CHAPTER 7

GENERAL CONCLUSIONS AND RECOMMENDATIONS

7.1 OVERVIEW OF THE STUDY

To meet the increasing demand for animal protein as human populations increase, there is a need to increase water (and land) productivity. Natural veld cannot fulfil this need alone and must be supplemented with irrigated and fertilised planted pastures. This requires intensive use of fertilisers and water, which leads to a higher cost of production and a greater risk of environmental pollution. Thus, farmers are under pressure to decrease their share of water and fertiliser usage, whilst at the same time, produce sufficient pasture to supply the protein (i.e. milk) demand of a growing population more efficiently. This study was conducted to improve N and water use efficiencies using adaptive management and modelling approaches, using annual ryegrass for dairy production as the case study. Hence, field experiments were conducted for testing selected on-farm equipment (FullStop® wetting front detector) and the SWB model for managing N and irrigation.

7.2 BALANCING FORAGE YIELD AND QUALITY USING ADAPTIVE N AND WATER MANAGEMENT

Generally, for most growth cycles, the highest forage yields were produced when N application rates ranged between 30 to 60 kg N ha^{-1} cycle^{-1}, except for the first growth cycles when there was high soil N carryover from the previous season. The amount of N fertiliser required for achieving a maximum forage yield and quality varies widely among growth cycles depending on soil N availability. N fertiliser application for the first two to three cycles did not improve forage yield but reduced quality (high CP).

Consequently, the current farmers' recommendation (fixed N application rate of 50 kg ha^{-1} per growth cycle) aimed at maximising biomass yield may not improve animal performance for all growth cycles. Similar overall animal performance or milk yield can be achieved by applying less N fertiliser and compensating the reduced yield with an improved quality of forage (lower CP), while also minimising environmental impact. This is important for a pasture based system, because farmers do not have the option of mixing rations to balance the change in pasture crude protein during the season.

Adaptive N fertiliser and irrigation management (Chapter 2) were effective in reducing N application without reducing forage yield. At the same time N and water use efficiencies were improved and the potential for N leaching reduced. Seasonal N application was reduced by 28% when components of the N balance (e.g. N mineralisation, N carry-over from previous growth cycle etc) were measured at the start of each cutting cycle (N_{MB}). However, the expense of such monitoring may not be justifiable on economic grounds. The adaptive approaches showed that N savings from routine monitoring could also be realised through a simpler adaptive approach based on thresholds for the nitrate concentration in the soil solution. Adaptive approaches of reduced N (N_{soil}) and water (N_{water}) applications resulted in 27% and 32% less N application than the baseline recommendations from the South African Department of Agriculture, respectively. Both adaptive treatments resulted in an improvement of forage quality with no yield reduction, and a lower risk of N leaching.

Apart from the early season harvests, the current study showed that the optimum N application per cycle was between 30-60 kg N ha^{-1} in 2007 and 40 kg N ha^{-1} in 2008 (Chapter 3). Hence, N application rate of 30-40 kg N ha^{-1} per growth cycle should give highest forage yields and ME yields with CP concentrations within the boundaries of CP_{opt} and CP_{max}. No fertiliser may be required for the first 2-3 growth cycles, when CP was very high, and this can be confirmed by considering soil N (as presented in Chapter 2).

The trade-off between yield and quality will depend on whether the pasture is managed for grazing or indoor ration based dairy production. For pasture based systems, trading-off forage yield for better forage quality is important. This can be achieved by reducing N application because high application rates reduce forage quality and energy value. However, for indoor ration based dairy production, targeting maximum biomass yield would be better because the feed can be supplemented with low-cost roughages.

7.3 ESTIMATING WATER REQUIREMENTS AND DEVELOPING IRRIGATION CALENDARS USING SIMPLE WEB-BASED SWB-PRO MODEL

This study has shown that the current irrigation guidelines of 25 mm of irrigation per week for most temperate grasses, including ryegrass, leads to over-irrigation in cooler part of the season or under-irrigation in warmer part of the season. To use the model for determining irrigation requirements and developing irrigation calendars, the SWB-Pro model was validated at two sites for different irrigation treatment practices (Chapter 4). The model performed well in simulating ryegrass growth and above ground biomass production (leaf area index and forage yield), root zone soil water deficit and daily evapotranspiration.

Once the performance of the model was satisfactory, site specific irrigation calendars were developed, for four major milk producing areas of South Africa (KwaZulu-Natal Midlands, Eastern Highveld, Eastern Cape and Southern Cape) using three different soil textural classes. Monthly irrigation calendars with variable intervals were also developed for a general deep, well drained and medium textured soil by replenishing the soil after 25 mm of soil water was depleted (similar to farmers' recommendation but scheduling the timing according to the long-term water requirement). The simpler monthly irrigation calendars can be used in the absence the more accurate site specific calendars.

The SWB-Pro model can be used by farmers or consultants to develop their own calendars using the following simple inputs: 1) nearest weather station data; 2) soil textural class 3) planting date 4) rooting depth; and 4) irrigation system, timing and refill options. Irrigators can also follow different strategies for making decisions on when and how much to irrigate depending on particular situations.

