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MAKE AGRICULTURE TRULY SUSTAINABLE NOW FOR FOOD SECURITY IN A CHANGING CLIMATE

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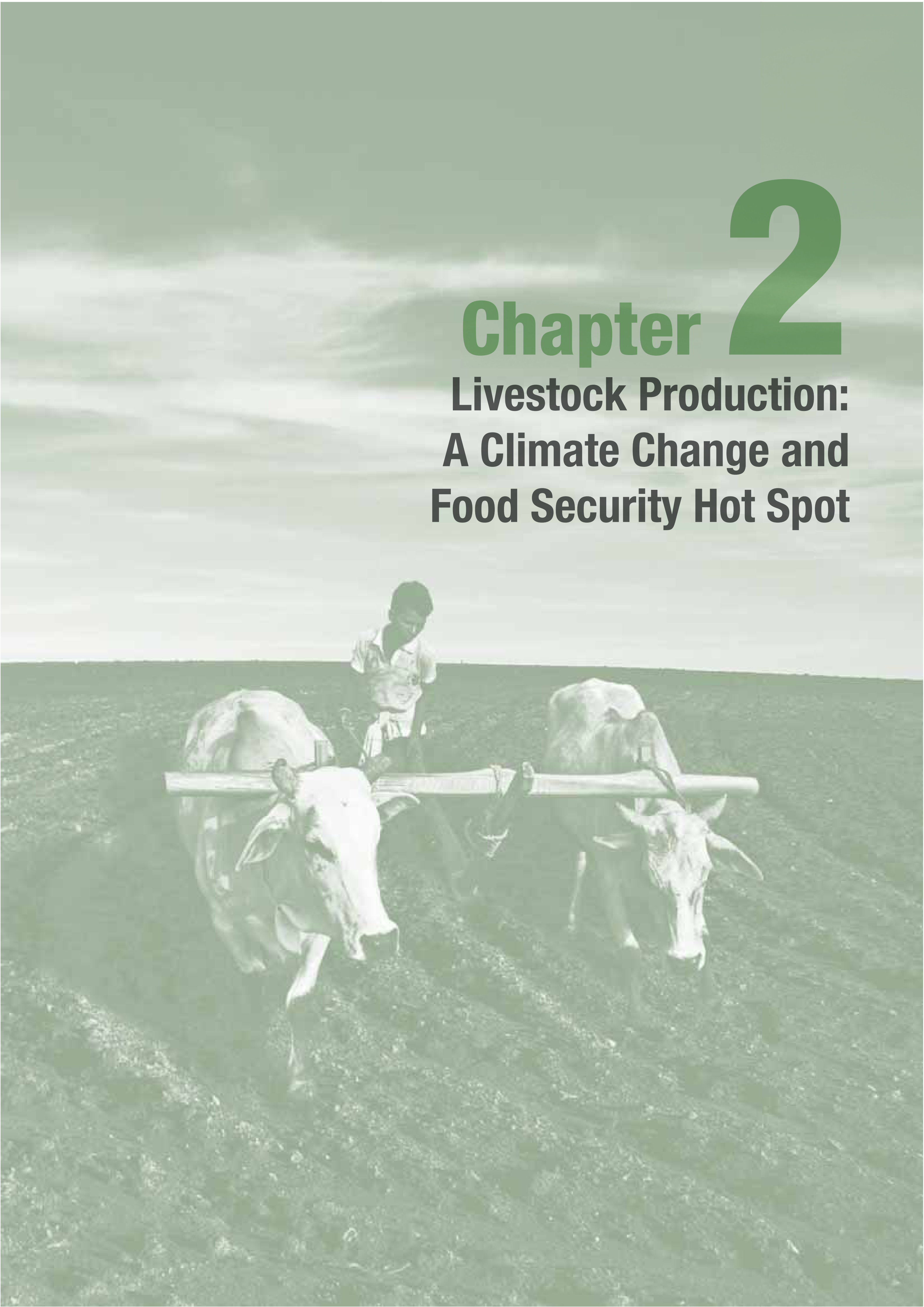

Chapter 2

Livestock Production: A Climate Change and Food Security Hot Spot

Lead Article: LIVESTOCK PRODUCTION AND FOOD SECURITY IN A CONTEXT OF CLIMATE CHANGE, AND ENVIRONMENTAL AND HEALTH CHALLENGES

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Abstract

To optimize the interrelationship between the global climate and cattle and maximize the latter's contribution to global food security, the following steps need to be taken:

- More research on grassland management aimed at optimizing its capacity to serve as a carbon sink.
- More support for grazing.
- Land-use change should be brought under strict control, including that related to imported animal feed.
- Livestock production should have a stronger link to the regional feed base.

Prevailing trends towards further industrialization of agriculture, along with landless, large-scale livestock production, are likely to contribute to an increase in greenhouse gas (GHG) emissions by more than a third till 2030. According to the 4th IPCC Assessment Report, "Without additional policies, agricultural N_2O [nitrous oxide] and CH_4 [methane] emissions are projected to increase by 35-60% and 60%, respectively, to 2030, thus increasing more rapidly than the 14% increase of non-CO_2 GHG observed from 1990 to 2005" (IPCC, 2007: 63).

There is a tendency to ignore the need to reduce meat consumption as well as to implement a legal framework for sustainable production methods to address their medium and long-term effects on climate, environment and animal welfare.[1] Industrial livestock production should be curbed so that the total stock of raised animals such as cattle, pigs, chickens and sheep is reduced and the consumption of animal feed should be commensurate with sustainable local production potential. Reduced consumption of animal products is a particular challenge for those countries where animal protein consumption is high – representing a false model of imaginary prosperity. The fact that an increasing number of people are becoming vegans may help (in terms of the reduced demand for animal protein and energy-rich food), but "to conclude that a vegan agricultural and food system would be the preferable solution, is far too simplistic" (Garnet, 2010; Fairlie, 2010, D'Silva and Webster, 2010).

Over the past few decades, feeding systems have turned more and more from being local/regional to global; the basic source of fodder is less and less the farm itself. The resulting problem of expansion and intensification of livestock production is associated with the shift from a feed system based on grass and plant remains to one based mainly on crops, even for ruminants. However, the major issue is not whether livestock is the world's largest user of land, but rather how the land and livestock are managed. While sustainable and animal-friendly systems are characterized by areas/space for outdoor keeping and grazing, industrial animal rearing is characterized as landless. Thus the data indicating livestock as the world's largest user of land are average values that also include a relevant part of sustainably used grasslands.

The intensification of livestock systems, and especially feeding systems, has gone hand in hand with more specialization and rationalization, thereby creating livestock systems that are increasingly dependent on energy input and foreign fodder sources. The growing demand for such feed has led to a huge demand for land, which is a crucial factor - leading to land-grabbing and land conversion, including the deforestation of rainforests. Only little by little is a wider public realizing in the context of land-grabbing that there is a huge demand for land in the South resulting mainly from demand for animal feed in the North. In a recent study, von Witzke and Noleppa (2011) estimate that in order to produce those agricultural products that were imported by the European Union (EU) in 2007-2008, 53 million hectares (ha) of arable land were used in other parts of the world. The EU, on the other hand, used only 18 million ha for products it exported during that period. As a result, the EU imports "virtual land" in the order of 35 million ha. This represents a third of the 105 million ha used in the EU as arable land. The single biggest factor that contributes to this imbalance is the import of soy, which uses 18 million ha outside the EU, mainly in Latin America (see below). This spatial separation of industrial livestock systems from feed crop production is clearly linked with less rigid environmental regulations (Naylor et al., 2005).

Greater standardization and specialization in industrial agriculture is closely related to the de-linking of crop and livestock production. This separation causes higher energy and fertilizer consumption, which while increasing the scale of production and yields, both of crops and livestock, gives rise to enormous risks such as pest infestation and diseases. The prevailing system of industrial livestock production with its specific breeding, feeding and general husbandry practices leads to ever larger numbers of animals being subjected to enormous and irresponsible performance and rearing stress.

Irrespective of the animal protection aspect, the concept of "biosecurity" in livestock production can be considered a failure. This is because the attempt to treat low immunity and the increasing threat of infection by an ever increasing use of drugs and disinfectants gives rise to resistance problems, the inevitable selection of dangerous microbes and alarming levels of residues in water, soil, food and animal feed.[2]

A sustainable approach requires a drastic reduction of industrial animal feed production and a concomitant decline in the production of animal products. Instead of replacing the production of human food by animal feed, animal and crop production should be reintegrated in order to:

- Use the nutrients contained in grass and harvesting residues as animal feed that cannot be directly used for human consumption; and
- Use manure as fertilizer on grasslands and croplands.

This requires a move from the existing one-sided orientation and selection aimed at maximum performance of both crops and livestock, towards a more holistic view that promotes interactions and the productivity of the system as a whole. Furthermore, it is imperative to reduce the environmental, health and climate-related impacts from the massive use of synthetic nitrogen fertilizers, and promote the use of animal excrement as natural fertilizer. Discarding the latter and defining it as waste constitutes a huge loss of nutrients and minerals (similar to post-harvest losses of food).[3]

The sustainable production of food of animal origin requires the development of cooperation on a regional level, as well as cooperation between small and medium-sized farms and pastoralists. There is a significant untapped potential for sustainable grassland and ruminant management, including their use by pastoralists. The importance of working animals has also been underestimated. Yet they are particularly useful in the context of peak oil, which leads to higher costs of mechanization. However, their effective utilization needs to be optimized at the local level, in particular as regards feed selection, right of passage[4] and the functionality of mostly inadequate equipment.

A. Effects of inexpensive energy and nitrogen fertilizers

The availability of cheap fossil fuel has driven the expansion of animal food production (i.e. the mast of cattle, pigs and chickens as well as the production of milk and eggs) (see the comments of Rundgren in chapter 1 and Heinberg in chapter 5 of this Review). This concerns the production, processing and transportation of animal products as well as plant and equipment. The ecological, climatic and socio-economic problems resulting from intensive animal husbandry and the related animal welfare violations analysed in this article are largely the result of the ample availability of inexpensive energy.[5]

Energy for the production of cheap synthetic nitrogen fertilizer is the main contributing factor in the expansion and intensification of animal production. Higher nitrogen fertilizer use becomes the leading driver of the increases in agricultural production in general. Its use has increased eightfold in the past 40 years (figure 1), while global cereal production has scarcely doubled. The still increasing amount of synthetic N fertilizer use is not only out of scale but is compensable by organic methods as animal fertilizer and compost as well as legumes in crop rotation. The increase in synthetic N fertilizer use, through its direct and indirect effects, is responsible for the biggest contribution of agriculture to climate change. In the production of synthetic nitrogen fertilizer (through the Haber-Bosch process)[6] some 5 tons of carbon dioxide (CO_2) are released per ton of ammonia, (Hellebrand and Scholz, 2005) and 2–5 per cent of the nitrogen fertilizer applied to the soil is released as nitrous oxide (N_2O), which has a global warming potential 296 times higher than that of CO_2. Some ammonia (NH_3) is also released (Sutton et al., 2011, see below).[7]

