1. INTRODUCTION

Historically, lucerne has been viewed as a low-value pasture or rotation crop, of economic importance primarily as a supplement to other higher-value speciality crops. However, in recent decades, lucerne has become a valuable and profitable crop, competing successfully with many higher-value speciality crops. Today, many producers approach lucerne as a serious business enterprise, with careful consideration of costs, value, and markets.

Whether you are in the business of producing and selling lucerne hay or feeding animals, correctly assigning the economic value of lucerne hay can impact the profitability of the business. A lucerne hay quality and grading system must therefore be fair to both the producer and the buyer and must ultimately accurately represent the product. Change is not always welcome, but as we all know change is inevitable. Over the past 50 years, there have been profound changes in the way that lucerne hay is produced, evaluated, sold, and fed, and there is likely to be even further changes in the future as well. The way lucerne hay quality in terms of economic value is evaluated, is one of those ways that will require periodic examination.

Considering inputs from different industry role-players and following nearly a year of analysing different model factors, the National Lucerne Trust (NLT) has decided to implement a revised lucerne hay grading table during the 2021 annual validations of all near-infrared spectrophotometers (NIR-instruments) registered at the National Lucerne Hay Quality and Grading Scheme (NLT-Scheme). With a dynamic and expanding lucerne hay market, revised standards were necessary to establish a more uniform national lucerne hay quality and grading system, to provide local and international consumers with improved estimates of the feeding value in terms of animal production prior to purchase and to better align the local with international quality standards.

2. NATIONAL LUCERNE HAY QUALITY AND GRADING SCHEME

In 2008, the NLT-Scheme, developed by the NLT, specifically designed for South African lucerne hay, was implemented. Since then, it has been successfully maintained and managed by the NLT. During the past four years much time and effort were invested into the research and further development, as well as the marketing of the NLT-Scheme. Lucerne hay locally produced and certified by the NLT during 2020|21 (416 862 tonnes) increased by 33.59% compared to 2016|17 (276 820 tonnes). The increase seen in lucerne hay certified by the NLT during the past few years, is mostly because more producers, traders, exporters, and end-users are using the NLT-Scheme to grade their lucerne hay, and not necessarily due to an increase in lucerne hay being produced in South Africa. It is therefore clear that the NLT certificate has become an indispensable tool for the marketing of South African lucerne hay.

2.1. Development of the National Lucerne Quality Index and grading table standards

The grading and marketing of lucerne hay in South Africa has historically been by means of subjective evaluation based upon organoleptic properties such as colour, leafiness, smell and the presence or absence of foreign material and mould. Traditionally, major emphasis has been given to the production of high yields of lucerne hay. Over the last 30 or so years, greater emphasis has been placed on producing a higher quality product for the market.

Whether you are buying or selling, producing, or feeding, the quality of lucerne hay should be a major consideration. The ultimate test of lucerne hay quality is animal performance. The quality is considered satisfactory when animals consuming it perform as desired. Since lucerne hay quality has a large impact on market price and profitability, the South African lucerne industry identified the need to establish a more uniform quality and grading system for lucerne hay.

Lucerne hay is typically much more variable in quality than grains and concentrated feeds. Several factors can influence the quality of lucerne hay, namely locality, seasonal variation in light, moisture, temperature, and photoperiod, soil conditions, ferritization, water supply, disease and insects, harvesting, curing, handling, storage, cultivar choice and presence of other plant species. Lucerne hay also contributes to multiple quality attributes to an animal diet. This created a challenge for the South African lucerne hay industry to fix an economic value on a variable but very important product.

Several indices of forage quality have been developed over the history of forage quality evaluation research, including Relative Feed Value, Total Forage Index, Adjusted Total Forage Index, Forage Quality Index and Relative Forage Quality. A study conducted by Dr Gerrie Scholtz at the University of the Free State, evaluated different parameters used to assess lucerne hay quality and found large differences in the accuracy of these parameters in predicting milk production of dairy herds. The relatively poor performance of crude protein (CP) and other protein related parameters in predicting milk production suggested that protein content of lucerne hay is an unreliable indicator of hay quality.

Dr Scholtz found that by including acid detergent fibre (ADF), ash and lignin in a multiple linear regression equation, the accuracy in predicting milk production with the Cornell Net Carbohydrate and Protein System (CNCPS), improved remarkably, which then formed the basis of the empirical model, the National Lucerne Hay Quality Index (NLQI). The NLQI model was found to be the most practical, simplistic, economical, and accurate quality evaluation model for commercial application. Although the NLQI was developed on milk production potential, ranking of the index is based on digestible energy content or production potential. This will be universal among all species that utilise lucerne hay.

During 2008, the NLQI, as well as the original grading standards table (Table 1) was implemented through the NLT-Scheme. The NLQI that appears on the NLT certificate integrates nutritive value metrics and animal production in a single value.

Table 1: Lucerne hay grading table, 2008 - 2021.

GRADE	NLQI*	FOREIGN MATERIAL
Prime	104 and higher	Absent
Grade 1	97 - 103	Absent
Grade 2	93 - 96	Present
Grade 3	92 and less	Present

The NLQI has since 2008 been widely used to determine the quality of lucerne hay and therefore add some objectivity to determining a market value. It has become a tool for ranking the quality of lucerne hay and for matching the lucerne hay quality with the nutritional demands of an animal. It is important to note that the initial index cut-off points for the different grades on the lucerne hay grading table was guided by the lucerne hay quality standards set by the United States (US) during that time.

2.2. Development and maintenance of the NLT lucerne hay calibration model

Forage analysis by near infrared reflectance (NIR) spectroscopy has had many advancements since it began in the 1970s. There have been steady improvements in instrumentation, in computers, and chemometric algorithms for developing calibrations. Therefore, making NIR the most used technique to routinely analyse samples for forage producers, plant breeders, animal nutritionists, animal producers, and feed companies.

The NLT's NIR calibration equations were developed for the prediction of crude protein, moisture, ADF, Neutral detergent fiber (NDF), lignin and ash of South African lucerne hay. Results obtained by Dr Scholtz showed that the NIR calibration equations greatly explained the variation in the composition existing in lucerne hay grown in South Africa. The NIR calibrations were developed through the process of creating spectro-chemical prediction models for the different parameters. Once the selected laboratory reference data and spectra were obtained and coordinated, mathematical and statistical procedures were performed. The NIR-instruments were then trained to recognise different constituents. The process of "training" is called the calibration procedure and herein lies the secret of success of this revolutionary technology. In essence, the process relates chemical information contained in the spectral properties of a substance to chemical information revealed by reference laboratory methods. Thus, calibration equations can be used to estimate the chemical composition of corresponding samples of unfamiliar composition.

Due to annual climatic variations that affect soil and growing conditions and consequently cause high variability in chemical and physical composition of lucerne hay, the NLT continuously collects samples throughout the season to identify variation (outliers), which has developed a robust calibration for the industry today. The NLT's calibration model on all NIR-instruments registered at the NLT-Scheme is also validated annually against a set of samples, in which reference analytical values have been determined by the NLT's reference laboratory in the US.

Outlier detection is an essential part of the NIR technology use in the South African lucerne hay industry. An outlier is identified as a sample that does not conform to most of the population in terms of spectral data and differs from such population (Figure 1) by more than three times the standard error of prediction (SEP).

