MILK SA

Sustainability in the SA dairy Industry: A Status and Progress Report

To be endorsed by all sectors of the Dairy Industry

Authors: Heinz Meissner and Colin Ohlhoff

June 2022

Contents

Executive summary

The overall purpose and goal of the dairy industry is to provide nutritious food to the population in an economic, social and environmental friendly way.

The report on sustainability is structured according to the FAO-IDF Dairy Declaration of Rotterdam (DDoR) and the Dairy Sustainability Framework (DSF), which endorses the UN 2030 Agenda for Sustainable Development and provides guidelines for sustainable development. The report in particular pays attention to (1) environmental integrity as it pertains to greenhouse gas (GHG) emissions, soil health and nutrient supply, waste management, water quality and quantity, and biodiversity; (2) socio-economics in terms of market development, rural stability and farm worker conditions; (3) dairy product quality and safety, and (4) animal care.

Previously, measurements indicated CH_4 (methane) emissions of dairy cattle to be 179 Gg/annum, whereas the total of all livestock in the country was 1327 Gg/annum. Recent SA updates for total livestock ruminants show CH_4 numbers of 1301 Gg/annum and 123 Gg /annum (or 3444 Gg/annum CO_2 equivalent) for dairy cattle respectively. Accepting that the calculation error is relatively large, it does appear that enteric emissions of dairy cows have declined; increased efficiency possibly being one of the reasons. This equates to 1.2 to 1.4 kg CO_2 eq/kg milk, which compares favourably with some prominent dairy producing countries.

A further development which affects the calculations needs to be mentioned. The accepted global warming potential (GWP) of CH_4 as determined by the International Panel for Climate Change (IPCC) of the UN is 28 times that of CO_2. Recently, the IPCC GWP number was challenged on account of the fact that the staying time in the atmosphere of CH_4 is much shorter than that of CO_2. The new calculation over a finite period of 20 years indicates a GWP of only 8. Accepting this principle, enteric CH_4 emissions of dairy cattle in SA equate to a mere 984 Gg CO_2 eq/annum, and in a recent study on six pasture-based dairy farms in the Eastern Cape, emissions on this basis were calculated as varying between 0.49 and 1.14 kg CO_{2e}/kg FPCM, suggesting still much improvement to be achieved on some farms.

Since 1990, the number of cows in South Africa has declined by 24 % while total milk production has increased by 56 %. This implies that efficiency has improved, whereas GHG emissions, waste and water use per unit product have declined. A more effective way of reducing GHG is to sequester atmospheric CO_2 into soils which can be achieved with regenerative and conservation driven agriculture methods. These methods can also improve soil quality and carbon stocks substantially. In an experiment on soil analysis from Swellendam to Humansdorp, soils from kikuyu-ryegrass systems and shallow tilled soils recorded carbon contents of 50.3 kg C/m^3 and 54.3 kg C/m^3 respectively, vs only 34.6 kg C/m^3 for deep tilled (conventional) soils. In the Tsitsikamma it has been shown that carbon sequestration can nullify GHG emissions although much work is still required on many farms.

Healthy soils support proliferation of soil microbes and nutrient cycling, in turn supporting sustainable production and reduced costs associated with fertilizer application. Generally, an improvement of 1% carbon in the upper 30 cm soil will coincide with atmospheric N fixation of 25 kg. If soil health is also improved, turnover will increase and more NH_4–N which results from chemical fertilizer, and otherwise will be converted into the GHG N_2O, can be utilized to the benefit of plant growth. The N and P use efficiency on pastures in the Eastern Cape was 29 and 36% respectively which compares favourably with figures elsewhere in the world. It should be noted that the variation from farm to farm and area to area is substantial (in the vicinity of seven-fold), which suggests that further input into research, extension and training is required.

Waste is of concern from pre-farm gate through to dairy processing plants. Most dairy farms have waste disposal and sewage systems that allow them to use the solids as fertilizers and the water either in irrigation or to recycle for cleaning. Some of the large dairy processing companies have waste reduction and water cleaning operations, some of which generate CH_4 for electricity generation, whilst the purified water is recycled for cleaning operations. The best route for disposal or reuse of industrial waste depends on specific characteristics of the waste stream. In recent years there has been development in the ability of dairy processors to collect and harness the economic value of various waste streams, which ultimately also drives more environmentally sound methods of disposal. The threat which plastic pollution poses to the environment remains a topic of concern. South Africa is fortunate in that it has a fairly robust plastic recycling industry which contributes to the ability of dairy operations to divert this form of solid waste from landfill disposal sites. Cross-contamination of packaging with dairy product waste remains a limiting factor which can devalue the material before being received by recyclers. This highlights the need for efficient 'at source' separation of waste which has become a standard practice for dairy processors. Government is now also in the process of proposing stricter regulations with the introduction of the Extended Producer Responsibility (EPR) regulations. The aim is to encourage processors to shift their packaging materials to formats which are deemed 'more recyclable' and therefore hold a higher value in the post-consumer recycling market.

Water is a finite and vulnerable resource and must be dealt with responsibly, both as it applies to quantity and quality. Recent developments and initiatives around water in the South African Dairy Sector are steadily contributing towards creating a culture of circularity and sustainability. A water stewardship program has been introduced by the MPO in collaboration with the WWF-SA, encouraging innovative initiatives in water management, ecosystem protection, recycling, and effluent treatment in dairy factories. Participation by several processors and farmers in this initiative over the past year indicates that water is a growing concern in the sector and that the program has established a platform for knowledge-sharing. A second initiative is to develop best practice guidelines for determining aquatic and wetland buffer zones for dairy farms, a third is to investigate and treat effluent from dairy farms, and a fourth is to establish minimum water requirements of forage species. The latter aims to compare and calibrate different irrigation scheduling systems of different pasture mixes for various topographic, soil and climatic conditions under normal and restricted water conditions.

South Africa is a country with a rich endowment of natural resources, which include its biodiversity and ecosystems. The National Biodiversity Strategy and Action Plan (NBSAP) is responsible to fulfil the objectives of the Convention on Biological Diversity (CBD). With the adoption of the CBD's Strategic Plan for Biodiversity, the NBSAP has outlined a path to ensure that the management of biodiversity assets and ecological infrastructure continue to support South Africa's development path and play an important role in underpinning the economy. As the demand for agricultural products has increased, driven by the nutritional needs of a growing population, the importance of developing a biodiversity-based agricultural system to ensure future sustainability should be regarded as a key driver for the Industry. Dairy farms across South Africa have widely undertaken (although still not always to a formal extent, especially among smaller-scale farmers) to integrate biodiversity-conscious approaches in their businesses. The vast costs involved in repairing damaged soils are understood and therefore the benefits in monitoring soil health, structure, nutrients and biological activity are recognised. In general, therefore, the dairy industry supports the vision and strategies of the NBSAP.

The dairy industry in South Africa is one of the most deregulated industries in the world. The industry is not subject to any statutory intervention in the production and marketing of its products aimed at managing or influencing the supply and demand of unprocessed milk and dairy products, and it is not supported by government subsidies. A totally free and competitive dairy market prevails which creates a very dynamic industry that continuously adapts to the changing needs of consumers and industrial users. However, this results in other challenges which require sophisticated and continuous analyses of market signals and the collection of information, also from consumers. Consumers and dieticians are also trained and informed through a Consumer Education Project which has received accolades by the International Dairy Federation (IDF). Various important markets have been identified with the potential of serving as trading partners, with the Sub-Sahara African market perhaps being the most prominent, especially as an export market.

In rural development the core emphasis is to promote competitive, profitable, and sustainable existing black and new enterprises by contributing to the reduction of commercial venture constraints. One should also not underestimate the value of milk production as a stimulus in rural development as it provides infrastructure, electricity, service delivery etc. The Milk SA initiative is aligned with the South African developmental priorities, namely food security, poverty reduction, promoting equitable economic transformation and contributing to general economic development and growth. Skills and knowledge development are supported by Milk SA to ensure the continuation of an appropriate skills and knowledge dispensation. In the context of rural economy development, Milk SA's Skills & Knowledge

Development Program supports training at new and black-owned dairy enterprises. However, the rural dairy economy is of course not only supported by the organized dairy industry through Milk SA, but also by several provincial departments associated with agriculture which drive entrepreneurial programs and training. The training and development initiative is therefore well served.

Working conditions in the Dairy Industry, as in other industries, are informed by several Acts associated with the Bill of Rights of the National Constitution. These provide regulations and guidelines for the right of freedom of association of both the employer and employee, the protection of employers and those seeking employment, the protection of the rights of employees, the organizational rights of employees such as access to the workplace by a representative of the trade union, collective bargaining rights, the right of employees to strike and the right of an employer's recourse to lockout, unfair dismissal and unfair labour practices. Employers in the dairy industry should commit themselves to the following, if they have not done so already:

- Comply with the conditions legislated for fair labour practice.
- Contribute to employee unemployment benefits.
- Contribute to the skills development of employees.
- Provide for compensation of death or disablement resulting from occupational activities.
- Provide for the safety and health of the employees at work.
- Uphold the rights of labour tenants and farm occupiers to reside on land and to acquire land where appropriate.
- Ensure that recreational areas on the farm are available.
- Participate in actions towards establishment of a sustainable local economy.

