Assessing and Managing Intensification in Smallholder Dairy Systems for Food and Nutrition Security in Sub-Saharan Africa

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Abstract

Smallholder farmers play an important part in the dairy value chain in most countries in Sub-Saharan Africa. Over the past two decades, three technological approaches have been used. First, applying agricultural ecological processes (ecological intensification), the other, utilising modern livestock breeding (genetic intensification), and socio-economic intensification. In terms of ecological intensification, some of strategies that have been applied are, continuous housing of cows applying a cut-and-carry feeding system, introduction of purpose-bred forages and pastures, and the introduction of agro-forestry within the dairy systems. Genetic intensification strategies have included; importation of the world-renown dairy breeds such as Holstein Friesian (HF) and Jerseys, crossbreeding of the indigenous breeds with HF with the aim of upgrading towards HF. Training and capacity building activities to create sustainable livelihoods have been initiated to not only impart farming and technological practices of animal husbandry but also to enhance appropriate leadership and corporative-building skills that would create and support an enabling environment for sustainability. These improvements and initiatives in the service delivery have been championed by either the national governments, or development partner institutions and non-governmental organisations through different programmes and projects. Challenges of intensification include matching management to genetic potential of imported and crossbred improved dairy breeds, ensuring low post-harvest losses, proper utilisation, and environmental impact challenges. Using examples from Kenya, Malawi, Mozambique, Tanzania and Zambia, this paper examines the management and assessment approaches used in fostering smallholder dairy development strategies and dairy's contribution to sustainable livelihoods in the face of intensification.

Keywords: Sustainable Intensification, Smallholder, Dairying

Introduction

In most African countries, milk is produced on both small and large-scale dairy farms. Small-scale dairy farms are commonly referred to as smallholder dairy farms. Among others, the major differentiating features of these two dairy sub-sectors are the holding size, the genotype of cattle raised and the level of management (Chagunda, et al 2004). Smallholder dairy production is an important agricultural activity, producing a valuable food product and providing a regular income and work for poor households. Although smallholder dairy farms on average have anything from one to five milking cows, their contribution to national dairy production is high and play an important part in the dairy value chain. For example, in Malawi, smallholder dairying supplies about 60% of the milk that is processed at the formal processing plants every year. In Zambia, smallholder dairy farmers own an average of 4 dairy cows, yet more than half of the milk in the country is produced by them and most of them are organized in cooperative societies around milk collection centres from which processors collect the raw milk (Mumba et al 2011). Smallholder dairy farmers use mostly mixed-breed cows and sell the bulk of their output to processors in the formal market or consumers in the informal market (Mumba et al 2011). The Malawi Milk Producers' Association (MMPA) indicates that current milk production in one of its dairy regions (Blantyre) is 49,000 litres of liquid milk per day, an increase from 10,000 litres per day in 1997. The breeds/genotypes used, and cow management in smallholder dairying varies significantly.

Over the past two decades, two technological approaches have been used to improve small scale dairy productivity in sub-Saharan Africa. The application of agricultural ecological processes (ecological intensification), and utilising modern livestock breeding (genetic intensification) have both been used. In terms of ecological intensification, some of strategies that have been applied are, continuous housing of cows applying a cut-and-carry feeding system, the introduction of purpose-bred forages and pastures, and the introduction of agro-forestry within the dairy systems. Genetic intensification strategies have included the importation of world-renown dairy breeds such as Holstein Friesian (HF) and Jerseys, crossbreeding of the indigenous breeds with HF with the aim of upgrading towards HF. Training and capacity building activities to create sustainable livelihoods have been initiated to not only impart farming and technological practices of animal husbandry but also to enhance appropriate leadership and corporative-building skills that would create and support an enabling environment for sustainability. Using examples from Kenya, Malawi, Mozambique, Tanzania and Zambia, this paper examines the management and assessment approaches used in fostering smallholder dairy development strategies and dairy's contribution to sustainable livelihoods in the face of intensification.