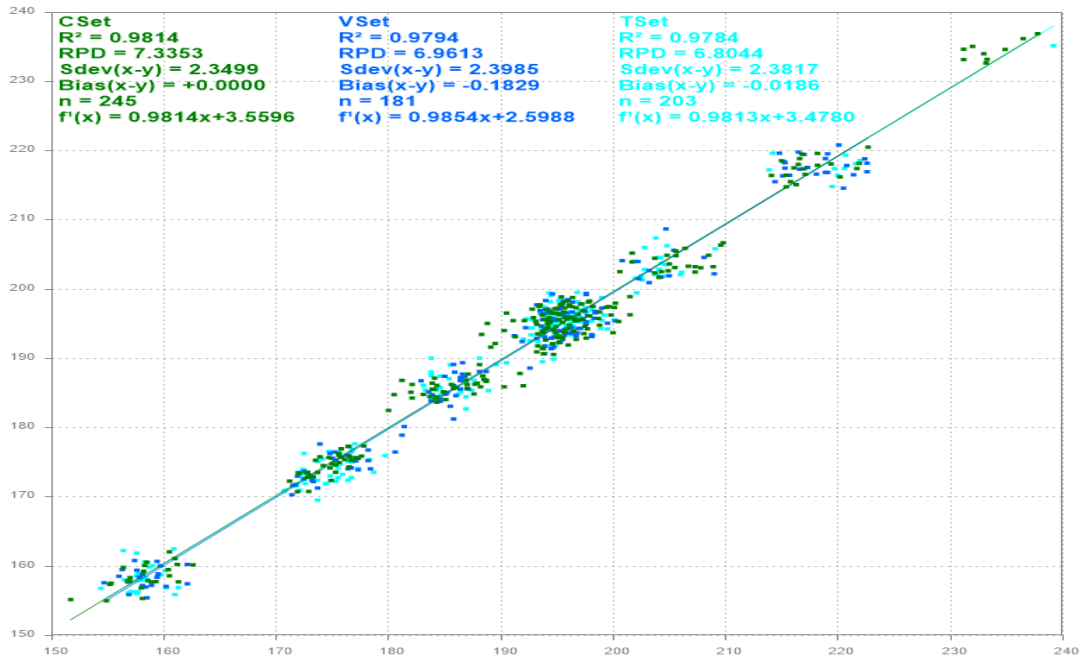

Figure 1: Population in terms of spectra data.

While there already exist numerous approaches for the detection of outliers, some significant challenges remain relevant. Two prominent such challenges are that outliers are rare and not precisely defined. These both have serious consequences, especially on the calibration and evaluation of detection methods.

Seasonal variation, as seen in the *Influence of Weather on Lucerne Hay Production and Quality, 2020|21* report has the biggest influence on changing the lucerne hay matrix and consequently detecting outliers. Extreme seasonal variation, as was experienced during 2020|21, causes dramatic unforeseen changes in the lucerne hay matrix. The existing calibration consist of spectra collected during normal seasonal variation and operated for the last few years with limited spectral outliers detected. However, the past season delivered a fair number of spectral outliers caused by abnormal fluctuation in temperature and rainfall.

During the 2020|21 production season a total of 105 samples were collected, scanned, and analysed by means of wet chemical analysis at Cumberland Valley Analytical Services (CVAS). Of these samples, roughly 65, were identified as spectral outliers. In previous years, only 2 or 3 were detected annually. The outliers identified were incorporated into the existing calibration to identify these unknown samples. Please note, no alterations were made to the NIR-instruments during the season. Once these samples were added to the calibration the NIR-instruments could recognise these outliers and results could be predicted more accurately.

Even though the existing calibration proofs to be robust, the past season showed that spectral variance will always need to be fine-tuned due to constant climatic and seasonal changes. This phenomenon is not new and will be with us if climate change continues.

2.3. Annual validation of the NLT lucerne hay calibration model

It is important that all NIR-instruments registered at the NLT-Scheme is validated annually by an accredited network controller before the start of the new lucerne hay production year. The annual validation is done to ensure that samples analysed by NIR-instruments corresponds with wet chemistry analysis done at the NLT's reference laboratory, CVAS, as well as between all NIR-instruments registered at the NLT. The accreditation of NIR-instrument owners that does not form part of the annual validation, expires automatically, and the NIR-instrument owner will not be able to use the NLT's calibration model for the coming season.

Figure 2: Annual validation of the NLT lucerne hay calibration model

A total of 44 NIR-instruments (17 x Perten DA 7200; 22 x Perten DA 7250; 5 x Viavi MicroNIR) was part of the 2021 annual validation, that took place between 16 – 20 August in Modderrivier (Figure 2). All NIR-instruments were serviced, software updates were done, and the NLT calibration model was validated against wet chemistry results by the NLT's accredited network controller, Agri-Enviro Solutions (AES). Outliers identified during the previous season were also accordingly incorporated into the current calibration model, to include all variation observed during the 2020|21 season. A post-validation process was executed by the NLT to test and validate the procedure. According to the results obtained from the validation and post-

validation process (Annexure 1), it is evident that all NIR-instruments registered at the NLT-Scheme are well within limits for accurate and repeatable generation of certificates.