In terms of product quality and safety, the dairy quality and safety initiatives of Milk SA are the responsibility of the Dairy Standard Agency (DSA), a non-profit company established by the industry. The DSA monitors and supports procedures to promote product compliance with product composition and food safety standards. Promotion of compliance with standards relating to milk and other dairy products is a demanding and multi-dimensional task which the DSA fulfils. Complexity through regulations relating to product composition, food safety, animal health, animal feed, milking parlours, transportation of milk, processing plants and storage, all of which are regulated by different Acts (also managed in different government departments), requires careful monitoring. In terms of its mandate the DSA has progressively moved to a landscape where today it is well-recognised by the respective government bodies, the organised primary and secondary dairy industry and other stakeholders, for example national consumer bodies and the retail sector. The DSA has the capacity to maintain successful milk and dairy product monitoring programs; maintain a remedial action program for regular contraveners of legal standards; identify non-conformances in the industry in respect of milk and other dairy products; and maintain an effective communication program with all stakeholders concerned. The lack of a harmonised (standardised) system at national level for the calibration of laboratory instruments for the measurement of fat, protein, lactose, milk urea nitrogen, somatic cell count, and other quality parameters of milk, also created a need for the DSA to initiate a national independent laboratory service. Expansion to the services and tests provided by the DSA are continuously evaluated. To that effect methods of analyses need to be developed or compared, a recent example being a comparison of methods to determine antibiotic and other residues in milk. Also, in association with the UFS a rapid test to detect psychrotolerant bacteria has been developed to supplement the alizarol test.

Animal care in the DSF criteria is only defined in the context of welfare. However, health and production are also components of animal care, with the different components influencing one another. From a scientific and farmer perspective, an animal is in a good state of welfare if it is healthy, comfortable, well-nourished, safe, relatively able to express its innate behaviour, and not suffering from negative states such as pain, fear and distress. Good animal welfare requires amongst others disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling, transport and eventually, humane slaughter. The dairy industry is committed to the implementation of best practices to ensure animal welfare. As a member of the IDF and by consulting the IDF's Guide to Good Animal Welfare in Dairy Production and the SABS SANS 1694 guide for dairy cattle welfare, the DSA with the assistance of other stakeholders has developed auditable criteria to measure compliance with relevant animal welfare standards. The purpose is to assist farmers in the process of risk identification, to evaluate the risks, and to implement management practises which can improve welfare.

In animal health, research programs are done to control and prevent mastitis, liver fluke infestation and hoof health. The focus is on prevention and alternative treatment to limit the use of antibiotics and drugs. New developments include the control of brucellosis, sporidesmin toxicity (facial eczema) and mRNA-based vaccine development against brucellosis.

In conclusion, the Dairy Industry has recorded significant progress in most of the sustainability goals as defined in the DDoR and the DSF. It should be recognised that this is an endeavour which requires continuous attention through research, monitoring and training, and ultimately adoption by all role players across the dairy value-chain in South Africa. Several programs have therefore been documented. The report should be viewed as dynamic and shall be updated regularly to reflect changes in the industry as additional information becomes available and new initiatives are developed. An Addendum to the document shows the structure, functions, programs and responsibilities of the organised dairy industry.

The Report

1. Guidelines and principles

The South African (SA) dairy Industry is a signatory to the FAO-IDF Dairy Declaration of Rotterdam[1] which endorses the UN 2030 Agenda for Sustainable Development[2] in so far as it guides sustainable development from a social, environmental, economic and health perspective. The Declaration highlights the following:

- The vital role of dairy for food security and poverty reduction and the important livelihood and development opportunities for family farmers, small holders and pastoralists.
- The critical contribution the industry makes toward ensuring balanced, nutritious and healthy foods, countries' economies, income and employment; in the management of terrestrial ecosystems, and the need to address environmental degradation, climate change and biodiversity.
- The diversity of dairy production systems and dairy breeds, contexts and priorities.
- The need for continuous and open dialogue and joint actions at all levels.

The SA dairy industry is a member of the Dairy Sustainability Framework (DSF)[3] whose vision aligns with the Rotterdam Declaration, and states that it is: "A vibrant dairy sector committed to continuously improving its ability to provide safe and nutritious products from healthy cattle, while preserving natural resources and ensuring decent livelihoods across the industry". The DSF focuses on 11 key globally accepted dairy sustainability criteria. Each criterion has an indicator on which the DSF reports on an aggregated basis for the global dairy value chain. The criteria with their respective goals are:

- *Greenhouse gas emissions (GHG):* GHG emissions across the full value chain are quantified and reduced through all economically viable mechanisms.
- *Soil nutrients:* Nutrient application is managed to minimize impacts on water and air, while maintaining and enhancing soil quality.
- *Waste:* Waste generation is minimized and, where unavoidable, waste is re-used and recycled.
- *Water:* Water availability, as well as water quality, is managed responsibly throughout the dairy value chain.
- *Soil:* Soil quality and retention is proactively managed and enhanced to ensure optimal productivity.
- *Biodiversity:* Direct and indirect biodiversity risks and opportunities are understood, and strategies to maintain or enhance it are established.
- *Market development:* Participants along the dairy value chain are able to build economically viable businesses through the development of transparent and effective markets.
- *Rural economies:* The dairy sector contributes to the resilience and economic viability of farmers and rural communities.
- *Working conditions:* Across the dairy value chain, workers operate in a safe environment, and their rights are respected and promoted.

- *Product safety & quality:* The integrity and transparency of the dairy supply chain is safeguarded, so as to ensure the optimal nutrition, quality and safety of products.
- *Animal care:* Dairy animals are treated with care and are free from hunger and thirst, discomfort, pain, injury and disease, fear and distress, and are able to engage in relatively normal patterns of animal behaviour.

The status of the SA dairy industry and the progress made are provided according to the 11 DSF criteria.

2. Advances in key DSF criteria

Greenhouse Gas Emissions

Prelude: Plants when growing use carbon dioxide (CO_2) from the atmosphere and nitrogen (N) from the soil and re-distribute it among different pools, including both above and below-ground living biomass, dead residues and soil organic matter (stocks). The CO_2 and other greenhouse gases (GHG), such as methane (CH_4) and nitrous oxide (N_2O), are in turn released to the atmosphere by plant respiration, by decomposition of dead plant biomass and soil organic matter, and by combustion. Thus, there is a continuous flux in and out of pools. Anthropogenic activities (e.g. cultivation of croplands, deforestation, poor rangeland management and destroying wetlands/ecosystems) and changes in land use or cover (e.g. conversion of forest lands and grasslands to cropland and pasture) can cause additional changes to these natural stocks and fluxes. These agricultural activities lead to increased emission of CO_2 and non-CO_2 emissions primarily from CH_4 from enteric fermentation in livestock and N_2O from manure storage, agricultural soils (primarily chemical N fertilization) and biomass burning. The increase in GHG is associated with rising atmospheric temperature with already experienced profound climatic alterations with mostly negative effects, such as increased flooding, droughts, wild fires, early frosts and frequency and intensity of severe weather events, across the globe, also in South Africa. To counteract these negative effects GHG emissions of agriculture and all other sectors must be reduced, preferably to pre-industrial levels.

Status of GHG knowledge: The 2016 Government accepted estimate of annual GHG of all cattle in SA is 35.4 million ton (Mt) CO_2 eq/annum[4] and of dairy cattle *per sé* 3.72 Mt CO_2 eq/annum, or about 10.5% of all cattle emissions. Per kg of milk this figure amounts to about 1.2 to 1.4 kg CO_2 eq/kg milk which compares satisfactorily with numbers reported in Australia, Europe, the UK and the US[5]. From low to high it nevertheless illustrates the vast potential in mitigation, which in this case largely reflects the amount of milk produced per unit input, i.e. efficiency.

The main contributor to GHG emissions in ruminant livestock is enteric CH_4. Previously, measurements indicated methane emissions of dairy cattle to be 179 Gg/annum, whereas the total of all livestock in the country was 1327 Gg/annum[6]. Recent SA updates for total livestock ruminants show CH_4 numbers of 1301 Gg/annum and 123 Gg /annum for dairy cattle in a publication in 2017[7]. Accepting that the calculation error is relatively large, it does appear that enteric emissions of dairy cows have declined; increased efficiency possibly being one of the reasons.

A further development which affects the calculations needs to be mentioned: The accepted global warming potential (GWP) of CH_4 as determined by the International Panel for Climate Change (IPCC) of the UN is 28 times that of CO_2, which implies that the per annum CO_2 equivalent number for dairy cattle equates to 3444 Gg. Recently, Physicists at Oxford University[8,9] challenged the IPCC GWP number on account of the fact that the staying time in the atmosphere of CH_4 is much shorter than that of CO_2. Their calculation over a finite period of 20 years indicates a GWP of only 8 provided entry into the atmosphere of CH_4 is not more than the previous 20 year period. Accepting this principle, enteric CH_4 emissions of dairy cattle in SA equate to a mere 984 Gg CO_2 eq/annum. In accordance, in a recent study on six pasture-based dairy farms in the Eastern Cape emissions on this basis were calculated as varying between 0.49 and 1.14 kg CO_{2e}/kg FPCM[10], suggesting still much improvement to be achieved on some farms. Apart from following the new approach in calculating CH_4 emissions, we believe that the net emissions which also consider carbon sequestration should rather be calculated. We have endorsed on such a programme.