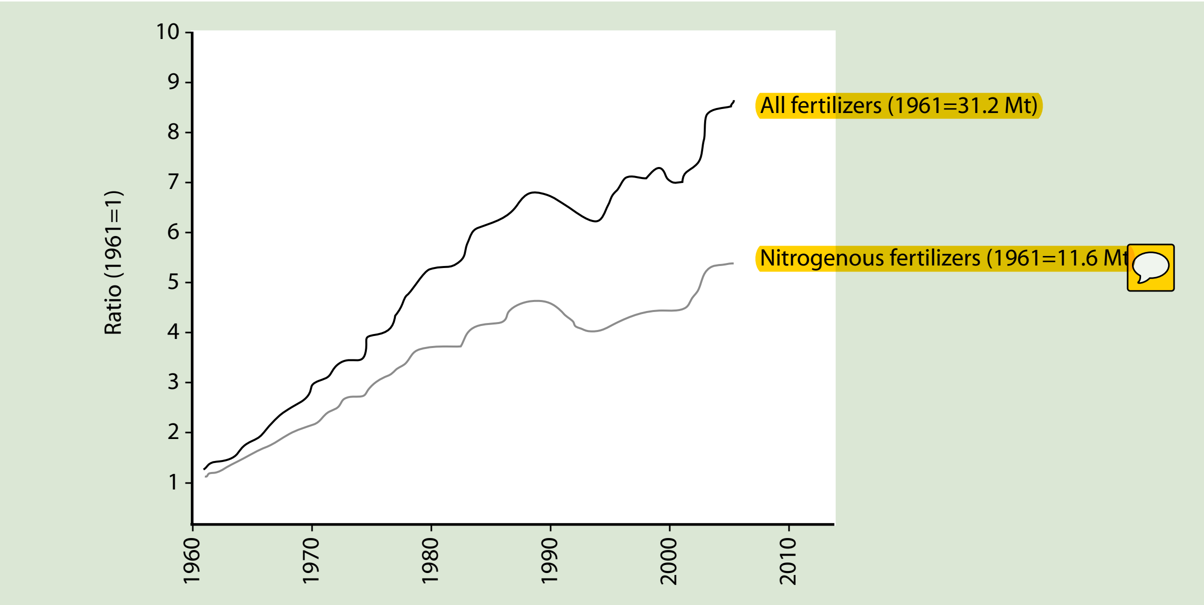
Over the past few years, livestock systems, have been identified as the main contributor to agricultural GHG emissions. One critical aspect is the increase in the total number of livestock. However, the extent of GHGs emitted depends on the given agricultural system. The system boundaries are key determinants of the resulting data concerning the GHG balance. Therefore, transparency regarding these system boundaries is a necessary condition for comparing the results of different studies. Since these boundaries are often either not clearly defined or set inadequately, most of the available studies are of limited analytical value and are hardly comparable.

As monocultures for animal feed cover almost 40 per cent of the global cropland, and animal feed absorbs virtually half of global cereal production, livestock is the main driver of climate change from agriculture.[8] In other words, the sustainability or intensity of feeding systems is key to the GHG balance of given agricultural systems (Schulze et al., 2009). Schulze et al. believe that the damage caused by N_2O as calculated by the Intergovernmental Panel on Climate Change (IPCC) is an underestimation, and suggest doubling the damage factor at the very least.

The high energy and fertilizer inputs in intensive livestock production have the following impacts, apart from the direct and indirect impacts on climate:

- The economies of scale associated with the non-internalization of ecological, social, health and climate costs allow cheap mass production of animal feed based on monocropping without crop rotation.
- The worldwide availability of inexpensive concentrate feed allows the rampant expansion of the number of animals, independent from the locally available animal feed supply.
- Synthetic fertilizers and pesticides substitute for crop rotation, including the green fertilizers and legumes required for nitrogen enrichment of the

Figure 1: World fertilizer consumption, 1960–2005



Source: Royal Society, 2009 (citing FAO, Fertilizer, 2009).

soil. As a result, the farm's internal supply of animal feed is drastically reduced.

With mounting numbers of livestock, the volume of animal excrements (faeces and urine) drastically soars. Most of the proteins fed to livestock in the EU originate from countries in South America, but the excrements are produced in European countries. At the same time, however, excrements lose their importance as natural fertilizers because of the high use of mineral fertilizers on the fields. For decades, research has been focusing on how to use synthetic nitrogen fertilizers more efficiently. Due to the contamination of the excrements with animal-administered drugs and disinfectants, they pose a huge disposal problem. As excrements are used less and less as natural fertilizers, related skills diminish and research on this subject is no longer done. A common way of getting rid of slurry is to dump it on pasture lands – often as a kind of waste disposal – which greatly reduces pasture quality.[9]

Box 1: Key findings of the European Nitrogen Assessment

The European Nitrogen Assessment (ENA), implemented in the 6th EU Research Framework Programme, focuses on the implications of the mounting use of nitrogen fertilizers in agriculture (Sutton et al., 2011). The authors of the Assessment reviewed the direct connection between inexpensive energy and the production of synthetic nitrogen fertilizer. The Assessment recommends more research on the interplay between the carbon and nitrogen cycles and their impact on soil fertility, climate and the ecosystem.

In the technical summary of the Assessment, Sutton and Billen (2011:XXXV), emphasize that "the deliberate production and release of N(r) [reactive nitrogen] in the Haber-Bosch process can be considered as perhaps the greatest single experiment in global geo-engineering that humans have ever made. (…) What was not anticipated was that this experiment would lead to a 'nitrogen inheritance' of unintended consequences with N(r) leaking into the environment in multiple forms, causing an even larger number of environmental effects."

The Assessment focuses on "five key societal threats" from excess nitrogen use, in terms of its impact on water quality, air quality, greenhouse balance, ecosystems and biodiversity. The authors state that "the understanding of N cycling has undergone a paradigm shift since 1990. Until then, the perception was that: (1) N(r) mineralization is the limiting step in N cycling; (2) plants only take up inorganic N(r); and (3) plants compete poorly for N(r) against microbes and use only the N(r) which is 'left over' by microbes. Since then studies have shown that plants compete effectively for N(r) with micro-organisms and take up organic N in a broad range of ecosystems" (Sutton and Billen, 2011: XXXVII). The authors also point out that till 1990 the impression that plants only take up inorganic N(r) demonstrates how industrialization of agriculture has influenced research and extension services in a one-sided way, and has eroded the importance of related local farming knowledge.

The authors highlight how little that "paradigm shift" has been taken into account in advisory and counselling services. They note, "In cereal farming, the use of only mineral N(r) fertilizers, instead of animal manures or composts, as well as the simplification of the crop rotation scheme that this had made possible, has in some cases resulted in a decline of soil organic matter. In the long-term this practice of using only mineral fertilizer has decreased the buffer capacity of the soil towards inorganic N inputs, thus increasing its propensity to N leaching." They add that "nitrogen-enriched terrestial ecosystems lose significant amounts of N via nitrate leaching and gaseous emissions (N_2, N_2O, NO, NH_3) to the environment. Estimates of denitrification to N_2 remain highly uncertain, due to difficulties in measurement and a high degree of temporal and spatial variability. There remain substantial uncertainties in the average fraction of N(r) applied to fields that is emitted as N_2O, ranging from 1% to 3,5-4,5% of fertilizer N applied, using bottom-up and top-down estimates, respectively." And regarding ammoniac, the authors conclude: "Further research is needed to better understand the relative contribution of direct and indirect N_2O emissions." (Sutton and Billen, 2011:XXXVIII).

How ineffective enforcement and implementation of existing nitrogen and related EU directives[a] have been becomes apparent in the authors' summary: "Europe (EU-27) is a hot spot in this sense, producing 10% of global anthropogenic N(r) even though its surface covers less than 3% of the total world continental area." (Sutton and Billen, 2011: XXXV). The authors also criticize the low procurement costs: "(...) the low price of N(r) fertiliser, combined with its clear benefits to agricultural production, does not provide a strong incentive for farmers to use less than the (private) economic optimum" (Sutton and Billen, 2011: XXXVI).

Source: (Sutton et al., 2011).

Note: [a] For instance, Nitrates Directive, Water Framework Directive, Groundwater Directive, Ambient Air Quality Directive, National Emissions Ceilings Directive, Urban Waste Water Treatment Directive, Marine Strategy Framework Directive, Integrated Pollution and Control (IPPC) and Habitats Directive.

Through economies of scale, farms where livestock production is still based on farm-generated feed come under increasing economic pressure. Industrial mega-farms or farms that are much larger than the regional average drive this trend (see also the commentary of Ostendorff in this chapter).

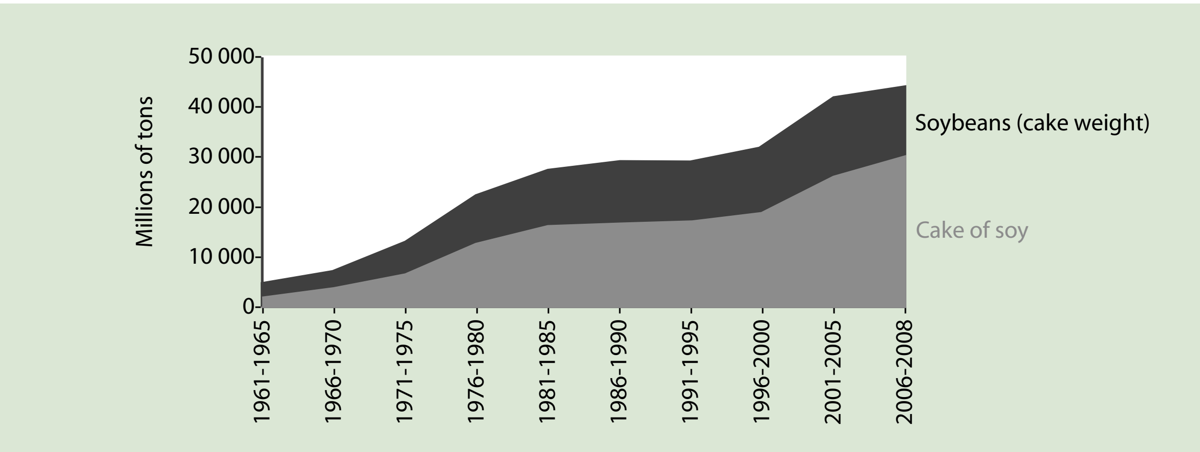
B. Sustainability requires a new definition of the terms productivity and growth

The conventional approach to agricultural growth aims at increasing crop yields per hectare, taking into account the costs of procured inputs such as energy, fertilizer, pesticides and labour. This calculation fails to consider not only the externalized costs (damage to soil, water bodies and air pollution through residues and contamination, as well as the social implications), but also the decline in soil fertility through soil erosion, compaction and nitrification – a development that has not yet been fully appreciated because of the ample availability of cheap synthetic fertilizers (Troeh, Hobbs and Donahue, 1991). For example, farmers in the United States apply fertilizers worth about $20 billion annually to offset the effects of soil nutrient loss due to soil erosion (Troeh et al., 1991).

There is a deplorable problem of perception, because efforts to strengthen intensive agricultural production and increase yields through enhanced use of synthetic fertilizers give the wrong impression that the production of animal feed is not in competition with food production. The negative impacts of the enhanced use of synthetic nitrogen fertilizers are not taken into account, and related costs remain externalized. According to the European Nitrogen Assessment (Sutton et al., 2011), the total costs of nitrogen pollution of water, the atmosphere, and other impacts on ecosystems and climate change are estimated to be between €70 billion and €320 billion per annum (i.e. €150–€736 per person per year), which is more than twice the monetary benefits derived from nitrogen in agriculture.

