Food and Agriculture Organization of the United Nations

FAO ANIMAL PRODUCTION AND HEALTH

working paper

IDENTIFICATION OF INDICATORS FOR EVALUATING SUSTAINABILITY OF ANIMAL DIETS

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IDENTIFICATION OF INDICATORS FOR EVALUATING SUSTAINABILITY OF ANIMAL DIETS

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Executive Summary

Given the large increase in demand for animal products, sustainability challenges of animal production systems are becoming increasingly important. Animal feeding has a large influence on the sustainability performance of animal production systems and are therefore a suitable focus point in the challenge to improve sustainability. The Sustainable Animal Diets (StAnD) concept, developed by FAO, aims to reduce the adverse impact of animal diets by developing a methodology that could evaluate animal diets for their sustainability performance. Results of a StAnD assessment can contribute to identification of effective options for practice change at the levels of farmers, farmer organizations, feed industry and other stakeholders in the feed production and feed use chain.

The aim of this study was to explore and identify indicators to assess sustainability performance of animal diets, based on the eleven sustainability elements selected in the StAnD concept (four elements relating to the planet dimension; four to the people dimension; and three to the profit dimension of sustainability). Besides this, this study aimed to propose possible quantification methods for each of the identified indicators.

Based on literature research, indicators were identified for stages in the animal production chain that are related to animal feed production and feeding and that can affect the people, planet or profit dimension of sustainability. The working method included identification of all production processes or activities within each stage of the feed production chain and their impact on the sustainability dimensions. These activities and their possible impacts guided the identification of relevant indicators for the eleven sustainability elements. The indicators that were identified following this method were discussed with FAO experts to select the most important ones.

Twenty indicators to assess sustainability performance of animal diets were identified for the three dimensions of sustainability: ten indicators for the planet dimension; eight for the people dimension; and three for the profit dimension. For each sustainability indicator, a quantification method was proposed. For instance, the indicator for land degradation was the soil organic carbon (SOC) content, which can be quantified by measuring the percentage of SOC or by use of databases on average SOC content per regional ecosystem.

Results of this study provide a basis for further definition of indicators and assessment methods of sustainability of animal diets, finally resulting in, for example, a tool to assess and compare sustainability of animal diets. To further develop and implement actual methods and tools for assessing the sustainability performance of animal diets by stakeholders, we recommend performing case studies for specific sectors, production systems and regions. These case studies may help to gain insight into the practical dimension of developing easy-to-use tools and to validate the StAnD approach.

Abbreviations

Codex	Codex Alimentarius Commission
EMRL	Extraneous Maximum Residue limit [of Codex]
EQS	Environmental Quality Standard
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
LK	Local knowledge
MRL	Maximum Residue Limit [of Codex]
SOC	Soil organic carbon
StAnD	Sustainable Animal Diet

Glossary

Activity Action or operation in the feed production chain.

Animal diet A particular selection of feed, designed or prescribed to meet an animal's needs.

Element Possible consequence of feed production and feeding affecting sustainability performance of animal diets.

Feed Any single or compound material, whether processed, semi-processed or raw, intended to be fed directly to food producing animals (FAO/WHO, 2004).

Indicator Factor or variable providing evidence that a condition exists or certain results have or have not been achieved (FAO, 2014a).

People Dimension Division of sustainability, referring to fair and beneficial practices towards human rights, health and wellbeing in the community and region in which an entity operates, and towards stakeholders involved.

Planet Dimension Division of sustainability, referring to sustainable environmental practices and to minimizing environmental impact.

Profit Dimension Division of sustainability, referring to the economic value created by an entity, or the economic benefit created for the surrounding community and society.

Sustainable Animal Diet (StAnD) A concept developed by FAO to assess sustainability of animal diets, encompassing the feed production and feeding chain, aiming to reduce the adverse impact of animal diets and improve its sustainability performance.

Sustainable development Development processes that protect the natural resource base and ecosystem functions, enhance economic resilience and promote human rights and well-being in a manner that preserves future generations' ability to secure their needs (FAO, 2014a). People, Planet and Profit dimension of the triple-bottom-line approach would have to be balanced in order to achieve sustainability.

Introduction

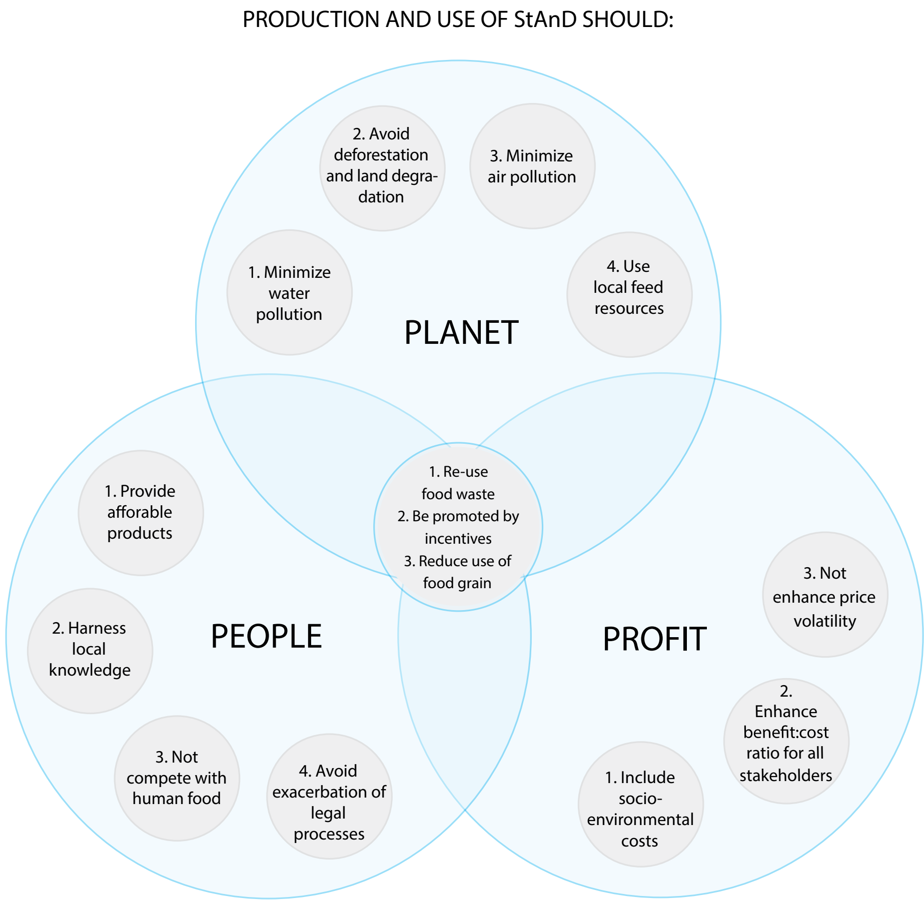
Worldwide, animal production systems are facing challenges of environmental, economic and social sustainability. Regarding environmental sustainability, for example, the livestock sector contributes 14.5 percent to the total human-induced emissions of greenhouse gases (GHGs; FAO, 2013). Economic challenges lay, for example, with consumer and producer risks associated with the price volatility of agricultural commodities. Social challenges include, for example, the loss of local knowledge through increasing modern agricultural systems (Altieri, 2004, 2009). The sustainability challenges of animal production are expected to further increase because of the expected growth in demand for animal products caused by the growing human population, growing economies in developing countries, urbanization and changes in dietary habits (Herrero et al., 2013; Makkar, 2013). Animal production can also contribute positively to sustainability of food production systems, for example, higher social equity, higher economic growth and/or improved biodiversity through extensively managed grasslands (FAO, 2015b; World Bank, 2009). Strengthening these positive impacts is another way to improve sustainability.

Animal feed plays a large role in the sustainability performance of animal production systems. The choice of diet affects the animal production chain downstream on, for example, GHG emissions, animal productivity, animal health, product safety and quality; and animal welfare (Makkar, 2013). Upstream the production chain, feed production and on-farm feeding affects, for example, water quality, GHG emissions and land use. In addition, feed processing, storage and transportation consumes a large amount of energy (FAO, 2011).

Globally, the production, processing and transport of feed accounts for about 45 percent of GHG emission from the livestock sector (FAO, 2013). Methane from enteric fermentation from ruminants is the single largest global source of anthropogenic methane, responsible for 30 percent of global methane emission. Type of feed is one of the most important factors affecting enteric methane production. Also land use change is affected by feed production and use, which has been estimated to contribute approximately 9 percent to the GHG emission from livestock sector. Examples of land use change are the conversion of forests and grasslands to pastures and croplands (IPCC, 2000). Livestock consumes 8 to 15 percent of global water use and about 90 percent of this water is used for feed production (FAO, 2013). Financially, feed is an important component in the costs of animal products because it constitutes up to 70 percent of the production costs (Luiting, 1990; Makkar, 2013). Socially, feed production affects, among others, competition for land suitable for growing food crops.

As current animal production grows and intensifies, it depends less on locally available feed and has a higher input of feed concentrates. Especially in developing countries, use of concentrate feed greatly increased, from 239.6 million ton of feed concentrates in 1980 to 602.7 million ton in 2005 (FAO, 2010). Concentrate feeds include cereals, brans, pulses, oil crops, roots and tubers, and fishmeal. Other feeds used for animal production are roughages and agro-industrial by-products. Global compound feed production has reached almost 1 billion ton (Alltech, 2015).

Figure 1
Elements per sustainability dimension prioritized in the sustainable animal diets (StAnD) survey



Notes: The numbers represent the ranking importance per dimension. The three elements in the middle represent elements covering more than one dimension.
Source: Makkar and Ankers, 2014

Towards 2050, the demand for animal products, mainly meat, milk and eggs, is projected to be 60-70 percent higher than in 2013, which will result in an increased demand for animal feed and introduce further sustainability challenges for the livestock sector (FAO, 2012).