Using BFAP[11] and other models, baselines were projected towards 2050, which take into account growth in the sector and the food requirements of an increasing population. The 'business-as-usual' scenario projection indicates increases for Agriculture to 69.6 Mt CO_2 eq/annum and for livestock to 41.2 Mt CO_2 eq/annum by 2050, which is a 38 % increase, presumably about the same for milk production if milk production per cow and per unit input is not addressed. To that effect significant strides have been made in the commercial dairy sector: Since 1990, the number of dairy farms has declined by 92 % and the number of cows by 24 %, yet total milk production has increased by 56 %[12]. This, obviously, implies that not only GHG emissions but also waste and water use per unit product have declined to the benefit of sustainability.

In comprehensive studies on pasture based dairy systems in the south-eastern Cape area of SA, the measured GHG (calculated in the LPCC way) of respectively 1.39 kg CO_2 eq/kg ECM[13] and 1.30 kg CO_2 eq/kg ECM[14] were higher than an average of 1.00 kg CO_2 eq/kg ECM reported in a New Zealand study. In line with the discussion above, the most logical approach to mitigating the potential negative environmental impacts associated is to increase farm productivity and efficiency. An example of this is the association between purchased concentrates fed per kg milk produced and the environmental impact measures: More efficient feed conversion was associated with higher N use efficiency and lower GHG emissions. Another example of increased efficiency contributing to reduced environmental impacts is the association of these measures with milk production per hectare: Increased milk production per hectare was associated with higher N use efficiency and lower GHG emissions.

Milk production was closely correlated to stocking rate which is logical as stocking rate and milk production per hectare are positively influenced by various practices which also contribute to higher N use efficiency and lower GHG emissions. These practices include rotational grazing management, improved genetic value of cows, increased weight of replacement heifers, improved health care of animals and more effective feeding practices.

As implied above we believe that a more effective way of reducing GHG is to sequester atmospheric CO_2 into plants and, in particular, into soils. Soils rich in organic carbon are associated with enhanced biodiversity, water cycling, agricultural productivity, and climate change mitigation and adaptation[15]. The global carbon pool in soils to a depth of 2 m is triple that of the atmosphere (~3,000 billion tons (Bt) C compared to ~830 Bt C)[16]. In this context, both increases in soil organic carbon and protection against losses from this pool are important strategies to counteract CO_2 accumulation in the atmosphere. Management practices that raise soil organic carbon are furthermore largely low in cost compared to alternative greenhouse gas abatement[17].

Carbon sequestration into soils will be increased upon conversion of conventional till to no-till farming, generally referred to as conservation agriculture (CA). Application of manures and other organic amendments is another significant strategy. Several long-term experiments in Europe have shown that the rate of soil organic carbon sequestration is greater with application of organic manures than with chemical fertilizers[18]. Furthermore, soils under diverse cropping systems generally have a higher soil organic carbon pool than those under monoculture. Work in this context is being undertaken in SA in general, but specifically also in dairy pastures, as discussed below.

On the south-eastern seaboard of SA milk production is primarily from cultivated pastures. Before 1990 monoculture pastures were conventionally established with deep tillage, resulting in deterioration of soil quality and loss of organic carbon. Since the late-nineties minimum tillage practices have been introduced, including at the time the successful pasture management system of kikuyu over-sown with ryegrass. This has improved soil quality and carbon was dramatically sequestered. In an experiment on soil analysis from Swellendam to Humansdorp[19], soils from kikuyu-ryegrass systems and shallow tilled soils recorded carbon contents of 50.3 kg C/m^3 and 54.3 kg C/m^3 respectively, vs only 34.6 kg C/m^3 for conventional deep tilled soils. This represents an improvement of 50% in soil carbon stocks. Pastures established with minimum tillage including the kikuyu-ryegrass management system, but now expanded to multi-species pasture compositions, comprise 70-80 % of commercial dairy farms in this area, which amounts to about 60 000 ha and a grazing capacity in the order of 240 000 dairy cattle. The improvement in soil carbon stocks on the 60 000 ha approximately amounts to 10.4 Mt carbon (38.1 Mt CO_2 eq), whereas the methane emission of 240 000 dairy cattle amounts to a mere 25 000 ton CO_2 eq/year.

GHG work in progress: Despite the favourable results discussed above, there is a lack of scientific evidence to exploit eco-efficient ways of farming, e.g. reducing CO_2 emissions, on pasture based dairy systems in SA. These pastures are usually irrigated and dairy farmers still use high concentrations of fertilizers to promote plant growth, even though CA is practiced and soil carbon is improved. As a result, nutrient loading (N and P in particular)[13,19] on dairy farms is a problem generally experienced, which in turn is associated with leaching and environmental pollution.

In an ongoing study to develop management guidelines for N application[20], the importance of N fertilisation following multiple years of no-tillage in the Eastern Cape was investigated. The study also determined whether P and K have an influence on pasture response to N. Fertiliser application rates were grouped into three treatments viz., <200, 200-350 and >350 kg N/ha. Yield response was recorded over five years. There were no differences found in treatment yields over years. Fields that were treated with high N did not accumulate extra growth with the high rates of N. The average herbage yield was 16.1±1.8 tons/ ha across all N treatments. There was even a trend of a negative correlation between herbage yield and N level. As a consequence, when less than 200 kg N/ha was applied, the N use efficiency was highest as only 11.3 kg N was required to produce 1 ton of herbage. When more than 350 kg N/ha was applied, 25 kg N was required per ton of herbage produced. There was also a significant shift of farms from high to low N application rates over years. The shift indicates a gradual trend of the adoption of low N systems by dairy-pasture farmers. It is evident that N fixation by legumes, cycling of N via manure and urine, and the mineralizable pool of N, contribute enough N to sustain plant productivity.

Soil and Soil Nutrients

These two DSF criteria are discussed together as soil nutrient status is influenced by soil health.

Prelude: High rates of soil organic carbon sequestration are obtained with no-till farming, crop residue retention as mulch, growing cover crops in the rotation cycle and integrated nutrient management, including applying manure and through restoration of degraded soils. While improving soil quality and agronomic productivity, agricultural intensification through adoption of these principles also improves water quality, increases fixation of N from the atmosphere, reduces general pollution by decreasing dissolved and sediment loads, and reduces net rate of CO_2 emission through carbon sequestration[17,21,22].

Pasture growth is a highly active process and therefore cannot be sustained without the replenishment of nutrients removed during the growth phase. The supply of soil nutrients to plants can be through natural processes like mineralisation (i.e. the conversion of organic nutrients into inorganic, plant available forms) following CA and the preferred management options described above, or in the form of chemical fertilisers. Nutrient cycling in soil relies on soil microbes and soil fauna, such as earthworms[23]. A healthy soil supports proliferation of soil microbes and nutrient cycling, thereby supporting sustainable production and guaranteeing reduced costs associated with fertiliser application[20]. There is also an interaction between soil microbes and earthworms, as earthworms act as biochemical reactors to convert labile plant compounds into stabilized soil microbial biomass[23].

Status: A generally accepted norm in crop production is that an improvement of 1% carbon in the upper 30 cm soil will coincide with fixation of 25 kg N from the atmosphere[23]. If however soil health is improved, turnover can be improved and more NH_4 –N, which results from chemical fertilizer, and otherwise will be converted into the GHG N_2O, can be utilized to the benefit of plant growth. As an adjunct, in a study at Delmas, improvement in soil organic carbon coincided with a 27 ppm increase in utilizable P. This equated to 100 kg P at a soil depth of 30 cm and when calculated relative to the equivalent cost of applying the chemical fertilizer MAP 33, the saving was R3000/ha, or R10 million for the farm of 3300 ha[24]. Thus, improved soil health status can result in considerable savings in fertilizer costs.

Excessive N fertilizer application could result in excess imported N and in more GHG emissions. The N efficiency range in an Eastern Cape dairy pasture based study[13] was 9%—76% with an average of 29%. Thus, a higher maximum, but a similar average N-use efficiency, was found when compared with the results of other studies conducted globally. Similarly, wide ranges of P use efficiency have also been found across dairy farms worldwide and the average P use efficiency of 36% found in the Eastern Cape study was similar to the average of 32% reported in Australia. In general, the nutrient use efficiency was low, resulting in excessive N and P generated from pasture-based dairy farms in the Eastern Cape. These excess nutrients have the potential to generate negative environmental impacts through accumulation in the soil, loss to the atmosphere through volatilization, loss to surface water through run-off, and/or loss to ground water through leaching. The concern is shared by others[19]. The authors recommended that future research should be directed at better understanding the cycling and loss of nutrients on pasture-based dairy farms, so that the environmental impact of these farms can be minimized.

Soil work initiated: To address the wide range in nutrient use efficiencies discussed above, a project[21] was initiated to investigate the influence of fertilizer application rates on the health of dairy farm pasture soils as well as soil health with the aim of identifying fertilizer guidelines which will optimise soil health, pasture productivity and profitability. The motivation results because the health of many South African soils under pasture is poor and therefore lacks the ability to support high productivity. The poor health is also associated with area as in one area the response to N application was 17kg N required per ton of pasture produced and in another only 11kg N per ton[22]. Due to uncertainty, large amounts of chemical fertilizer are used by farmers as a supplementary source of nutrients. However, farmers should be made conscious of how over-fertilization poses an environmental risk and inhibits the natural processes in soils, and furthermore results in reduced profitability. It is crucial that nutrients are replaced according to the specific demand of plants. Complete elimination of chemical fertilization is unlikely, as pasture systems in South Africa, specifically in the Tsitsikamma, lose more nutrients than what they can naturally replace. These soils are sandy with poor soil organic matter content, leaving them prone to nutrient leaching. Improving the health of these soils is a sustainable mechanism to improve pasture yield, and farm productivity and thus reducing the need to fertilize frequently.