Intensification

Intensification of production can take many forms. However, as was stipulated by the Montpellier Panel (2013), intensification is not a viable solution if it comes at the expense of damaging the environmental and social resources on which it depends. Sustainable intensification strives to utilise the existing resources to produce greater yields, better nutrition and higher net incomes while improving the resources use efficiency and lowering emissions of harmful greenhouse gases. Possible components of sustainable intensification can be categorized into three major constellations, following the scheme introduced in The Montpellier Panel (2013) report: ecological intensification, genetic intensification, and socio-economic intensification

Ecological intensification

In terms of ecological intensification, several initiatives have been carried out in the livestock sector in Sub-Saharan Africa. These initiatives include the introduction of more intensive cattle management systems than the extensive communal grazing commonly found, integration of crop and tree species, and the introduction of non-conversional livestock feeds. Availability of animal feed is one of the greatest constraints to the expansion of the livestock industry in developing countries. Apart from the high and fluctuating costs and some of the ingredients used in mixed feeds, notably cereal grains are in high demand for human consumption (Oguntimein, 1988).

The majority of smallholder farmers have adopted cut-and-carry feeding system. Cut-and-carry feeding system are a form of zero grazing, an approach in which livestock are permanently housed and provided with fodder and water. The benefits of using zero grazing management on dairy farms include increased monitoring of the health of the animals, reduced energy and time costs to livestock, and reduced risk of tick-borne diseases. The other common initiative is that of agroforestry, the integration of crops with trees. Agroforestry provides some very important sustainable advantage for the farmer through nutrient recycling and adding additional value to the system by providing extra forage that would otherwise be underutilised. In addition, livestock also provide an incentive for farmers to plant legumes. In addition to fixing nitrogen into the soil and hence serving to improve soil fertility and reduce soil erosion, legumes provide protein to livestock (FAO, 2007). The introduction of feed that have traditionally not been fed to livestock on a regular basis has been another initiative that has been utilised in ecological intensification. One crop that has been utilised in the recent years is cassava. Cassava products and by-products are a good alternative source of carbohydrate and protein for conventional feed ingredients and have a major role to play as a grain substitute in animal diets in developing countries (Correa and Henry, 1991). Cassava can be used for animals fed in two ways. Of most importance is dried cassava root (chips or pellets) used as partial raw material for commercial animal feed rations. Secondly, and of much lesser importance, is on-farm utilization of cassava leaves for animal feeding. Although cassava is a good source of carbohydrates, rations based on cassava require additional vitamins and proteins. In Kenya, Sanda and Methu (1998) evaluated the effect of substitution of maize by cassava in dairy Friesian, Ayrshire and cross-bred cows, and reported that cassava products are good energy feed ingredient for dairy cows and it can totally replace maize meal in the concentrate diets for cows producing 12 kg of milk per day. In addition, there is no significant difference in vivo digestibility of either the dry matter or organic matter of the cassava, and the feed cost per ton were reduced. In Mozambique, farmers have widely adopted the use of cassava roots and leaves as livestock feed. It is estimated that 4% of total cassava output is used as a livestock feed resource (dos Anjos, 2007).