3. LUCERNE HAY MARKET POTENTIAL AND CHALLENGES

Local lucerne hay market price fluctuate widely between and within seasons, and greatly depends on supply and demand, as well as the performance of the markets of which the hay is intended for. Lucerne hay locally produced (Figure 3) and certified by the NLT during the 2020|21 (416 862 tonnes) increased on average by 31.31% compared to production certified during 2014|15 (300 901 tonnes), 2015|16 (281 280 tonnes), and 2016|17 (267 820 tonnes). As mentioned previously, the increase seen in lucerne hay certified by the NLT during the past few years, is mostly because more producers, traders, exporters, and end-users are using the NLT-Scheme to grade their lucerne hay, and not necessarily due to an increase in lucerne hay being produced in South Africa.

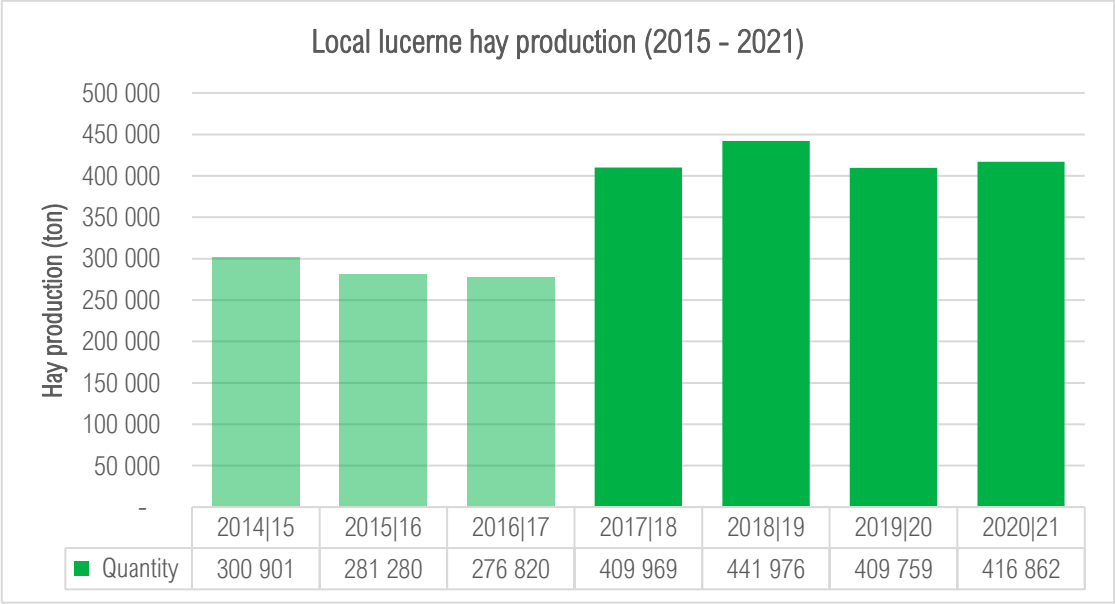

Figure 3: Lucerne hay production 2014 - 2021

It has been a challenging past two production seasons in terms of quantity and quality of hay produced across South Africa, and more specifically in the Northern Cape Province of South Africa. Lucerne hay produced during 2020|21 and 2019|20 (409 759 tonnes) decreased by 6.02% and 7.86%, respectively, compared to 2018|19 (441 976 tonnes). Reports received indicated that lucerne hay producers could not achieve the maximum potential yield and quality of hay as expected from the established lucerne hectares, and this is mainly due to erratic weather conditions and excessive rain. A further decline in lucerne hay production, as well as newly established lucerne hectares, is expected for the 2021|22 season.