Soil protection and improvement: Maintaining soil health is pivotal towards ensuring that the soil can function as a living ecosystem, keeping it in biological balance to ensure productive agriculture. Through the implementation of careful manure management, regenerative farming practices and sustainable cultivation in South Africa, many dairy farmers contribute to the sequestration of carbon into soil, as well as replenishing soils with other nutrients which are essential for crop cultivation. Controlled manure application is used in South Africa towards the restoration of soils and has shown to reduce dependence on fertilizer inputs. Fertilizers are widely considered to be of greater environmental detriment as implied above, with lower phosphorus and nitrogen application typically linked to better overall health of the environment. The application of pesticides to crops is also being recommended to be done in a controlled manner to minimise the threat of impacting soil quality, biodiversity and the spreading of contamination through water run-off and wind.

Typical effluent management on South Africa Dairy Farms relies on the waste stream to be collected and stored in ponds before being spread onto lands or pastures using a variety of methods. It is essential that this should be carefully managed to prevent seepage and pollution of sub-surface water. There are examples of farms where all slurry manure is collected in specifically designed concrete-lined channels and diverted to a contained sump. From there, the solid and liquid manure fractions can be separated, either by gravity or mechanical means. Liquid-solid separation of manure slurry provides several benefits including the production of value-added products (eg. bedding). Care must still be taken to divert, collect and contain liquid effluent run-off from stalls and cow housing. Ground water and soil contamination with faecal coliforms, nitrates and salts can occur through leaching of run-off if not controlled properly. To acquire more knowledge and develop guidelines, Milk SA is funding a project with the title: ''A feasibility analysis of low cost biological wastewater treatment options for dairy farms in South Africa[25]''.

Manure and slurry application rates on soil is best managed through soil testing. Routine sampling and soil testing allows farmers to accurately determine the status and availability of nutrients and to be informed of any specific nutrient deficiency or excess. The results can further be used to determine specific crop nutrient needs which allow fertilizers to be applied 'only as required' thereby benefitting the farm both economically and environmentally. Effective manure management on a dairy farm is critical to using this waste stream in a sustainable manner. Numerous farms across South Africa have appropriate effluent management measures in place and there are examples of innovative practices in this regard.

Other threats to soil health: Soil pollution mitigation in South Africa also extends to other potentially harmful substances. Any operation that deals with chemicals or petrochemicals must consider the environmental risks associated with storage, handling and potential spills and leakage. Underground fuel tanks for instance, should be positioned within a concrete or bricked wall, with the space underneath the tank filled with an inert material to prevent the fuel from seeping into the soil below. It is preferable to use above ground storage as any problems or leaks can be attended to easily. Routine inspections and maintenance should be performed, taking note, of flanges, valves and pumps with any noticeable leaks being attended to immediately. Legislation requires that a bund wall be in place surrounding any above ground fuel tank. It is advised that written instructions be available of the procedures to be followed in the event of spillage or any emergency.

SANS 10206:2010 provides a general guide for the handling, storage and disposal of pesticides. It also describes procedures to reduce environmental as well as human health when handling pesticides. Generally, the basic guide is that all chemicals/hazardous substances/pesticides must be stored in a lockable store. The store should be well ventilated and have a contained/bunded floor area. Signage should be displayed, and personal protective equipment be available for staff when handling these substances. Staff should also have the required training to safely handle chemicals and must be declared medically fit to do so. Legislation further requires material data safety sheets to be displayed or be readily available on file, while care should be taken to store flammable and non-flammable substances apart.

Used or spent machine/motor oil should also be stored and disposed of properly. There are numerous registered oil collectors and recycling centres that would assist in the collection and safe disposal on behalf of the farmer. If disposed of appropriately, the risk of soil or general environmental pollution is mitigated, and the used oil can be recovered and repurposed through a variety of treatment processes.

Waste

Prelude: Waste is of concern pre-farm gate as well as at the dairy processing plant. Waste at the farm level is both a safety and a resource pollution risk. For example, syringe needles which are not properly disposed of may be dangerous to children and animals, whereas milk obtained from antibiotic or drug treated cows which are flooded to pasture may affect soil chemistry and biology. Although whey disposal into streams/natural river systems is controlled by strict legal regulations, there are challenges in terms of proper handling especially in terms of dilution and ability to remove residual milk solids. The project mentioned above deals with some of these issues[25]. Furthermore, recycling and value-addition largely depends on yield, infrastructure as well as energy and water costs. This would typically require a comprehensive analysis and feasibility assessment. Post-consumer packaging waste is also receiving increased attention with mounting pressure on Brand Owners to utilise more environmentally sound materials and incorporate packaging design which is better suited for recycling.

Status: Most dairy farms have waste disposal and sewage systems that allow them to use the solids as fertilizers and the water either in irrigation or to recycle for cleaning. Some of the large dairy processing companies have waste reduction and water cleaning operations, some of which generate CH_4 for electricity generation, whilst the purified water is recycled for cleaning operations.

Manure slurry is recognised as a valuable resource which, through the application of efficient management, farmers can re-invest valuable nutrients and organic matter back into soils. Dairy farmers should be encouraged to adopt nutrient management plans which in turn contribute towards the alleviation of water pollution and improved environmental control. This is widely practiced by commercial farms in South Africa with recommended manure management practices contributing to enhanced soil infiltration rates, improved water holding capacity and increasing soil carbon levels. Although many regions in the country have experienced severe drought conditions, inclement weather can place pressure on slurry storage capacity and restricts slurry spreading opportunities. Slurry separators are used in some cases to separate solids from the slurry mixture. This enables reuse of the liquid fraction, either for flushing of walkways and milking parlour floors or for convenient pumping out onto fields for irrigation of crops. The solids can readily be accumulated, composted and further incorporated as part of a soil fertilization regime.

Efficient and safe industrial waste management is a critical contributor towards maintaining environmental integrity. Due to its high organic load and nutrient content, dairy effluents should be managed carefully. Solid waste emanating from dairy processing can be either organic or inorganic in nature. Typical organic waste includes milk solids, effluent sludge, spent product, paper and cardboard. In comparison, inorganic solid waste would include materials that are derived from non-renewable resources such as metals, glass and plastics. The best route for disposal or reuse depends on specific characteristics of the waste stream. In recent years there has been much development in the ability of dairy processors to collect and harness the economic value of various waste streams, which ultimately also drives more environmentally sound methods of disposal. As has been experienced in the International landscape, the waste market in South Africa is being placed under increasing pressure due to escalating landfill costs, which means that processors and waste producers are more likely to seek alternative means to dispose of spent organics or packaging materials. Regulation from National Government and local municipalities ensure that adherence to legislation is followed. The Department of Environmental Affairs and Development have developed the Integrated Pollutant and Waste Information System through which waste generators and handlers are controlled. Compliance to this, as well as local municipal by-laws, ensures that waste is disposed of in the most environmentally sound manner possible. Record keeping of all generated and discarded waste is considered essential towards implementing sound waste management practices and enables the establishment of waste recycling baselines which can be used to benchmark waste recovery activities.

Through the implementation of controlled waste sorting operations and in many cases, the appointment of dedicated waste contractors to assist in waste recovery operations, dairy processors in South Africa are minimizing waste generation while improving on their waste recovery and recycling ability on waste streams which are unavoidable. This includes a combination of solid and organic waste streams. Key waste metrics based on DSF guidelines at farm level should be whether a farm has implemented a Waste Management Plan (WMP), while at the Processor level being able to report on the amount of waste being sent to landfill is regarded as a valuable sustainability criterion. These should be the basis on which the industry develops baselines for waste disposal and management.

The threat which plastic pollution poses to the environment remains a topic of concern internationally, with South African consumers also increasingly aware of its negative impact. South Africa is fortunate in that it has, in particular, a fairly robust plastic recycling industry which contributes to the ability of dairy operations to divert this form of solid waste from landfill disposal sites with varying degrees of success. Cross-contamination of packaging with dairy product waste remains a limiting factor which can devalue the material before being received by recyclers. This highlights the need for efficient 'at source' separation of waste which has become a standard practice for processors.

Producers and manufacturers of dairy products will need to continue efforts towards finding alternative packaging solutions which are environmentally sound without compromising product integrity. Commitment and progress have been demonstrated through manufacturers using packaging which comprises a percentage of recycled material as well as using materials which are sustainably sourced, such as cardboard which is certified by the Forest Stewardship Council (FSC). Processors are further encouraged to reduce or if possible, eliminate any unnecessary plastic packaging from their supply chain which will contribute to the prevention of unintended and environmentally harmful consequences. Ultimately, the ability to recycle is dependent on the availability of recycling facilities and the locality of dairy processing operations to such sites. Developing the recycling industry post-consumer in this country will unlock our potential to divert waste from landfill.

Extended Producer Responsibility (EPR) regulations were first gazetted by the Department of Environment, Forestry and Fisheries (DEFF) under Section 18 of the National Environmental Management Waste Act (NEMWA) on the 5th November 2020. These regulations aim to extend the responsibility of producers (deemed "brand owners") based on the type and volume of packaging which they put out into the market. Government envisions that this system will provide a framework for the development, implementation, and monitoring of EPR schemes by producers towards ensuring efficient management of the identified packaging materials at the end of its life as well as the stimulation of new circular economy initiatives. The EPR scheme is expected to announce a regulatory fee structure for packaging by which producers need to be registered both with DEFF as well as a designated Producer Responsibility Organization (PRO) for each packaging material. These fees shall be levied per ton of each specific packaging type. There has been much interaction between stakeholders over the past six months, with many brand owners having registered with suitable PRO's and DEFF respectively.

'Zero waste to landfill' could be viewed as the ultimate long-term waste disposal target for the sector although this presently is still not the most economically viable route. Waste incineration offers a means to combust organic materials to release heat which in turn can be used to generate electricity while also fulfilling a role in reducing landfill volumes. Although there are emission concerns with this technology, advances in emission control can circumvent exposure to toxic by-products. South African manufacturers face increasing public scrutiny around the topic of plastic packaging, while food waste is a topic which will need to be addressed by the sector as the Carbon Footprint of this form of waste has been shown to be significant[26]. The new EPR system additionally aims to encourage producers to shift their packaging materials to formats which are deemed 'more recyclable' and therefore hold a higher value in the post-consumer recycling market. To enable the circular transition of packaging materials, design for recycling is considered a key enabler. The compatibility of materials coupled with ease of separation, have a role in determining the recyclability of a particular product.

Waste to Energy projects in the South African Dairy Industry have been challenged by National and Provincial policy, especially gaining the required approvals which can be a lengthy and costly process. This is often accompanied by the need for numerous specialist studies to adhere to all the relevant regulations which escalate project costs and can impact feasibility. Successful implementation of such technology has been achieved by Woodlands Dairy in the Eastern Cape Province using a combined effluent stream which emanates from several different production processes. The membrane bioreactor system converts wastewater into energy and clean water, which can then be safely discharged or reused for other applications. The methane gas produced through this process serves as a clean energy source which is used to fuel the onsite biogas boiler.

Thus far, 2022 has presented numerous challenges to the dairy industry, none more so that the exponential rising cost of fuel and its impact on the entire dairy value chain. Coupled to the severe National electricity shortfalls and more frequent load-shedding, emphasis should be directed towards the potential energy value of manure and other organic waste streams which will become highly sought after as industry needs to find alternative energy solutions to continue with business.

In addition to more conventional waste streams, dairy farmers and processors are also responsible for controlling the disposal of chemical and hazardous wastes. From an agricultural perspective, chemical waste would include insecticides and pesticides used for crop spraying. The National Environmental Management Act provides clear guidelines as to how these wastes should be discarded, as spillage or improper disposal has the potential to cause severe environmental degradation. Irrigation run-off can transfer chemical residues into natural river systems and this need to be managed responsibly. These have been eluded to in the chapter on soil health preservation.

Waste is generated during the processing of milk and dairy products and this poses a threat to water quality. Chemical Oxygen Demand (COD) is used by most dairies as an indicator to assess the level of organic compounds in their effluent stream. Through using either onsite treatment systems or preventative measures to reduce organics from entering their effluent stream, dairies can reduce their relative COD load, thereby minimising the impact of their effluent. Emphasis should be placed on reducing COD levels before primary treatment. In the case of most processors this would be before final discharge. As per the DSF guidelines, the adoption or implementation of an Effluent Management Plan (EMP) is regarded as the most important sustainability indicator around controlling the impact of dairy effluent on the environment.

Water

Principles and initiatives: Water in South Africa is a finite and vulnerable resource and must be dealt with responsibly, both as it applies to quantity and quality. Importantly, water is essential towards ensuring the production of high-quality dairy products as it is required throughout the processing chain serving critical functions in cooling, heating, washing and cleaning. Apart from rain water, dairy pasture based systems use irrigation to promote productivity of pastures; the general use being high compared to other agricultural systems and with the further implication of nutrient leaching and pollution of watercourses and wetlands. This initiated several projects which promote sustainable methods of production and stimulates innovation.

Recent developments and initiatives around water in the South African Dairy Sector are steadily contributing towards creating a culture of circularity and sustainability. A water stewardship program has been introduced by the MPO in collaboration with the WWF-SA[27], encouraging innovative initiatives in water management, ecosystem protection, and recycling, and effluent treatment in dairy factories. As per the WWF definition, water stewardship encompasses increased improvement in water usage, a reduction in all water related impacts and a commitment to collective action which includes other businesses, NGO’s, communities and government departments. The program needs to be rolled out to as many participants as possible, the initial action being to conduct a survey to establish needs and application. Participation by several processors and farmers over the past year indicates that water is a growing concern in the sector and that the initiative has established a platform for knowledge-sharing around water throughout the dairy value chain in this country. It further emphasizes recognition from the wider dairy industry that water stewardship is of great importance.

A second initiative is to develop best practice guidelines for determining aquatic and wetland buffer zones for dairy farms. The supporting research[28] is refining the current approach which has been developed by the WWF-SA for a wide range of sectors, through focusing on sector specific aspects that would allow for improved wetland and watercourse management; and secondly undertaking a cost-benefit analysis to inform sustainable wetland and watercourse management. The benefit to the dairy industry will be a sector specific approach to determine buffer zones and therefore directly focusing on aquatic and wetland ecosystem sustainability, in addition to maintaining biodiversity. The work carried out in KZN and the Western Cape has shown thus far that not only establishment or protection of buffer zones may be required but also under particular circumstances constructed wetlands for effective water flow management. It is anticipated that such constructed wetlands will provide an indication of the additional benefits to the implementation of the buffer zones.

In view of the envisaged impact of climate change of progressively increasing temperatures and therefore more evaporation, together with decreasing precipitation, it is important to establish minimum water requirements of forage species of importance to dairy farming. However, despite significant advances in irrigation equipment and precision technology there is still a lack of reliable information regarding water requirements of over-sown pasture systems. Therefore, as a third initiative, water requirements and irrigation scheduling systems and their suitability to topography, climate, soil, irrigation system and water availability need to be established[29]. The aim is to compare and calibrate different irrigation scheduling systems for different pasture mixes for various topographic, soil and climatic conditions under normal and restricted water conditions. In association, the various scheduling systems need to be compared against common pasture irrigation types to identify compatibility.

For farmers to control and effectively manage their environmental footprint as depicted by the variables water, soil and nutrients, and GHG, they need an integrated tool which (1) quantifies the contribution or influence of individual variables in the integrated system, and (2) relate these to the financial results of the farm. This has been achieved by a systems dynamic model[30] and accompanying app to assist farmers to calculate and monitor the impact of environmental variables on the economic outcome of their operations. The model and the app will combine as a hands-on tool for farmers to pro-actively engage environmental indicators with associated financial and economic costs and benefits. This will enable the farmer to provide inputs to key parameters of his/her operation, followed by real-time estimates of the impacts. The farmer will thus be able to select an optimum management intervention from both a bio-physical and economic vantage point.

From a dairy processing perspective, organizations across South Africa have adopted a wide range of approaches to improve their water resilience and operational efficiencies. Dairy processing, along with many other agro-processing industries, requires a high net usage of water and in turn also contributes to higher effluent outputs. Depending on the process requirements, each factory or processing facility has unique opportunities for water use reduction, water recovery and re-use as well as effluent recovery and cleansing. Through technological advancements in the re-use of water as well as wastewater recovery and treatment, processors are driving down consumption while reducing the demand on municipal water supply systems.

Many South African Dairies have placed their focus on areas of water consumption that can readily be managed and where immediate reductions in water usage are possible. Processors across the country use staff training and awareness as a primary means to reduce water wastage. Optimization of CIP systems has presented dairies with steady water savings through efficient sequence planning of product batches as well as modifications which enable the re-routing of rinse water to ensure collection and re-use. Water use efficiency (typically the volume of water used per volume of product manufactured) reporting is the key metric to initiate and measure continuous improvement programs or projects related to water consumption.

Though water scarcity challenges face numerous provinces in South Africa, it is possible to augment water through alternative means while doing so in an environmentally beneficial manner. This has been successfully demonstrated by the establishment of an integrated water and waste recovery system implemented by Woodlands Dairy in the Eastern Cape Province. The wastewater treatment plant was required due to under-capacity and inefficiency of the municipal wastewater treatment system to effectively deal with effluent. The integrated system can recycle wastewater using reverse osmosis technology to convert it back to a potable standard. This allows for reuse of the water inside the factory. In addition to reclaiming water, an anaerobic bioreactor enables methane to be produced from the organic content. This gas in turn serves as a fuel source to drive a boiler which supplements a portion of the processing plant's steam requirements.

Biodiversity

Vision and strategy: South Africa is a country with a rich endowment of natural resources, which include its biodiversity and ecosystems. The diversity of these ecosystems delivers a range of services that are essential to people and the development and growth of the economy. The National Biodiversity Strategy and Action Plan (NBSAP) nested in the Department of Forestry, Fisheries and the Environment is responsible of fulfilling the objectives of the Convention on Biological Diversity (CBD). With the adoption of the CBD's Strategic Plan for Biodiversity, the NBSAP has outlined a path to ensure that the management of biodiversity assets and ecological infrastructure continue to support South Africa's development path and play an important role in underpinning the economy[31]. The vision is to: Conserve, manage and sustainably use biodiversity to ensure equitable benefits to the people of South Africa, now and in the future.