Genetic intensification

Animal breeding strategies support livestock development by focusing on genetic improvement in a continuous manner (Madalena, 2012). In dairy production in Sub-Saharan Africa the major genetic driving force that has been employed are genotype migration and crossbreeding (Hodges, 1984)). Only in a few cases has selection within local breeds been used (Seo and Mendelsohn, 2008). Migration has been applied through the importation of germplasm and stock from the traditional global dairy regions of Europe, and North America, and to a lesser extent from within Africa for breed substitution and crossbreeding. The majority of these initiatives have been carried out by either national governments or practical entrepreneurs. For example, in 1979 the Malawi Government and the Canadian Government through the Canadian International Development agency (CIDA) approved a dairy development project: the Malawi Canada Dairy Development project. Consequently, over a period of 5 years, a foundation stock of 400 Canadian Holstein Friesian heifers was imported to the 5500 hectare Ndata farm in the southern region of Malawi and the 2250-hectare Katete farm in the central region. In 1988 the project was combined with Malawi Milk Marketing to form Malawi Dairy Industries Corporation (MDI), a statutory organisation involved in producing, processing and marketing milk and milk products (Chagunda et al., 2004). When animals are imported their production environment is not restricted to large scale intensive farms. As an example, animal donation programs mostly run by non-profit development agencies, have become an increasingly popular way for people living in developed countries to transfer resources to families living in developing countries (Rawlins et al., 2014). Smallholder farmers seem to have a special liking for imported dairy breeds. In a study with smallholder dairy farmers in the Kenya highlands, Bebe et al. (2003) reported that the dominance of *Bos taurus* dairy breeds (78% of the farms) over *Bos indicus* breeds (22% of the farms) indicating high priority to exotic dairy breeds.

Crossbreeding has been another genetic improvement strategy that has been employed widely in Sub-Saharan Africa. In Malawi, Mozambique and Zambia, most of the crossbreeding is aimed at upgrading the indigenous Zebu cattle towards the productivity levels of the traditional dairy breeds such as the Holstein Friesian. Crossbreeding has traditionally explored the difference in milk yield and tropical stress adaptability between the *Bos Indicus* and *Bos Taurus* breeds

(Cunningham and Syrstad, 1987). Crossbreeding has produced has produced new genotypes with high milk production as well as good adaptation to tropical environments. The key to improvement through crossbreeding is heterosis or ‘hybrid vigour’, a phenomenon that makes the half-bred cattle more vigorous in performance and better survivability than the expected average of the two parent populations. Previous studies have shown that heterosis for production traits such as milk yield, butter fat, and milk protein range from 2% to 10% (Hurst, 2002).

Socio-economic intensification

Socio-economic intensification centres on enabling the environment of the production system efficient, resilient and contributing to the stock of natural environmental capital. Training and capacity building activities to create sustainable livelihoods have been initiated to not only impart farming and technological practices of animal husbandry but also to enhance appropriate leadership and corporative-building skills that would create and support an enabling environment for sustainability. Examples of the result of these initiatives are the emergence of rural artisanal groups such as village farmer technicians, para-veterinary practitioners, lead farmers and farmer extension workers.

Improvements and policy shift initiatives in the service delivery have been championed by either the national governments or development partner institutions and non-governmental organisations through different programmes and projects. . Market access has been identified as one of the foremost factors influencing the performance of small scale producers in developing countries, particularly in least developing countries. Smallholder access to markets stimulates higher values for agricultural and food products is recognised as a vital opportunity to enhance and diversify the livelihood of lower income farm household and reduce poverty (World Bank 2007). An example is in Malawi and Zambia where national governments have shown interest in using smallholder dairying to accelerate economic growth and poverty reduction, especially among the rural poor. In Malawi, the government has made smallholder dairying its flagship in the livestock sector (Malawi Government, 2006). For the period between 2008 and 2013, the Malawi Government implemented strategies such as the importation of improved exotic dairy breeds, enhancing artificial insemination (AI) services, and the promotion of local stud-breeding by farmers. In addition, some NGOs have introduced smallholder dairying into their food security programs. Further, the Malawian Government has recently launched the Presidential Initiative on Poverty and Hunger Reduction with the one cow a family programme to promoted smallholder dairying to majority rural areas. In Zambia, the capabilities of smallholder dairy farmers are strengthened through the provision of resource persons, materials and financial support mainly by NGOs in collaboration with the national government (Mumba et al 2011).

Why does smallholder dairying matter?

