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Review article

Sustainable livestock production: Low emission farm – The innovative combination of nutrient, emission and waste management with special emphasis on Chinese pig production

Thomas Kaufmann

Evonik Nutrition & Care GmbH, Hanau 63457, Germany

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ABSTRACT

Global livestock production is going to be more and more sophisticated in order to improve efficiency needed to supply the rising demand for animal protein of a growing, more urban and affluent population. To cope with the rising public importance of sustainability is a big challenge for all animal farmers and more industrialized operations especially. Confined animal farming operations (CAFO) are seen very critical by many consumers with regard to their sustainability performance, however, the need to improve the sustainability performance especially in the ecological and social dimension exists at both ends of the intensity, i.e., also for the small holder and family owned animal farming models. As in livestock operations, feed and manure contribute the majority to the three most critical environmental impact categories global warming potential (GWP), acidification (AP) and eutrophication potential (EP) any effort for improvement should start there. Intelligent combination of nutrient-, emission- and waste management in an integrated low emission farm (LEF) concept not only significantly reduces the environmental footprint in the ecological dimension of sustainability, but by producing renewable energy (heat, electricity, biomethane) with animal manure as major feedstock in an anaerobic digester also the economic dimension can be improved. Model calculations using new software show the ecological improvement potential of low protein diets using more supplemented amino acids for the Chinese pig production. The ecological impact of producing biogas or upgraded biomethane, of further treatment of the digestate and producing defined fertilizers is discussed. Finally, the LEF concept allows the integration of an insect protein plant module which offers additional ecological and economical sustainability improvement potential in the future. Active stakeholder communication about implementation steps of LEF examples improves also the social aspect of sustainability.

1. Introduction

Over the last few years, sustainability has become a new megatrend and even a business imperative (Lubin and Esty, 2010). It has also become the key driver for innovation (Nidumolu et al., 2009) and Cargill President and Chief Executive Officer Dave MacLennan declared that sustainability is even the "new normal" (Cargill, 2015). Sustainability related risks and opportunities become standard elements in the non-financial reporting of stock-listed US meat companies (SASB, 2015). In the broad sense "sustainability" means the ability to maintain a process. The term is frequently used in connection with biological systems and can be defined as the ability of an ecosystem to maintain ecological processes, biodiversity and productivity into the future. Livestock is a major contributor to global environmental issues (Steinfeld et al., 2006; FAO, 2009). The huge and fast growing demand for feed crop production shapes entire landscapes and can reduce natural habitats, causing degradation in some areas. In terms of environmental degradation, agriculture in general – and livestock farming in particular – are very important sources of pollution globally and especially in livestock production areas with a high animal density. In China for example, livestock farms produce

E-mail address: Thomas.Kaufmann@evonik.com

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more than 4 billion tons of manure annually, much of which contributes to nutrient overload in waterways and subsequent eutrophication and dead zones. Globally, as more and more land is converted to intensive monocrop production of soybeans and corn (and others in a narrow range of industrial feed crops), pesticide and fertilizers pollute waterways, biodiversity declines, natural carbon sinks are destroyed mainly due to direct and indirect land use change (dLUC, iLUC), and greenhouse gases (GHG) are emitted in all stages of intensive feed production and transport. Technological improvement is a key driver of global livestock production. Growing productivity has been achieved through advanced breeding and feeding technology, and through irrigation and fertilizer technology in crop production, leading to higher yields per hectare. Intensification, the vertical integration and up-scaling of production also lead to larger units and larger and more intensive livestock operations. There are also geographic shifts, with production moving away from local natural resources. Animal production is very often separated from crop production and is seen responsible of more than 14.5% of human induced GHG emissions in terms of CO_2-equivalents (CO_2e) (Gerber et al., 2013). According to the same authors (2013) it is important to set up advanced technologies such like modern feed strategies using beneficial feed additives like enzymes, amino acids and gut modulation products, manure management practices and energy use efficiency to further reduce livestock production related emissions. Modern livestock production is characterized by efficient nutrient management to reduce feed consumption and reduced use of feed ingredients with critical environmental load, i.e., soybean meal (SBM) originating from areas having undergone LUC, waste management to reduce waste volumes and finally emission management to reduce environmental impacts. All three are followed by efficient energy use and recycling trying to achieve closed loops as much as possible. This is what is generally understood as "sustainable intensification" and is seen by many as the key element how to satisfy the rising demand for animal protein without depleting natural resources. As production intensity enhances biological efficiency and as production intensity and emission intensity are inversely related, more intensive animal production systems generally show lower values for important global environmental impact categories like global warming potential, eutrophication potential, acidification potential, energy use and land use (de Vries and de Boer, 2010; MacLeod et al., 2013, Dourmad et al., 2014) when the functional unit selected is kg of product (i.e., life weight, milk, egg, meat) in life cycle assessment (LCA) studies.

2. Sustainability – definition and challenge for livestock

The United Nations Brundtland commission in 1989 defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". Fig. 1 Shows a typical sustainability model, the so called triple P model. There are three overlapping ellipses which reflect the social (people), the economic (profit) and the ecological (planet) dimensions. Overlapping of only two dimensions might be viable, bearable or equitable, but only the intersection of all three can be regarded as sustainable.

At a fundamental level, impacts of human activities are now seen in harmful changes to the global geochemical cycles that are critical for life on earth and thus the elementary pillars of the ecological dimension of sustainability. They are the nitrogen cycle, the water cycle, the carbon cycle and the oxygen cycle. To achieve globally sustainability, management of these cycles at all levels is essential. Narrowing the scope in this review on agricultural livestock farms and industrial like livestock operations, the most important and most frequently mentioned critical challenges from the market (consumers and retailers), the general public [media, non governmental organisations (NGOs)], and politics (regulatory authorities) are the impact of livestock on the different elements of the ecological footprint like climate change, land use and degradation, water footprint and biodiversity as well as the social elements food safety and security, animal welfare and workforce health and safety. In 2006 the FAO report "Livestock's long shadow" (Steinfeld et al., 2006) came as a shockwave. It stated, that the global animal industry contributed more than traffic to global warming, i.e., 18% of the global warming potential (GWP) expressed in CO_2e. It also stated, that damage to environment occurred at both the high and low end of the intensity of livestock production systems and that it should be a major policy focus dealing with problems of land degradation, climate change and air pollution and loss of biodiversity. In the report "The state of food and agriculture – Livestock in the balance" (FAO, 2009) the positive social aspects of the livestock sector in contributing to food security and poverty reduction especially in developing countries is underlined. However, the livestock sector must improve its environmental performance at one hand, but can play a key role in mitigating climate change through adoption of improved technologies. To do this, feed conversion efficacy and feed quality are key tools to reduce GHG emissions. The most recent publication (Gerber et al., 2013) points out specific mitigation opportunities in tackling climate change through livestock like improving production efficiency, improving breeding and animal health, using manure management practices to recycle and recover nutrients and energy contained in manure, sourcing low emission inputs such as feed and use of feed additives like amino acids, enzymes and gut modulating products such as pre- and probiotics, organic acids and phytobiotics. Due to its substantial environmental impact, more and more the livestock industry comes under scrutiny of strict legal framework in an effort to reduce this impact. As in the case of the European Union (EU), there are significant reduction targets to be achieved by 2030 compared to the 2009 level. For the EU 28, theses targets are 27% for ammonia (NH_3) and 33% for methane (CH_4) (Agrarzeitung, 2014). These ambitious reduction targets can not be achieved by a single measure only, they call for an intelligent combination of several mitigation technologies like precision animal feeding and handling concepts, improved manure storage, -handling, -treatment and -application technologies to optimize the animal feed to food chain with regard to its environmental impact. On the other hand, there are also examples, where companies do not wait for the legal framework to tighten, but try to proactively create niche markets for their more sustainable produce. Australian Pork, a producer-owned company delivering integrated services that enhance the viability of Australia's pig producers, is aiming for zero-carbon pig farms by applying new feeding concepts, effective effluent management, reduction of GHG emissions through fertilizer applications and most efficient recovery of emissions (CH_4) from the manure for use as "green energy" (Pig International, 2013).

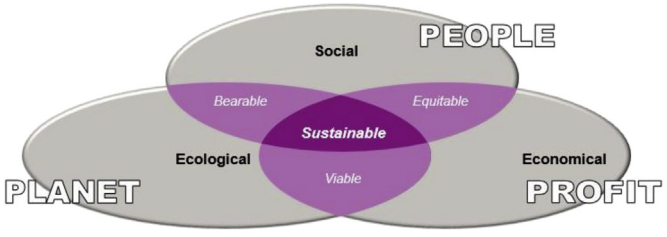

Fig. 1. 3-dimensions model of sustainability.