The strategic objectives are:

- Management of biodiversity assets and their contribution to the economy, rural development, job creation and social wellbeing to ensure that it is enhanced and secured.
- Investments in ecological infrastructure to enhance resilience and ensure benefits to society.
- Biodiversity considerations are mainstreamed into policies, strategies and practices of a range of sectors.
- People are mobilized to adopt practices that sustain the long-term benefits of biodiversity.
- Conservation and management of biodiversity is improved through the development of an equitable and suitably skilled workforce.
- Effective knowledge foundations, including indigenous knowledge and citizen science, and supporting the management, conservation and sustainable use of biodiversity.

Prelude: Agriculture is widely affected by the loss of biodiversity, largely through habitat destruction because of the conversion of natural lands for agricultural use, coupled with the intensification of agricultural practices. These have contributed to the pollution of soils through the application of fertilizers and pesticides, whereas soil erosion through unsustainable farming practices places mounting pressure on ecosystems. This is a pressing issue and one which the industry must address. As the demand for agricultural products has increased, driven by the nutritional needs of a growing population, the importance of developing a biodiversity-sensitive agricultural system to ensure future sustainability should be regarded as a key driver for the South African Dairy Industry. Such a system aims to develop input services without significantly decreasing effective agricultural production[30]. These ecosystem services are defined by land use management practices coupled with soil and climatic conditions. The development of a resilient agricultural system relies on a balance between the exploitation and use of biodiversity, ecosystem services and the natural environment. Both agriculture and the relevant ecosystems will ultimately benefit through the adoption of approaches towards resilient systems. These would focus on optimising the use of agro-biodiversity while reducing both economic and natural long-term risks through the application of effective ecosystem practices, rather than external inputs[32]. Dairy farms across South Africa have widely undertaken (although still not always to a formal extent, especially among smaller-scale farmers) to integrate biodiversity-conscious approaches in their businesses. The vast costs involved in repairing damaged soils are understood and therefore the benefits in monitoring soil health, structure, nutrients and biological activity are recognised. This extends to the careful management of fertilizers, manure and pesticides, with specific attention to application rates and timing to maximize soil retention of nutrients and prevent unwanted leaching into waterways. Other key services include the diversity of animals and gene pools which contribute to the overall resilience of the ecosystem. This also holds true for crops, where a mixture of crop varieties tend to reduce vulnerability against diseases, pests and nutrient deficiencies. The CBD vision and objectives could be aligned to the South African Dairy Industry as dairy production does impact biodiversity and ecosystems, not only through changes made to habitats but also factors such as the application of fertilizers and other input products, nutrient losses and associated greenhouse gas emissions.

The dairy industry supports the vision and strategies of the NBSAP

Status: South Africa is known for preserving animal and plant genetic resources, although there are concerns regarding scarce gene pools. Dairy farming operates primarily in intensive and closed environments, but the industry is conscious of the importance of conserving bordering wetlands and ecosystems as the stewardship programme and the implementation of programmes to enhance soil microbial and fauna contents discussed above suggest. They also are, as elsewhere in the world, conscious of the narrowing of genetic diversity within dairy breeds resulting from semen use of international sires with exceptional breeding values. However, this is closely monitored and occasionally crossbreeding is implemented as a way out, usually with coinciding benefits to the immune system and longevity. In support, a programme has been implemented to incorporate genomic testing[34] to identify superior South African sires which should be helpful.

Market development*:*

Prelude: Internationally compared, the South African dairy industry is one of the most deregulated industries. The industry is not subject to any statutory intervention in the production and marketing of its products aimed at managing or influencing the supply and demand of unprocessed milk and dairy products, and it is not supported by government subsidies. A totally free and competitive dairy market prevails in South Africa which created a very dynamic dairy industry that continuously adapts to the changing needs of consumers and industrial users. Functionally, market development is supported by (1) market signals and information, which are made available to the industry through formal publications and other measures; (2) customs and market access, by being involved with an initiative in international trade relations, export certification activities, import monitoring activities and animal health; (3) consumer education, which aims to empower the consumer with information to enable them to make informed and responsible choices, and (4) pursuance of new market opportunities.

Status and initiatives: Market signals and information are made available to the industry through formal publications and other measures on a continuous basis. A selection of variables includes:

- Import and export statistics quarterly;
- Unprocessed milk production monthly;
- Processing of unprocessed milk into various dairy products monthly;
- Geographic distribution of unprocessed milk production;

- Composition of the concentrated and liquid products markets;
- Year-on-year change in demand and prices of dairy products;
- The domestic and international economic situation;
- International unprocessed milk production and dairy product volumes and prices.

Consumer information and education is provided by the Consumer Education Project (CEP) of Milk SA[35]. The project aims to convey the health and nutritional benefits of dairy and is continuously evaluated and developed. The project is multidisciplinary as it uses expert knowledge from different disciplines that is communicated to the target audiences through television, radio and print. A combination of sound scientific information and good understanding of consumer perceptions anchors the project. The project conveys messages that cannot be communicated adequately through conventional branded advertising. The purpose of the project is not only to serve the interests of the dairy industry but also to empower consumers with information to help them make informed and responsible choices on dairy.

Of important markets which have been identified with potential as trading partners, the Sub-Sahara (SS) African market is maybe the most prominent, especially as export market. However, because the industry does not have knowledge of their regulatory environment, food safety and other control measures, a dedicated project has been conducted[36] to acquire information in order to: promote and stimulate export; provide informed contributions on the contents of the trade agreements which South Africa may negotiate; harmonize the legal standards of SS African countries which are applicable to the composition, safety and metrology of unprocessed/fresh milk and dairy products, and protects the country against unfair competition from imported dairy products. The project covered 15 countries in eastern and southern Africa and the reports are available from the Milk SA office.

Rural economies

Goals and developments: The core emphasis is to promote competitive, profitable and sustainable existing black and new enterprises by contributing to the reduction of commercial venture constraints. The initiative is aligned with the South African developmental priorities, namely food security, poverty reduction, promoting equitable economic transformation and contributing to general economic development and growth. Based on needs assessment of existing dairy enterprises along the dairy value chain and according to Milk SA criteria, Milk SA intervenes with the following assistance: supply of electricity, pregnant heifers, veterinary services, on-farm infrastructure, technical know–how, establishment of permanent pasture, technical training, development of business plans and feed supply during critical drought periods. After the initial support for assets which was funded 100% by Milk SA, entrepreneurs are encouraged to acquire additional assets such as heifers on a 40/60% cost sharing basis between the entrepreneur and Milk SA respectively. The goal of this approach is to instil an enterprise / entrepreneurial culture in project beneficiaries.

Skills and knowledge development are supported by Milk SA to ensure the continuation of an appropriate skills and knowledge dispensation. In the context of rural economy development, Milk SA's Skills & Knowledge Development Program supports training at new and black dairy enterprises.

The rural dairy economy is not only supported by the organized dairy industry through Milk SA, but several provincial departments associated with agriculture which drive entrepreneurial programs and training. The most notable programs are offered by KZN, the Eastern Cape and the Western Cape. For example, the Eastern Cape's initiative[37] is in association with the company Amadlelo as strategic partner with community based large dairy operations such as at the Fort Hare University Dairy Trust; Middledrift Dairy Production; Keiskammahoek Dairy Production; Ncora Dairy Production; Shiloh Dairy Production; Mantusini Dairy Production, and with the Du Plessis brothers at Wittekleibos Dairy Production.

As an adjunct to training and development, the value of milk production as a stimulus in rural development should not be underestimated as it provides infrastructure, electricity, service delivery etc.

Working conditions

Applicable Acts: This section is informed by The Labour Relations Act (Act 66 of 1995)[38], The Employment Equity Act (Act 55 of 1998)[39], The Basic Conditions of Employment Act (Act 75 of 1999)[40], The Skills Development Act (Act 97 of 1998)[41], The Compensation for Occupational Injuries and Diseases Act (Act 130 of 1993)[42] and The Land Reform (Labour Tenants) Act (Act 3 of 1996)[43].The overriding principle is that farmers need to ensure that the rights and well-being of farm workers and their families are upheld and that they contribute to the social and economic development of the local community and on the periphery.

The Labour Relations Act deals with rights as contained in the Bill of Rights in the Constitution of South Africa. Those relevant to the dairy industry are: the right of freedom of association of both employer and employee, the protection of employers and those seeking employment, the protection of the rights of employees (Sections 4 and 9), the organizational rights of employees such as access to the workplace by a representative of the trade union, collective bargaining rights, the right of employees to strike and the right of an employer's recourse to lockout (Sections 64-71), unfair dismissal and unfair labour practices (Sections 185-197).

The Basic Conditions of Employment Act was promulgated to advance economic development and social justice by giving effect to the right to fair labour practices. It is supported by a Code of Good Practice which deals with fair working hours and the impact of working time on the health, safety and family responsibilities of employees. The Skills Development Act was introduced to develop the skills of the South African workforce, improve their quality of life, their prospects of work and labour-associated mobility, improve the productivity in the workplace and therefore the competitiveness of employers, promote self-employment and improve the employment prospects through training and education. The Compensation for Occupational Injuries and Diseases Act is designed amongst others to provide for the health and safety of people at work, those that use or are exposed to potentially dangerous equipment and those on the periphery of where the work is conducted. Finally, The Land Reform (Labour Tenants) Act was introduced to provide for security of tenure of labour tenants and people occupying or using land because of their association with labour tenants. The Act also deals with the acquisition of land and the rights to land by labour tenants.

Employer obligations: Employers in the dairy industry should commit themselves to the following, if they have not done so already:

- Comply with the conditions legislated for fair labour practice.
- Contribute to employee unemployment benefits.
- Contribute to the skills development of employees.
- Provide for compensation of death or disablement resulting from occupational activities.
- Provide for the safety and health of the employees at work.
- Uphold the rights of labour tenants and farm occupiers to reside on land and to acquire land where applicable.
- Ensure that recreational areas on the farm are available.
- Participate in actions towards establishment of a sustainable local economy.

One way of participating in such actions is to adopt a policy of preferential employment of residents from the local community or from labour tenants on the farm. Applicable research results suggest that agricultural growth and efficient management of natural resources are dependent on the political, legal and administrative capabilities of rural communities to determine their own future and to protect their natural resources and other economic interests. The umbrella principle is that farmers are the mainstay of the economy of towns, townships and the surrounding rural environment, and they have the knowledge and skills to support development towards a viable and sustainable local economy.

Product safety and quality

Prelude: The dairy quality and safety initiatives of Milk SA are the responsibility of the Dairy Standard Agency (DSA), a non-profit company established by the industry. The DSA monitors and supports procedures that actively promote product compliance with product composition and food safety standards. This is a prerequisite for the growth of the dairy industry, as substandard products reaching the retail market can harm both the industry and the consumer. Promotion of compliance with standards relating to milk and other dairy products is a demanding and multi-dimensional task of the DSA, because of the involvement of regulations relating to product composition, food safety, animal health and welfare, animal feed, milking parlours, transportation of milk, processing plants and storage, all of which are regulated by different Acts which are managed in different government departments.

Status and progress: In terms of its mandate the DSA has progressively moved to a landscape where today it is well-recognised and respected by the respective government bodies, the organised primary and secondary dairy industry and other stakeholders, for example national consumer bodies and the retail sector.

The main objective of the Company is to promote the quality and safety of milk (unprocessed and processed milk) and other dairy products in respect of, especially food safety and product compositional standards by:

- Providing dairy technical and scientific knowledge and advice regarding compulsory and voluntary standards, to members of the dairy industry and bodies in the public sector;
- Contributing to the maintenance and development of functional, compulsory and voluntary standards relevant to the dairy industry;
- Participating in international forums and organizations dealing with standards relevant to the dairy industry;
- Monitoring compliance with compulsory and voluntary standards, relevant to the dairy industry and taking the required action;
- Facilitating and providing support to bodies in the public sector that are responsible for the application and involved in the amendment of standards relevant to the dairy industry;
- Effectively liaising, communicating and co-operating with governmental and dairy industry structures, as well as with any other organisations which are active in respect of regulations relevant to the dairy industry;
- Promoting in especially the African Union, the harmonization of standards applicable to dairy products, especially food safety, product compositional and metrology standards.

Laboratory support: The lack of a harmonised (standardised) system at national level for the calibration of laboratory instruments for the measurement of fat, protein, lactose, milk urea nitrogen, somatic cell count, and other quality parameters of milk, created technical barriers and added to potential legal disputes. As a result the DSA Laboratory Services was established. The resulting infrastructure also addresses the need for an independent proficiency testing scheme (laboratory ring test) for dairy laboratories in South Africa. Milk SA considers the harmonisation of standards as critical to the dairy industry of which some of the benefits are:

- Uniform standards for the calibration and use of measuring equipment to the benefit of the primary and secondary dairy industry;
- Improved reliability of test results obtained from individual in house laboratories;
- Comparative test results from external test laboratories;
- Test results to support research and development as well as statistical data used during herd health management programs;
- Mitigation of disputes between milk producers and milk buyers as a result of payment on quality parameters of milk from the use of calibrated equipment using harmonised standards.

Expansion to the services and tests provided by the DSA are continuously evaluated to provide a more comprehensive service to the industry. To that effect methods of analysis need to be developed or compared, a recent example being a comparison of methods to determine antibiotic and other residues in milk: A variety of commercial kits are used by milk buyers and external laboratories in the industry for detecting antibiotic residues in milk during milk reception. Most of these kits provide qualitative data, indicating the presence or absence of such residues without being able to specify/identify the type of antimicrobial compound(s). A newer testing system, the AOAC approved Randox methods, is able to detect and identify a wide range of antibiotic residues and antimicrobial substances. A project was therefore registered[44] to compare the results of the Randox system with the generally applied methods used in the industry, amongst others the Copan Milk test. In addition, other methods are standardized from time to time to be used by the industry.

The quality of milk country wide has recently been affected by the condition known as flocculation/gelation, which is associated with coagulation of milk protein. In raw milk the destabilisation of the milk protein results in coagulation with the alizarol alcohol platform test, which is referred to as flocculation. This may be caused by a variety of factors, including probably acid production by bacteria, mastitis which causes the pH of the milk to increase, bacterial enzymes produced by psychrotrophic bacteria due to unhygienic practices, low urea-nitrogen and/or too low or too high levels of calcium, phosphates and citrate in the feed of the cows. In Ultra-High-Temperature (UHT) milk the type of coagulation is referred to as gelation which affects shelf life, and occurs when the milk protein becomes destabilized during storage as a result of residual intrinsic milk enzymes such as plasmin; residual psychrotrophic bacterial enzymes; or proteolytic enzymes from *Bacillus* contaminants in the processing factory. A research project has been run over five years, the results of which have been summarized[45] and is available from the Milk SA office. Since contamination with psychrotrophic bacteria such as *Pseudomonas* arguably is the major cause of the flocculation/gelation problem, a rapid test was developed in support of the alizarol test[46].

Animal care

Prelude: Although animal care in the DSF criteria is only defined in the context of welfare, health and production are also components of animal care, with all components having an effect on one another. Whereas health and production are well understood, what people interpret to be acceptable animal welfare can be influenced by many factors including personal values, religion, nationality, gender, previous experiences, age, socio-economic status, etc. From a scientific[47] and farmer perspective, however, an animal is in a good state of welfare if it is healthy, comfortable, well nourished, safe, relatively able to express its innate behaviour, and is not suffering from negative states such as pain, fear and distress. Good animal welfare requires amongst others disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling, transport and eventually, humane slaughter. For farmers, the interaction between the three components of animal care is recognisable through the following[48]:

- A realization that there is a critical relationship between animal health and welfare.
- The recognized “five freedoms” provide valuable guidance in animal welfare management (these are: freedom from hunger, thirst and malnutrition; freedom from fear and distress; freedom from physical and thermal discomfort; freedom from pain, injury and disease; and freedom to express relatively normal patterns of behaviour).
- The use of animals carries with it a duty to ensure the welfare of such animals to the greatest extent practically possible.
- Improvements in farm animal (livestock) care can often improve productivity and lead to economic benefits.

Developments: The dairy industry is committed to implementation of best practices to ensure animal welfare based on scientific evidence. As member of the IDF and by consulting the IDF’s Guide to Good Animal Welfare in Dairy Production[49] and the SABS SANS 1694 guide for dairy cattle welfare[50], the DSA with the assistance of Milk SA, the Milk Producers Organisation (MPO), South African Milk Processors Organisation (Sampro) and other stakeholders developed auditable criteria to measure compliance with relevant animal welfare standards at the milk production level. The purpose of this outcome based driven auditable and assessment criteria is to assist farmers in the process of identification of risk areas, to evaluate the risks, and to implement management practices which can improve welfare. The audit programme has been successfully tested and is in operation on pilot scale in 2022.

Animal health research programmes in South Africa are currently running to control and prevent mastitis, liver fluke, hoof health and. A summary of progress in both mastitis[51] and liver fluke[52] research is available from the Milk SA office. The focus where possible is on prevention and alternative treatments to limit the use of antibiotics and drugs. New developments include mRNA-based vaccine possibilities for brucellosis in association with the other livestock organisations and selection for functional traits such as disease resistance through genomic testing[53].

In animal production new developments for evaluation include selection of more drought resistant forages, alternatives to rye grass such as plantain, alternatives to grain in supplements, a SA forage index for cows, and reasons for the autumn slump in milk production.

3. Concluding remarks

The South African Dairy Industry has recorded significant progress in most of the sustainability goals as defined in the Dairy Declaration of Rotterdam and the Dairy Sustainability Framework, particularly as it applies to the environment. It should be recognised that this is an endeavour which requires continuous attention through research, monitoring and training, and ultimately adoption by all role players across the dairy value-chain in the country. Several programmes, which are either existing or in various phases of development, and which align to the aforementioned sustainability goals, have therefore been documented. The report should be viewed as dynamic and will be updated regularly to reflect changes in the industry as new information becomes available and progress is made in related initiatives. A summary of sustainability activities and responsible projects is also provided in the accompanying Addendum.