Growing agricultural productivity attacks poverty from three different ways. It increases the productivity and incomes of the majority of Africa's poor, who work primarily in agriculture. It reduces food prices, which govern real incomes and poverty in urban areas. It generates important spill-overs to the rest of the economy (Haggblade et al., 2010). Quashigah (2002) defined food security as 'good quality, nutritious food, hygienically packaged and attractively presented, and available in sufficient quantities all year round and located at the right places at affordable prices'. The World Food Summit of 1996 established four dimensions of food security: availability, access, stability and utilisation (FAO, IFAD and WFP 2014). It is the elements of food quality and nutrition that link food security to nutritional security and human health. The utilisation dimension of food security is the one that deals with nutritional security. Livestock provides 27.9% of protein world wide and 47.8% in developed countries. Smallholder farmers are mainly in the rural community, and thus are best placed to fulfil the role especially in countries where there is an essential weakness in the logistics chains to transport foods. Milk can improve the nutritional outcomes of household members as an important source of energy, protein and essential amino acids and vitamins A and D which are deficient in carbohydrate based diets (Nicholson et al, 1999). Milk is also a good source of other nutrients such as magnesium, zinc, phosphorus and calcium which are essential for body growth (Njarui et al, 2009). Studies conducted in Kenya, Malawi and Tanzania have shown that monthly consumption of milk and milk products is up to 58% more in households with dairy cattle than those without dairy animals. (Lwelamira et al, 2010; Nicholson et al, 1999).

Animal food products such as meat and milk are concentrated sources of high-quality protein, vitamins, minerals and other micro nutrients, vital to human health (McLaren, 1984). For example, when children consume even modest amounts, these products help to alleviate poor growth, poor cognitive development and impaired physical health (Neumann, et al 2003; Hoppe et al 2004). According to the MDHS, about 5% of infants under the age of two years receive other milk other than breast milk and 14% of non breastfeeding infants consume milk other than infant formulas (NSO, 2010). According to Kalumikiza (2012), in a study conducted in the central region of Malawi, children below the age of five years among the dairy farming households consumed more milk than any other age groups. Consumption of milk by children was mainly due to the respondent's belief that children needed more milk for good growth and health. In most cases children tend to be given some milk during or immediately after milking. The 2012 Integrated Household Survey for Malawi revealed that 11% of people in the rural areas and 9% of people in urban areas of Malawi reported that when resources are scarce or inadequate to provide sufficient food for all household members, children are usually protected from the disruption of eating patterns and reduced food intake that may reflect food insecurity (NSO, 2012), more than 80% of the under five children consumed milk daily as compared to adults. In a study on the impact of adopting dairy technology in the coastal region of Kenya, children coming from households with improved dairy cattle were taller than children coming from households with unimproved breeds (Nicholson et al, 1999). Similarly Children between the ages of two and five years from households with dairy cattle and goats in rural Rwanda were found to be significantly taller than children from households that did not rear dairy animals. The ownership of dairy animals in this case has been shown to be a contributing factor towards the difference in child growth as compared to household wealth, access to land or the mother's education (FAO, 2012). However, this is not always the case. Walingo (2012) demonstrated performed a study that assessed food intake patterns and nutritional status in households of beneficiaries of a livestock distribution project and those that were not supported by the livestock project in western Kenya. They found that levels of underweight (1.25%) and stunted (1.25%) preschool children of women participating in the dairy program was no different from those preschool children from women not participating in the dairy program whose children were underweight (2.9%) and stunted (1%). Similarly the proportion of women who were severely malnourished (BMI less than 16) was not significantly different between beneficiary women