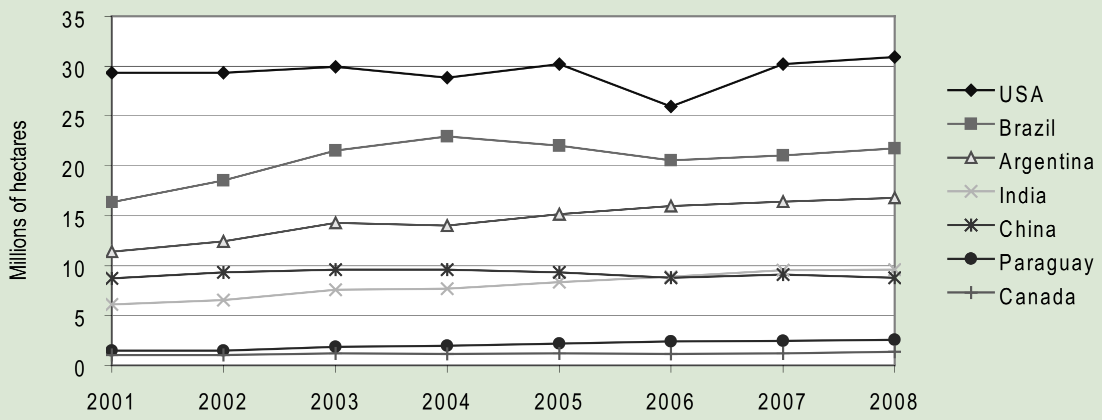
Between 1961 and 2009 the number of animals reared for meat and dairy production increased rapidly. According to the FAO (FAOSTAT, 2011), in 2009 a total amount of 1.38 billion heads of cattle and buffalo were reared globally – the number doubled during the last 50 years. During the same period, the number of pigs more than doubled, from 406 million to 941 million. The number of chickens grew the most dramatically: almost fivefold, from 3.8 billion to 18.6 billion. Since not only the number of animals increased, but also the average weight per animal, meat production rose at an even faster rate: beef production more than doubled, to 62.8 billion tons in 2009, pork production quadrupled, to 106.3 billion tons, and chicken meat production increased tenfold, to 80.3 billion tons. This rapid expansion of global meat production was only possible because the feed supply for the animals increased at a similarly dramatic rate. The EU is a prime example in this respect. Its imports of soybean cake – a crucial source of protein in intensive and industrial animal production – rose tenfold between 1961 and 2009, and now stands at almost 44 billion tons per year (figure 2). The focus on cake is because

Figure 2: EU imports of soybean cake and soybeans 1961–1965 to 2006–2008 (millions of tons)



Source: Authors' calculations based on FAOSTAT, 2010.

Figure 3: Area under soy cultivation: selected countries, 1991–2007 (millions of hectares)



Source: Authors' calculations based on FAOSTAT.

only this is used as animal feed, while soybean oil is used for human consumption, industrial and energy use.

C. The role of agricultural and trade policy in the industrialization of animal production

An important driver of this development has been the EU's Common Agricultural Policy (CAP) and its link to trade policy. Until the early 1990s, the EU guaranteed prices for livestock products – especially beef and dairy products – that were significantly higher than world market prices. This provided an effective incentive for European farmers to increase production. At the same time, the CAP intervened in the markets for feedstock. While high prices for cereals in the EU were also guaranteed, there was no support for oilseeds and their products – oils and cakes. This situation is also reflected in the EU's agricultural trade policy: while livestock products and cereals were, and generally still are, protected by high tariffs, oilseeds and their products have experienced no, or only very low, tariffs. These tariffs were fixed multilaterally in the General Agreement on Tariffs and Trade (GATT), the predecessor of the World Trade Organization (WTO).

In the 1980s, the EU attempted, relatively successfully, to support oilseed production with other policy instruments, such as production premiums. However, these were found to run counter to its GATT commitments. With the shift from price support to payments based on the area planted with certain crops, some support for oilseed production could be provided. However, the Blair House Agreement, a bilateral agreement between the European Community and the United States, which paved the way for the WTO Agreement on Agriculture, placed a limit on the area planted with oilseeds in the EU that could benefit from payments. As a result, the EU's imports of soybeans and soybean cake, which had remained at roughly a constant level in the 1980s, started to increase in the 1990s. The BSE crisis in 2000–2001 gave an additional boost to EU soy imports. In these years alone, the EU's soy imports jumped from 33.7 million tons to 40.2 million tons (FAOSTAT and authors'calculations).

The EU's rising import demand was mainly met by South America, especially Argentina and Brazil, where the area planted with soy rose from just over 10 million ha (in both countries combined) in 1980 to over 48 million ha in 2009 (figure 3). This triggered the massive deforestation of the tropical rainforests in Brazil and the conversion of grasslands (*cerrado* in Brazil and *pampas* in Argentina) to cropland.

It is estimated that the land-use changes directly related to the expanded soy production in Argentina, Brazil and Paraguay were responsible for, on average, over 420 million tons of CO_2-equivalent (CO_2e) emissions annually between 2000 and 2009 (Reichert and Reichardt, 2011). This amounts to about 18 per cent of the total GHG emissions of these countries.[10]

The rapid expansion of feed, in particular, enabled the EU not only to meet its rising demand for meat and dairy products, but also to become a net exporter of beef, dairy products and pork. Since the guaranteed domestic prices were usually significantly higher than world market prices, exports were only possible through "refunds" for exporters, which covered the difference between the internal and external prices. These "export subsidies" turned out to be a major issue of conflict in international trade. The significant European exports of animal products (as well as wheat and sugar) gave the wrong impression that the EU was producing overall agricultural surpluses. The fact that this was only possible because of the ever-increasing imports of animal feed was largely neglected in the public debate.

Consequently, the reforms of the CAP in the early 1990s focused on cutting down surplus production by reducing guaranteed prices for cereals and beef, and (initially) to a much lesser extent, for milk. The income losses were partly compensated by specific area payments to farmers. One condition for receiving those payments was that a certain proportion of arable land would have to be kept idle – the most direct instrument for addressing the "overproduction" problem. The amount of land to be "set aside" was fixed by the EU on an annual basis, depending on market conditions. On average, it was around 10 per cent of the cropland. As a result, exports of cereals and beef fell significantly, and while the EU remains a net exporter of wheat, it is now a net importer of beef and sugar. At the same time, net exports of pork more than doubled, from around 400,000 tons annually in the late 1980s to around one million tons annually in recent years. The figure for 2008 was as high as 1.4 million tons (FAOSTAT). The expansion of pork production and exports was less directly linked to agricultural policy instruments, and more a result of the increasing industrialization of animal production discussed earlier.

Since the animals are separated from their natural environment, and feed can be sourced globally, the suitability of a certain area for animal and feed production is less important than the infrastructure for transporting and processing feed and animals. The animal breeds and the barns for industrial animal production have also become globally standardized. As a result, northern France, northern Germany, Denmark and the Netherlands, with their proximity to Rotterdam as the largest port for receiving imports of soybeans and soybean cake, along with a well-developed infrastructure and a mature food industry, have become the main pork (and chicken) producing regions in the EU. This has been partly supported by CAP-related investment assistance through subsidized interest rates.

In sum, the intensity of livestock production is decisively determined by the intensity of animal feed, which in turn is correlated with the enhanced use of energy and synthetic fertilizers for the production of that feed. This is why a comparative analysis of the ecological and climate balance of livestock production requires data on where and how the animal feed was produced. In this regard, the land-use changes required for intensive and monoculture-based feed production are a particular source of concern with regard to their social, ecological and climate impacts.

The dependence on foreign fodder sources is only one outcome of the fundamental change in agricultural livestock systems. Another main driver of industrial agriculture is that food retailers are demanding increasingly standardized products in terms of quantities, sizes and fattening periods. Since the 1960s, standardization by and for industrialized meat and dairy production systems has resulted in the replacement of wild and cultured, biodiversity-rich land by monotonous landscapes. As a result, wild biodiversity suffers, as reflected in the decrease in wild bees (in many areas sufficient pollinators are lacking), butterflies and hedges, for example. The loss of breeds and the low, regular utilization of the remaining ones lead to the loss of traditional knowledge.

The many years of State support for performance testing and estimation of breeding values, aimed uniquely at achieving more (financial) yield per unit, ran contrary to the goals relating to "genetic diversity" as embodied in the Convention on Biological Diversity (CBD) (IOeW et al., 2004). The CBD is based upon three pillars that represent the aims of international policy in future development: (i) conservation of biological diversity, (ii) fair and equitable access and benefit sharing of biological diversity, and (iii) the sustainable use of animal and plant genetic resources and their habitats. As wildlife and wild plants need their specific environments/habitats, plants and livestock breeds need a "cultured habitat" of which they are a part, and thus influence and are influenced by that habitat. If the genetic resources of animals and plants are not used, they disappear as part of the whole system and can no longer play their part in their system. Agro-biodiversity should be used in a way that develops it further, rather than being "underutilized" as at present, and therefore risking disappearance.

D. Risks associated with selective breeding for higher productivity

Although selection is aimed at high performance in both animal and crop breeding, there is a major distinction between the two. A certain and increasing proportion of crops, such as vegetables, are grown in greenhouses or under plastic foil for commercial purposes. However, the vast majority of crops are still planted in the open and are exposed to the vagaries of the weather (unlike animals). Since the 1950s, animal production, by increasingly relying on animal feed (and their imports), synthetic growth hormones, vitamins, amino acids and mineral supplements, has become less dependent on location (Idel and Petschow, 2004). A growing number of chickens, pigs and, increasingly, cattle are raised in a way that completely shields them from the effects of the sun and the weather.[11]

Breeding increasingly overburdens animals that have been selected to maximize their production. For example, hens that are bred to maximize egg production generate about 300 eggs per annum; chickens selected for meat production reach their slaughter weight after less than five weeks of intensive raising; young pigs, less than six months old, are slaughtered when they reach about 100 kg; and some cows are bred to maximize milk production, delivering over 10,000 litres during one lactation period alone (most of them do not get older than five years, because of these excessive performance requirements). Many of these animals suffer from "occupational" diseases, such as inflammation of the fallopian tubes in hens, udder inflammation of cows, or problems with joints in pigs, hens and cattle caused by excessively rapid weight gain (see also the commentary on animal welfare issues of D'Silva in this chapter).

The tenet that "performance is an expression of good health" is no longer valid. Indeed, forcing their enhanced performance causes animal stress and "burnout" (in poultry, pigs and cattle for mast) resulting in a short life span (dairy) and requiring the frequent administering of drugs such as antibiotics and analgesics. In addition, hormones are being widely used to overcome fertility problems of cows that are bred for maximizing milk production. Generally, high external input systems aim at minimizing the energy losses of animal bodies caused by physical movement and adaptation to changes in temperature and feed. This ostensibly reduces the energy consumption of body functions and maximizes the production of animal products. These consistently restrictive conditions are a major factor that contributes to the breeding of uniform animals and their selection for high performance.

As a result, the flexible adaptive capacity of animals to changing and divergent production conditions has been replaced by inflexible, static and location-specific behaviour. An extreme example is the use of standardized cages for hybrid hens, whether in California, Hong Kong, Norway or Oman. The light and temperature in the sheds where the cages are kept, along with the concentrated feed and limited physical movement, are all designed to ensure maximum and standardized egg production. Generally, the adaptation is achieved at the cost of adaptive capacity: the animals have few reserves to respond to changing environmental conditions such as variations in temperature, feed or stress from transport. Despite this being common knowledge, this stress from breeding is dealt with not by changes in breeding practices, including breeding goals, but only by changing the raising methods: chickens' beaks and pigs' tails are trimmed and the animals are often held in stress-reducing dimmed light in order to reduce the extent and consequences of cannibalism among the animals that results from enhanced stress (Compassion in World Farming, 2009a). In addition, antibiotics are increasingly used to treat the greater incidence of illness among animals resulting from high-performance breeding.

The development of a solid immune system in animals, which is so important for open-air rearing of animals, receives little attention under such conditions. Besides the greater susceptibility to illness in animals, the targeted selection for maximum performance raises other animal protection and welfare issues. As the performance of female animals directly correlates with the targeted selection in breeding, fattening performance declines and with it the performance of male animals. For example, the fattening of brothers of egg-producing hens is considered uneconomical. As a result, in the EU more than 300 million male chickens are killed each year as soon as they hatch. Similarly, in the United Kingdom, for instance, male calves of breeds that are selected for maximizing milk performance are killed – some 150,000 each year (Weeks, 2007).

Ignoring the animal health and welfare issues associated with this development, genetic engineering has been used for decades to maximize animal performance. And in spite of extensive public and private research on genetic manipulation over the past 30 years, until today no transgenic animals are used for commercial agriculture purposes owing to significant biological and technical problems (Then 2011, and 2012). As early as the mid-1980s, some researchers envisaged the technology-linked failure of transgenic manipulation. This failure became the engine for cloning research. The objective was to clone transgenic individuals in those exceptional cases where they had desirable properties and no or few unintended problems. Yet cloning too has been relatively unsuccessful in the past 25 years, with the rare successes due mainly to coincidence.

Only a few viable animals have been produced using the "Dolly method".[12] According to the European Food Safety Authority (EFSA, 2007: 9), "(T)he overall success rate of the cloning procedure is still low and differs greatly between species. The overall success rate, expressed as the percentage of viable offspring born from transferred embryo clones, ranges approximately from 0.5 to 5 %, depending on the species." Of the surviving cloned animals, "Dolly" remained a unique specimen. The hope that whole stables could be filled with animals cloned from one individual in order to achieve an identical fattening result with a standard and economical feeding and treatment regime – a hope of unlimited mass industrial production – has remained a distant dream. In any case, sameness in terms of desirable fattening and other performances would lead to greater vulnerability to sickness and contagion.

Already, the current practice of the use of only a few commercial animal races and hybrids for industrial livestock production is leading to a loss of genetic diversity, and carries the risk that animals are more vulnerable to infectious diseases and pests. This interrelationship has been analysed at length by an international team of researchers (Muir, Gane and Zhang, 2008). With regard to chickens, for example, the findings confirm that almost all animals raised for poultry meat (some 19 billion worldwide) are based on only three races, and hens raised for maximum egg production stem from only one race.

E. The push for biosecurity poses a threat to animal and consumer protection

Over the past few decades, the immune system has increasingly been perceived as a mere protection system, primarily against bacteria, rather than as an interface between the worlds of micro- and macroorganisms. As a result, two facts have been overlooked: bacteria are an indispensable component of our immune system; and bacteria have existed much longer on our planet than humans, so that our development over millions of years has been more with rather than against bacteria.[13]

Since the immune system links us to our environment, reacting to each pathogenic problem by enhancing sterility (by attempting to eradicate all microorganisms) poses a risk to our future development. Thus the belief that this strategy enhances security – also called biosecurity – is a fallacy. It *m*ay work in some individual cases, but it increases the inherent risks and may compound future problems. In particular, the regular and extensive use of antibiotics and disinfectants for human and animal health unavoidably leads to the emergence of pathogens with higher resistance and infection potential.

By way of illustration, the bacterium *Pseudomonas aeruginosa*, which is resistant to many antibiotics, can survive disinfectants and even thrives on hygiene products. Such extremes have been known for decades as "hospital germs", because they have mushroomed in hospitals. The principle is the same: the unintentional selection of more and more dangerous germs. The more resistant a germ already is to treatment with antibiotics, the greater the likelihood that it will survive the next wave of treatment with antibiotics and disinfectants.

Against this background, "biosecurity", through repeated use of new antibiotics and disinfectants, is not only no solution, but in the long term it is also highly risky. Humans and animals need the contact with microorganisms for strengthening their immune system, in particular at the juvenile stage. Thus ostensible "biosecurity" in intensive livestock production is a problem in that it hampers the development of a healthy immune system and it strengthens the resistance of germs and pathogens, making it increasingly difficult for the chemical and pharmaceutical industry to contain those germs and pathogens. The evolutionary dynamics of germs allows them to (quickly) adjust to new antibiotics or

Box 2: Reasons for the insufficient perception of the potential of sustainable agriculture to contribute to food security and sustainable rural development

- The destruction, waste and contamination of resources associated with the industrialization of agriculture have created a misconception that agriculture always and generally poses a problem. Thus it proves to be extremely difficult to perceive the potential for sustainable agricultural development in grassland, livestock and cropland management.
- For decades, more and more intensified agricultural practices have damaged the environment. Thus, one of the main objectives of nature protection has been seen as taking land away from any kind of agricultural production. This has indirectly and unwittingly led to more "collateral damage" by creating greater pressure for further intensifying production on the remaining agricultural land. It has been based on the perception that the more intensively existing land is used, the greater will be the available area for nature conservation. It overlooks the fact that it is industrial agriculture that has exerted pressure on resources and land use, and led to widespread contamination of land in general.
- The availability of ample, relatively inexpensive energy and synthetic fertilizers has distracted attention from the importance of soil fertility, as the most basic and precious resource of agriculture, and its loss through erosion. Related to that, the potential of sustainable grassland management and pastoralism for global food security, soil and climate protection has been, and still is, underestimated, and therefore the long-term dangers of converting permanent grassland to other uses are overlooked.
- The inherent growth and productivity pressure of industrial agriculture has devastating impacts on our environment and well-being, and thus violates the third pillar of the CBD (i.e. the sustainable use of animal and plant genetic resources and their habitats).
- Any attempt at maximizing single crop yields is irreconcilable with the optimization of ecological services. Yet public and private support to seeds, cultivation, plant protection and fertilization focus entirely on such a yield maximizing strategy. Conversely, the means for exploring and studying the ecosystemic potential of agriculture and specific production systems or methods in different landscapes have been woefully inadequate.
- The economic interests of different economic actors that derive significant profits from the industrialization of agriculture, including the use of chemical inputs, are one of the main reasons for the lack of implementation of the key recommendations of the International Assessment of Agricultural Knowledge, Science and Technology (IAASTD), namely the prevention of social, environmental and climate damage; internalization of environmental externalities; and analysis and further development of the multi-functionality of ecosystems (McIntyre et al., 2009).

antiviral drugs. This often happens much faster than the time required by research teams to develop new and effective medicines.

There should never have been a competitive race between chemical treatments and microorganisms, as the latter have evolved over a period of about 2.5 billion years. Only exceptionally aggressive and resistant cases are perceived by the general public as a real danger, but even those cases have become more frequent over time. Even so, the general tendency and the fatally latent danger are being ignored.

F. Deforestation and animal feed production

Box 2 lists some explanatory factors for the lack of awareness of the potential of sustainable grassland management with ruminants for achieving food security and sustainable development. There is a widespread belief, that rainforests are being destroyed only to be converted to land for pasture. In reality, however, the cutting of forests is often triggered by a sequence of income-generating cycles, of which pasture for cattle is one. Contrary to prairies and pampas, the soils of tropical rainforests have a lower content of grass seeds and are less fertile because of the washing out of nutrients. This is why deforested areas tend to be used sometimes only temporarily as pasture, and thereafter for growing crops for fodder production and, increasingly, for biofuel production.[14] The expansion of agrofuel production and related land-grabbing offer the opportunity to raise the public's awareness of the ecological and social consequences of animal feed production on former forest and pasture land.

Through the pressing of soy, about 20 per cent of oil can be generated in volume terms and 80 per cent is left over as cake (bruised grain). Future discussions on soy cultivation should include an understanding of this commercially attractive dual character of soybeans relative to other leguminous crops such as rape seeds. Apart from attractive prices in different markets, it is also likely that demand in the three market segments – soy cake for animal feed, and soy oil for vegetable oil and biodiesel – will increase further, and thus provide producers and milling companies with greater flexibility. Moreover, soy cake for animal feed provides approximately the same income as the 20 per cent share of the soy oil used as vegetable oil and biodiesel.[15]

As is the case for permanent grassland, in (mostly non-rain-)forests too the largest share of the stored carbon can be found in the soil. Because of the visible above-ground biomass, it is generally perceived that forests are more important for carbon storage than grasslands, when in fact grasslands are globally as important. In addition, there are two distinctions between grasslands and forests: unlike permanent grasslands, the storage of carbon in forests is subject to saturation; and, in contrast to permanent grasslands, commercially used forests will, in the long term, always be harvested and large parts of the carbon stored in the biomass of the soils will end up being released into the atmosphere. Instead soils under grazed pastures are always covered.

G. Grasslands and ruminants: an example of misconceptions and opportunities[16]

Cattle rearing is an illustrative example of how non-transparent and illogical system boundaries can lead to wrong conclusions, including the misconception of the cow being a major contributor to climate change.

First, there is the issue of an excessively generic analysis of animal husbandry, which does not distinguish between different production systems. Instead of a comparative analysis of data of resource-efficient sustainable production, on the one hand, and energy-intensive industrial production, on the other, very often average values are used. Second, the analysis is mostly confined to only one GHG – methane – and excludes N_2O emissions mainly caused by the use of synthetic nitrogen fertilizers for intensive production of animal feed. Third, a sound assessment of the effects of agricultural production on climate requires taking into account not only emissions, but also cycles, as sustainable agriculture and forestry are the only economic activities with the potential to provide natural sink functions (carbon sequestration).

However, regarding the relevance for climate, in the relatively common emission comparisons between cattle raising and vehicular traffic, cattle tend to fare badly. As an apparently logical result of such comparisons, even more intensive livestock production is being advocated, in particular that of chickens and pigs (Würger, 2010). But this neglects to take account of carbon and nitrogen cycles, and, in particular, the positive effects of sustainable grassland management for the climate as a whole. The related importance of grassland is based on the vast area it covers, accounting for 40 per cent of the global land surface. Sustainable pasture management enhances soil fertility linked to carbon-rich humus, and thereby 1,0 ton of humus removes 1,8 tons of CO_2 from the atmosphere, as each ton of humus contains more than 500 kg of carbon.[17] A prominent example in this regard is grazing, which allowed prairie soils over millennia to reach a depth of several metres.

Why do cows generate methane, which has a global warming potential 25 times higher than CO_2?

Cows can only digest grass through the symbiosis of billions of microorganisms in their rumen (paunch). Part of these microorganisms can decompose cellulose and lignin in grass and thus make the nutrients contained therein available to the cows. In the course of this digestion process methane is generated by microorganisms. And just as humans exhale CO_2, cows exhale both CO_2 and methane. Through this symbiosis, ruminants such as cows do not compete with human beings for food – an ability inevitably linked to methane production.

The exclusive focus on methane from cows is short-sighted, if the analysis is confined to emissions and their potential negative effects. Some data from Europe illustrates this crucial point. It is N_2O, and not methane, that constitutes the largest threat to climate in the context of livestock production. Livestock production is responsible for 75 per cent of all N_2O emissions and 90 per cent of all ammonia emissions, in particular due to intensive fertilizer use for the production of animal feed. Whereas methane has a global warming potential 25 times higher than CO_2, the global warming potential of N_2O is 296 times higher than that of CO_2. It is assumed that, on average, 2–5 per cent of consumed nitrogen fertilizers are converted into N_2O (Sutton and Billen, 2011; Schulze et al., 2009).

Against this background, besides its adverse ecological impacts, intensive feeding of livestock in the context of global hunger and warming has three

Box 3: Erroneous conclusions on extensive and intensive livestock production systems due to ill-defined system boundaries

In order to give a stronger impetus to sustainable production in agricultural policy, research and extension in the future, it is imperative to objectively evaluate the different agrarian systems. To date, sufficient comparative studies are lacking. In addition, there are significant deficiencies in terms of the comparability of data and the lack of transparency concerning the specific system boundaries. This often leads to data not being correctly assigned, which risks leading to erroneous conclusions. A prominent example in this regard is the study by Steinfeld et al. (2010), which does not distinguish between extensive and intensive production systems. In that study, only one table on major fluxes of carbon associated with intensive and extensive livestock production systems (Asner and Archer, 2010: 73, table 5.1) attempts to provide a separate account of carbon fluxes for each system. But that table has numerous analytical problems and goes so far as to suggest that extensive livestock systems would have significantly higher negative climate effects than intensive systems.

Important carbon streams under intensive and extensive livestock production systems

Category	Extensive	Intensive
CO_2 emissions from production	**(Gt)**	**(Gt)**
Nitrogen fertilizers for animal feed crop production		0.04
Fuel for transport of feed to production facility		0.06
Fuel for transport of animals in the production facility	0.03	0.03
Plouged cropland		0.02
Unploughed cropland		0.01
Processing of animals		0.03
Fuel for transport outside the production facility	0.001	0.001
Ecologically-related CO_2 emissions		
Desertification	0.2	
Deforestation in the tropics	1.2 (1.7)	
Spreading of bushy areas	- 0.3	
Methane emissions of livestock		
Digestion of ruminants	1.5	0.2
Liquid and solid manure	0.2	0.2
Total CO_2 emissions	1.1	0.2
Total methane emissions	1.7	0.4
Total GHG emissions in CO_2 equivalent	3.2	

Source: Asner and Archer, 2010: 73, table 5.1.

First and foremost, it is surprising that the sum of emissions from extensive livestock production systems is estimated to be 3.2 gigatonnes (Gt) and thus is higher than the sum of emissions of the individual items. An explanation for this is not provided. Estimates for total emissions from intensive production are not provided at all.

Our criticism regarding this accounting approach concerns, in particular, the assignment methodology:

- Emissions caused by deforestation are entirely accorded to grassland management (i.e. to extensive management methods). However, in reality, pasture usage is often only an interim use of the conversion of land that is eventually changed to cropland (nutrient-poor soils of tropical forests are converted to cropland relying on external fertilizer inputs). The fact that soy cultivation is responsible for some 17 per cent of deforestation is mentioned in the study's text, but the table accords these emissions entirely to extensive production systems, even though soy meal as animal feed is a central component of intensive production systems.

- Although a figure for CO_2 emissions related to fertilizer production for animal feed production is provided and is related to intensive livestock production, N_2O emissions are not accounted for. A footnote explains that those emissions are excluded because they are dealt with in another chapter. Although the importance of N_2O emissions in intensive systems is indeed highlighted in that other chapter, its impact on climate is not quantified.

Box 3: (continued)

- Emissions caused by land degradation are only calculated for extensive systems, whereas land degradation resulting from intensive animal feed production remains unaccounted for.
- Methane emissions linked to faeces generation are considered to be of the same magnitude in extensive and intensive systems, although methane is not generated in manure under the aerobic conditions of extensive pasturing.

As a result, even this analysis, which purports to provide an overview of the available scientific knowledge regarding intensive versus extensive production systems, contains some serious methodological shortcomings. It is apparent that the comparative analysis underestimates the negative environmental and climate impacts of intensive production systems and overestimates those of extensive production systems. This renders the results and the policy recommendations scientifically questionable.[a]

Note: [a] For a more elaborate critique, see Idel, 2010 and 2012.

additional adverse effects:

- Livestock are competing with humans for food. Normally, livestock, particularly cattle, should derive their feed from agricultural land or soils that cannot be used for direct food production for humans. On the contrary, cattle can generate milk and meat from grass and they can also provide productive power.
- The intensive production of animal feed has direct and indirect impacts on climate through
  - Nitrous oxide, ammonia and CO_2 emissions caused by synthetic nitrogen fertilizers;
  - Increased methane emissions linked to the huge scale of industrial livestock production and the excessive use of (unnatural) concentrate feed;
  - Excessive generation of animal excrements related to large-scale production and unnatural feeding;
  - Higher gas emissions through the mixing of urine and faeces caused by a lack of pasturing that would allow natural segregation.
- The increased use of concentrate feed displaces the consumption of grass, and thereby removes the following positive effects of pasture on climate:
  - The permanent and dense grass cover protects soils and prevents their erosion.
  - Sustainable pasture and grassland management promotes the biological activity (photosynthesis) of grass and its roots. In addition, microorganisms, particularly worms, convert biomass into humus, which contains over 50 per cent of carbon.[18]

H. Grasslands of the world[19]

In 2005, the Food and Agriculture Organization of the United Nations (FAO) published a survey of worldwide grasslands (Sutti, Reynolds and Batello, 2005). Grasslands in semi-arid zones contain *green* grass only for a short period after the rainy season, which is otherwise characteristic of the rain-intensive regions of the world. Climate experts of the Grassland Carbon Working Group studied the importance of grasslands as carbon sinks and published country-specific information on grassland ecosystems. Grassland covers a total area of 52.5 million km^2, i.e. about 40 per cent of the total land surface of our planet.[20] (White, Murray, and Rohweder, 2000). According to the FAO, grassland accounts for about three quarters of the 4.9 billion ha of agriculturally used land. Even so, knowledge about its specific properties for each climatic zone is surprisingly limited. As a result, the potentials of grasslands[21] are grossly underestimated and are not part of the debate on the future of our planet. This could and should change.

The giant grasslands of the world store in their soil more than a third of the global carbon stock. In savannah soils, it is estimated that more than 80 per cent of the biomass can be found in the roots (Reichholf, 2004; Grace et al., 2006). However, as grasslands receive little attention, it is highly likely that their ecological, agricultural and climate potentials are not fully perceived. The ploughing of grassland causes huge losses of carbon and biomass contained in the soil – in many regions up to a third of the stored amount (Guo and Gifford, 2002; Poeplau et al., 2011). So far, the increasing demand for protein- and energy-rich animal feed for industrial livestock production has been one of the main factors behind the removal of tropical rainforests and the conversion of grassland to cropland (Don et al., 2011). Additionally, the rising consumption of biofuels is taking its toll. Many monocultures not only destroy ecosystems, but are also questionable from an energy point of view, if one deducts the energy input for their production from the energy output (particularly due to the expanding production of both concentrate feed and biofuels). Sustainably used grassland can generate a higher volume of usable energy per unit of land than ethanol from maize. At the same time, it can make a higher contribution to the reduction of GHG emissions and increase soil fertility. Trials in the United States have shown that yields from permanent grasslands over a decade surpassed those of monocultures by 238 per cent (Tilman, Hill and Lehman, 2006).

I. Global landscape gardeners

In grasslands, roots play a crucial role in humus generation. Simply put: the roots of today are the humus of tomorrow. Whereas crops only grow during their vegetation period until they are harvested, grass in permanent grassland forms more and more root biomass virtually on a permanent basis as long as daylight and a minimum of humidity are available and temperatures are still slightly above zero. The formation of roots directly depends on the rhythm of the pasturing. Very important in this regard is that grassland should have constructive pauses during pasturing so that grass plants can recover and obtain, besides water and CO_2, sufficient organic nitrogen and other nutrients from the excrements of grazing animals. Thereafter, solar energy through photosynthesis drives the growth of new grass and additional root biomass.

An illustrative example for such a natural process – including regenerative periods – can be found in the biggest annual migration of animals on our planet: the migration of the huge herds of gnus in Africa. Safaris there offer a retrospective view of nature's history: as all other grasslands, savannahs emerged from the co-evolution of grass plants and grazing animals. Huge herds of bison and aurochs (ancestors of today's domestic cattle) contributed to the development of soils in Eurasia, although they have disappeared from the collective memory of human settlers. In contrast, many Americans today still recall stories of their ancestors about the huge herds of bison. The number of bison that populated the prairies of North America in the early decades of the nineteenth century is estimated to have been about 30 million animals. Today, North American soils suffer from an average humus loss of more than 25 per cent. This also applies to prairie soils several metres thick on which monocultures such as soy, maize or cereals have been cultivated for decades. However, the better the situation in some preferential locations, the lower is the perception of existing problems. In order to show that soil quality and fertility are suffering from industrial soil management systems, the humus content of soils needs to be regularly monitored and documented.

J. Cattle as ideal users of feed

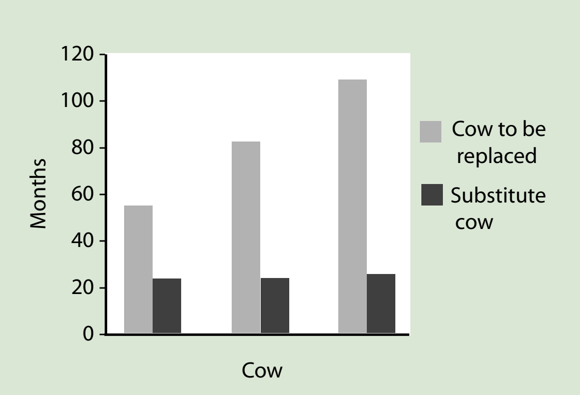
Taking account of carbon and nitrogen cycles not only leads to a different assessment of the impacts of agriculture on climate; it also provides a different perspective of animal husbandry, particularly that of ruminants. Ignorance with regard to the potential of grasslands arises from the misconception that cattle are poor feed users, which, since the end of the 1970s, has also been taught to students. In this regard, cattle and other ruminants are not contextualized as animals that developed in co-evolution with grasslands over thousand of years, using grass and hay as fodder that, without additional labour, was turned into meat and milk. Instead these ruminants are assessed in terms of their efficiency in digesting cereals, maize and soy.

The fact that cattle consume, on average, 7 kg or more of cereals per kilogram of beef (a figure which exceeds the intake of pigs and chickens[22]) is a result of a faulty system, not faulty animals. It does not take into consideration their negative impact on resource consumption because of inappropriate system boundaries. The widespread assumption that one cow, which produces some 10,000 litres of milk annually, would be better for the ecosystem and the climate than two animals providing 5,000 litres each is questionable because:

1. The higher the production performance of cows per day or per year, the more intensive the required feeding practices. It is only possible to achieve a production of more than 6,000 liters of milk per cow per annum through greater intensity of feeding based on concentrate feed. Such feed in turn is produced as a result of very high inputs of biological and fossil resources, involving higher emissions of CO_2 and N_2O.
2. Non-high-performance cattle can satisfy their entire demand for feed by consuming roughage without any external fodder supply.
3. Sustainably used pastures can contribute to humus accumulation and thus help to reduce atmospheric CO_2 through carbon fixation.

4. Nearly all cows with an annual milk production of 5,000 liters have a longer than average life span. Conversely, most cows with an annual milk performance of 10,000 liters have a shorter than average life span. The higher the milk production of the animal per day or per year, the higher the risk of its vulnerability to diseases and burnout. This is the reason why the average life span of a cow in Germany, for instance, has fallen to less than five years. Burnout, infertility and mastitis have become "occupational diseases" of dairy cows, resulting in their being slaughtered prematurely, and statistically they produce only 2.3 calves.

Figure 4: The importance of cow longevity to protect the environment, the climate and the economy



5. In addition to the life span of the cow to be replaced, fodder and additional labour as well as GHG emissions by the substitute cow need to be taken into account. Figure 4 shows that irrespective of the age of the cow destined for slaughter, the age of the substitute cow is always the same. The latter is about 28 months old: 19 months at the time of insemination plus nine months gestation. The replacement rate of a production unit indicates the percentage of cows that will have to be replaced annually to keep the dairy production rate unchanged. In production units with a very high dairy performance, the replacement rate often exceeds 50 per cent. That is why longevity leads to lower replacement rates. High replacement rates thus imply that, in addition to the direct ecological effects of dairy cows, the ecological and climate impacts of the substitute cows have to be taken into consideration in evaluating their dairy performance. The earlier a dairy cow has to be slaughtered, the longer is the period that a substitute animal needs feeding and emits GHGs. For a dairy cow younger than 5 years, a substitute animal will have to be reared during half of the lifetime of the cow to be replaced. Thus, any productivity calculation of a dairy cow should not be confined to its annual milk, but should also take into account its performance over its lifetime (Idel, 2008).

6. In the performance balance, all too often only data for produced milk are provided, which do not represent the volume of marketable milk. Pressures for increasing dairy production result in a certain share of milk originating from diseased cows, which cannot be sold because the cows are being treated with antibiotics.

7. To arrive at a correct calculation of the productivity and the impact on climate of a dairy cow, its own beef production and that of its progeny also have to be taken into account. Dairy and beef performance are normally negatively correlated – the higher the dairy production of a cow breed, the lower its meat output, in particular that of the sons and brothers.[23] Comparing a production system with an average milk production of 5,500 litres relative to one producing 9,000 litres per year, Rosenberger and Rutzmoser (2002) note that the latter shows significantly higher emissions of methane (15.7 per cent higher), nitrogen (32 per cent higher), and phosphorous (31.7 per cent higher).[24]

The industrialized agricultural production system excludes livestock from grasslands and increases the input of protein-rich concentrate feed derived from maize, soy and cereals, resulting in a situation where cows and humans compete for food. In the context of such intensive feeding systems, ruminants, confusingly, are considered inefficient fodder consumers relative to pigs and chickens. In terms of feed consumption and output, one cow does therefore not equal another.

Cattle, sheep and buffaloes have the wonderful capacity to digest pasture forage in symbiosis with microorganisms in the rumen and turn it into milk and meat. In this sense, cattle are ideal fodder consumers and are therefore predestined for grazing in those areas that are suitable as pastures or grasslands. In addition they can use grass resulting from green fertilization through sustainable crop rotation in order to produce milk, meat and labour. Accordingly, it is only at first glance that milk and meat from intensive production appear to be cheap. The true costs of intensive animal feed production are reflected in terms of: (i) damage to the ecosystem and the climate; (ii) reduction of biological diversity; (iii) the conversion of permanent grassland and converted rainforests (including the CO_2 thus released from their carbon-rich soils); (iv) oil consumption for the production of synthetic nitrogen fertilizers and agrochemicals; (v) N_2O emissions caused by excessive use of synthetic fertilizers; (vi) the nitrification of soils and water courses; and (vii) enhanced ammonia load in the atmosphere.

It is true that cattle emit methane, but they and other ruminants are indispensable for global food security. Under sustainable pasture conditions, cattle produce milk and meat from grass and forage, and thereby make a significant contribution to the preservation of soil fertility and to climate change mitigation. This is why not only do cows have to be rehabilitated, but the correct agricultural system needs to be adopted. The decision whether we will protect or destroy the climate through the way we choose to rear cattle is up to us.

Commentary I: Excessive Industrialization of Livestock Production: The Need for a New Agricultural Paradigm

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Abstract

The excessive industrialization of chicken and pork production is a glaring example of the industrial model of agriculture, which has turned agriculture into a major climate, environmental, social and animal welfare hazard. In order to redress this situation, policies should adopt a post-industrial paradigm for agriculture, which supports multi-functional farms instead of agricultural factories. This should include the application of the forerunner and the polluter pays principle to financial incentives schemes, the tightening of regulatory laws, better market stewardship and preference for transparency, and farmer and consumer participation in policy-making.

Treating a farm as a factory that uses inputs such as pesticides, feed, fertilizers and fuel to produce outputs such as corn, chicken and pork has become the dominating principle of today's agriculture, which is exposed to the drivers and pressures of globalization. Although this model of industrialized agriculture produces impressive economies of scale, it is highly problematic owing to its detrimental impact on climate, the environment, human health and animal welfare, particularly as the associated costs remain externalized.

The vertically integrated and geographically concentrated chicken industry has been the iconic example of industrialized agriculture for decades. Between 1961 and 2009, chicken production worldwide grew from 7.5 to 80.3 million tons and pork production increased from 24.7 to 106.3 million tons (FAOStat, 2011).

This increase in production occurred in parallel with the massive industrialization and concentration of production structures. At the beginning of this century, around 74 per cent of poultry production was controlled by industrial companies (FAO, 2002). In the major poultry producing countries, a few players dominate the markets, such as Tyson in the United States, which holds 23 per cent of the national market share and processes 41 million chickens per week (Rohstoffe kompakt, 2010); or the PHW Group in Germany, which holds around 40 per cent of the national market share in chicken production and accounts for 70 per cent of chicken breeding (FAZ, 2011; Fichtel, 2009), as well as 80 per cent of the world market in poultry vaccine production (Winters, 2008).

The problem with industrialized agriculture is that it creates massive environmental and social collateral damage. Industrial chicken and pork production is part of globally integrated production chains. They largely depend on imported feedstuff, mainly soybeans from South America, often grown on land formerly occupied by rainforests and planted as monocultures with high fertilizer and pesticide inputs. The soybeans are then shipped over thousands of miles before they reach the chicken and pork factories, which are concentrated around harbours and along highways. In these factories, chickens of very few breeds are fattened within four to six weeks, often under inhumane living conditions.

The worldwide distribution of frozen chicken parts (whose production benefits to a large extent from significant direct and indirect subsidies) can have devastating impacts on many local markets in developing countries, as illustrated by the example of European chicken parts exported to West Africa.

Industrialization has turned agriculture upside down: the source of food has become a reason for hunger in many regions of the world and the main source of biodiversity has become one of its greatest threats. At the same time, what used to be a GHG sink has become a major polluter. According to the FAO (2006a), the major sources of GHG emissions related mainly to pork and chicken production are the production of nitrogen fertilizer for feed crops (41 million tons of CO_2 for the main producing countries), on-farm fossil fuel consumption (90 million tons of CO_2 per year), livestock-related land-use changes (2.4 billion tons of CO_2 per year) and methane emissions (more than 10 million tons per year).

The question then is how can agricultural production be reorganized so that it becomes a solution rather than a problem? Five basic principles to reform agricultural policies are proposed here.

A. A new agricultural paradigm

Although industrial agriculture is still widely promoted by current agricultural policies, there are growing calls for change. Jacques Diouf, former Director-General of the FAO, stated: "The present paradigm of intensive crop production cannot meet the challenges of the new millennium" (FAO, 2011). If this is true for agriculture as a whole, what we need is a new, post-industrial paradigm for agriculture.

The problem with factory farming lies first of all in its fundamental misconception of agriculture. Farms should not be factories – they should not be places of large-scale production halls; instead they should be highly integrated, living systems where every part of the system plays a crucial role in the functioning of the system as a whole. A traditional farm is based on its internal resources rather than on external inputs. Its main source of energy is solar, and not fossil. The animals of the farm produce – besides organic fertilizers – food (milk, eggs, meat) based on products that humans cannot consume and digest (e.g. grass, fibre and organic waste).

By ignoring the integrated nature of the farm, industrialization has turned agriculture into a major environmental, social, health and animal welfare hazard. Agricultural policies should therefore no longer follow the industrial model of agriculture. Rather, the farm model should become the new paradigm for agricultural policies. This concept of a farm is not a blueprint, but it can teach us how to tackle the great challenges to agriculture of our time, such as climate change, biodiversity, energy, water and food security.

B. Financial incentives: reversing rules and exceptions

Rules and exceptions relating to current public support schemes for agriculture should be reversed. Sustainable farming practices should become the rule, and industrial farming treated and regulated as the exception to this rule. Agricultural policies should apply the forerunner and the polluter-pays principles. The forerunner principle, which sets the best sustainable practices available in a region or production sector as a reference for farming systems, should be mainstreamed. Public farm payments should move from a "logic of compensation" to a "logic of investment in best practices". "Public money for public goods" should become the driving principle for financial support to agriculture.

The polluter pays principle, on the other hand, obliges farm industries that use unsustainable practices to compensate society for their negative impacts on the environment and on public health. This principle needs to replace the practice of compensating farmers for not polluting the environment.

C. Tightening regulatory law

Normally, industrial farming is undertaken within the rule of law, even though it may be threatening to health, the environment and animal welfare. Therefore, regulatory laws should be tightened in order to prevent negative externalities and the ability of industrial agriculture to gain comparative advantages by imposing external costs on society. Tightened regulatory laws should be internationalized so as to allow better law enforcement and prevent the transfer of agricultural factories to countries with weaker legislation. Also, health, environmental, social and animal welfare standards for agricultural products should be more effectively harmonized internationally than is currently the case.

D. Better market stewardship

Agricultural policies should establish new forms of market organization, which support farmers and consumers in regaining ownership of their regional and local markets. Farmers should be supported in establishing producer organizations that strengthen their bargaining power and enable them to gear food products to more regionalized and local markets. Such an approach should also involve a change of regulations relating to competition in order to stop the abuse of buyer power by oligopolistic processing and retailing companies and reverse the current concentration in the food chain.

E. Transparency and participation

Transparency should become a key principle of agricultural policy. Information about the reality of agricultural production, the social situation of farmers and farm workers, the environmental implications of production processes, and the living conditions of animals should not be hidden any more behind factory doors and lobby brochures; it must be made public. The first big agriculture-related crises of the twenty-first century in Europe – BSE and the foot-and-mouth outbreak in 2001 – resulted in calls for a fundamental change in agriculture. As a consequence, Germany implemented an “agricultural turnaround”, at the core of which was consumer involvement and greater transparency in agriculture.

The development of a new agricultural model should no longer emerge from top-down policies implemented in closed-door factories. Instead, farmers and consumers should play an active part in policy-making. Examples from the current reform of the EU Common Agricultural Policy show the demand for and success of participatory policy approaches.

Agricultural research should also become more participative and inclusive, as stressed by the International Assessment of Agricultural Science and Technology for Development (IAASTD). After a period of almost exclusive financing of biotechnology and genetic engineering, public support should be redirected towards integrated research that embraces farmers’ local knowledge of best practices as well as the knowledge of scientists from the various disciplines concerned. Investments in participatory research schemes should specifically focus on the new challenges, supporting modern low-input, organic and solar-based production, small-scale farming, enhancement of on-farm biodiversity, improved grassland management and crop diversification to reduce vulnerability.

Commentary II: Why Industrial Livestock Farming Is Unsustainable

Joyce D'Silva
Compassion in World Farming

But for the sake of some little mouthful of flesh we deprive a soul of the sun and light, and of that proportion of life and time it had been born into the world to enjoy. Plutarch

Abstract

- Farm animals are sentient beings whose well-being needs to be protected.
- Industrial farming keeps animals in isolation or crowded together in totally unnatural conditions.
- Animals have been selectively bred for their meat or high milk yield, with devastating impacts on their health and welfare.
- Industrial livestock farming uses huge amounts of grain and soy to feed the animals in a world where many go hungry.

Over millennia, we humans have developed sophisticated forms of shelter for ourselves, from rudimentary huts to air-conditioned houses. We may well have become less hardy in the process, but a lot more comfortable and weather-proofed.

Non-human creatures have used the natural shelter of woodlands and earth burrows or built their own more sophisticated housing, such as bird and pig nests or beehives, but they have always remained in contact with the land, with trees, vegetation and water and enjoyed the freedom of the skies. (Perhaps the human substitute for this is the garden or yard attached to the house, or our attempts to "go for a walk" in the countryside or swim in the sea.)

While a huge proportion of the earth's population make their living from farming the land, often including breeding or tending to some farm animals, the confinement of vast numbers of animals in industrial farms is a relatively new experience for both farmers and animals. This experiment in the industrialization of livestock farming has proved a disaster for the well-being of the animals, provided short-lived gains for agribusiness interests, led to the devastation of precious ecosystems and generated huge amounts of toxic gases and other harmful wastes. It may also be a contributory factor to the growing epidemic of obesity and the scandalous growth in numbers of malnourished people.

Removing animals from the land has led to unnatural systems of indoor animal confinement, either individually or in huge numbers, in vast sheds. This has broken up the social bonds which are so vital to animal well-being. Isolated animals, such as calves in narrow veal crates, or pregnant sows in even narrower sow stalls (gestation crates), suffer not only from physical discomfort but from psychological deprivation. This can be observed in their tendency to develop stereotypic behaviour, similar to the lion in a zoo cage. Sows kept in these narrow crates may spend up to 22 per cent of their active time with such stereotypic behaviour (Jensen, 1980). Larger numbers of animals crowded together can become aggressive, finding nothing to do all day and no escape from their pen-mates, often resulting in injury.

Science today confirms what most of us know through common sense, that animals are intelligent, sentient beings, capable of a range of emotional states and capacities. We no longer hark back to Descartes who believed that a screaming dog being dissected alive was exhibiting a purely mechanical reaction. Darwin himself recognized that animals were capable of many emotions similar to humans, when he stated: "We have seen that the senses and intuitions, the various emotions and faculties, such as love, memory, attention and curiosity, imitation, reason etc, of which man boasts, may be found in an incipient, or even sometimes a well developed condition, in the lower animals" (Darwin, 1871). Sadly, Darwin's wisdom in this respect lay forgotten for decades.

Pigs can operate computer challenges with more ability than dogs – but that only proves that some element of pigs' intelligence is not unlike our own. Pigs are, of course, uniquely intelligent at being pigs. The concrete and slatted floor of the average pig factory farm frustrates the natural exploratory or rooting behaviour of pigs, who like to spend 73 per cent of their daylight hours in such behaviour (Stolba and Wood-Gush, 1989). The metal bars surrounding and immobilizing the pregnant sow can reduce her to desperate despondency (SVC, 1997) or frantic stereotypic, repetitive behaviour, such as chewing on the bars (Broom et al., 1995).

Laying hens kept from puberty in a crowded cage, with often less floor space than a sheet of typing paper, can produce eggs for around a year and could carry on for longer. But by the time these "spent" hens reach the slaughter house, one survey showed that 36 per cent have broken bones (Gregory et al., 1990). Producing enough calcium to provide the shells for the 300+ eggs she lays each year, coupled with lack of exercise from being caged, render the hen's bones fragile and brittle. In addition, the cage prevents the hen from carrying out the regular sequence of activities she would do in a natural environment – pecking at the ground for food, stretching and flapping her wings, dust-bathing to clean her feathers, flying up to a perch at night (away from predators) and laying her eggs in a secluded nest. Thus the cages constitute a combination of physiological and mental deprivation.

More and more animals, particularly pigs and poultry, but also cattle, are being kept in industrial farms throughout the world. The FAO reports that industrial animal production systems are increasing at six times the rate of traditional mixed farming systems (FAO, 2006b). Around 70 per cent of farm animals are now kept in these systems, permanently housed, out of sight and, sadly, out of mind. And the global burden of farm animal suffering is only likely to increase.

This is not a conflict between scientific progress and human empathy with animals. The scientific dossier on the suffering caused to animals in industrial farming systems is constantly growing. New research shows the capacity of chickens – and fish – to feel pain (Danbury et al., 2000; Sneddon, Braithwaite and Gentle, 2003). Other research shows states of neuroticism in crated sows (SVC, 1997; Athene Trust, 1986) or distressed behaviour in cows deprived of their calves.

Apart from keeping these animals throughout their lives in totally unnatural social groupings and conditions of deprivation, industrial farming has inflicted another scandalous technology upon these creatures. It has taken selective breeding to a whole new level of sophistication, with disastrous impacts on the day-to-day lives of the animals. For example, there are three global companies now responsible for the breeds of chickens bred for meat (broiler chickens) sold widely worldwide. Those chickens now grow so fast that they reach slaughter weight in five or six weeks – half the time it took 40 years ago. Bred for more breast muscle (meat), they tend to tip forward and, unable to support their heavy bodies, have become prone to appallingly painful leg problems. A research team sponsored by the Government of the United Kingdom found that 27 per cent of chickens were painfully lame for days before they went to slaughter (Knowles et al., 2008). John Webster (Emeritus Professor at Bristol University and former head of the Veterinary School) observed that "approximately one quarter of heavy strains of broiler chicken and turkeys are in chronic pain for approximately one third of their lives" (Webster, 1994).

Dairy cows such as the ubiquitous black-and-white Holsteins have been bred to produce so much milk that they are metabolically being pushed to the limit, now producing up to or even more than 20,000 litres a year, many times more than calves would have drunk from their mothers. They are prone to suffering from high rates of painful conditions like mastitis and lameness, associated with their breeding, feeding and housing conditions. Cows that are kept in zero-grazing indoor systems are at higher risk of mastitis, lameness, metritis, ketosis, teat tramp, difficult births and some bacterial infections (EFSA, 2009). Again, the combination of breeding for productivity and the totally unnatural environments has proved highly injurious to the animals' welfare. Yet some go so far as to advocate keeping dairy cows in sealed units (LUCCG, 2010) so that their methane emissions can be "scrubbed" and put to good use. Such a myopic recommendation, which directly affects the lives of the animals themselves, should surely be subject to an assessment of its effects on animal health and welfare.

So where do the best solutions lie? Perhaps the answers to these problems of toxic emissions from factory farms, overexploitation of the earth's resources, rural poverty, urban obesity and poor animal welfare can be found in applying a mixture of good science, common sense and compassion to produce genuine win-win situations.

It is now well known that permanent pasture can act as a carbon sink. Recent research comparing the environmental impacts of four different kinds of dairy farms found that a well-managed dairy herd kept outdoors year-round left a carbon footprint 6 per cent smaller than that of a high-production dairy herd kept in permanent housing. In addition, average net farm greenhouse gas emissions declined by about 10 per cent by keeping the herd outdoors year-round and cut ammonia emissions by around 30 per cent (Rotz et al., 2009). As ruminant animals, these cows could pursue their natural grazing behaviour, and although their productivity was lower in terms of litres produced, their milk was higher in protein and fat content. Thus the nutritional output from indoor and outdoor cows was similar.

To achieve high welfare standards the needs of the animals themselves should be considered. If poultry such as chickens, turkeys and ducks have wings with which to fly, they should not be bred to become so heavy that they are no longer able to fly, and, in the case of turkeys, no longer able to mate naturally due to their weight. Animals should not be bred in ways that their own physiology becomes their worst enemy, as is the case with broiler chickens. If hens stretch their wings and flap them, they should have space to do so. If pigs spend most of their time rooting with their highly sensitive snouts, they should never be kept on fully slatted floors, where such behaviour is impossible. If the animals are kept indoors, they must be provided with a deeply enriched environment, which provides comfortable bedding material, plenty of space and opportunities for natural behaviour to flourish.

Animals' bodies should not be mutilated through practices, such as docking pigs' tails, in order to keep them in factory farm conditions. Animals should be fed with as near a natural diet as possible, and not be deprived of normal quantities of food as is the case with the breeder birds of the broiler variety. They should not be deprived of necessary nutrients as happens with calves that are fed a low-iron, liquid diet to produce "white" veal; nor should they be force-fed for gourmet purposes, such as for the production of *foie gras*. Moreover, animals should be provided with the company of their own kind, in numbers as close as possible to natural conditions. Isolation and overcrowding should not be allowed.

Box 4: Twelve Farm Animal Welfare Criteria

Society is progressively recognizing animals' capacities and needs. The Lisbon Treaty of the European Union (EU) includes an article which recognizes that animals are "sentient beings" and requires member States to protect their welfare (EU, 2008). From the EU to some states in the United States to New Zealand and Australia, there are moves to phase out and ban some of the more extreme confinement systems associated with industrial farming.

The European Commission-sponsored Welfare Quality research project established a list of twelve farm animal welfare criteria. These are:

- Animals should not suffer from prolonged hunger,
- Animals should not suffer from prolonged thirst,
- Animals should have comfort around resting,
- Animals should have thermal comfort,
- Animals should have enough space to move around freely,
- Animals should be free of physical injuries,
- Animals should be free of disease,
- Animals should not suffer pain from inappropriate management or handling,
- Animals should be able to express normal, non-harmful behaviours,
- Animals should be able to express other species-specific normal behaviours,
- Animals should be handled well in all situations,
- Positive emotions should be promoted and negative emotions, such as fear, distress, frustration and apathy should be avoided.

Source: www.animalwelfareplatform.eu/.

Box 5: The Five Freedoms

1. Freedom from hunger and thirst – by ready access to fresh water and a diet to maintain full health and vigour.
2. Freedom from discomfort – by providing an appropriate environment including shelter and a comfortable resting area.
3. Freedom from pain, injury or disease – by prevention or rapid diagnosis and treatment.
4. Freedom to express normal behaviour – by providing sufficient space, proper facilities and company of the animal's own kind.
5. Freedom from fear and distress – by ensuring conditions and treatment which avoid mental suffering.

Source: www.fawc.org.uk/freedoms.htm.

It is vital that those in charge of the animals are not only trained but are also compassionate. However, good management is never an excuse for keeping animals in a poor environment in the first place. Well-managed industrial pig farms are still detrimental to animal well-being, even if their managers do their best to mitigate the harmful impacts.

Various methods to ensure good animal welfare standards have been developed, such as the much admired Five Freedoms and the Twelve Farm Animal Welfare Criteria, developed for the European Commission's Welfare Quality project (see boxes 4 and 5).

It is not just farmers or agribusiness companies that need to act to achieve animal-friendly farming. If consumers continue to call for "cheap meat", the factory farms will continue. The irony is that such farms are in fact costly to the environment, to the animals and to small-scale farmers who cannot compete. The message to consumers who can afford meat every day is to reduce their consumption, and, when they buy meat, to spend a little more – but less frequently – on purchasing only animal-friendly, environmentally friendly products. A report commissioned by Compassion in World Farming and Friends of the Earth (United Kingdom) shows that it will be possible to feed the world population in 2050 using a combination of mixed farming and organic methods, along with good animal welfare systems, but only if, globally, consumers of large quantities of animal products cut back on their consumption (Compassion in World Farming and Friends of the Earth, 2009b).

Genuine win-wins are possible. It is up to individuals, governments, lending banks and global agricultural and food institutions to make ethical choices and drive policies and practices in the right direction. The earth, the animals and our fellow humans need such a commitment.

Commentary III: Integrated Crop, Livestock and Energy Management: The Case of Biogas in Rural Ethiopia

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Abstract

- Biogas technology enhances synergies in crop, livestock and energy systems because the by-product of fermentation (slurry) from saved dung is used as fertilizer and the saved crop residues are used as animal feed.
- Labour otherwise used for collecting firewood and dung can be directed towards economically productive activities such as agriculture.
- Increased agricultural productivity and/or overall income improve the attractiveness of biogas as a labour-saving technology so that a positive synergy effect (limited to households collecting their own energy sources and in the absence of a subsidy) between economic development and improved energy utilization can be realized.

A. Introduction and background

Biomass, consisting of firewood, charcoal, dung and crop residues, remains the main source of energy in sub-Saharan Africa (Davidson and Sokona, 2001). In Ethiopia, for instance, biomass supplies over 90 per cent of the total national energy demand, and rural households are almost entirely dependent on this source for their energy needs. The main sources of energy are woody biomass (78 per cent), dung (8 per cent), crop residues (7 per cent) and petroleum (5 per cent). Households account for 90 per cent of national energy consumption, while rural households account for 82 per cent of the national energy consumption derived mainly from biomass energy sources (Esthete, Sonder and Heedge, 2006).

The widespread use of biomass energy sources has been found to be largely inefficient, adversely affecting the environment, human health and food security (Dewees, 1989; Dang, 1993; IEA, 2006). Environmental problems arise from deforestation, land degradation and air pollution that lead to greenhouse gas (GHG) emissions. Annual deaths from indoor air pollution resulting from the use of biomass-sourced energy have been estimated at around 1.3 million worldwide, which is higher than deaths from malaria, and almost half of all HIV/AIDS deaths, the majority of which occur in sub-Saharan Africa (IEA, 2006). Although firewood remains the main biomass energy source, it is becoming scarce in the rural areas of Ethiopia, and households are increasingly using dung and crop residues instead. The growing scarcity of firewood is leading to reduced agricultural production as households allocate labour away from agriculture, as more agricultural land is allocated to firewood production, and as households use more dung and crop residues for fuel rather than for fertilizer and animal feed respectively (Cooke, Köhlin and Hyde, 2008). Scarcity of firewood also places an increasing burden on women and children who are its main collectors.

Biogas, which offers one technically possible energy alternative for rural areas, can help mitigate some of the consequences of an overreliance on biomass energy and is gaining popularity in Africa (UNESCO and Tata Energy Research Institute, 1982). With the potential to serve up to 2 million family units, biogas technology has been promoted since 1979 in order to help overcome the increasing energy crisis in Ethiopia (ESMAP, 1996). However, studies indicate that community digesters are prone to failure compared with individual family units. A feasibility study carried out by Esthete, Sonder and Heedge (2006) revealed that of the 600 to 700 domestic plants in Ethiopia, about 60 per cent had stopped functioning due to a range of problems, including water shortage, dung shortage, technical problems, abandonment and loss of interest. Despite past failures, there is renewed interest in biogas energy in Ethiopia. In 2007, the National Biogas Programme Ethiopia (NBPE) initiated a multi-stakeholder-driven programme to develop a viable and sustainable commercial biogas sector (Ethiopia Rural Energy Development and Promotion Center and SNV Ethiopia, 2008). Initially, family size biogas plants ranging from 4 m^3 to 10 m^3 are being constructed in selected regions of Tigray, Amhara, Oromia and Southern Nations Nationalities and Peoples Region (SNNPR).