To assess sustainability of animal diets, the Sustainable Animal Diets (StAnD) concept was developed by the Food and Agriculture Organization of the United Nations (FAO) in consultation with a large international group of experts (Makkar and Ankers, 2014). This concept aims to reduce adverse impacts of animal diets and provides a framework to introduce practice change to impart greater sustainability to livestock production systems. A vital step in the implementation of the StAnD concept is to provide a methodology that facilitates the assessment and comparison of various diets for sustainability performance and are applicable for all types of animal feed production systems. The StAnD concept is based on the three dimensions of sustainability: Planet; People; and Profit. It integrates the importance of efficient use of natural resources, protection of the environment, socio-cultural benefits and ethical integrity and sensitivity, in addition to currently recognized nutrition-based criteria of delivering economically viable and safe animal products by producing safe feed. Initially a list of 32 elements of feed production and feeding affecting sustainability of animal diets was composed for all dimensions of sustainability, and miscellaneous elements covering more than one dimension. Elements are possible consequences of feed production and feeding affecting sustainability performance of animal diets and thus represent criteria for a sustainable animal diet, such as feed production and feeding: 'should result in animal products that are affordable to consumers' and 'should minimize water pollution'. A survey among many different stakeholders was performed to prioritize the elements of sustainable animal diets. A questionnaire was completed by 1195 respondents ranging across academia, industry, farmer associations, government organizations, non-governmental organizations (NGOs) and intergovernmental organizations. This resulted in a selection of elements presented in order of importance per dimension in Figure 1 (adapted from Makkar and Ankers, 2014). An overview of the results of the survey with all elements is provided in Appendix A.

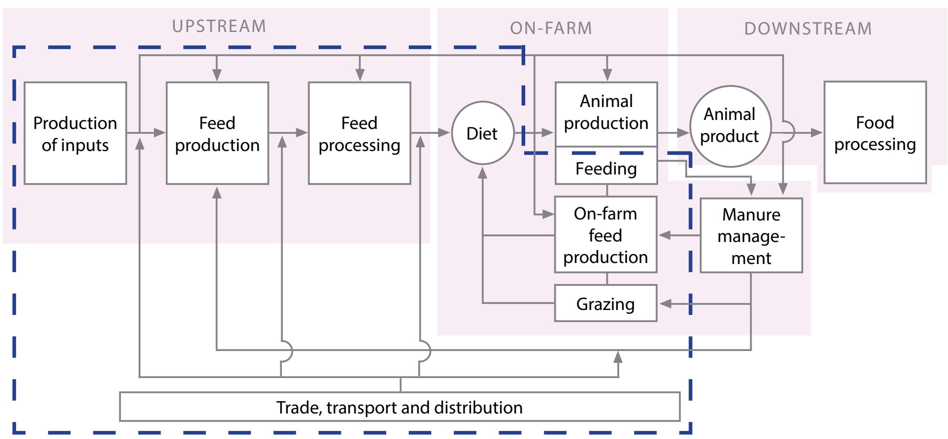
The present study forms an intermediate and exploratory step in developing the StAnD methodology. The goal of this exploratory study was to identify key indicators for sustainable animal diets for the eleven elements of the people, planet and profit dimension selected in the StAnD survey, and to propose methods for quantifying these indicators.

Materials and Methods

This exploratory study was performed by means of scientific literature searches and consultations with FAO experts. Indicators were identified for those stages in the animal production chain that are related to animal feed production and consumption and that can affect environmental, social or economic sustainability (Figure 2). These stages are: primary resource production (e.g. production of fertilizer, pesticides, seed and energy), on-farm and off-farm feed production (e.g. land cultivation, fertilization, pesticide use), on-farm and off-farm feed processing (e.g. production of concentrates and feed additives, processing of industrial by-products, fodder conservation), animal production (e.g. feeding practices, choice of diet) and trade, transport and distribution.

Within each stage of the feed production chain, production processes or activities (hereinafter called activities) were identified, having an impact on one of the elements that were selected by the StAnD survey. The identified activities and related impacts were used as guidance for further literature searches to identify indicators for the sustainability performance of animal diets. One hundred thirty studies were reviewed to identify indicators for each element, covering the most important impacts on sustainability. For example, an activity in the feed production chain is fertilizer use. This activity influences sustainability within the planet dimension, because it may affect air, water and soil quality. Literature on this topic indicates that nitrogen and phosphorus content are important indicators for the degradation of water quality, as is organic carbon content for soil quality. An example of an activity

Figure 2
Generic animal production chain with feed production chain included



Notes: The feed production system consists of on-farm activities and upstream and downstream activities and is indicated by the dashed line. The squares indicate processes and the circles indicate products.

in primary resource production affecting social sustainability is employment and an activity in animal production affecting economic sustainability is procurement of raw materials. Some of these activities can be applicable for multiple dimensions or production stages.

Based on the literature review, the meaning of elements was elucidated and indicators were identified based on three criteria: the indicator must be quantifiable; easy to use; and applicable to different types of feed production system. Because applicability to all types of animal feed production systems and geographical regions was a prerequisite, a generic approach was favoured. During the study it became clear that the requested criterion 'easy-to-use' can only be valued when the actual user is known. This is not the case in the current state of the StAnD concept, so 'easy-to-use' was merely assessed by considering quantification methods that were relatively easy to measure. If quantification methods were not described in literature, methods were identified based on expert opinion and authors' own insights. The Sustainability Assessment of Food and Agriculture system (SAFA) of FAO was used as a guide and as an example for how sustainability issues can be transformed into indicators. SAFA was searched for issues matching the elements and indicators suggested by SAFA were taken into account. Several rounds of consultation with FAO experts were held during the process of indicator selection to discuss indicators identified and to select the most important ones.

Results: Sustainability indicators

In the following paragraphs, the five main production stages and activities in the animal production chain related to animal diets are presented in concentric diagrams for each sustainability dimension, together with their different impacts on sustainability performance. The meaning of each element is discussed and the identified indicators are presented with possible quantification methods. The elements are presented in order of importance as prioritized in the StAnD survey. Some activities and impacts shown in the diagrams were not related to the elements considered in this study, and therefore not further discussed.

Table 1 provides an overview of all identified indicators with their corresponding dimension, element and unit of measurement. The units of measurement indicated in the table are provisional and need to be further refined in future StAnD work. Indicators will be described in detail in the next paragraphs.

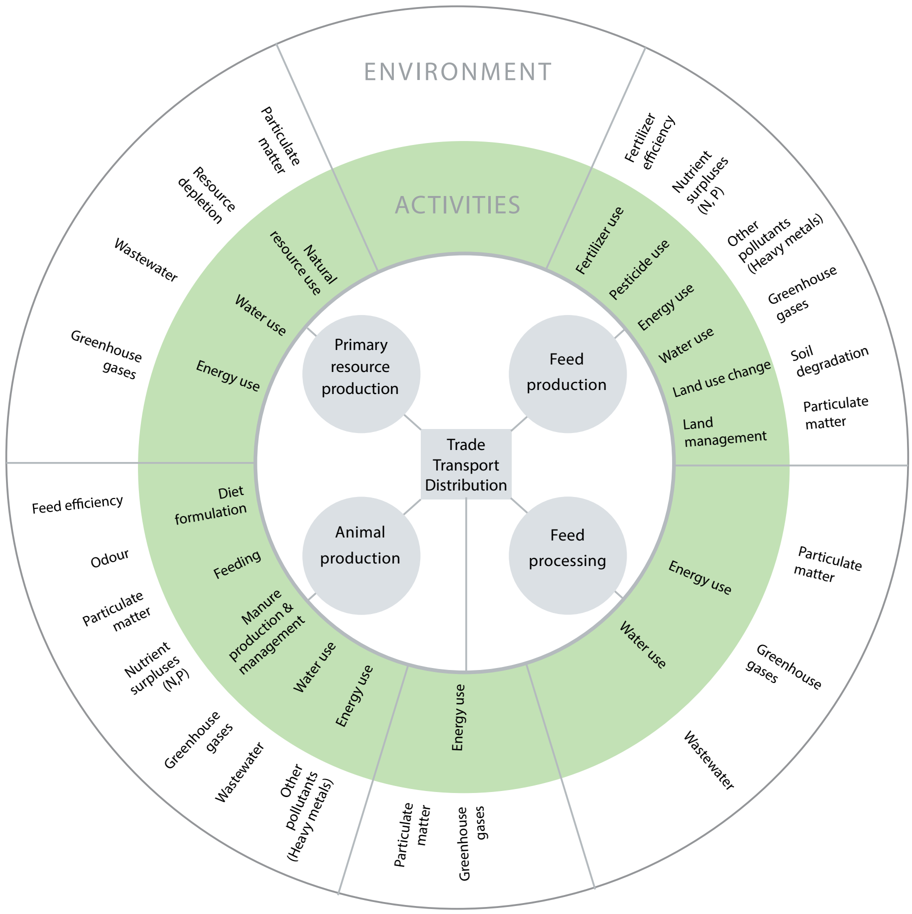
Table 1. Overview of the identified indicators with corresponding unit of measurement, presented for each element and dimension

Dimension	Element	Indicator	Unit
Planet	Walter pollution	Nitrogen content	mg/L, %[1]
		Phosphorus content	mg/L, %[1]
		Heavy metals content	µg/L, %[1]
		Pesticides content	µg/L, %[1]
	Deforestation and land degradation	Forest removed	m^2/kg diet
		Soil organic carbon (SOC) content	%[2]
	Air pollution	GHG emission	kg CO_2-eq /tonne diet
		Ammonia emission	ppm, %[1]
		Particulate matter in air	µg/m^3 air, %[1]
	Local feed resources	Total distance of ingredients in animal diet	km/tonne diet
People	Affordable animal products	Feed costs relative to the consumer price of an animal product	%
		Consumer spending on animal product relative to total spending of a household food basket	%
	Local knowledge (LK)	Extent of use of local knowledge in feed production or feeding	+, ++, +++
		Documentation of local knowledge	Yes/No, %
	Competition with human food	Extent of use of human edible products in animal diet	%
		Extent of use of feed produced on land not suitable for food crop production	%
	Exacerbation of unfavourable legal processes	The extent of formal and informal resistance to agricultural land rights issues	%
Profit	Internaliza socio-environmental costs	Degree of internalization of socio-environmental costs	%
	Benefit-cost ratio of all stakeholders	Benefit-cost ratio above one for all stakeholders	%
	Volatility in prieces of feed ingredients	Proportion of feed ingredients sensitive to price fluctuations	%

[1] Percentage of days over a certain time period when the limit is exceeded.

[2] Average SOC over a certain period.

Figure 3
Diagram of activities in the animal production chain related to animal diets, with corresponding impact on the environment



Notes: The inner circle contains the stages of the animal production chain. The second circle contains the activities in the animal production chain relevant for animal diets. The outer circle contains the impacts of these activities on the environment.

PLANET DIMENSION

For each of the five feed production stages, activities with corresponding impact on the environment are presented in Figure 3. For example, fertilizer use and pesticide use for feed production may contribute to the environmental impact through nutrient surpluses, differences in fertilizer efficiency, soil degradation and loss of pollutants like heavy metals to the environment.

Minimize water pollution

Water pollutants are commonly described as substances in water bodies that, at certain concentrations, can compromise the health of humans, animals and ecosystems. Most water pollution comes from non-point sources, being diffuse discharges of pollutants over large areas of agricultural land with intensive farming. Point-source water pollution occurs where wastewater is discharged, for example at feed processing companies (FAO, 2014a). Water pollution can occur in all stages of the animal production chain.

A current environmental issue is the pollution of water by excessive amounts of nutrients (Tilman *et al.*, 2002). Excessive use of nutrient-rich products like fertilizers and nutrient-rich diets can pollute ground and surface waters by leaching and runoff to water bodies, or loss of these nutrients directly in the water; and cause eutrophication, groundwater pollution and harmful algal blooms. The amount of nutrients leaching or run off into water bodies depends on many environmental and management factors like climate, soil condition, tillage and fertilizer management (Di and Cameron, 2002; Tilman *et al.*, 2002). Other water pollutants such as heavy metals, pesticides, pathogens or antibiotic residues can have toxic effects for aquatic organisms, affect human health, or cause antibiotic resistance (Schwarzenbach *et al.*, 2006). To quantify water pollution related to feed production and feeding, three indicators were proposed.

Nitrogen content. A first indicator for water pollution is the nitrogen (N) content of the water, expressed in, for example, mg/L. Nitrogen is often the limiting nutrient for eutrophication in coastal and marine ecosystems (Correll, 1999; Howarth and Marino, 2006). A high nitrogen content can contribute to eutrophication, accelerating algae growth, acidification and cause degradation of organic material, which consumes oxygen, resulting in oxygen deficiency (FAO, 2006; Murdoch, Burns and Lawrence, 1998; Wright et al., 2001). In other words, a high N content increases the risk of disturbing the balance of aquatic ecosystems. Also, nitrogen from, for example fertilizers or manures, can be converted into nitrate by micro-organisms, polluting groundwater. High concentrations of nitrate that end up in drinking water can cause several health problems like methaemoglobinaemia, the blue baby syndrome (Majumdar and Gupta, 2000; Nosengo, 2003).

Most of the excessive N present in water bodies comes from crop production and animal production farms (Bouwman, 2013). The main sources of N surpluses are manure and other fertilizers. The amount of N present in the animal diet affects N losses due to excess N in feed, ending up in manure. Prevention of accumulation of N in the soil is essential in minimizing the excess N content of water bodies. To a lesser extent, wastewater from primary resource production or feed processing can also add to the N content in water bodies (de-Bashan and Bashan, 2004; Losso, 1999).

Phosphorus content. Phosphorus (P) is another nutrient contributing to water pollution. The P content in water bodies is often expressed in mg/L. P is naturally a growth-limiting nutrient for algae in freshwater lakes, reservoirs, streams and estuarine systems (Conley et al., 2009; Correll, 1999). The faction of 'reactive P' available for algae growth may increase due to agricultural practices (EUROSTAT, 2013a). Excessive P content of water bodies leads to eutrophication (Goel, 2006; Tilman et al., 2001).

Two main sources of excessive P present in water bodies are manure and other fertilizers. Current application rates of fertilizers are designed to meet N requirements of crops resulting in a build up of excess P in soils, which increases the potential for P runoff or leaching into water bodies (Sharpley, McDowell and Kleinman, 2001). As stated by Hart, Quin and Nguyen (2004), application of fertilizer should be considered an important tool to reduce P losses to the environment. Similar to N, the amount of P present in the animal diet affects P losses (Bennett, Carpenter and Caraco, 2001). Excess P in feed ends up in manure that can pollute waters adjacent to the animal farm.

Heavy metals. The presence of heavy metals in water bodies is another important indicator for water pollution and is often expressed in µg/L. Several common heavy metals in water bodies and soils are arsenic (Ar), cadmium (Cd), lead (Pb), chromium (Co), copper (Cu) and zinc (Zn). Some (e.g. Cu and Zn) are naturally present in soil, water and sediments, and serve as micronutrients for organisms (De Vries et al., 2002). Excess amounts of heavy metals affect the quality of drinking water and form a threat to human health (De Vries et al., 2002; Kar et al., 2008). Also, the aquatic biodiversity is threatened because of toxicity problems for aquatic organisms (De Vries et al., 2002).

Water pollution by heavy metals in the animal production chain is mainly caused by crop and animal production farms. Factors affecting the heavy metal levels are animal manure, animal feed, fertilizers, pesticides, and indirectly through atmospheric deposition (De Vries *et al.*, 2002; Hariprasad and Dayananda, 2013; Kar *et al.*, 2008). For example, some heavy metals such as Cu and Zn in animal feed are present in higher concentrations than needed according to the animal's requirements (Li *et al.*, 2005). The excess heavy metals are excreted in the manure and end up on agricultural land where the heavy metals enter the soil and water systems (Menzi and Kessler, in press).

Pesticides content. Herbicides, insecticides, fungicides and other biocides are widely used in agriculture to control pests. Pesticides present in ground and surface waters have a large impact on water quality and restricts use as drinking water. Pesticides end up in ground and surface waters through runoff after application on agricultural land (FAO, 1996). Moreover, point discharges occurring through spillage (e.g. sprayer loading, inappropriate storage and disposal) are an important source of pesticides affecting water quality (EUROSTAT, 2013b).

Pesticide use may lead to harmful effects upon (aquatic) ecosystems by loss of biodiversity, reduction in population density and disturbing predator-prey relationships (EUROSTAT, 2013b; FAO, 1996). Also, pesticides can have significant human health consequences. Every type of pesticide has a different toxicity level and this level varies for different types of organisms (FAO, 1996). Therefore it is difficult to assess the ecological impact of pesticides in ground- and surface waters. *Codex* Maximum Residue Limits (MRLs) or *Codex* Extraneous Maximum Residue limits (EMRLs) indicate the maximum pesticide residues allowed on crops according to *Codex Alimentarius* for food standards (FAO/WHO, 2013). These limits do not indicate the impact on water quality, however; exceeding these limits may be useful as proxy parameters. Other useful indicators are provided by the European Union's agri-environmental indicators: 'groundwater with pesticides above Environmental Quality Standards (EQS)' and 'rivers with annual average pesticide concentrations above EQS'. When pesticide concentrations exceed EQS (for most pesticides the limit is 0.1 µg/L) it is considered harmful to the environment (EUROSTAT, 2013b).

How to quantify the water pollution indicators

For precise determination of water pollutants, pollutants are preferably measured in the discharge of each individual entity, such as a farm or a feed producing unit. With a set threshold or critical value it can be determined when levels of a pollutant are too high. The European Commission, for example, set the threshold for N in rivers at 11.3 mg/L (EUROSTAT, 2012). Consequently, the impact of the pollutant content on water quality will be determined by the number of days per year when the threshold has been exceeded (FAO, 2014a). A disadvantage is that many nutrients reaching water bodies through leaching and runoff from the soil cannot be measured in the effluent stream of an entity. Moreover, measurements in waters adjacent to the entity may contain pollutants caused by other sources and therefore are not a suitable representative for the water pollution caused by the considered entity.

Another possibility is to use existing data on the average pollutant content of water bodies in the region where the entity is located, provided in databases from for example governments or organizations. Disadvantages are the uncertainty of the availability of such data and the fact that pollution is not specified at lower system levels, e.g. at farm level. Pollution can differ considerably between entities and is dependent on multiple management practices and environmental factors.

A third possibility is to calculate nutrient balances (e.g. Godinot *et al.*, 2014; Vitousek *et al.*, 2009) to determine the surplus of N, P or heavy metals lost to the environment. The share of surplus nutrients entering water bodies can be estimated based on several parameters affecting runoff and leaching, including: fertilizer management, manure management, soil quality, climate, land management (e.g. tillage, irrigation) and crop diversity.

Avoid deforestation and land degradation

Deforestation is the clearing of forest for agricultural expansion, wood extraction and infrastructure expansion. On a global scale a decrease of forest area exists because of the development of market economies and expansion of cropland (Geist and Lambin, 2002). The removal of forest is considered unsustainable because it can lead to carbon release to the air and causes biodiversity loss (FAO, 2006).

As stated by the United Nations Environment Programme (UNEP) "land degradation implies a reduction of resources potential by one or a combination of processes acting on the land"(UNEP, 2002). Processes like deforestation and removal of natural vegetation, overgrazing, and agricultural activities (e.g. tillage, intensive cropping systems) can lead to overexploitation of the soil, reducing fertility and consequently productivity (Bridges and Oldeman, 1999; FAO, 2006).

Deforestation and land degradation in the animal production chain occur mostly in the feed production and animal production stages. Both deforestation and land degradation can affect each other. Deforestation can cause land degradation because of loss of the natural vegetation maintaining the land (An *et al.*, 2008) and land degradation can result in deforestation to create fertile agricultural land elsewhere. Factors affecting deforestation or land degradation are often region specific and are difficult to point out (Geist and Lambin, 2002). When determining the extent of deforestation or land degradation caused by feed production and feeding practices, it is suggested to make a distinction between direct and indirect cause of deforestation and land degradation. Direct cause considers the land used for feed production or feeding. Indirect cause considers the contribution of factors causing deforestation or land degradation elsewhere than the place of feed production used for feeding. Under most situations, the latter is extremely difficult to determine and is not included in the indicators proposed in this section.

Forest removed. The surface of forest removed to clear land for feed production and feeding practices (e.g. crop production or grazing) is an indicator to quantify direct deforestation (Geist and Lambin, 2002). This indicator is less easily quantified than indicators identified for water and air pollution. Once forest is removed, multiple production cycles of crops or grazing animals can occur on the cleared land. This needs to be taken into account when determining the surface of forest removed for a certain animal diet. Other difficulties are to determine whether or not the considered agricultural land was previously forest, the minimum density of trees to be called a forest and where to set the time boundary for the definition of forest removal (e.g. 5, 20, or 100 years after forest removal).

Soil organic carbon content. An indication of land degradation is low soil productivity (Tóth, Jones and Montanarella, 2013). Organic matter in soils originates from residual plant and animal material and is essential for soil productivity (Fenton, Albers and Ketterings, 2008). Soil organic carbon (SOC) is a major component of the organic matter in soils. If not enough residues are returned to the soil it will cause a decrease in SOC content (National Research Council, 1993). The SOC content is highly influenced by agricultural practices performed on land (Tóth, Jones and Montanarella, 2013) for crop and animal production. Factors influencing the SOC content are, for example, the soil type (e.g. clay, sand, silt, loam), tillage, plant residues, crop rotation and soil micro-organisms. To give an impression of the impact of agriculture on SOC content: in the Midwestern United States of America, the majority of soils converted from natural to agricultural systems have lost 30 to 50 percent of the original SOC level (Lal, 2002).

The SOC content can be quantified by measuring the percentage of SOC (Jobbágy and Jackson, 2000). Another, more feasible option is the use of databases on average SOC content per region. Disadvantages are the uncertainty of the availability of such data and the fact that impact is not specified per farm. Besides this, impacts can differ considerably between farms depending on management practices and environmental factors. A third option is to estimate the contribution of a farm based on several parameters affecting the SOC content, such as: tillage, crop rotation, return of plant residues to soil, soil micro-organisms and climate.

Minimize air pollution

In each step of the animal feed production chain air pollutants are emitted. Pesticides (Curtis *et al.*, 2006), fossil fuels, fertilizers and enteric fermentation of ruminants can considerably contribute to air pollution. Air pollutants like sulphur dioxide, nitrogen oxides and ammonia can cause acid rain, endangering biodiversity (Erisman *et al.*, 2008; FAO, 2006). Other air pollutants cause global warming or affect human and animal health. In this section, greenhouse gases (GHGs; including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)), ammonia (NH_3) and particulate matter (PM) are considered. To quantify the air pollution, three indicators were proposed.

Greenhouse gas emission. GHGs are air pollutants known to contribute to global warming. From the amount of GHGs emitted, the global warming potential (GWP) can be calculated, expressed in kg CO_2-eq per kg product. One kg of CO_2 is 1 kg CO_2-eq, 1 kg CH_4 corresponds to 25 kg CO_2 and 1 kg N_2O corresponds to 298 kg CO_2 over a period of 100 years, according to the fourth IPCC assessment report (AR4; Forster et al. (2007)).
The emission of GHGs occurs at every step of the animal feed production chain. Especially the production and use of energy and fertilizers, and the emission of CH_4 by ruminants contribute to GHG emission. For example, the production of fertilizers emits 41 milliont ton of CO_2 per year through use of fossil fuels (FAO, 2006). Also, the use of fertilizers on land affects the natural process of denitrification and nitrification in the soil and can increase N_2O emissions (Aneja, Schlesinger and Erisman, 2009). FAO provides guidelines for assessing environmental performance (including GHGs) using the Life Cycle Assessment methodology (FAO, 2015a).

Ammonia emission. Current agricultural practices produce very large ammonia (NH_3) amounts because of high N inputs into agricultural systems, including the animal feed production chain. In 2011, agriculture was responsible for 94 percent of the NH_3 emissions (Aneja, Schlesinger and Erisman, 2008; EEA, 2014). As stated by Arogo, Westerman and Heber (2003), NH_3 emission to air is problematic mainly because of: (1) atmospheric deposition in nutrient sensitive ecosystems, (2) formation of light scattering aerosols causing haze and visibility impairment, and (3) formation of respirable aerosol particles affecting human health. NH_3 also contributes to odours emitted by animal production systems, affecting people living in the neighbourhood of the farm (McGinn, Janzen and Coates, 2003). High levels of NH_3 in the barn also affect animal health, for example pigs are highly sensitive to NH_3 (Wathes *et al.*, 2004).
Factors affecting NH_3 emission are fertilization, soil condition, manure management, feed N content and environmental conditions (Arogo, Westerman and Heber, 2003; Gay and Knowlton, 2009; Sommer, Schjoerring and Denmead, 2004; USDA, 2005). NH_3 can also be emitted by biomass burning (UNEP and WHRC, 2007). This can be of importance, for example, in slash and burn agriculture involved in feed production and feeding practices or manure burning.

Particulate matter. Particulate matter (PM) are particles often found in the air caused by many agricultural practices and is often measured in $\mu g/m^3$ air. PM can negatively affect the respiratory system of humans and animals and cause respiratory and cardiovascular diseases (Brunekreef and Holgate, 2002; Cambra-López et al., 2010). Air quality guidelines of the World Health Organization indicate that a threshold cannot be determined because health effects differ greatly for each individual. Nevertheless, exposure guidelines are identified as 10 $\mu g/m^3$ annual mean and 25 $\mu g/m^3$ 24-hour mean for PM2.5, and 20 $\mu g/m^3$ annual mean and 50 µg/m3 24-hour mean for PM10 (WHO, 2006). Factors affecting the emission of PM are feeding management, cultivation, harvesting, fertilizer use, agricultural field burning, climate and other environmental factors (Aneja, Schlesinger and Erisman, 2008; Cambra-López et al., 2010). Also the transport of feed contributes to PM concentrations in the air originating from combustion sources (WHO, 2006).

How to quantify the air pollution indicators

As with determining water pollutants, it would be most accurate to measure the air pollutants emitted by each entity, for example a farm or feed manufacturing plant, setting threshold values for maximum air concentrations of pollutants. However, this may not be considered a practical and feasible method, considering that many pollutants are emitted directly to open air, and pollutants can be caused by other sources.

Existing data can be used to determine the average emission of an air pollutant in a certain sector, provided in databases of, for example, governments or organizations. Disadvantages are the uncertainty of the availability of such data and the fact that pollution is not specified per entity. Another option is to estimate the contribution of an entity based on several parameters affecting the emission of air pollutants, for example: fertilizer use and management, manure management, feed composition and land cultivation and tillage.

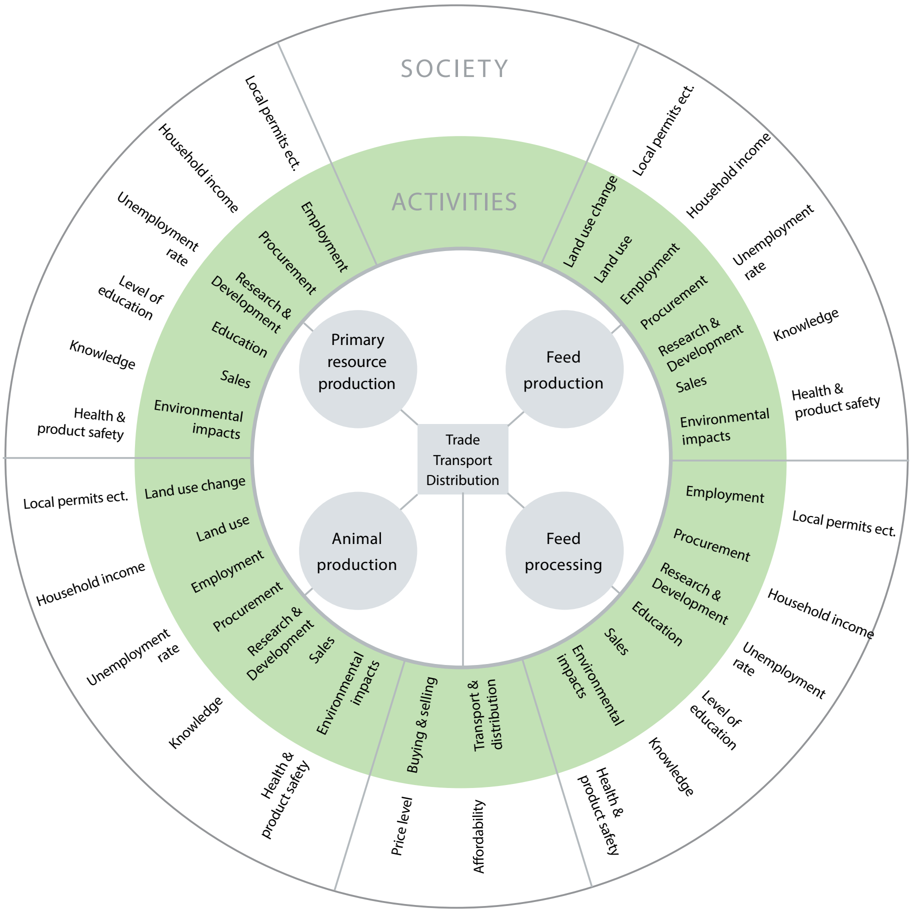
Use locally available feed resources

The locality of feed resources is an important element in sustainable animal diets because it involves environmental issues like nutrient cycling and GHG emissions from transport of feed products. Use of locally available feed resources also has an impact on the people dimension because it may promote local economies and generation of employment. For example, most soybean meal used to feed production animals in Europe is produced in Latin America (Dalgaard, 2008). Here, nutrient cycling is disturbed because nutrients are extracted from soils in Latin America and end up in manure produced in Europe. In general, local production of feed makes the feed production system more resource efficient and less polluting per kg of feed produced (Stern *et al.*, 2005).

Locality of feed is also of importance for economic sustainability. Use of feed ingredients from other regions can also contribute to volatility in feed cost, which is not healthy for livestock operations because it impedes taking of sound management decisions on resource uses and enhances risk (H.P.S. Makkar, pers. comm, 2015) As stated by Djajanegara (1999), the impact of the economic crisis in 1997 in Indonesia highlights the importance of using locally available feed. During an economic crisis entities cannot afford imported feed and are dependent on locally available products. To quantify the locality of feed resources used in an animal diet, one indicator was proposed.

Total distance of ingredients in animal diet. Locality of the used feed can be determined by the distance the feed has travelled before it arrives at the animal farm. This can be expressed as the total kilometres travelled of all ingredients in an animal diet. The amount of kilometres from the location of feed production or feed processing to the animal production farm need to be determined per ingredient in order to obtain the total distance of an animal diet. Another option could be to measure the proportion of metabolizable energy being contributed in the diet from resources that are available locally. A definition for locally available feeds is required, e.g. defining a region or radius around a farm.

Figure 4
Diagram of activities in the animal production chain related to animal diets, with corresponding impact on the society



Notes: The inner circle contains the stages of the animal production chain.
The second circle contains the activities in the animal production chain relevant for animal diets.
The outer circle contains the impacts of these activities on the society.

PEOPLE DIMENSION

For each of the five feed production stages, activities with corresponding impact on the society are presented in Figure 4. For example, the employment of people in feed producing units may have an impact on the unemployment rate in the region of the entity.

Provide affordable animal products for consumers

Affordability is a consumer's perception. The amount of money a consumer is willing to spend on an animal product depends on what they consider important or how they prioritize their values (De Pelsmacker, Driesen and Rayp, 2005). Three examples of extreme situations could be: one consumer wants as much food as possible for a given amount of money; another wants to buy the food that is healthy; while a third one focuses on the environmental aspects. In real life, every consumer is somewhere in the grey zone in between.

A certain limitation exists for the affordability of animal products related to the consumer price of other groceries. This also differs for each consumer and depends on the prioritization of their values. In addition, the quality and value of a product influences affordability (Senauer, 2001). For example, when a farmer uses a certain feed ingredient that results in a higher consumer price of the animal product, but also results in a higher quality of the product, consumers can still consider it affordable. Vermeir and Verbeke (2006) showed that consumers are not willing to pay much more for sustainable products, although they have a positive attitude towards it. This unwillingness can partly be explained by the finding of Senauer (2001) that 74 percent of the consumers consider the price very to extremely important, and that Western consumers are used to spend solely around 10 to 16 percent of their income on food (Hocquette and Gigli, 2005; Hodges, 2005). For many people, affordability appears to be a state of mind that may be influenced by knowledge, standards and values.

Naturally, affordability is also related to the income of the consumer and the consumer price. It is generally the case that a lower consumer price results in higher affordability. In that sense it may be essential to achieve the lowest possible consumer price. This implies that not only the cost price of the product, but also costs for transportation, handling, storage and distribution must be as low as possible. These additional distribution, storage and handling costs often represent the biggest share in the overall consumer price (Rujis, Schweigman and Lutz, 2004). The more transparent and simple the distribution chain, the lower is the consumer price. In the context of feed production and feeding practices, factors affecting the affordability of animal product are the cost price of feed and feed related practices such as transportation, handling and storage. Quantification of the affordability, however, is difficult and complicated because many factors affecting the affordability are not quantifiable. Two indicators were proposed in an attempt to make affordability quantifiable.

Feed costs relative to the consumer price of an animal product. Considering sustainable animal diets, it is important to look at the impact of feed on the affordability of animal products. For this, the feed costs relative to the consumer price of an animal product can be determined. Knowing the share of existing feed costs in the consumer price might help assessing the impact of changing feed costs on the consumer price. However, it remains difficult to assess the effect of increased consumer prices (resulting from higher feed costs) on the affordability for consumers.

Consumer spending on animal product relative to total spending of a household food basket. Whereas the previous indicator yields information about the contribution of feed costs to affordability at the product level, consumer spending on an animal product relative to total spending on a household food basket yields information about affordability at the household level. Per household this ratio may differ, depending inter alia on income and consumer values (see page 14, section 'Provide affordable animal products'). Based on such information, a critical level for animal product spending can be determined, above which the majority of consumers, e.g. in a specific socio-economic group or region, consider the specific product unaffordable. In addition, the availability of data on consumer spending and household spending on food basket for certain targeted users (e.g. farmers, feed producers) should be critically assessed.

A disadvantage is that this indicator does not show the impact of the animal diet on the affordability. However, the two suggested indicators together cover the impact of feed costs to the affordability at household level.

Promote and preserve local knowledge

Local knowledge (LK) of agriculture is built upon many generations of act and response (trial and error) between farmers and their local environment (Mazzocchi, 2006). Because practices are adapted to the local environment, the agricultural ways are generally robust and resilient (Altieri, 2009; Briggs, 2005). This is often missing in the modern agricultural systems that evolved from the green revolution (Altieri, 2004, 2009). LK is often part of a lifestyle, involves traditions and symbolic beliefs (Mazzocchi, 2006), belongs to culture and can contribute to food security for poor rural households (Upreti and Upreti, 1999), making the promotion and preservation of LK important for social sustainability.

Although promotion and preservation of LK can contribute to social sustainability, application for some LK can have negative effects on economic or ecological sustainability. For example, farmers in Northern Karnataka, India, believed that feeding hay of a single crop causes diarrhoea to the animal and has to be fed as hay of mixed crop, but according to 80 percent of the scientists approached, this is scientifically incorrect (Biradar, Ramesh and Pathak, 2007). Also, although certain practices of LK may benefit environmental sustainability of feed production and feeding, others may increase environmental impacts. If LK is not used in the feed production system, it can still be promoted to preserve the knowledge. For example through contributing to organizing cultural festivities, contributing to teaching children about traditional/local activities, or contributing to document local knowledge (UNESCO, 2011). Similar to affordability, quantification of promotion of local knowledge is a highly challenging task. Two indicators were proposed.

Extent of use of local knowledge in feed production or feeding. An indicator can be the extent of use of LK in feed production and feeding practices. To determine this, the first step could be to make a distinction between LK about feed production and feeding and other LK. This can be decided based on expert knowledge and literature review. The determination of extent of use of local knowledge in percentage terms is difficult. Nevertheless, using expert opinion it can be categorized as minor, moderate or high, which can be presented as +, ++ and +++ respectively.

Effects of applying LK in feed production and feeding on other aspects of sustainability is not included in this indicator, but will become apparent from the other indicators in the present study.

Documentation of local knowledge. Documentation of local knowledge is a possible indicator for the preservation of local knowledge. It considers the extent of local knowledge that is preserved through documentation by entities involved in the animal feed production chain or by government agencies. This can be expressed simply by deciding whether or not LK is documented in a certain region, which can be assessed by a local expert. A good definition of local knowledge need to be established because no universal definition is yet available (Mazzocchi, 2006).

Minimize competition with human food

Feed can compete with human food in two ways. First is the competition for the product. Several crops that are fed to animals can also be consumed directly by humans (Goodland, 1997). Instinctively, it seems wrong to feed human-edible crops to animals when globally 804 million people are chronically undernourished (FAO, 2014b). Second is the competition for land. Agricultural land is becoming a scarce resource. Around 30 percent of the world's cropland is used for animal feed production (Foley *et al.*, 2011). Parts of this agricultural land are also suitable for food crop production. It is generally the case that a lower quantity of food will be produced when using land and products suitable for human consumption for animal feed than using the land and products to feed humans directly (Foley *et al.*, 2011). To quantify the competition with human food two indicators were proposed.

Percentage of human-edible products in animal diet. This indicator considers the competition between humans and livestock for a product. As mentioned in section 'Minimize competition with human food' above, use of human edible products as animal feed competes with human food. This indicator points out the percentage of human edible products in the animal diet. Human edible products that are frequently used in animal diets are mainly soybean and cereal grains like maize (Rosegrant et al., 2001; Wilkinson, 2011).

Extent of use of feed produced on land not suitable for food crop production. This indicator considers competition for agricultural land. If land suitable for food production is used for feed production and/or feeding (e.g. grazing animals) it competes with human food. The extent of feed produced on land not suitable for food crop production therefore does not compete with human food. It can be expressed as a percentage of the animal diet. For example: an animal diet consists 40 percent of ingredients produced on land not suitable for food production (including the grass grazed by the animal). Another option could be to express the percentage of metabolizable energy that is derived from feed ingredients produced on land not suitable for food production. Issues that need to be resolved in order to use this indicator are: (1) when is agricultural land considered 'not suitable' for food production? The GAEZ database on agro-ecological suitability and productivity is an option to determine the suitability of land to grow food crops (IIASA/FAO, 2012); and (2) how to determine if a certain feed ingredient is produced on such land.

Avoid exacerbation of unfavourable legal processes

For the purpose of this study, it is assumed that unfavourable legal processes involved in feed production and feeding involves mainly land grab and land rights issues (H.P.S. Makkar, pers. comm, 2014) The main issue is the competition for land between different groups of land users like farmers, herders, urban elites and foreign investors (Cotula, Toulmin and Hesse, 2004). Land available for many small-scale farmers to grow crops or keep livestock is diminishing, because of industrialization and urbanization. Uncertainties also exist with respect to land ownership (tenure) and land rights. In southern Africa, for example, extremely inequitable land distribution is causing tensions and can result in unfavourable legal processes (Cotula, Toulmin and Hesse, 2004). Avoiding the exacerbation of these legal processes can be achieved by improving land ownership and land rights.

This is important for reducing poverty among small-scale farmers. Land ownership encourages farmers to invest in inputs and technology, resulting in generation of income and in improvement in their food security status (Neto, 2004).

Quantification of the avoidance of unfavourable legal processes is a challenge. One way to determine this is by the occurrence of legal processes or community-level problems on agricultural land in a region where agricultural land is used for animal feed production and feeding. Therefore, the following indicator was proposed.

The extent of formal and informal resistance to agricultural land rights issues. For identifying this indicator a broader approach was adopted than the one described in the element from the StAnD survey, wherein the element mainly relates to formal legal processes (proceedings of law suits, litigations, etc.). Informal resistance from civil society is another relevant aspect in land rights issues and needs to be considered as well. For example, in some societies with occurrence of land grabbing, the farmers do not have access to courts. These forms of land rights issues should not be overlooked. The indicator therefore relates to the number of recorded formal and informal resistance actions from stakeholders and civil societies on agricultural land rights issues in a certain region where agricultural land is used for animal feed production and feeding. Data on resistance actions can be gathered through local governmental bodies and newspaper archives. Quantification of these actions provides a notion of the extent of the resistance to agricultural land rights issues.

PROFIT DIMENSION

The diagram of activities with corresponding impact on the economy is presented in Figure 5. For example, sales, and research and development (R&D) performed by a feed producing and feed manufacturing entity influences market access.

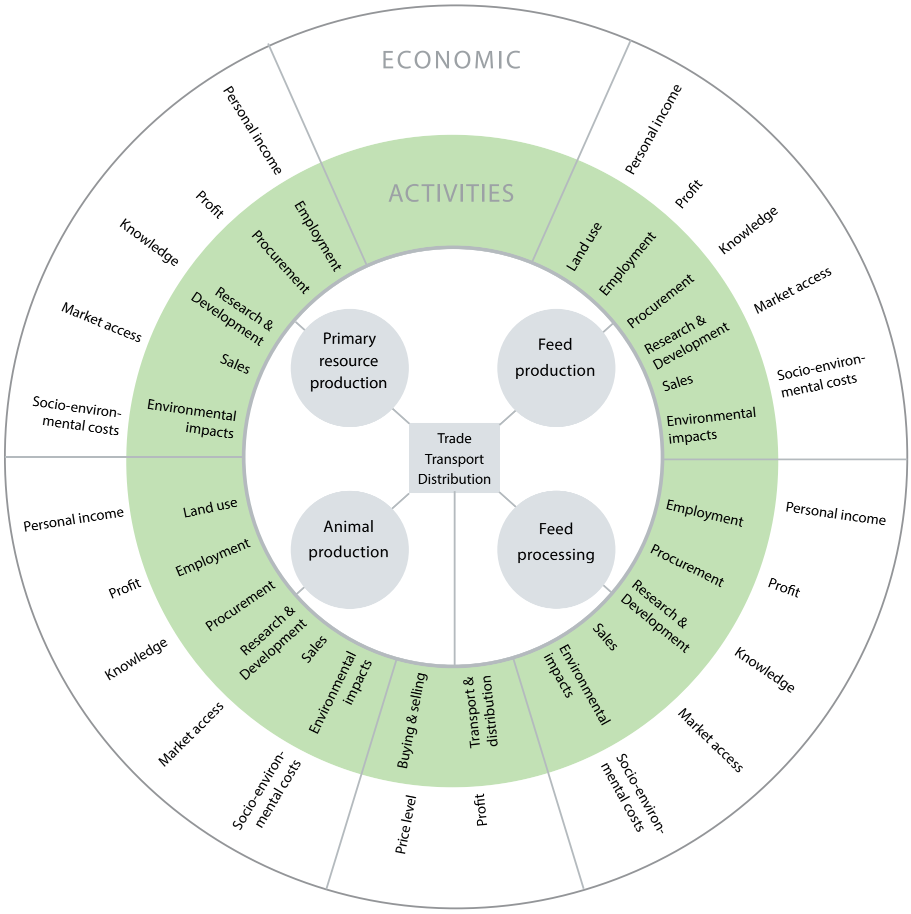
Internalize socio-environmental costs to the true costs of production

Hidden costs of production may result from agricultural intensification (Hodges, 2005). These costs arise because of negative effects of feed production and feeding, for example as a result of environment degradation, biodiversity loss, loss of ecosystem services and the emergence of pathogens (Tilman *et al.*, 2002). Elements mentioned in this report like water pollution, air pollution, or loss of local knowledge can also be considered as hidden costs or socio-environmental costs which are currently not included in the production costs.

It is important not only to include socio-environmental costs in the production costs, but also in the product price in order to be economically viable. Higher consumer prices with socio-environmental costs included may affect affordability. There is value added to the product, so as to reduce the socio-environmental impact. However, not all consumers will value this price increase and will consider the product less affordable.

It is a challenge to determine and quantify environmental and social impacts which are typically unmeasured hitherto (Tilman *et al.*, 2002) and to express them in monetary terms. The proposed indicator, therefore, only mentions the main steps for quantifying the socio-environmental costs of animal diets.

Figure 5
Diagram of activities in the animal production chain related to animal diets, with corresponding impact on the economy



Notes: The inner circle contains the stages of the animal production chain.
The second circle contains the activities in the animal production chain relevant for animal diets.
The outer circle contains the impacts of these activities on the economy.

Degree of internalization of socio-environmental costs. For determining if socio-environmental costs are internalized in the true costs of production, first the social and environmental impacts need to be quantified. Next step is to make an estimation of the costs for undoing these socio-environmental impacts. The final step is to determine the amount of the socio-environmental costs that originate exclusively from feed production and feeding included in the production costs. This can be expressed as the percentage of the total socio-environmental costs.

This approach is challenging and time consuming. Currently FAO is working on a project to determine the economic value of ecosystem services and biodiversity (The Economics of Ecosystems and Biodiversity ;TEEB), which could be useful for future work on the StAnD concept.

Enhance benefit-cost ratio for all stakeholders

The benefit-cost ratio is a well-known indicator that expresses the amount of monetary gain. If an animal feed production chain has a benefit-cost ratio below one, it is unsustainable from an economic point of view. There are a number of stakeholders involved in an animal feed production chain, which all have their own benefit-cost ratio related to the product they deliver.

In current international markets and global trade, there is generally unequitable distribution of profit among stakeholders. Farmers generally receive a low share of the product price (Buller and Morris, 2004). They do not have bargaining power against buyers in trading, processing and retailing industries, which are powerful and better organized (Dobson, 2003; Vorley, 2003). For example, Pretty (2002) estimated that around 7.5 percent of every pound spend on food in the UK goes to farmers, this was 50 to 60 percent around sixty years ago. The low share of product price for producers results in a negative benefit-cost ratio. Until now, many producers are able to continue their production, thanks to subsidies from the government (Hodges, 2005). For assessing the enhancement of the benefit-cost ratio for all stakeholders, the following indicator was proposed.

Benefit-cost ratio above one for all stakeholders. The enhancement of the benefit-cost ratio can be determined by calculating the benefit-cost ratio for all stakeholders in the chain. This is relatively easy. First, all stakeholders involved are to be identified. Next would be determination of the benefit-cost ratio for their operation. It is assumed that every stakeholder knows their average benefits and costs incurred. When the benefit-cost ratio is above one for all stakeholders, an animal diet can be considered to enhance the benefit-cost ratio. Ideally, this ratio should increase with time.

Not enhance volatility in prices of feed ingredients

Volatility in prices means price fluctuations which are large and unforeseen, creating risks for producers, traders, consumers and governments (FAO *et al.*, 2011). Price volatility is high in most agricultural markets and based on changes in supply and demand. These changes come from fluctuations in annual agricultural output because of weather conditions or other unforeseen circumstances (FAO *et al.*, 2011). The financial sector and policy measures can also cause price volatility, for example the embargo on grain export in Russia in 2014. Grain being a substrate for production of biofuels makes its price susceptible to change in the oil price. Price fluctuations in the oil market, therefore, will affect the grain market (Halsema, 2011).

Volatility can, for example, be enhanced by use of feed ingredients from the global market which are cheapest at the moment. If everyone buys the cheapest products, supply will decrease fast and prices will rise. Prediction of buyer behaviour is a challenge. A good understanding of the factors affecting volatility in prices of feed ingredients is required. The historical price volatility values of feed ingredients, showing ingredients that are sensitive to price fluctuations, could serve as an indicator.

Proportion of feed ingredients sensitive to price fluctuations. To determine if volatility in prices of feed ingredients is enhanced by a certain diet, one option is to identify the use of ingredients sensitive to price fluctuations based on the historical price volatility of the ingredients used. This involves gathering data on volatility over a period of time for each feed ingredient. It would be useful to compile a database with historical volatility data of all feed ingredients and possible factors affecting the prices. The percentage of feed ingredients used in the diet with a relatively historical high price volatility will provide an indication of the enhancement of price volatility.

FEED EFFICIENCY

Feed efficiency can be defined as the amount of animal product produced per kg feed, and can differ between animal diets. The feed efficiency of an animal diet is an important indicator to take into account, even though it does not belong to an element. Comparing animal diets, for example, for their impact on air pollution, competition with human food, or impact on price volatility, may give biased results when the feed efficiency is not taken into account. Results need to be corrected for the different feed efficiencies of diets. It is therefore essential to include feed efficiency in the methodology and for tools to be developed for the comparison of sustainable animal diets. In fact a number of parameters used for measuring feed efficiency, such as nitrogen use efficiency or phosphorus use efficiency could be proxy indicators of nitrogen and phosphorus release in water or in the environment, as well as for enteric methane emission from ruminants. For lactating animals, milk nitrogen could be an indicator of feed-nitrogen use efficiency. Also ratio of urinary purine-nitrogen to total urine nitrogen in spot urine samples could also reflect feed-nitrogen use efficiency in the rumen (Makkar and Chen, 2004). In most situations formation and use of a low cost diet using locally available resources that meets the nutrient requirement of the animals would decrease air and water pollution, lower farm gate price of animal product, not enhance price volatility of ingredients and not lead to deforestation (H.P.S. Makkar, pers. comm, 2015).

Discussion

This exploratory study was a first attempt to identify quantifiable indicators for a part of the sustainability elements that were selected for StAnD. A general approach was applied, using a generic animal production chain representing all the types of animal species, production systems and locations in the world, for identifying activities affecting environmental, social and economic sustainability. Based on these activities, indicators were identified and clustered according to the elements selected by StAnD. The following remarks can be made in relation to the results and methods used.

This study resulted in a list of indicators that are generally considered important for sustainable animal diets. During the process of indicator identification it appeared that the criteria 'quantifiable' and 'easy-to-measure' were difficult to meet. First of all, some elements or indicators (e.g. promote and preserve local knowledge or avoid exacerbation of unfavourable legal processes) cannot be easily measured or quantified. In particular, issues of social sustainability are more difficult to quantify (McKenzie, 2004). Qualitative assessment methods are preferred to valuate the sustainability performance of an animal diet for these specific elements or its indicators. Second, for the indicators that can be measured, quantitative measurements might be impractical because they are often time consuming and costly (Tilman *et al.*, 2002). An option is to use readily available data for estimating these indicators. Estimates based on these data can be inaccurate, however, because these data may not sufficiently relate to the context of the animal diet (e.g. agro-ecological region, farm management and type of production system). For example, regions with less fertile soils can show lower forage yields per hectare and poorer digestibility of forages, leading to more intensive land use and emissions of animal-source foods (De Vries, Yigrem and Vellinga, 2016).

The identified indicators were based on the StAnD elements that were selected for this study. Therefore, the indicators identified in this study do not give a 'complete' picture of sustainability. Some important indicators might be overlooked using the generic approach and the guidance of elements selected in the StAnD concept. Other indicators could emerge when a specific sector or region is more closely studied. For example, odour emitted by intensive pig production may contribute to air pollution, especially for local residents (Tajik *et al.*, 2008). As presented by Sutton *et al.* (1999), these odours may be reduced through diet modification. Moreover, the selected elements used in this study and the other elements from the StAnD concept represent a current view of participating experts on sustainability. Other sustainability issues not included in the elements of the StAnD concept could emerge, focusing on specific sectors, systems or regions.

This study was meant as an exploratory step towards the goal of implementation of the StAnD concept, which was to develop a generic methodology and tools, suitable for all types of animal diets, to be able to compare diets for sustainability performance, and to assist farmers and feed industry in choosing a more sustainable diet. It resulted in a list of indicators generally considered important for assessing sustainability of animal diets. A next step in achieving this goal is to develop a method that facilitates the conversion of all sustainability indicators, with their respective impacts, into an overall sustainability index that further enables the comparison and selection of animal diets. To achieve this, impacts per indicator need to be quantified, not only in relation to the amount of feed or feed-component, but also in relation to the amount of animal product resulting from it. Also a way must be found to value indicators that are expressed in other units on the same scale. As mentioned previously, a universally applicable evaluation method should be interpreted with care, because it may not provide sufficient detail to sensibly value the impact of the indicators relating to a specific sector, system or region.

Prioritization of the identified indicators can differ depending on the context in which the animal diet is used. Other indicators can appear more important or relevant. The same applies to the elements. For example, the element 'not enhance price volatility of feed ingredients' may be more relevant and of greater importance to large-scale industrial feed production systems, compared with smaller systems with locally produced feed. Another example is the avoidance of exacerbation of legal processes. This element may be of greater importance in countries with conflicts on land ownership (e.g. many African countries) compared with Europe or North America. These issues reflect that, in general, if a comparison is to be made of the sustainability performance of animal diets to assist a farmer in the choice for a diet, the assessment needs to be context related. As stated by Herrero *et al.* (2013), the benefits and negative impacts of animal systems on the environment and climate change are heavily differentiated spatially and need to be put into the local context to develop suitable research agendas to determine sustainability.

Another approach could be that separate methods and tools are developed for the indicators that can sensibly be quantified and compared on a generic and universally applicable scale (e.g. SAFA guidelines, indicators and tool (FAO, 2014a)), while another set of methods and tools be developed for the indicators that can only sensibly be assessed and quantified in the context of the specific sector or region under investigation. For the latter, flexible methods and tools can then be developed that also allow and facilitate adaptation to the local situations. These issues could be addressed through conducting case studies.

Conclusion

Twenty key indicators were identified for the eleven selected elements from the StAnD survey that are considered important for assessing and comparing animal diets for their sustainability performance. Ten indicators were identified for the Planet dimension, eight indicators were identified for the People dimension and three indicators were identified for the Profit dimension. Possible quantification methods were proposed that facilitate measurement of sustainability performance of animal diets. This study can form a basis for further work aiming at implementation of the StAnD concept. However, more sector-specific research is needed to help further develop the overarching methodology for assessing the sustainability performance of animal diets.

RECOMMENDATIONS

The generic approach used in this study serves the aim of developing an overarching methodology for assessing the sustainability of animal diets; and this approach might form the basis for the development of targeted and easy-to-use tools. Because the primary goal of the StAnD concept is to promote the use of more sustainable animal diets by farmers, as well as the production of sustainable animal diets by the feed industry, it is recommended that case studies are performed for specific sectors, production systems and regions, using the generic approach of StAnD developed in this study. These case studies would help the transformation of the overarching StAnD methodology to practical and easy-to-use tools.

In a first step some animal production sectors can be identified (e.g. entities producing the same animal product, using similar production methods in a certain geographical region) for which the same approach is used as for this study to assess sustainability of animal diets being used. In such a situation the animal product, the production system and the production chain will be known, the identification of important indicators for assessing sustainability of animal diets can be more purposeful and accurate. Also the ways to quantify these indicators can more easily be determined because availability of data on this specific sector can be checked and tested. It could be helpful to compile data sets relevant to specific sectors. And finally, because the parties involved and the DMU (Decision Making Unit) can then be identified, more tailored methods, instruments and calculation tools can be developed that may help and encourage farmers in this sector to compare, select and use more sustainable animal diets. Approaches outlined in this study, nevertheless, can be useful in conducting sector- and production system-specific studies.

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Appendix A
Results from the StAnD survey

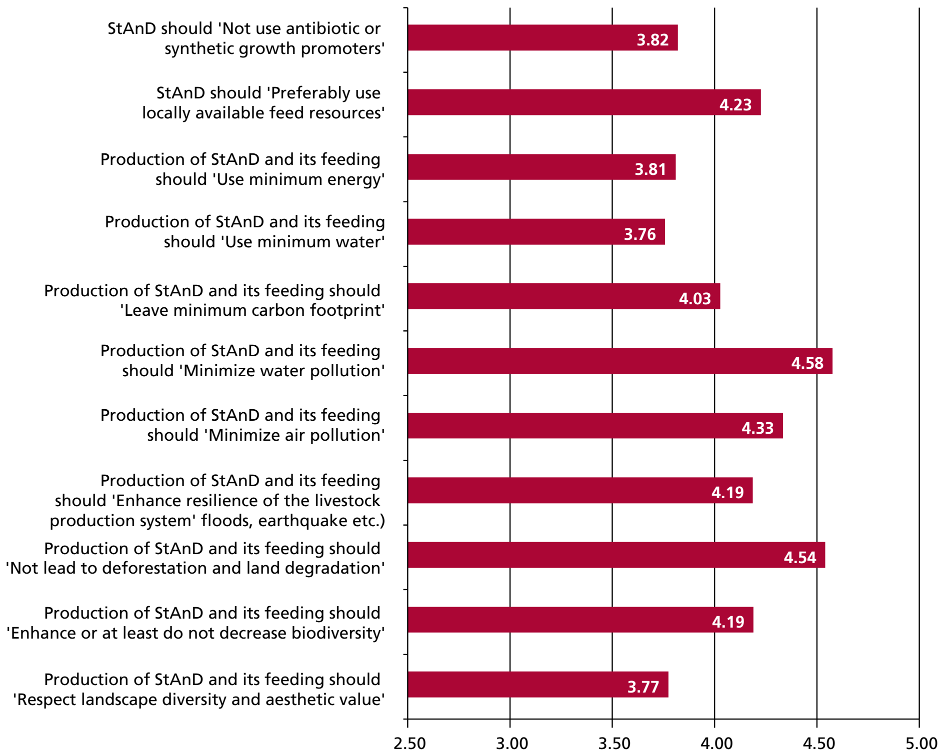
The StAnD survey included the following elements:

