FINAL REPORT 2016/32

OPTIMISING PRODUCTIVITY, VARIETY RECOMMENDATIONS AND MILL OPERATIONS THROUGH ANALYSIS OF MILL DATA

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ABSTRACT

The annual productivity of the Australia sugarcane industry fluctuates significantly across most sugarcane growing regions. Although some of this regional variation can be explained by extreme weather events or disease incursions it is important to identify those causes which can be controlled in order to increase profitability for industry. Development of innovative tools to analyse and summarise mill data within a region can be used to identify those farm production units performing below potential and the factors associated with this. An increased understanding of these factors will broaden the adoption of improved farming practices by working with local industry to enable more appropriate selection of varieties to match field conditions, addressing impediments to farm productivity and Nutrient Management Planning.

The project developed an Industry Productivity Data Analysis and Reporting Tool (IP-DART) which assisted advisory groups, mills and research organisations to identify factors that can improve productivity and extension advice to growers and millers in the Tully, Burdekin and Herbert mill areas.

A ratoonability index was developed that combines the economic return of first ratoon crops and the rate of decline of economic returns between first and third ratoon to estimate the number of years until the crop reaches a defined economic threshold for profitability. This ratoonability index had a high correlation with the percentage of area ploughed out before 3R for the major varieties in the Herbert.

Machine learning techniques were used to explore what variables are most correlated with varieties that become commercially successful in Queensland. The results demonstrated that these approaches can be applied to practical questions on sugarcane productivity. However, linking the very large and distributed data from experimental clones in the breeding program with the small number of commercially dominant varieties resulted in a number of confounding factors influencing trait predictions. Large changes such as disease incursions also introduce bias into the data with the demise of Q124 resulting in orange rust resistance ranking very highly as a key success indicator. In practice orange rust resistance is a maintenance trait offering little in terms of future gains. There was also 100% accuracy from the confusion matrix which is a concern as the model may fail to generalize to future datasets. The trait hierarchy predicted for commercial success is not considered informative, but the application of the technique has demonstrated the importance of the underlying datasets. The methods could be further refined using data from a specific region as varieties are released on a regional basis. Use of climatic factors and a larger more balanced dataset could also be explored.

EXECUTIVE SUMMARY

The annual productivity of the Australia sugarcane industry fluctuates significantly across most sugarcane growing regions. Although some of this regional variation can be explained by extreme weather events or disease incursions it is important to identify those causes which can be controlled in order to increase production/profitability for industry. Sugar mills in Australia collect and store valuable data on yield, variety and crop class for every consignment of cane received at the mill (commonly called a rake). These data are matched to paddock and farm for payment purposes and to sub-district/productivity group, variety information, soil maps and climatic information obtained by collaboration with productivity groups, research organisations and government authorities for analysis of productivity. This vast amount of data captured annually by each sugarcane mill, however, is significantly under-utilised in decision making by the sugar industry value chain. Development of innovative tools to analyse and summarise mill data within a region will be used to identify those farm production units performing below potential and the factors associated with this. Extension and advisory service companies could then design strategic adoption strategies for targeted audiences. This will result in increased production in all regions by optimising extension programs and variety recommendations and management practices

Preliminary studies were conducted in the Herbert region (Stringer *et al.* 2016 and Stringer *et al.* 2017). These studies used cluster analysis to identify groups of farms with similar size and productivity and then looked at factors that the different groups had in common. For example, what was the rate of adoption of new varieties in the groups of small farms with high and low yield or were these groups of farms more likely to occur in certain subdistricts. Other analyses looked at the relationship between yield and the history of planting varieties with certain characteristics such as resistance to Pachymetra root rot. The analyses allowed extension staff to show growers the yield advantage of different practices so that growers with lower yield could be encouraged to change their practices and increase their profitability and productivity for the whole region.

This project aims to analyse mill data from the Burdekin, Tully and Herbert to assist productivity groups, mills and research organisations to identify factors that can improve productivity and extension advice to growers and millers.

Analysis of productivity data – Burdekin

To identify and understand the key factors affecting productivity an exploratory data mining tool called *cluster analysis* was used. This method groups a set of objects in such a way that objects in the same group (cluster) are more similar to each other than to those in other groups. In the Burdekin the cluster analysis identified productivity zones with a higher proportion of lower producing farms (cluster 2). The productivity zones with a higher proportion of lower TCH farms were Inkerman, Lower Clare, Millaroo and Burstalls. The productivity zones with a higher proportion of lower CCS farms were Airville, Burstalls, Causeway, Down River, