and perhaps 28 percent of protein, livestock products are a significant and routine component of human diets. Misconceptions of vegetarianism in India, for example, commonly omit the country's role as the world's leading dairy product producer and consumer;<sup>xxii</sup> likewise Western fads of vegetarianism show little impact on the quantum of what may be termed localized overconsumption of some livestock products. Table 4 presents the rankings of consumption levels among major food stuffs of some animal products for developing and low-income developing countries compared to world averages, and indicates the continuing importance of animal food products.

**Table 4. Calorie Consumption Ranking of Animal Products<sup>xxiii</sup>**

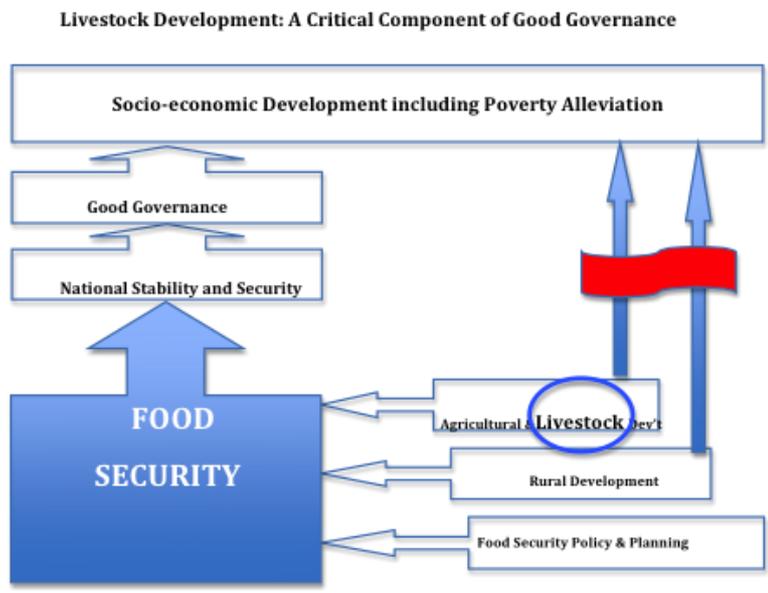
Commodity	World	Developing Countries	Low-Income Developing
Milk	6	7	9
Pork	7	6	13
Beef	14	16	17
Poultry	12	17	19
Eggs	17	18	22
Lamb	23	23	20

## Animal Production in Food-insecure World

Livestock production has increased markedly in East and Southeast Asia in recent decades while sub-Saharan Africa production has lagged. Intensive production systems are responsible for most of the increase. China produces about 70 million tons of eggs and 15 million of poultry meat compared to India's 3 million and 0.6 million. Nevertheless, poultry production in India is rising fast and consumption rose from around 22 percent in 1985 to some 50 percent of livestock protein consumed per person in 2003.<sup>xxiv</sup> As in Thailand, Vietnam increased dairy product consumption by 300 percent between 1996 and 2002.<sup>xxv</sup> The traditional dairy country of India has increased consumption from 178 grams per day in 1992 to 258 in 2009.<sup>xxvi</sup> While such trends are less evident in poorer Asian countries like Bangladesh,<sup>xxvii</sup> the increased production and consumption of animal products in Asia is a significant development phenomenon.

Some Asian nations are major exporters – Thailand is a case in point as one of the world's major agricultural exporters and home to one of the world's multinational agribusiness groups, CP. And other nations also export animal products, including milk products from Malaysia. But this does not add much to basic survival food security for such product mainly serves wealthy markets. The response is not to seek a means of directing exported product to the hungry poor but to see the international food trade as business – and national food security in food-insecure countries as good governance.

Good governance for food security requires a special national plan in poor food-insecure nations, unlike Western and other food-sufficient countries. However,



policies for animal production in food-insecure countries are often similar to those in food exporting nations, which can increase the risk of food shortages and malnutrition. For example, Western approaches to monogastric and feedlot ruminant diets compete with humans for grain. While it is logical that ruminants

should be raised on extensive non-arable lands utilizing plants inedible to humans, dietary preferences override logic in market-driven production systems. Even when one country is in food deficit, another country's decision to continue feeding grain to livestock is usually based on price signals. Such reliance on market signals to provide needed food seems to work under

conditions of surplus and when the hungry in the deficit country have purchasing power – but not if either one of these factors fails. In any case, totally grazing-based ruminant production accounts for only about 12 and nine percent of world milk and meat respectively. More important is the system of mixed grazing and crop residues occasionally supplemented with concentrates, which produces some 88 percent of world milk (but only six percent of meat).<sup>xxviii</sup>

*In a food-insecure country, animals increase food security by:*

- 1. consuming products unsuited to humans*
- 2. occupying lands unsuited to agriculture*
- 3. providing manure for crop nutrient recycling*
- 4. providing draught or traction for agriculture and other purposes*
- 5. remediating key nutrient deficiencies – usually amino-acid-related*
- 6. acting as self-reproducing food (protein) bank, used timely<sup>xxix</sup>*
- 7. being a food producing asset for landless farmers<sup>xxx</sup>*
- 8. preserving meat and dairy products – for food insecure times.*

Practicing animal scientists know the contributions of animals to food security, such as highlighted in the Box above. These contributions are reduced by situations where animal production may reduce food security by diverting feed from humans. An attempt to quantify this by FAO<sup>xxxi</sup> based on trade, animal feed and crop statistics standardized by protein content indicated ‘a tendency for countries with intensive livestock systems to consume more human-edible protein than they provide compared to countries with extensive ruminant systems that augment overall supply of protein’. In confirming accepted viewpoints, such international agency work can lead to nebulous recommendations such as reductions of intensive animal production and expansion of mixed systems of ruminant grazing or animal consumption of biological waste products. But this is unlikely to occur since demand for grain-fed livestock – both monogastrics and ruminants – is correlated with rising affluence. A more practical recommendation in such situations is to address the options available for the nutritionally marginalized proportion of the population. Such alternative animal production thinking leads to a wider spectrum of species and production efficiencies being considered, such as rabbits in China and paddy rats in Thailand.

## **Animal Production Systems**

A conventional breakdown of animal production systems is presented in Table 5, which is anomalous in terms of poor country landless animal producers and feedlot-based milk and sheep meat. Useful for most purposes, such presentations do not provide direct information about food security. In this respect it becomes clear that food production has been a focus rather than food security, two consequences of which have been a reliance on average food availability figures that misses food insecure hotspots, and inadvertent support for free trade in food including essential food for survival. The latter assumption of free trade

arguments for essential foods has been shown to be false in the 2007 closure of exports of rice when wheat crops failed and national food shortages loomed.<sup>xxxii</sup> It is thus more useful to break animal production into the social segments that rely on a specific production system for their nutrition, survival and livelihood.

**Table 5. World Animal Production (mill. t.) by Production System, 2001-03**

	<b>Grazing</b>	<b>Mixed Rainfed</b>	<b>Mixed Irrigated</b>	<b>Industrial</b>	<b>Total</b>
Milk	72	319	203	?	594
Pork	1	13	29	52	95
Poultry	1	8	12	53	74
Beef	15	29	13	4	61
Eggs	1	6	17	36	59
Sheep meat	4	4	4	?	59

One useful categorization of animal food products in relation to food security is that used by the recent FAO discussion,<sup>xxxiii</sup> namely:

1. Livestock-dependent societies
2. Small mixed farmers
3. Urban populations

**1. Livestock-dependent societies:** Comprising some 120 million people who raise mainly ruminants on uncultivated and usually non-arable areas, such societies may derive 90 percent of total farm production from livestock.<sup>xxxiv</sup> Including both pastoralists and ranchers, these systems are said to produce about 19 percent of world meat production and about 12 percent of milk. On the margins of Asia, such systems in Australia make it the world's second largest sheep meat producer and largest exporter (some 45 percent of production).<sup>xxxv</sup> Likewise in Mongolia, extensive livestock production contributes some 30 percent of GDP and 20 percent of export earnings. Extensive livestock production and nomadic systems are often mistakenly viewed as primitive or simple – derogatory views of Mongol herder invaders and misreadings of Cain and Able myths seem to fuel the bias toward sedentary agriculture without acknowledgement of the continuing useful role of nomadic and rangeland herders. In fact they represent a highly evolved interaction with otherwise uninhabitable landscapes. While it may seem that they may be declining, livestock dependant societies need not be forced into cities, which would increase the overall demand for food of such persons by at least 30 percent above current consumption levels. Thus we might estimate that by continuing in their extensive lifestyles, animal products contribute directly to food security to the extent of about 160 million persons.

**2. Small mixed farmers:** Defining a mixed farm as one where more than 10 percent of animal feed is from agricultural by-products or more than 10 percent of the farm production value is from other agricultural enterprises<sup>xxxvi</sup> leads to a wide range of animal production systems. It is these systems that produce much of world meat and milk – 48 percent of beef, 53 percent of milk and 33 percent of mutton from rain-fed mixed systems. Often such farms are subject to single-product analyses of efficiency, which can lead to unnecessary reductions in the

draught and traction functions of large animals with concomitant losses of protein production. For this reason it may be more constructive to use the Asian integrated farming system as the basis for small-scale mixed farms rather than the more generalized global definitions.

Yet even the small-scale integrated farms of Asia take myriad forms, one of which is described in Figure 1. In such farms animals perform a range in functions including waste usage, insect pest control, provision of fertilizer, integration with other animal production as well as routine edible and other products. Small animals are more efficient in such systems as numbers can be varied more easily across seasons and conditions, and provide a more regular source of protein in diets. An important consideration in such farms is that they follow the same systems that have evolved through trial and error over millennia; much development literature about such farms and ideals such as Permaculture may be viewed as a belated Western appreciation of their internal efficiencies and resilience. At the same time, the miracle of China becoming an agricultural exporter when mass starvation was predicted to have occurred by now has relied in part on such small-scale farms integrated with diverse small animal species.

**Figure 1. A Stylized Version of an Integrated Small Farm in Asia<sup>xxxvii</sup>**



Small integrated farms, which support some two billion persons, are a major contributor to food security because they allow that third of humanity to continue feeding themselves in rural settings and so not add to the major food security issue that has arisen in cities. We may estimate the food security benefit of such small farmers as being the higher potential yields of small farmers plus the at least 30 percent extra food required for food to reach urban dwellers; that is, two-and-a-half billion persons. Within this rough total, the contribution attributable to animal production is difficult to estimate, but should be at the very least 250 million persons based on the earlier definition of small mixed farms. A figure of 500 million persons is used for the sake of continuing this discussion.

**3. Urban populations:** With more than half of the world's population now living in cities, although the proportion may be only 35 percent in developing countries, supply of food to cities is a critical and rising aspect of food security. It is in this urban environment that the nexus between food and poverty is important – on farms the association is more complex and variable. With already 300 million urban dwellers considered to be extremely poor and the majority of these in Asia,<sup>xxxviii</sup> food security related to severe undernourishment and precarious access to food is a major issue. Animal food products play a role in meeting this need, but less than has been espoused in work that has focused in the animal product consumption of the emerging middle classes of Asia. The contribution of that segment to food security is not through nutrition of consumers as much as through possible returns to animal producers who may circulate the additional wealth in rural areas and so perhaps have some limited effect on price induced food insecurity in rural towns.

In large cities, animal products are highly accessible to the urban rich and middle classes, but much less so to the price sensitive poor, who are in turn subject to risks of unsafe products resulting from poor hygiene, poor refrigeration and unregulated toxin and residue levels. Having no viable connections to agriculture, the urban poor have no buffer from animal products and no protein reserve and are thus the most vulnerable to disease and early death. Similarly, the usual animal products do not readily lend themselves to the trend for urban households to hoard food when prices become volatile. For example, the food crisis of 2007–08 led to poor households in urban Bangladesh limiting their purchases of meat, fish and eggs.<sup>xxxix</sup> Where such a situation is not ameliorated by good governance through national food security plans, malnutrition results – or mayhem as urban groups riot.

How can cheap and reliable animal product supply to urban dwellers be managed? In fact, while the question continues to be asked in some aid arenas, it has been faced by various responsible governments, which use such mechanisms as:

- animal businesses kept within city limits
- periurban farms
- small-farms including contract-growers supply linked to cities
- large commercial operations with integrated market chains
- home production
- international trade, including low-value animal parts
- alternative foods.

Urban-based livestock production is under constant pressure from concerns about compromised lifestyle amenity and risks to human health. Consequently animals are more common in poor urban areas whereby their product provides some measure of compensation to those who cannot afford supermarket prices. But even these producers are now being forced out as planners allocate priority to health risk mitigation without regard to food security for the poorest persons. For example, a constant population of more than 200,000 poultry was raised within Jakarta in 2003 and was increasing until was banned in the Avian

Influenza programs of 2008;<sup>xi</sup> in Thailand tax incentives were provided to urban livestock producers to move out of Bangkok.<sup>xli</sup> But China provides a better example.

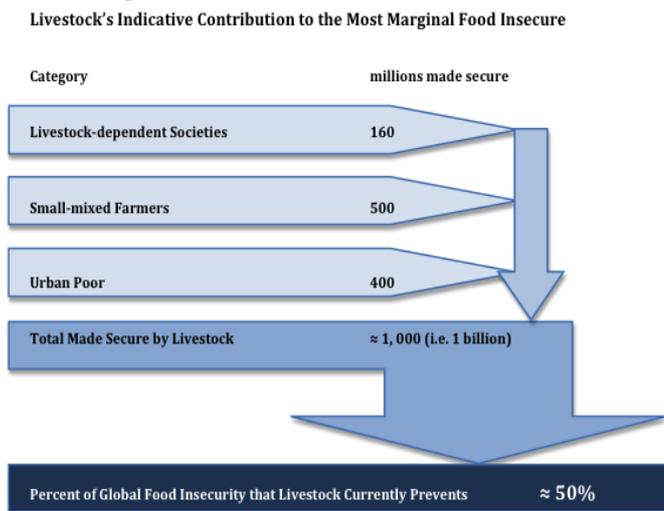
The success of Chinese governments in maintaining food security in huge urban agglomerations has been linked to a much higher emphasis on self-sufficiency – much higher than is encouraged by international agencies. I have elsewhere criticized such international agency agendas for their trade assumptions related to food security for survival, and noted the responsible actions of India and China in this regard. Rather than claim that Chinese *'preoccupation with self-sufficiency is partly attributable to changes in city boundaries under the Great Leap Forward'*,<sup>xlii</sup> it would be more reasonable to acknowledge a sound Chinese understanding of food security and its management as a primary responsibility.

One component of the Chinese approach is to define city limits much wider than elsewhere to allow urban agricultural production within the urban governance ambit. Beijing is said to supply 70 percent of vegetables and milk internally<sup>xliii</sup> and Shanghai meets at least milk and egg demand from within city limits by governance of an area that elsewhere would be defined as 87 percent rural.<sup>xliv</sup> It is not a matter of simply noting that such land might be classified as periurban agriculture, and has long been known as the major source of food for cities – estimated to supply 34 percent of meat and 70 percent of egg production worldwide in the late 1990s<sup>xlv</sup> – the important difference is that urban food needs are managed as a priority by the city administration. The destabilizing urban-rural divide that Western nations bemoan at home has been addressed in China to the benefit of both.

As less than 10 percent of food crosses national borders, and as most internationally traded food comes from wealthy nations, it is no exaggeration to say that the absolute priority for food security is for national governments to focus on domestic production and delivery. At its most basic level, food security for survival should not be a component of discussions about free trade in food. In the case of animals, their mobility has facilitated some live cross-border trade in mainland Asia, such as the traditional walking of cattle and buffalo into Thailand.<sup>xlvi</sup> This includes animal smuggling – it is estimated that unofficially one million birds per month enter Vietnam from China.<sup>xlvii</sup> Such market chains are being increasingly regulated in the interests of epidemic disease control and food hygiene, but improvements remain compromised as food demand outstrips regulatory controls.

Other means of ensuring the security of animal food products in cities can be elicited, including home production of small animals including rodents, fish tanks, penned small ruminants and elevated poultry pens. These measures are ultimately more important than postulations about international trade in animal products as a basis for food security of the urban poor. However, the minor contributor of international trade is studied in much more detail perhaps because it is of greater familiarity to those trained in Western research modes.

One example is an excellent use of several complex models to examine the



impact of 15 combinations of population, income and climate change on food security through to the year 2050.<sup>xlvi</sup> The conclusion that the deleterious impacts of climate change on food security can be forestalled by economic growth based on increases in agricultural productivity and international trade in food products addresses the needs of urban dwellers and assumes downward

trends in food prices. These are the best theoretical results available, but they contrast with the successful approach taken in China, which is based on the historical lesson that cities without secure food supplies are ungovernable; food security is thus seen as the basis of national security, and for this reason is increasingly attracting the interest of military intelligence agencies.

Estimating the number of persons kept productively alive by animal products meeting the increased demand in cities is more difficult than for pastoral (160 million) and small mixed farms (500 million). If we say that the situation is grave for about 30 percent of urban inhabitants of third world cities, we arrive at the usual figure of about one billion food insecure persons globally. If, for the sake of argument, we take the same figure of 30 percent for highly urbanized China, then perhaps some 200 million persons otherwise food insecure persons are rendered food secure by such urban policies as China's. Add to this, elements of such policies in other nations, and we could guess that the figure might be more than 400 million. That is, about one billion persons that might otherwise be subject to health-debilitating diseases were it not for animal protein being included in their diet. But such estimates are gross at best, and do not include the some 800-1,000 million food insecure whose primary need is not necessarily animal protein.

Having described aspects of the role of animal production in real food security as currently critical to maybe one billion persons with more remaining food insecure, some discussion of the possible futures for animal production in this role is presented in the following section.

### **Future Animal Production in Food Security**

Demand for animal products by the middle class will rise with wealth and population increase – both of which are an increasingly urban and Asian phenomena. By 2050, poultry meat demand is estimated to 230 percent of that in 2005 and other livestock products about 160 percent.<sup>xlix</sup> Requirements for

about double the current animal product consumption with at least some increase in price represents another future food security impost on the urban poor. We know that production systems can be increased in efficiency, and that wastage can be reduced, but these do not obviously lead to a doubling of availability of animal food products. The only other path for either increased availability or decreased price is technological innovation, and with declines in investment in agricultural research, large breakthroughs are no longer predicted. That is, except where research investment has been maintained or increased, and again China stands out as the leader. This may be one continuing factor in future animal production for food security – adapting from the experience of whoever are the world leaders in the field.

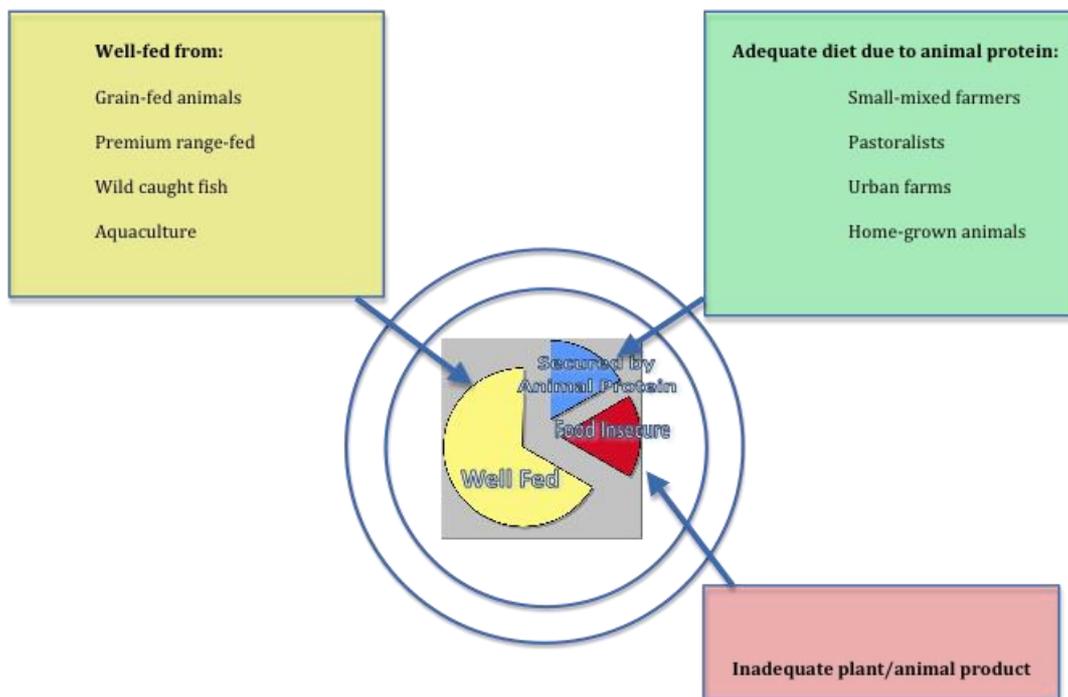
Another factor is a change in focus from the same old animals to embrace those most suited to the production environment – one of the fundamental tenets of the science of animal production. For example, one field of animal production that may provide needed animal protein is aquaculture. Having increased from about 40 to 52 billion tons between 2002 and 2006, with more than 60 percent of production being in China,<sup>i</sup> aquaculture now represents about half of global fish consumption.<sup>ii</sup> The high feed conversion rates of some farmed species, and the adaptability of some to small production facilities, make this form of animal production of increasing importance in food security.

Following the above tenet of producing what is most suited to an environment, which includes markets, it may be postulated that in general future animal foods may be sourced from:

- current grain-based animal industries for the wealthy
- current subsistence animal protein for pastoralists and small integrated producers
- aquacultured fish at household level, even in cities
- farmed and home-caged efficient roughage convertors such as rodents and rabbits
- large and small-scale farmed insect and larvae protein
- laboratory/factory produced meat-type protein products<sup>lii</sup>
- factory-produced ‘protein biscuits’ produced from treated animal and other product wastes.

Some animal scientists may consider these points to be fanciful, which illustrates the problem of entrenching ideas in silos of existing domestic animal production, particularly those based on Western mores. As Nobel Laureate and veterinarian Peter Doherty notes, *‘following the obvious path is not likely to lead to a novel question, interpretation or solution’*.<sup>liii</sup> It should be axiomatic to global-thinking animal scientists that to accept that Western food focus in a poor and food insecure country is to orient animal science to the wealthy, not to food security. I am not arguing that animal science should not serve wealthy markets, just that we should not delude ourselves into thinking that research on grain-fed ruminants – and many other subjects – are contributing to the wellbeing of the food-poor, and that we should acknowledge that expansion of such production may even reduce overall food security.

**Livestock Secures Food for 85% of World Population: For One Billion its Critical, for Another Billion Inadequate**



Between the futuristic foods and current animal production lies a key opportunity for the urban poor through increased efficiency of use of byproducts and waste resources. Without such efficiencies, producing 100 percent more poultry, 80 percent more sheep and goats, 50 percent more cattle and buffalo and 40 percent more pigs is not feasible using current technologies without taking existing food resources from some segment of the population – most likely the food-poor. In my writings I have the conservative figures of 25 to 30 percent wastage of food delivered to cities compared to food consumed on subsistence farms; others suggest even higher figures.<sup>liv</sup>

Reducing wastage is presently approached by concentrating animal production in intensive farms. This serves market economies where luxury livestock products effectively displace basic foods of the poor. But it relies on grain being fed to poultry, pigs and cattle. If grass-fed steak was considered superior to grain-fed, then perhaps pastoral livestock production might be linked to market forces and save grain currently wasted on ruminant production. But is it that easy? No, because such grain may not be suited to human consumption as a function of its coarseness, or weather and pest damage. It is apposite to recall that 15 years ago, one major grain user and exporter tried to claim that grains fed to livestock served as a food security reserve for emergency support to other nations.<sup>lv</sup>

Small mixed farmers feed agricultural byproducts, food waste and small animals including insects to their livestock foraging near fields and houses. They also cut and carry forage for ruminants in systems that are extremely efficient compared to large-scale commercial and intensive production systems. With adequate disease control and remediation of nutrient deficiencies these systems based on

indigenous breeds can show production levels similar to higher-cost commercial systems using exotic breeds. But production efficiencies do not necessarily translate into meeting the needs of the urban poor since most infrastructure to deliver food to cities is based on capturing profits along the supply chain, and the profits from supplying middle and upper class demand are greater.

### **Where To From Here?**

We are left with the conclusion that while extensive ruminant grazing systems and small mixed farms are the most efficient production systems, the vast majority of animal products that can be delivered to cities is and will be from specialized intensive production, particularly for poultry and pigs. The trend is already well established. Further intensification, with increased appreciation of animal welfare, can hone efficiencies in financial terms, but will almost certainly incur some additional natural resource costs. Asian production systems that utilize agro-industrial and other wastes already demonstrate greater efficiencies than Western-style production systems. Under this scenario, the urban poor may access livestock products that the wealthy classes reject – offal in some markets, suspect-quality meat or milk in others. It sounds inequitable, but it is consistent with historical precedents.

Livestock food security also requires resilience, which has been approached in China by ensuring that its large cities are generally food self-sufficient through the inclusion of food production zones within urban boundaries assisted by judicious use of subsidies. This means is not favoured by many in the international development community, which remains enamored of free trade to allow food to flow *'to where it is needed'* under assumptions that the poor somehow having purchasing power. It is time that we, as animal scientists, considered that the future for livestock food security for those most at risk – the urban poor – may be more likely to follow the Chinese than the Western model, which will incidentally produce constant challenges to animal welfare and environmental management.

It is usual these days in a paper such as this to include a large section on climate change. I have not done this because I consider it to be subsumed within the concept of resilience. Production and delivery systems that can withstand or recover from shocks of climate variability, political instability and other disasters should characterize responsible government planning and international development assistance related to food security. Thus livestock food security like national food security in general includes a disaster risk management approach that acknowledges the slow-acting environmental changes that may increase vulnerability to sudden events.<sup>lvi</sup>

So we may conclude that intensive production will continue to be important and become more efficient, with associated animal welfare and environmental concerns – but that this has little relevance to real food security. A range of simple urban and home-based animal protein production may better serve food security of the urban poor. And we may note that food reserves against poor

seasons and disasters need to be reintroduced regardless of trade-based arguments for food security<sup>lvii</sup> and that for animal foods such reserves include a wide range of traditional preserved products, animals that graze and scavenge by themselves and urban animal production including home-based production systems – that is why they are called ‘live’-stock. Complementing these are the small mixed farmers and pastoralists in poor countries that are both producers and consumers of livestock products and whose livestock food security maintains healthy persons outside cities. The alternative of massive urban migration would increase livestock production requirements from industrial systems by more than 130 percent.

Research to increase the efficiency of the livestock production systems that meet each of the needs of pastoralists, small mixed farms and urban consumers is a primary responsibility of future animal science. Each requires a multidisciplinary approach. This is not the same as the actions of international development agencies. For example, the Asian Development Bank sees the main drivers of change in agriculture in the Greater Mekong Subregion as: accelerated globalization and trade liberalization; climate change; degradation of the agricultural resource base, and investments in transport infrastructure that facilitate cross-border trade and economic growth.<sup>lviii</sup> To guide development in the sector to meet future needs, the ADB has determined to focus on agricultural research and development; private sector involvement, and institutional mechanisms for regional cooperation. With rates of return to public investment 40–50 percent from agricultural research this makes financial sense, but the approach conceives livestock as a source of high value traded food, contributing to food security only through trade. In fact, returns to small-farm research are usually much higher.<sup>lix</sup>

ADB is a major influence on livestock policy in Asia and its late appreciation of food security continues to be hampered by a focus on trade. This is evident in their discussion about global food prices, which rose by more than 30 percent year-on-year to 2011 mainly resulting from large increases in cereal, edible oil, and meat prices.<sup>lx</sup> While it is convenient to relate price rises to adverse weather events, the spectre of the 2007–2008 food crisis continues today as a result of reduced food stocks and increasingly unpredictable weather. Thus ADB calculates food price inflation in Asia to be around 10 percent per annum, which with growing population they translate into increased poverty – in fact the result is likely to be worse, as it leads to increased urban food insecurity. In such international agency documents, monetized arguments commonly lead to conclusions of poverty when a worse fate looms – hunger, which in cities is linked to anarchy. Food security is a relatively new concern in such agencies, to the extent that some food-insecure island states have only recently considered the concept of real food security.<sup>lxi</sup>

The danger of entrenched views of agencies is mirrored by those who become attached to alternative forms of food production, such as nature farming or non-GMO foods. In both cases I have argued for open-minded consideration of all forms of agriculture in order to meet world food needs. Matters, such as individual environmental beliefs, that prejudice the lives of other persons should

be subjugated to meeting basic food needs of the world.<sup>lxii</sup> The same was true of once-held Western prejudices against assistance to dairying in the tropics, which with Dr. Charan we worked to overcome.<sup>lxiii</sup> A similar blindspot remains about the role of small farmers in food production, and the personal benefits of their lifestyles in many cases in Asia – a phenomenon that linked self-sufficiency to ‘gross domestic happiness’ as he presented in the plenary session of an earlier AAAP congress in Hanoi.<sup>lxiv</sup> In each case, a tendency to denigrate what works has been exacerbated by a partial understanding of the role and conduct of science, including animal science. It occurs when we forget that science is a methodology that aims to correct our inherent biases, and that the reductionism required for much experimentation can limit our worldview unless we consciously practice to remain aware of interactions.

Let me conclude by repeating the message from the Hanoi AAAP: returning to long-held values, remnants of which continue in the rural sector, to guide policy, development and education offers major benefits. In the quest for food security, these allow a clearer view of such pillars of food security as small farmers, food reserves and national food security planning – all of which contain major components of animal production. These pillars have been toppled by a cut-down application of economics. Yet essential human values and risk management are present in Western economic models – they have simply not been applied in the race for financial accumulations. Through reflection and that wisdom that is embedded in all healthy cultures’ actions, from national decision-making down to individual integrity, an enhanced understanding can be expected to lead to an increased role for animal production development in food security.

## References:

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- <sup>i</sup> Lindsay Falvey (2011) *Small Farmers Secure Food: Survival Food Security, the World’s Kitchen and the Critical Role of Small Farmers*. Thaksin University Press in association with the Institute for International Development. Pp232.
- <sup>ii</sup> FAO (2011) *World Livestock 2011 – Livestock in Food Security*. FAO, Rome.
- <sup>iii</sup> Falvey, L. (2001) Re-conceiving Food Security and Environmental Protection. Keynote Lecture, Asian Agriculture Congress Organised by the Combined Ninth Congress of the Society for the Advancement of Breeding Researchers in Asia and Oceania, the Fourth Conference of the Asian Crop Science Association, and the Sixteenth Conference of the Federation of Crop Science Societies of the Philippines, held at the Westin Philippine Plaza, Manila, 24-27 April, 2001. Re-presented at the SEARCA Conference ‘Food Security and Environmental Protection for the 21<sup>st</sup> Century’, held at the University of the Philippines, Los Banos, April 26, 2001.
- <sup>iv</sup> FAO (2011) *World Livestock 2011 – Livestock in Food Security*. FAO, Rome.
- <sup>v</sup> ILRI (2012) <http://ilristrategy.wordpress.com/2012/05/10/strategy-directions>
- <sup>vi</sup> ILRI (2012) High-Level Consultation for a Global Livestock Agenda to 2020. <<http://www.ilri.org/ilrinews/index.php/archives/8751>>
- <sup>vii</sup> CGIAR Science Council (2008) Report of the Second External Program and Management Review of the International Livestock Center (ILRI). Rome, Italy: Science Council Secretariat. Pp145.
- <sup>viii</sup> Falvey, J.L. and Leake, J.E. (1993) Sustainable Management for Livestock: Mongolia. First Plenary Session of the 7th World Conference on Animal Production, Edmonton, Alberta Canada, June 28-July 2, 1993. Volume 1 (invited papers): 17-32.
- <sup>ix</sup> FAO (2011) *World Livestock 2011 – Livestock in Food Security*. FAO, Rome.
- <sup>x</sup> Harding, Jeremy (2010) What We Are About to Receive. <<http://www.lrb.co.uk/v32/n09/jeremy-harding/what-were-about-to-receive>>
- <sup>xi</sup> Lindsay Falvey (2011) *Small Farmers Secure Food: Survival Food Security, the World’s Kitchen and the Critical Role of Small Farmers*. Thaksin University Press in association with the Institute for International Development. Pp232.
- <sup>xii</sup> FAO (2008) *State of Food Insecurity in the World 2008: High Food Prices and Food Security – Threats and Opportunities*. FAO, Rome.

- <sup>xiii</sup> UN Standing Committee on Nutrition 2010. Sixth Report on the World Nutrition Situation <[http://www.unscn.org/files/Publications/RWNS6/report/SCN\\_report.pdf](http://www.unscn.org/files/Publications/RWNS6/report/SCN_report.pdf)>
- <sup>xiv</sup> FAOSTAT
- <sup>xv</sup> FAOSTAT
- <sup>xvi</sup> Bender, A. (1992) Meat and Meat Products in Human Nutrition in the Developing World. Food and Nutrition paper No. 53. Rome, Food and Agriculture Organisation, Rome.
- <sup>xvii</sup> DeBenoist, B., McLean, E., Egli, I. and Cogswell, M. (2008) Worldwide Prevalence of Anaemia 1993–2005: WHO Global Database on Anaemia <[http://whqlibdoc.who.int/publications/2008/9789241596657\\_eng.pdf](http://whqlibdoc.who.int/publications/2008/9789241596657_eng.pdf)>
- <sup>xviii</sup> UNICEF (2007) The State of the World's Children 2007. New York.
- <sup>xix</sup> FAO (2011) World Livestock 2011 – Livestock in Food Security. FAO, Rome.
- <sup>xx</sup> Delgado, C.L. (2003) Rising Consumption of Meat and Milk in Developing Countries has Created a New Food Revolution. *Journal of Nutrition* 133:3907S-3910S. <<http://jn.nutrition.org/cgi/content/full/133/11/3907S>; <http://www.lrrd.org/lrrd21/9/betr21143.htm>>
- <sup>xxi</sup> Griffin, M. (2004) Issues in the Development of School Milk. Paper presented at School Milk Workshop, FAO Intergovernmental Group on Meat and Dairy Products. Winnipeg, Canada, 17-19 June 2004. <[http://www.fao.org/es/esc/common/ecg/169/en/School\\_Milk\\_FAO\\_background.pdf](http://www.fao.org/es/esc/common/ecg/169/en/School_Milk_FAO_background.pdf)>
- <sup>xxii</sup> Lindsay Falvey and Charan Chantalakhana (1999) Smallholder Dairying in the Tropics, International Livestock Research Institute, CGIAR, Nairobi. Pp447.
- <sup>xxiii</sup> Adapted from: IFPRI (2010) Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options. Pp155.
- <sup>xxiv</sup> Pica-Ciamarra, U. and Otte, J. (2009) Poultry, Food Security and Poverty in India: Looking Beyond the Farm Gate. PPLPI Research Report. Pro-Poor Livestock Policy Initiative, FAO, Rome.
- <sup>xxv</sup> Garcia, O., Hemme, T., Huong Tra, H. and Tat Nho, L. (2006) The Economics of Milk Production in Hanoi, Vietnam, with Particular Emphasis on Small-scale Producers. PPLPI Working Paper no. 33. Rome, Pro-Poor Livestock Policy Initiative, FAO, Rome.
- <sup>xxvi</sup> NDDB (2010) <<http://dahd.nic.in>>
- <sup>xxvii</sup> Halderman, M. (2005) The Political Economy of Pro-Poor Livestock Policy-making in Ethiopia. PPLPI Working Paper no. 19. Pro-Poor Livestock Policy Initiative, FAO, Rome.
- <sup>xxviii</sup> FAO (2011) World Livestock 2011 – Livestock in Food Security. FAO, Rome.
- <sup>xxix</sup> Ritual large animal sacrifices in the Meo hilltribes of 1970s Thailand were found to often coincide with the period of the year when food was scarce and protein deficiency most severe. See Falvey, J.L. (1979). Sacrifices Involving Large Livestock in the Northern Thailand Highlands. *Journal of Developing Areas* 13:275-282.
- <sup>xxx</sup> Garcia, O., Hemme, T. and Mahmood, K. (2003) A Review of Milk Production in Pakistan with Particular Emphasis on Small-Scale Producers. PPLPI Working Paper no. 3. Pro-Poor Livestock Policy Initiative, FAO, Rome.
- <sup>xxxi</sup> FAO (2011) World Livestock 2011 – Livestock in Food Security. FAO, Rome.
- <sup>xxxii</sup> Headley D., Malaiyandi S., and Shenggen F. (2009) Navigating the Perfect Storm: Reflections on the Food, Energy and Financial Crises. IFPRI Discussion Paper 0889. IFPRI, Washington, DC.
- <sup>xxxiii</sup> FAO (2011) World Livestock 2011 – Livestock in Food Security. FAO, Rome.
- <sup>xxxiv</sup> Sere, C. and Steinfeld, S. (1996) World Livestock Production Systems: Current Status, Issues and Trends <<http://www.fao.org/ag/againfo/programmes/en/lead/toolbox/Paper127/cover1.htm>>
- <sup>xxxv</sup> Meat and Livestock Australia 2011. <<http://www.mla.com.au/Prices-and-markets/Trends-and-analysis/Sheep-and-goats/Domestic-consumption>>
- <sup>xxxvi</sup> Sere, C. and Steinfeld, S. (1996) World Livestock Production Systems: Current Status, Issues and Trends <<http://www.fao.org/ag/againfo/programmes/en/lead/toolbox/Paper127/cover1.htm>>
- <sup>xxxvii</sup> Devendra, C. and Leng, R.A. (2011) Feed Resources for Animals in Asia: Issues, Strategies for Use, Intensification and Integration for Increased Productivity. *Asian-Australian Journal of Animal Science* 24: 303 – 321.
- <sup>xxxviii</sup> Ahmed, A.U., Hill, R.V., Smith, L.C., Wiesmann, D.M. and Frankenberger, T. (2007) The World's Most Deprived: Characteristics and Causes of Extreme Poverty and Hunger, 2020 Vision for Food, Agriculture and the Environment Discussion Paper No 43, International Food Policy Research Institute, Washington DC.
- <sup>xxxix</sup> Cohen, M.J. and Garrett, J.L. (2010) The Food Price Crisis and Urban Food (In)security. *Environment and Urbanization* 22: 467-482.
- <sup>xl</sup> FAO/ICASEPS (2008) Livelihood and Gender Impact of Rapid Changes to Bio-security Policy in the Jakarta Area and Lessons Learned for Future Approaches in Urban Areas. Indonesian Center for Agrosocioeconomic and Policy Studies and FAO, Rome.
- <sup>xli</sup> Costales, A., Gerber, P. and Steinfeld, H. (2006) Underneath the Livestock Revolution. In, The Livestock Report. FAO, Rome. <[www.fao.org/do-crep/099/a0255e05.htm](http://www.fao.org/do-crep/099/a0255e05.htm)>
- <sup>xlii</sup> FAO (2011) World Livestock 2011 – Livestock in Food Security. FAO, Rome.
- <sup>xliii</sup> Jianming, C. (2003) Periurban Agriculture Development in China. *Urban Agriculture*. 9: 40-42.
- <sup>xliv</sup> Yi-Zhong, C. and Zhang Z. (2000) Shanghai: Trends Towards Specialised and Capital-intense Urban Agriculture. In *Growing Cities, Growing Food: Urban Agriculture on the Policy Agenda*. N. Bakker, M. Dubbeling, S. Gündel, U. Sabel-Koschella and H. de Zeeuw, (eds) A Reader on Urban Agriculture, German Foundation for International Development, Feldafing, Germany. 467-75.
- <sup>xliv</sup> FAO (2011) World Livestock 2011 – Livestock in Food Security. FAO, Rome.

- 
- <sup>xlvi</sup> Falvey, L. (1982). Some Economic Aspects of the Livestock Industry in the Highlands of North Thailand. *The Journal of Tropical Geography* 49:11-18.
- <sup>xlvii</sup> FAO (2011) *World Livestock 2011 – Livestock in Food Security*. FAO, Rome.
- <sup>xlviii</sup> IFPRI (2010) *Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options*. International Food Policy Research Institute, Washington DC. Pp155.
- <sup>xlix</sup> FAO (2011) *World Livestock 2011 – Livestock in Food Security*. FAO, Rome.
- <sup>l</sup> FAO (2008) *The State of World Fisheries and Aquaculture 2008*. FAO, Rome.
- <sup>li</sup> FAO (2010) *The State of World Fisheries and Aquaculture*. FAO, Rome.
- <sup>lii</sup> Datar, I. and Betti, M. (2010) Possibilities for an In-vitro Meat Production System. *Innovative Food Science and Emerging Technologies* 11:13–22.
- <sup>liii</sup> Peter Doherty (2005) *The Beginner’s Guide to Winning a Nobel Prize*. Miegunyah Press, Melbourne. Pp282. Page 245.
- <sup>liv</sup> Lindsay Falvey (2011) *Small Farmers Secure Food: Survival Food Security, the World’s Kitchen and the Critical Role of Small Farmers*. Thaksin University Press in association with the Institute for International Development. Pp232.
- <sup>lv</sup> USDA (1997) *Discussion Paper on International Food Security*.  
<<http://www.fas.usda.gov/icd/summit/discpapr.html>>
- <sup>lvi</sup> John Leake (in preparation) *Recovering from Disaster*. Thaksin University, Songkhla, Thailand in association with the Institute for International Development, Australia. (forthcoming).
- <sup>lvii</sup> Von Braun, J. and Torero, M. (2009) *Implementing Physical and Virtual Food Reserves to Protect the Poor and Prevent Market Failure*. IFPRI Policy Brief 10, February 2009. <<http://www.ifpri.org/sites/default/files/publications/bp010.pdf>>
- <sup>lviii</sup> ADB (2011) *Core Agriculture Support Program Phase II 2011–2015*. GMS Working Group on Agriculture 2011 Asian Development Bank, Manila. Pp28.
- <sup>lix</sup> See for example, ACIAR (2006) *Future Directions for ACIAR’s Animal Health Research*. Australian Centre for International Agricultural Research, Canberra. Pp106.
- <sup>lx</sup> ADB (2011) *Global Food Price Inflation and Developing Asia*. Asian Development Bank, Manila. Pp39.
- <sup>lxi</sup> ADB (2011) *Food Security and Climate Change in the Pacific Rethinking the Options*. Asian Development Bank, Manila. Pp85.
- <sup>lxii</sup> Lindsay Falvey (2012) *Feeding the Spirit while Feeding the Body: The Role of Technology*. In ‘The Coexistence Between Nature and Human Beings: Viewed through Agriculture’ Yoko Civilization Research Institute, Japan. (forthcoming)
- <sup>lxiii</sup> Lindsay Falvey and Charan Chantalexhanna (1999) *Smallholder Dairying in the Tropics*. International Livestock Research Institute, CGIAR, Nairobi. Pp447Pp.
- <sup>lxiv</sup> Charan Chantalexhanna and Lindsay Falvey (2008) *Sufficiency Economy: An Approach for Smallholder Agricultural Development to Enhance Peace and Stability*. Invited Plenary Paper, Thirteenth Asian Australasian Animal Production Congress, Hanoi.