References

1. FAO-IDF, 2016. The Dairy Declaration of Rotterdam. The dairy community accepts sustainability challenge. FAO, Rome and IDF Brussels.
2. United Nations, 2016. The 2030 Agenda for Sustainable Development. UNSSC Knowledge Centre for Sustainable Development, Bonn, www.unssc.org.
3. DSF, 2009. The Dairy Sustainability Framework. Programme of the Global Dairy Agenda for Action. GDAA, www.dairysustainabilityframework.org. GFAR, FAO, Rome
4. Research Report, 2016. Towards development of a GHG emissions baseline for the Agriculture, Forestry and Other Land Use (AFOLU) Sector in South Africa. Department of Environmental Affairs, Pretoria.
5. Meissner, H.H., Scholtz, M.M & Palmer, A.R., 2013. Sustainability of the South African Livestock Sector towards 2050. Part 1: Worth and impact of the sector. S. Afr. J. Anim. Sci. 43, 283-298.
6. Du Toit, C.J.L., Meissner, H.H. & van Niekerk, W.A., 2013. Direct methane and nitrous oxide emissions of South African dairy and beef cattle. S. Afr. J. Anim. Sci. 43, 320–339.

7. Moeletsi, M.E., Tongwane, M.I. & Tsubo, M., 2017. Enteric Methane Emissions Estimate for Livestock in South Africa for 1990–2014. Atmosphere 8, 69. doi:10.3390/atmos8050069.
8. Allen, M.R., Shine, K.P., Fuglesvedt, J.S. et al., 2018. A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. Climate and Atmospheric Science, 1:16 doi:10.1038/s41612-018-0026-8.
9. Lynch, J., Cain, M., Pierrehumbert, R., Allen, M. 2020. Demonstrating GWP: a means of reporting warming-equivalent emissions that captures the contrasting impacts of short- and longlived climate pollutants. Environmental research letters, 15:044023. https://doi.org/10.1088/1748-9326/ab6d7e.
10. Blignaut, J.N. & Reinecke, R., 2022. Determination of environmental and economic outcomes of dairy production systems in South Africa: a system dynamics approach. IDF Dairy Sustainability Outlook • Issue N° 5, page 28-29.
11. BFAP, 2015: BFAP Baseline. Agricultural outlook 2015-2024. Available at: www.bfap.co.za.]
12. Van Dijk, C., 2016. Mechanisation asks for precision dairy farming. The Dairy Mail, November 2016, page 1.
13. Galloway, C., Conradie, B. Prozesky, H. & Esler, K., 2018. Opportunities to improve sustainability on commercial pasture-based dairy farms by assessing environmental impact. Agricultural Systems 166, 1–9.
14. Smit, H.P.J. et al., 2021. Environmental Impact of Rotationally Grazed Pastures at Different Management Intensities in South Africa. *Animals 11*, 1214. https://doi.org/10.3390/ani11051214.
15. Chen, S. et al. *Proc. Natl Acad. Sci. USA* **115**, 4027–4032 (2018).
16. Global Commission on the Economy and Climate *Better Growth, Better Climate: The New Climate Economy Report* (New Climate Economy, 2014); https://go.nature.com/2B5xSEf.
17. Nkonya, E., Mirzabaev, A. & von Braun, J. *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development* (Springer, Cham, 2016)].
18. West, T. O. & Post, W. M. 2002 Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. Soil Sci. Soc. Am. J. 66, 1930–1946.
19. Swanepoel, P. A., Habig, J., du Preez, C.C., Snyman, H.A. & Botha, P.R., 2016. Tillage effects, soil quality and production potential of kikuyu–ryegrass pastures in South Africa. Grass and Forage Science, doi: 10.1111/gfs.12241.
20. Swanepoel, P.A. 2021. Impact of fertilizer application rates on soil health and pasture yield. US. Project supported by Milk SA, Pretoria.
21. Rattan, L., 2008. Carbon sequestration. Phil. Trans. R. Soc. B 363, 815–830.

22. Swanepoel, P.A., Hinck, S. & Phohlo, P., 2019. The impact of fertiliser application rates on soil health and pasture yield in the Eastern Cape, South Africa. US project supported by Milk SA. Pretoria.
23. Angst, G., Mueller, C.W., Prater, I., Angst, Š., Frouzz, J., Jilková, V., Peterse, F. & Nierop, K.G.J., 2019. Earthworms act as biochemical reactors to convert labile plant compounds into stabilized soil microbial necromass. Communications Biology 2, Article 441.
24. Otto, F.E. 2019. **fritz@makariosagri.co.za**. Pers. Comm.
25. Naidoo, S., Evans, W., Naidoo, T., Bux, F., Kumari, S., Rawat, I., Bhola, V. & Gordon, T., 2022. A feasibility analysis of low cost biological wastewater treatment options for dairy farms in South Africa. A Project of the Institute for Natural Resources and funded by Milk SA.
26. FAO, 2013. Food Wastage Footprint: Impacts on Natural Resources, Summary Report, Rome.
27. Dairy Industry – water stewardship working group kicks off., 2019. Milk Essay 11 (1), January-February 2019, Item 6.
28. Bredin, I., Dabrowski, J., Brown, M. & Viljoen, S., 2019. Buffer zones for wetlands and rivers in the dairy sector – A case study to determine best practice guidelines for improved wetland and river management. Project by Institute of Natural Resources, Confluent Environmental and WWF-SA, and funded by Milk SA, Pretoria.
29. Truter, W., Sehoole ,O., Murphy, M., Fessehazion, M., Annandale, J., Jarmain, C., Dlamini, M. & Everson, C., 2016. IRRIGATION GUIDELINES FOR MIXED PASTURES AND LUCERNE. WRC Report No. TT 697/16, December 2016.
30. Blignaut, J.N. & Reinecke, R. 2021. A systems dynamic approach to incorporate environmental indicators into economic outcomes of dairy production systems in SA. An Asset Research Project supported by Milk SA, Pretoria.
31. Government of South Africa, 2015. National Biodiversity Strategy and Action Plan, Department of Environmental Affairs, Pretoria.
32. Duru, M., Therond, O., Martin, G., Martin-Clouaire, R., Magne, M-A., Justes, E., Journet, E-P., Aubertot, J-N., Savary, S., Bergez, J-E. & Sarthou, J.P., 2015. How to implement biodiversity-based agriculture to enhance ecosystem services: a review. Agron. Sustain. Dev. 35: 1259-1281.
33. Erisman, J.W., van Eekeren, N., de Wit, J., Koopmans, C., Cuijpers, W., Oerlemans, N. & Koks, B.J., 2016. Agriculture and biodiversity: a better balance benefits both. AIMS Agriculture and Food 1(2): 157-174.
34. Joubert, R. & van Marle – Köster, E., 2015. Dairy Genomics Programme (DGP). Responsible institution University of Pretoria co-ordinating various stakeholders in the dairy industry. Project funded by the Technology Innovation Agency, Pretoria.
35. Consumer Education Project of Milk SA., 2014. Rediscover Dairy. Dairy CEP info@dairy.co.za.

36. Kraamwinkel, A., 2020. A desktop study to report the situation in all of the Sub-Saharan countries with regard to essential market information. A Milk SA project, Pretoria.
37. Rust, J., 2020. Project report ECDA and personal communication.
38. Labour Relations Act, No 66 of 1995. (www.gov.za/documents/download.php?f=70985)
39. Employment Equity Act, No 55 of 1998 (www.labour.gov.za/... / legislation / acts / employment-equity /employment-e)
40. Basic Conditions of Employment Act, No 75 of 1997 (www . acts .co.za / basic-conditions-of-employment-act -1997)
41. Skills Development Act, No 97 of 1998. (www.gov.za/documents/download.php?f=70755)
42. Compensation for Occupational Injuries and Diseases Act, No 130 of 1993. (www.labour.gov.za/.../ acts /.../compensation-for-occupational injuries-and-diseases- act)
43. Land Reform (Labour Tenants) Act, No 3 of 1996 (www.polity.org.za/.../ land-reform-labour-tenants-act-no3-of-1996).
44. Burger, J. 2019. A comparison of methods for determining of antibiotic and other residues in milk. DSA Laboratory Services. A Milk SA Project, Pretoria.
45. MSA: Summary of Research Progress with Milk Flocculation and Age Gelation 2017 to 2021. A Milk SA Project, Pretoria.
46. Hugo, C., Hugo, A., Xaba, L., Uys, L., Ndhlovu, L. & Jiyane, M., 2022. Evaluation and validation of methods for the detection of psychrotolerant bacteria and proteolytic enzymes in milk. UFS. Project funded by Milk SA.
47. O.I.E. – Terrestrial Animal Health Code, 2017. Chapter 7.11.- Animal welfare and dairy cattle production systems. Office International des Epizooties, Paris.
48. Meissner, H.H., 2014. RPO and NERPO Code of Best Practice for Sustainable and Profitable Red Meat Production: Section 7 – Animal health and well-being. RPO, Pretoria, August 2014.
49. International Dairy Federation, 2019. IDF's Guide to Good Animal Welfare in Dairy Production 2.0 of April 2019, ISO/TS 34700:2016 – Animal welfare management – General requirements and guidance for organisations in the food supply chain, Brussels.
50. South African Bureau of Standards, 2018. SANS 1694:2018 - The welfare of dairy cattle, SABS, Pretoria.
51. MSA: Summary of Research Progress with Mastitis 2015 to 2021. A Milk SA Project, Pretoria.
52. MSA: Summary of Research Progress with Liver fluke 2016 to 2021. A Milk SA Project, Pretoria.
53. Scheepers, R., 2021. An assessment of cow welfare traits in SA Holstein herds. Project supported by TIA and Milk SA, Pretoria.

RESGEN400