Dependence on lucerne hay for animal feed will continue to drive the South African lucerne hay market, locally and internationally. Lucerne hay makes a tremendous contribution to animal production, a contribution that often goes unrecognized. Lucerne hay provides dairy and beef cattle, sheep, goats, wildlife, and horses with a highly nutritious and digestible forage. The animal feed manufacturing industry also recognises lucerne as one of the most important protein sources for animal feeds in South Africa.

However, lucerne is often closely associated with dairy production, with the dairy feed industry utilizing a large proportion of lucerne hay produced in South Africa. Even today, when knowledge of dairy cattle nutritional requirements has never been more complete, most animal nutritionists and dairy producers like to see some lucerne hay in their lactation rations. The high nutritional quality of

lucerne hay grown and fed today has occurred because lucerne hay producers and dairy producers have been, and are, focused on improved hay quality, even at the expense of the lucerne producer's yield or a higher cost for the dairy producer.

With tight margins in the dairy industry, the industry usually looks to reduce cost as a method to improve margins. Since feed cost is the highest single cost component, it is often a primary target. However, in most cases, higher quality forage is also one of the most valuable things that can be added to the ration to widen feed margins. The quality of lucerne hay can vary considerably in accordance with the many factors influencing it. This variation in quality hampers the efficient utilisation of lucerne hay in animal diets. Therefore, knowing the quality of lucerne hay will have a marked effect on the income and profitability of a dairy concern, especially when milk prices are low and|or feed prices are high.

In recent years, lucerne hay exports have transitioned from a footnote to a major factor for the South African hay industry. Several major drivers boosted this growth, which includes the advent of inexpensive containerized shipping, technology of compression of hay, as well as the high quality, and accurate quality analysis of South African hay. Lucerne hay is exported to Saudi Arabia, United Arab Emirates, Qatar, Botswana, Namibia, Lesotho, and more recently China. Lucerne hay exported is estimated at approximately 150 000 tonnes annually, and nearly 40% of the total local production certified by the NLT-Scheme. The export market for South African lucerne hay is expected to grow as demand in Middle Eastern countries and China continues to rise, due to the strong growth in dairy product demand, and the production limitations, including water supplies and logistics in these destination countries. A growing demand will usually translate into firmer prices for lucerne hay producers.

While the local lucerne hay market is not as volatile as other higher value commodities, the fluctuations are great enough to influence whether lucerne as a crop option is profitable or not. However, the South African lucerne hay producer's price has seen an upward trend over the last number of years. Seasonal price fluctuation between in-and-out of season, have also decreased between 2017 and 2021. A case for higher demand and stronger prices will be found in shrinking lucerne hectares, lower than expected lucerne hay yield and quality produced and an expanding hay export market.

4. REVISED GRADING SYSTEM

Maintaining lucerne hay quality is important regardless of whether it is intended for the local or the export market. Local dairy markets have demanded and will continue to demand high quality hay. The demand for low-fibre, high quality hay has intensified, given that dairy cattle are much more productive, and rations significantly different from those in the 1970s. Given the dynamics, the importance of hay quality, and quality standards are likely to intensify, not diminish in the future.

To illustrate the large variation and consequently the financial implication within the original grading standards table (Table 1), a simulation program was used to calculate the difference between the NLQI value of 103 and 97, respectively. A basal diet for lactating dairy cows was formulated, using a modified version of CNCPS. It was based on the milk production level, feed ingredients and dry matter intake (DMI) of a typical high producing South African commercial Holstein herd. The age of cows was assumed to be 42 months, body weight 700 kg, days pregnant 0, days since calving 60, body condition scoring (BCS) 3.00, average daily gain (ADG) 0.079 kg|d, milk production 45 l|d, milk fat 3.55%, and milk protein 2.88%. Ambient temperature was 20ºC and relative humidity (RH) was 50%, with no wind or other sources of environmental stress. Milk yield (MY) derived from the CNCPS model indicated that lucerne hay variation within the original Grade 1 lead to enormous financial differences by replacing the average lucerne hay in a complete diet.