In the absence of irrigation scheduling tools, irrigation calendars developed using a model would be far better than a rigid guideline of 25 mm a week. It needs to be stressed, however, that irrigation scheduling with the aid of real time modelling or measurements is better than calendars developed using the SWB-Pro model with long-term historical weather data. The model is available on the web and can be downloaded free of charge.

7.4 EXPLORING POTENTIAL N AND WATER MANAGEMENT STRATEGIES USING SWB-SCI MODEL

Sustainable pasture production requires best fertiliser and water management practice in order to attain high biomass yield with minimum inputs to maximise profit. However, pasture systems are highly complex, involving interactions between crop growth, soil and plant nutrient dynamics and animal and pasture management systems. To increase our basic understanding of the effects of N and water stress in pasture production, the SWB-Sci model was calibrated and validated using data sets collected from two sites under a range of N fertiliser and irrigation levels (Chapter 5). The model predicted annual ryegrass growth, biomass N uptake, soil water content and mobile soil nitrate reasonably well. The model was sensitive to N application under water stressed and non-stressed conditions as yield, LAI, biomass, N uptake and soil nitrates increased as levels of N increase.

The SWB-Sci model's simulation results can be used in conjunction with data collected from field experiments to better understand systems and extrapolate findings in time and space. This can save money and time required for conducting long-term intensive field experiments for gathering information on potential pasture production with different resources management strategies.

Having gained confidence in modelling N and water interactions of pasture systems using SWB-Sci (Chapter 5), other scenarios and conditions, including nutrient leaching and non-point source pollution, climate and soil variability, crop management, alternative irrigation and N management strategies could now be explored using the this model. Therefore, SWB-Sci model was used to explore a range of irrigation management strategies (Chapter 6) including calendar based irrigation scheduling developed with the simple SWB-Pro model (Chapter 4), deficit irrigation and “room for rain” for the major annual ryegrass growing areas of South Africa.

The modelling exercise in this study showed that there are opportunities to improve irrigation use efficiency of irrigated pastures by using RR20 (20 mm room for rain) or mild deficit of FC80 (irrigation 80% of field capacity). These strategies have increased practical implications for medium to heavy soils (with relatively high water holding capacity) in the high rainfall areas of the Southern Cape and KwaZulu-Natal Midlands. Because evaporative demand changes throughout the season, it may be possible to limit or eliminate irrigation in months of high evaporative demand or VPD (towards the end of the growing season).

In 2010, of the total annual ryegrass production costs in South Africa, 25% was allocated to irrigation, and 55% to fertilisers (Whitehead and Archer, 2009). RR20 and FC80 strategies would improve nutrient use efficiencies and protect the environment by reducing pollution (leaching of nutrients and chemicals) and soil erosion (surface runoff). Using the cost savings made from reduced fertilisers, water and energy, a farmer could expand his pastures and improve his profits. This study demonstrated that the most appropriate management strategy for farmers is to integrate irrigation and N inputs, since N and water cannot be managed independently. In order to optimise yield and quality, and reduce N leaching, irrigation should be managed based on the wetness of the soil and nitrate concentration in the deeper part of root zone, with the aid of tools such as the wetting front detectors (presented in Chapter 2).

7.5 RECOMMENDATIONS

Farmers are subjective adaptive managers and the use of simple monitoring approaches and thresholds presents a way to structure their learning. However, the challenge is to find tools which allow effective implementation of adaptive management strategy. The wetting front detector is a robust, on-farm monitoring tool which is relatively simple, cost effective and readily adopted by farmers. It can be simultaneously used for managing irrigation water and observing N by monitoring depth of wetting and nitrate concentration of the passing wetting fronts. The thresholds obtained in the current study can be used as basis. Farmers are expected to improve these thresholds as more experience is gained.

Real-time monitoring is the best irrigation management approach. In the absence of such an approach, however, calendars developed using the SWB-Pro model with long-term historical weather data is better management option than the rigid guideline of 25 mm per week. SWB model could still be used for mixed pasture system in which ryegrass is the dominant species. However, the model needs to be evaluated for newly planted and already established annual and perennial pastures.

Scenario modelling demonstrated that the best management strategy of achieving maximum yield, low N leaching is by integrating N and water management. Thus, such integrated management can be achieved based on the wetness of the soil and nitrate concentration in the deep root zone using wetting front detectors. The model can be used to generate monitoring protocols such as depth of wetting front detectors placement and selecting N thresholds to be used adaptive management. Alternative integrated adaptive N and water management strategies need to be tested.

In pasture systems, N application is through surface broadcasting. This could result in increased N losses by surface runoff. Therefore, the inclusion of a runoff subroutine in SWB-Sci would most likely improve the accuracy of the simulation results.

The following areas are recommended for future studies:

1) Current field experiments were conducted under mechanical harvesting, therefore, studies need to be conducted under grazing conditions, especially for managing N.
2) Due to an increase in N fertiliser costs, other cheaper alternative N sources (e.g. mixed legume based) need to be assessed.
3) Real-time N and water management using remote sensing technology also needs to be tested for its applicability to pasture production.