(0.7%) and 1.3% non beneficiary women while 6% of the beneficiary women were obese as compared to 4.5% of non beneficiary women. This kind of data may imply that increase in milk production; income and income expenditure may not result to improved diets due to less income being used for food purchases, despite dairy having the potential to improve nutrient adequacy and BMI (Walingo, 2012). Although livestock keeping is no universal panacea, if animals are managed properly within an adequate agricultural system, it can be an important lever for reducing poverty and boosting human health (ILRI, 2003). Other studies have indicated that some specific constituents of milk and meat have beneficial human health effects. For example, conjugated linoleic acids (CLA), vitamin E, beta carotene and omega-3 fatty acids. CLA, for insitance, is best known for its anti-carcinogenic properties ((Tricon et al, 2004; Zulet et al, 2005; Dannenberger, et al., 2007). Although the smallholder farms play an important role in milk production, the effects of the different breed raised, feeding regimes, nutrition and cow management on nutritional quality of milk and its links to human health has not been quantified. One way in which this is happening is through the gradual increase in the rural market economy. Enterprises such as dairy production, which provide a regular source of income, are providing the platform for increased purchase of diversity of foods. For example, Kalumikiza (2012) reported that dairy farmers use the income from milk to purchase other food items such as rice, meat, maize, fish, vegetables, cooking oil, beans, sugar and salt. This behaviour would contribute toward better dietary diversity for the households.

Challenges

With reference to food and nutritional security, there are mainly four categories of challenges which arise due to the intensification process to smallholder dairying. These are, production challenges, product handling challenges, product utilization challenges, and environmental impact challenges. These challenges need to be managed accordingly in order to make smallholder dairy farming contribute to rural livelihoods in a sustainable way.

Animal production challenges

Genetic improvement of farmed livestock has had a major impact on productivity, resource use efficiency, and food security, in many temperate countries over the last 70 years. Being permanent, cumulative and usually highly cost effective, it is also of huge potential value in countries, like those in Sub-Saharan Africa, most in need of improved food security. However, this technology has not been widely used to date, largely because of small herd and flock sizes and a lack of animal performance recording infrastructure. Most genetic improvement efforts have often relied on importation of inappropriate exotic breeds, which often has the added disadvantage of marginalising indigenous genetic resources. In a study between sibs of Canadian sires performing in both Malawi and Canada the confounding effect of the production environment on the genotype that was used was significantly apparent (Chagunda, 2004), indicating that the production environment limited the full expression of genetic potential of the cows. The estimated genetic correlation for milk yield between Malawian and Canadian conditions was 0.44. This is substantially less than 0.8, which according to Robertson (1959) is the threshold genetic correlation below which genotype by environment interaction is considered of biological and agricultural importance. This entails a reduced accuracy for prediction of ranking of Canadian breeding bulls in Malawi based on their Canadian breeding values. This kind of mismatch between genetics and the production environment hampers progress and leads to perpetual low productivity which in turn slows down the lift of the poor out of the poverty trap. In addition, there is lack of detailed studies that would inform the appropriateness of different breeds, genotypes and breeding strategies to different production systems. Revesai et al., 2002 demonstrated that when only production traits such as milk yield, Holstein Friesian (HF) cows were the best performers followed by ¾ HF x Malawi Zebu crosses while Malawi Zebu was the lowest performer (mean = 12.1kg s.e. = 0.14 vs 11.9 kg s.e.= 0.20 and 5.4 s.e = 0.18). When a productivity index which included calving interval, age at first calving, number of services per conception, calf survival, and milk yield, was used, ½ HF x Malawi Zebu were the best. These results showed that in terms of both biological and economic efficiency, it was ½ HF x Malawi Zebu and ¾ HF x Malawi Zebu that were optimum genotypes for use on smallholder dairy farms in Malawi, rather than pure Holstein Friesians. The general lack of breeding planning and organisation is associated with indiscriminate breeding and hence lack of genetic progress. There is a critical need to match genotypes to particular managerial and environmental situations for optimal productivity. In this process there is need to ask critical question s pertaining to what to import. Examples of such questions are,

a) Which breed should be imported and why?
b) Should it be purebreds or crossbreeds?
c) Should it both male and female stock that need to be imported?
d) Should it be semen or embryos?
e) At what age should animals be imported?
f) How should individual animals be selected?

These and others are the kind of questions that can help develop strategies that can be used to explore the productivity potential and tropical stress adaptability of different breeds to be used in Sub Saharan Africa (Cunningham and Syrstad, 1987).