Planet

1. Production of StAnD and its feeding should minimize water pollution.
2. Production of StAnD and its feeding should not lead to deforestation and land degradation.
3. Production of StAnD and its feeding should minimize air pollution.
4. StAnD should preferable use locally available resources.
5. Production of StAnD and its feeding should enhance or at least do not decrease biodiversity.
6. Production of StAnD and its feeding should enhance resilience of the livestock production system.
7. Production of StAnD and its feeding should leave minimum carbon footprint.
8. StAnD should not use antibiotic or synthetic growth promotors.
9. Production of StAnD and its feeding should use minimum energy.
10. Production of StAnD and its feeding should respect landscape diversity and aesthetic value.
11. Production of StAnD and its feeding should use minimum water.

See Figure A.1 for an overview of the results for the planet dimension.

Figure A.1
Results of the StAnD survey for the planet dimension



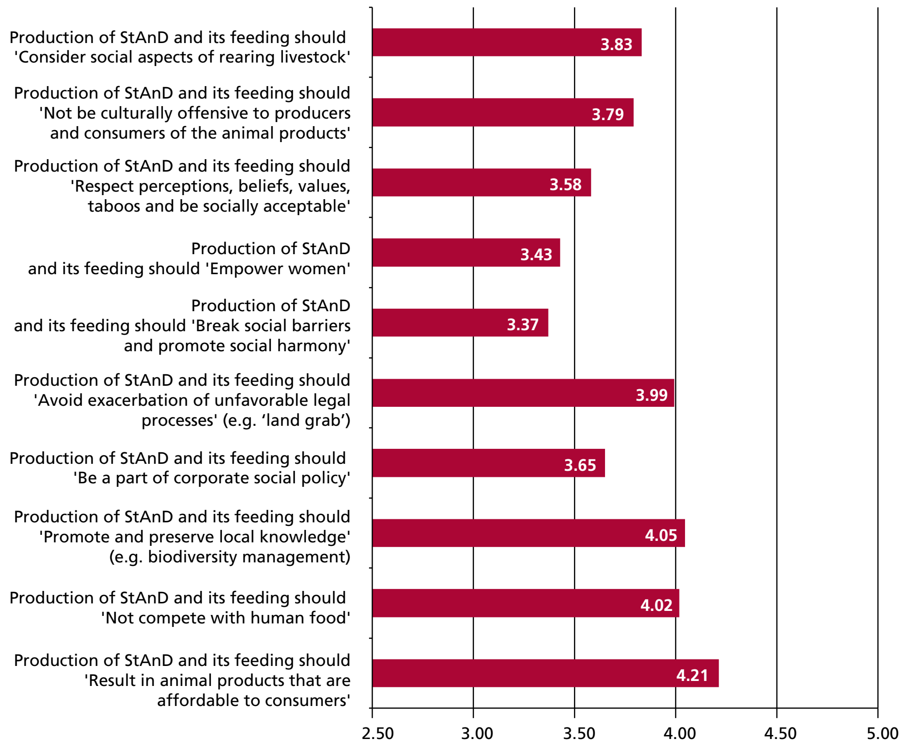
Source: Makkar and Ankers, 2014

People

1. Production of StAnD and its feeding should result in animal products that are affordable to consumers.
2. Production of StAnD and its feeding should promote and preserve local knowledge.
3. Production of StAnD and its feeding should not compete with human food.
4. Production of StAnD and its feeding should avoid exacerbation of unfavourable legal processes (e.g. land grab).
5. Production of StAnD and its feeding should consider social aspects of rearing livestock.
6. Production of StAnD and its feeding should not be culturally offensive to producers and consumers of the animal products.
7. Production of StAnD and its feeding should be a part of corporate social policy.
8. Production of StAnD and its feeding should respect perceptions, beliefs, values, taboos and be socially acceptable.
9. Production of StAnD and its feeding should empower women.
10. Production of StAnD and its feeding should break social barriers and promote social harmony.

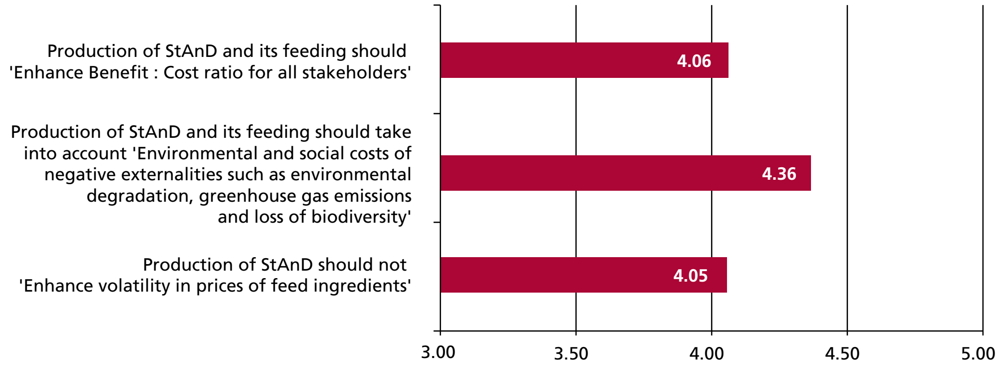
See Figure A.2 for an overview of the results for the people dimension.

Figure A.2
Results of the StAnD survey for the people dimension



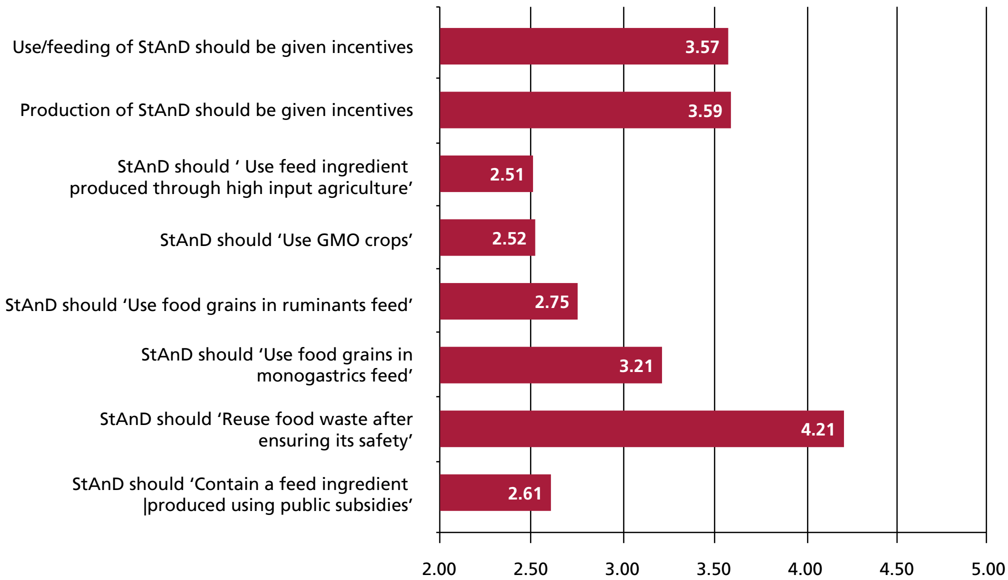
Source: Makkar and Ankers, 2014

Figure A.3
Results of the StAnD survey for the profit dimension



Source: Makkar and Ankers, 2014

Figure A.4
Results of the StAnD survey for the elements covering multiple dimensions (miscellaneous)



Source: Makkar and Ankers, 2014

Profit

1. Production of StAnD and its feeding should take into account environmental and social costs of negative externalities such as environmental degradation, greenhouse gas emissions and loss of biodiversity.
2. Production of StAnD and its feeding should enhance benefit-cost ratio for all stakeholders.
3. Production of StAnD and its feeding should not enhance volatility in prices of feed ingredients.

See Figure A.3 for an overview of the results for the profit dimension.

Miscellaneous

1. StAnD should re-use food waste after ensuring its safety
2. Production of StAnD should be given incentives
3. Use/feeding of StAnD should be given incentives
4. StAnD should use food grains in monogastrics feed
5. StAnD should use food grains in ruminants feed
6. StAnD should contain a feed ingredient produced using public subsidies
7. StAnD should use GMO crops
8. StAnD should use feed ingredient produced through high input agriculture

See Figure 4 for an overview of the results for the elements covering multiple dimensions.

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FAO has developed a concept on 'Sustainable Animal Diets' to assess sustainability of animal diets, encompassing the feed production and feeding chain, aiming to reduce the adverse impact of animal diets and improve its sustainability performance. It integrates the importance of efficient use of natural resources, protection of the environment, socio-cultural benefits and ethical integrity and sensitivity, in addition to currently recognized nutrition-based criteria of delivering economically viable and safe animal products by producing safe feed. This concept provides a framework to introduce practice change to impart greater sustainability to livestock production systems. This document identifies key indicators for sustainable animal diets for the elements of the People, Planet and Profit dimensions, and proposes methods for quantifying these indicators.

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