To put the financial implications in perspective, the following assumptions were made: lucerne price for grade one = R2 600 per ton; producer milk price = R5.25|l, lucerne daily DMI = 8kg|cow|day. A 2 litre drop in milk production were calculated when lucerne hay quality was reduced from NLQI 103 to NLQI 97, which were originally both classified as Grade 1. The 2 litres difference in production (R10.50|cow|day) between the lower and upper spectrum of the original Grade 1 has serious financial implications for the end user (lucerne DMI of 8kg|cow|day equals to a lucerne feed cost of R20.80|cow|day).

For South Africa to be competitive in the international arena, quality standards also need to be standardized, universally recognized, and applied. Local lucerne hay prices will implode if the export of South African lucerne hay stops. Irrespective of the decline in the quantity and quality of lucerne produced during the 2020|21 season, the market for lucerne is expected to grow as demand in the Middle Eastern countries and China continues to rise. With a difference in the standards set by the local and international markets, it is easy to see how confusion can be created by the different quality and grading systems between the lucerne's point of origin and its ultimate destination. It was therefore essential for the South African lucerne hay industry to try and better align the local with international standards.

As previously mentioned, the initial index cut-off points for the different grades on the lucerne hay grading table was guided by the lucerne hay quality standards set by the United States (US) during that time. Just to put in perspective, as late as the 1950's the highest quality category described by the United States Department of Agriculture (USDA) could contain significant bloom and even up to 49% seed pods. Today most high-quality dairy hay is harvested at pre-bud to bud stages, and little bloom is seen, much less, seed pods. In 1972, 52% Total Digestible Nutrients (TDN) hay (below 33% ADF, 100% DM basis) was considered excellent quality dairy hay. Today, many nutritionists consider high quality dairy hay to be above about 55-57% TDN (below 27-29% ADF; 100% DM basis). In 2002, the USDA Market News developed a set of guidelines for hay quality designation into 5 categories, these guidelines have also been revised over the years.

Whether you are in the business of producing and selling lucerne hay or feeding animals, correctly assigning the economic value of lucerne hay can impact the profitability of the business. A lucerne hay quality and grading system must therefore be fair to both the producer and the buyer and must ultimately accurately represent the product. Change is not always welcome, but as we all know change is inevitable. Over the past 50 years, there have been profound changes in the way that lucerne hay is produced, evaluated, sold, and fed, and there is likely to be even further changes in the future as well. The way lucerne hay quality in terms of economic value is evaluated, is one of those ways that will require periodic examination.

Considering inputs from different industry role-players and following nearly a year of analysing different model factors, the National Lucerne Trust (NLT) has decided to implement a revised lucerne hay grading table during the 2021 annual validations of all near-infrared spectrophotometers (NIR-instruments) registered at the National Lucerne Hay Quality and Grading Scheme (NLT-Scheme). With a dynamic and expanding lucerne hay market, revised standards were necessary to establish a more uniform national lucerne hay quality and grading system, to provide local and international consumers with improved estimates of the feeding value in terms of animal production prior to purchase and to better align the local with international quality standards.

Table 2: Revised lucerne hay grading table, 2021

GRADE	NLQI*	FOREIGN MATERIAL
Supreme	108 and higher	Absent
Prime	104 - 107	Absent
Grade 1	100 - 103	Absent
Grade 2	95 - 99	Present
Grade 3	94 and less	Present

The Supreme quality category was also added, which will allow the lucerne hay producer the possibility for an additional price premium for top quality lucerne produced. The bottom-line criteria for quality modelling are to make an objective assessment of chemical analyses that gives nutritionally useful information related to animal performance. The standards set for lucerne hay used at different production levels are universal and should be classified and used accordingly. The new revised standards are basically just a formality for non-official arrangements that have already been implemented by most of the buyers the last two years.

5. CONCLUSION

The NLT, as always, remains committed in maintaining a coordinated, unified, national lucerne hay quality and grading system, and believes these changes are positive, will promote South Africa's lucerne hay sales internationally, and will ultimately be to the benefit of the South African lucerne industry as whole.

For any question, please do not hesitate to contact the NLT.

NAME	CONTACT NUMBER	EMAIL ADDRESS
Sunet Vermeulen-Fenthum	044 272 8991	sunet@lusern.org