Product handling challenges

Milk is a perishable product with a shelf life of a day, when no preservation treatment is available. Milk losses which, mostly occur due to poor handling and keeping quality at both farm and milk selling points contribute significantly to farm-family economic losses. Reducing any post harvest losses in the milk production chain in the smallholder sector would empower farmers economically through sales of milk. This would directly contribute to food and nutritional security, and poverty reduction. Promoting smallholder dairy production and reducing post-harvest losses would provide a robust coping strategy where agro-ecological conditions and access to markets provide a favourable environment for dairy production. The smallholder dairy sector could significantly contribute to accelerating rural economic growth though multiplier effect. Recent reviews and studies have shown that critical and substantial amounts of milk are lost and also rejected for sale due to poor quality and hence deny the farmer the much needed income. For example, in Malawi (Chindime 2006) an average of 17% of milk produced in the smallholder sector goes sour and is rejected from the market.

Smallholder herd management practices in nutrition, milking procedure, sanitation and housing play major roles in predisposing the individual animals to diseases such as mastitis which in turn affect milk quality (Falvey and Chanthalaka, 1999). Although mastitis is usually perceived as a disease for high producing herds, it is one of the most common diseases in cows in smallholder dairy systems. This results in great economic losses due to high milk rejection rates at milk market (e.g. Kawonga et al., 2012). Kawonga (2012) reported that smallholder farmers lose up to 12 % of the potential monthly earnings from post harvest losses.

Utilisation challenges

The other challenge that leads to low impact of milk in terms of food and nutrition security is the perceptions towards milk from different species and breeds. Cow milk is the most widely available and preferred to milk from other species such as sheep and goat. Despite goat and sheep milk having more nutritional benefits in terms of high protein, energy and fat values than cow milk, goat and sheep milk is not popular. Goat and sheep milk, however is deficient in vitamins D and C and folic acid. With the supplementation of theses deficient nutrients (Vitamins D and C), sheep and goat milk would be ideal for infants and pregnant women (Banda, 2007). Goat milk protein molecules are better absorbed than other proteins (Banda, 2007). However the low consumption of goat and sheep milk is mainly attributed to the strong flavour and taste of goat and sheep milk and beliefs that consumption of goat and sheep milk reflects low social status. According to a study conducted in Malawi, people in the lakeshore area of Malawi never want to consume sheep milk due to the religious and personal beliefs. Out of the 172 respondents from Lilongwe involved in the study, 94% reported that it was not traditionally acceptable to consume goat milk. However from the blind organoleptic test conducted with willing subjects in the study, goat milk was voted to have the best flavour and taste, followed by sheep milk, and lastly cow milk (Banda, 2007).

Gender is a very important issue in household utilisation of milk and milk products In many countries of Sub- Saharan Africa, men are responsible for the larger livestock such as cattle and women are responsible for the smaller livestock such as sheep and goats and for activities such as feeding and milking of all livestock. A study conducted in Arumeru in Tanzania showed that as their traditional practice men and boys were not involved in milking while on the other hand women contributed to a larger amount of labour such as cleaning, milking and feeding of animals than other household members in dairy farming (Kimaro et al, 2013). However, when it came to decision making on how earnings from livestock wereused, women seem to be left out. An example is in Malawi where only 37% of married women aged between 15 and 49 years reported that they decided for themselves on how to use their earnings. About a quarter (21%) of the women make joint decisions with their husbands on how their earnings are to be used and 40% of the women reported that decisions on how their earnings are used are made by their husbands (NSO, 2010).