A survey of 80 randomly selected households in the Dale and Arsi Negele districts of Ethiopia was conducted between April and May 2010 to assess the economics of firewood and dung use in rural Ethiopia, to improve understanding of household energy use patterns and analyse the potential of biogas technology as a possible alternative, so as to increase the chances of success in promoting cleaner energy sources (Schlag and Zuzarte, 2008). The findings of the study are presented briefly in the next section, followed by some of its conclusions and recommendations.

B. Research findings from household surveys and cost benefit analysis

Agricultural production systems in the surveyed areas are mainly small-scale and subsistence-oriented, geared to livestock and crop production. The mainly rain-fed crop production has two seasons, the main season (*Meher*) beginning in April/May with harvests in November/December, and a shorter season (*Belg*) from February to June. The livestock and crop production systems are highly integrated: crop residues are stored as animal feed while dung is an important source of fertilizer. Households in the surveyed areas use a combination of energy sources throughout the year. Firewood is the largest source of energy with the highest amount being used in the third quarter of each year. Other cooking fuels consist mainly of dung and crop residues, but also kerosene, charcoal and electricity. Use of crop residue is high at harvest time, which runs from October to January, when more crop residues are available. Dung collection is more prominent during the dry season when it is easier to process. It is then stored for use during the wet season.

C. Analysis of the potential of biogas energy

A cost-benefit analysis of 4 m^3 and 6 m^3 biogas plants promoted by the NBPE was conducted. While the 6 m^3 plant is the most common, the 4 m^3 plant is appropriate under conditions where livestock numbers are low. For qualifying households, NBPE recommends a livestock holding of at least four cattle for the 4 m^3 biogas plant and six cattle for the 6 m^3 biogas plant. Among the surveyed households, about 38 per cent qualified for the 4 m^3 biogas plant and about 19 per cent for the 6 m^3 plant. Investment costs used in this study were based on data provided by the NBPE, based on prices prevailing in March 2010. The total costs of investing in a biogas plant amounted to 11,109 Ethiopian birr (ETB) ($855) for a 4 m^3 plant and 11,906 ETB ($916) for a 6 m^3 plant. The NBPE pays a subsidy of 4,000 ETB ($308) per plant regardless of size. The remaining costs for each of those plants are borne by the farmers. The costs of operating the plant also included the opportunity costs of time used in collecting dung and the costs of water needed to feed the biogas plant.

The 4 m^3 and 6 m^3 biogas plants have the potential to replace up to 2,208 kg and 3,319 kg, respectively, of firewood per year when operating at full capacity, and they can save up to 6,015 kg and 9,021 kg of dung, respectively, per year. However, the potential to replace firewood with biogas was assumed to be only 60 per cent, as the current set-up does not support *Injera* 25 baking which accounts for up to 60 per cent of rural households' total energy use (EESRC, 1995). Obtained biogas was valued in terms of replaced firewood and dung.

To capture the benefits for different household types in terms of energy management, a cost-benefit analysis was performed using three scenarios: (i) for households that invest in biogas to replace purchased firewood or (ii) to replace collected firewood; and (iii) for households that use dung as an energy source in addition to collected firewood. All three scenarios assumed that dung and slurry would be used as fertilizer. For collected energy sources with no market value, the marginal productivity of female labour in farm production was used. Dung carries additional value for its fertilizer content. According to laboratory tests conducted on dung samples taken, 1 kg of diammonium phosphate (DAP) is equivalent to approximately 16 kg of dry manure. According to the survey findings, DAP has an average farm gate price (purchase price plus transport costs) of 7.50 ETB ($0.59) per kilogram. This translates into 0.47 ETB per kilogram of dung. Combining collection costs and fertilizer opportunity costs, dung has a shadow price of 0.72 ETB ($0.04) per kilogram and 65.45 ETB ($5) per gigajoule when used as an energy source.

The survey found rates of return on capital invested in biogas plants to be above 10 per cent (table 1), which showed that adopting biogas technology is more beneficial for households that purchase all of their firewood. This factor also makes biogas attractive to this segment of rural households, as benefits are financially recovered through savings on firewood purchase. Households that use dung for combustion stand to benefit more (higher net present value (NPV)) than those collecting firewood by adopting biogas technology. Under all three scenarios, dung and slurry used as fertilizer accounted for over 65 per cent of costs and benefits respectively. These results are highly sensitive to changes in time savings, expenditure levels and price of replaced fuel in all three household scenarios. These factors are crucial, as they are likely to determine anticipated benefits and perceived opportunity costs of capital, which influence households' decision on whether to invest in biogas. Without the subsidy given to farmers by the NBPE, investing in the biogas plant is very risky for households that collect their own firewood.

D. Conclusions and recommendations

Biogas technology presents an opportunity to enhance synergies in crop, livestock and energy systems in rural Ethiopia. The by-product of the fermentation – slurry – retains the nutrient content that is otherwise lost through direct combustion of dung for energy. Crop residues that might otherwise be used for energy are saved for animal feed. However, low shadow prices of energy sources collected by households mean that biogas is unable to compete unless heavily subsidized. The present subsidy scheme makes biogas an attractive option, but this

Table 1: Cost-benefit analysis of biogas plants compared with different traditional sources of household energy in Ethiopia (Ethiopian birr*)

	Purchasing firewood		Collecting firewood		Collecting dung	
	4 m³	6 m³	4 m³	6 m³	4 m³	6 m³
Costs						
Investment costs	7 109	7 906	7 109	7906	7 109	7 906
Maintenance costs	680	680	680	680	680	680
Water costs	1 860	2 790	1 860	2 790	1 860	2 790
Dung value	41 965	62 948	41965	62 948	41 965	62 948
Total costs	51 614	74 324	51 614	74 324	51 614	74 324
Benefits						
Biogas value	17 101	25 651	1 650	2 475	4 650	5 475
Lighting energy saved	4 572	4 572	4 572	4 572	4 572	4 572
Time saved	3 720	3 720	3 720	3 720	3 720	3 720
Slurry value	46 628	69 943	46 628	69 943	46 628	69 943
Total benefits	72 021	103 886	56 570	80 710	59 570	83 710
Net present value	20 407	29 561	4 957	6 386	7 957	9 386
Internal rate of return (per cent)	28.29	34.78	10.52	11.90	14.57	15.13

Source: Survey data and SNV, 2010.
Note: * € 1=18 ETB, $1=13 ETB, a weighted average (April 2010).
Discount rate 4%; period of use of biogas plant 20 years.

would not be the case if subsidies were removed.

From the cost-benefit assessment of biogas plants, investing households stand to benefit mainly through the use of slurry as a fertilizer, as well as through cost savings on energy use for traditional cooking and lighting and the associated labour savings. Consequently, profitability depends largely on the use of slurry as a fertilizer and on the price of replaced energy sources. Thus, promotion of dung and slurry is vital for the success of the biogas programme in Ethiopia and for improving agricultural production for food security. A synergy to be further exploited is the labour-saving effect of biogas compared with wood or dung collection. Thus, the more incentives there are to switch to sustainable energy sources such as biogas, the greater will be the profitability and improvement of labour productivity in agriculture and other sectors.

The economic attractiveness of biogas plants would be considerably improved if suitable biogas *injera* stoves were developed for use by investing households. These stoves have the potential to enhance the use of biogas plants, thereby increasing the benefits accruing to households. Cheaper alternatives to biogas plants and improvements in the technology remain an option in catering to poor households.

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Notes

1 Animal suffering and welfare are directly affected by industrial livestock production. For more information, see the comment of Joyce D'Silva in this chapter; see also D'Silva and Webster, 2010.

2 It is beyond the scope of this article to analyse the damaging effects of legal and illegal disposal of dangerous substances in animal feed for industrial livestock production and the use of contaminated sludge as fertilizer on cropland.

3 This article does not discuss the non-recycling of human faeces in soil; for a discussion of this issue, see King, 1911.

4 By way of illustration, after its accession to the EU, Romania restricted the free movement of horse- or cow-drawn transport in favour of motorized transport.

5 "Inexpensive" or "cheap" here means that a considerable proportion of the costs of production remain externalized in prices.

6 This process, used for the industrial production of ammonia, involves the nitrogen fixation reaction of nitrogen gas and hydrogen gas over an enriched iron or ruthenium catalyst.

7 Ammonia is not categorized as a GHG that has a direct impact on the climate, such as CO_2, N_2O and CH_4, but it does have a relevant indirect impact through its effect on the atmosphere.

8 For some years, monocultures for agro-energy production are increasing the amount of N_2O emitted from agriculture (for a more elaborate analysis, see Hurni et al. in chapter 4 of this Review).

9 Besides the general use of animal excrements, this also concerns the separate use of urine and faeces. Normally the separation is done through pasturing: the natural separation for mammals prevents the modification of the nitrogen compounds in the urine through the bacteria contained in the faeces.

10 Calculated using the Climate Analysis Indicators' Tool of the World Resources Institute, at: http://cait.wri.org.

11 The fact that animal breeding is more advanced than crop breeding does not reflect a higher level of technological innovation. By way of illustration, the commercialization of some transgenic crops is far more developed than transgenic animals.

12 In 1996, the cloned sheep "Dolly" was born after thousands of attempts with embryos. Dolly was the first mammal that was created by and survived the technology of somatic cell nucleus transfer (SCNT). Although armed with a patent, the "Dolly" method is (as all other genetic and cloning methods) not a blue print to get identical copies.

13 Indeed the human-microbial relationship is extremely close. A massive amount of 10^{14} bacteria exist on and in humans – a number 10 times higher than the 10 billion cells in a human body.

14 Against this background, biofuel certificates that confirm that the feedstock was not produced on cropland derived from deforestation are only useful if the time span before conversion is well defined.

15 For more information, see, for instance, www.indexmundi.com/commodities/?commodity=soybean-oil, and Fairlie, 2010. Imbalances in the patterns of fatty acids through the rejection or replacement of other oils by cheaper soy oil are not further elaborated here. For more information in this regard, see Blasbalg, 2011.

16 For a more elaborate analysis, see Idel, 2010.

17 0,55 t of C + 1,25 t of O2 = 1,8 t of CO_2.

18 There is a crucial interplay between grassland and ruminant management; as mentioned above, 40 per cent of all land is grassland and perennial grass is very effective for carbon sequestration. Whilst forests expand their biomass volume by only about 10 per cent per year, savannahs can reproduce 150 per cent of their volume (Idel, 2010, 2012; Paul et al., 2009).

19 On the CO_2 assimilation potential of grasslands, see FAO, 2009.

20 Not accounted for are permanent ice-covered surfaces of Greenland and the Antarctic, where there is no grassland yet. In Europe, grassland covers about a quarter of the total land surface.

21 Inter alia carbon sink function, protection for erosion, protein and energy source, source of income for about one tenth of the world population.

22 As hybrid pigs and chickens are fed with concentrates in intensive production systems, grass-fed land races of rare pigs, geese, chickens and others cannot compete against them, so that they end up on the list of species that are threatened with extinction (for more information, see FAO: The State of the world's animal genetic resources for food and agriculture. www.fao.org/docrep/010/a1250e/a1250e00.htm).

23 This effect is a logical consequence of the increase of the sex-specific performance of female animals. The focus on boosting dairy performance is at the expense of the energy being used for meat generation. Based on the same logic, the brothers of hybrid laying hens gain weight very slowly.

24 In the United Kingdom, due to unsatisfactory fattening performance, a large percentage of male calves of high performance dairy cows (i.e. Holstein, Friesian, Jersey) are being killed every year immediately after they are born (Weeks, 2007).

25 Injera is a thin, flat and spongy bread made from teff flour with a diameter of about 60 cm, and is an important part of the traditional diet in Ethiopia. It is traditionally prepared on a flat clay pan of matching diameter.