Information obtained in a study conducted in Tanzania reported that men involved in dairy production have specific duties such as sales, purchase of animals and consulting veterinary services. Although women may provide most of the labour on dairy cattle farms and other livestock they rear, they may not realize the benefits from dairy production in relation to their contribution and this may limit their motivation to increase production (Kimaro et al, 2013). The Maasai women of Kenya, however are responsible for allocating how much milk should be used for home consumption, exchange and marketing (Tangka et al, 2000). Similarly, in Ethiopia the control of milk products belonged to women (Abebe and Galmessa, 2011). According to FAO

(2005) improvements in household food security and nutrition in Africa are linked to the increase in access to and control of income and decision making of household expenditure at household level by women. This is largely due to women spending a larger proportion of their finances on purchasing food for the household.

In light of this, most NGOs are formulating programmes that address gender related constraints and barriers that affect food and nutrition security. One of the organizations is Land O' Lakes, through its Zambian Dairy Development Program (2004- 2009), it has been able to improve household food security and livelihood of 829 female headed households and women participants. This programme ensured that there was 30% active representation of females in farmer associations, in a country where women were usually forbidden to enter cattle byres with the belief that chemicals used in cattle dips could lead to the prevention of pregnancies. From this programme, it was also noted that women given ownership of cattle, were more effectively able to use income obtained from the sale of dairy products to provide food for the household and other basic farming needs (Land O' Lakes, 2014).

Environmental impact challenge

The impacts of climate change on agriculture and food security are widely studied, but the sector is also an important contributor to global emissions. Livestock contributes about half of the agricultural greenhouse-gas emissions and the major gases such as methane from livestock is produced by the fermentation of feed within animals' digestive systems, a process referred to as enteric fermentation (Gnacadia and Mersmann, 2008). The amount of methane emitted is driven primarily by the number of animals, the type of digestive system, and the type and amount of feed consumed (Gnacadia and Mersmann, 2008; IPCC, 2007). A total CH_4 emission inventory from enteric fermentation and manure management for domestic livestock in Malawi, developed using Tier 1 emission factors of IPCC (2007), showed an increase from 81,957 t in 2010 to 86,774 t in 2012. These CH_4 emission figures are equal to 2,048,920 and 2,169,353 t/year of CO_2 equivalents, respectively, when assuming that the global warming potential of CH_4 is 25 times that of CO_2 (IPCC, 2007). Examining the contribution from individual species showed that the indigenous Zebu cattle were the biggest producers, followed by goats. However, smallholder dairy production was only responsible for 5% of the methane emissions.

Managing intensification towards more sustainable smallholder dairy systems

Several opportunities are available that would help smallholder farmers achieve more sustainable production than is currently the case. One example of such an opportunity is the availability of technology. Precision agriculture (PA) can be defined as a management strategy that uses information technologies to bring data from multiple sources for decision making in agricultural production (Bouma et al, 1999). For some time, the applications of precision farming techniques have been associated with intensive livestock farming (Frost, 2001). However, PA is possible in both intensive and low-input dairy systems, because the animal is in the centre of PA in livestock systems. PA allows farm animals to be managed on individual level in terms of controlling the inputs to the individual animal and measurement of individual outputs (Wathes et al. 2008). Deployment of high-tech sensor systems opens a wide range of options to use smart but low-cost technology as a bio-sensor for animals' energy state and health. Consequently, in the low-input farms, the potential for using high-tech but low-cost sensors to improve animals' management is very high.

Another technology that has the potential to help manage intensification achieve sustainable smallholder dairy production is the use of sexed semen. The use of sexed semen in the dairy herd would reduce the number of unwanted male calves and replace them with beef cross calves which would increase beef production at a time when a shortage of beef is predicted. Given programmes like Pass-on the Heifer which exist in most Sub-Saharan African countries in different formats, the use of sexed semen would help increase the number of heifers that could then be passed on. However, there is a need to consider any potential problems pertaining to low fertility that is associated with the use of sexed semen (Frijters et al., 2009). For any reproductive technology and breeding policies to be effective in smallholder dairy systems, the multi-functional roles that cattle play in these systems should always be taken into account (Bebe et al, 2003). Recognition of this broad basis for breeding decisions is central to managing genetic intensification in smallholder dairy production.

The increased attention of issues around the impact of dairying on the environment has raised the profile of issues around carbon management and climate-change mitigation options in dairying. Total global green house gas mitigation for livestock management is estimated to be 10 to 12% (Beach *et al*., 2008). Although data from Sub-Saharan Africa on mitigation of GHG emissions in the livestock sector are sparse, studies conducted elsewhere have shown different options. For example, improving animal productivity would reduce enteric methane emission by 20 to 30%; increasing concentrate levels at high level of feed intake reduces enteric methane emissions by 25%; while the use of high quality forages and pastures can reduce enteric methane by 25% (Boadi et al., 2004). In general, animal productivity through improvements in animal nutrition, fertility, genetics and management reduces CH_4 output per unit of desirable product e.g. milk.

These improvements could be made through the animals converting energy from feed into production in a more efficient way. Increasing feed efficiency and improving the digestibility of feed intake are potential ways to reduce GHG emissions and maximize production and gross efficiency. In dairy cattle, 50% of the amount of feed energy is associated with body maintenance (Mathison *et al.,* 1998). The rest is used for production. Although the amount of enteric CH_4 per animal increases as productivity increases, this increase is relatively small and hence CH_4 per unit of product decreases (Johnson *et al.*, 1996). This provides the opportunity for farmers to explore ways in which to improve the efficiency of their productions.

Assessing intensification

This review aimed at examining the management and assessment approaches used in fostering smallholder dairy development strategies and dairy's contribution to sustainable livelihoods in the face of intensification. Using the three intensification strategies of ecological, genetic and socioeconomic improvements, optimising feeding, mitigation of disease and improving general husbandry, the review demonstrated that the inter-linked policies should be promoted in order to achieve the desired goal of sustainable livelihoods. The traditional approach of assessing the impact of intensification to sustainable livelihoods is predominantly through use of univariate approaches that deal with either productivity or economic contribution. However, given the interrelated nature of the different outputs and the trade-offs that arise thereof, other approaches may be more appropriate. Multivariate statistical methods are designed to evaluate more than one variable at a time. Many of these methods are derived from models in which all the variables are assumed to follow a multivariate normal distribution. Examples of such approaches are, principal components analysis (PCA), risk index methods, and Bayesian clustering methods. The inputs into the model would be data reflecting degree of adaptation, productivity of the cattle, the production system, indigenous knowledge, socioeconomic importance of the traits involved, and the economic contribution of the traits. In such a method the model would be designed to calculate a risk value (a value between 0 and 1) to indicate the contribution of intensification. Bayesian networks have been used in biological sciences to build models of domains with inherent uncertainty. Bayesian networks appear naturally in several domains in biology. In pedigree analysis, for example, the joint distribution of genotypes in a pedigree is a product of conditional probabilities of the genotype of each individual given the genotypes of its two biological parents. Bayesian Networks are a combination of probability theory and graph theory. They provide a natural tool for dealing with two problems that occur throughout applied science. Fundamental to the idea of a graphical model is the notion of modularity - a complex system is built by combining simpler parts. Probability theory provides the glue whereby the parts are combined, ensuring that the system as a whole is consistent, and providing ways to interface models to data.

Conclusion

Smallholder dairy farming is becoming increasingly important. This is because of its potential to substantially contribute to sustainable household livelihoods through economic wellbeing, household food security and nutritional stability. However, just like other aspects of rural development, smallholder dairy development is multi-faceted and hence its long term sustainability trajectory is affected by the pull and push of social, economic, cultural, environmental, and technological factors. Using examples from Kenya, Malawi, Mozambique, Tanzania and Zambia, this paper has highlighted the need to use management and assessment approaches that utilise the synergies and accounts for trade-offs among the different facets of intensification in order to help smallholder dairy farming sustainably contribute to food and nutritional security in Sub-Saharan Africa. For intensification to be effective and sustainable it is important that appropriate strategies are correctly chosen based on the production systems in Sub-Saharan Africa.

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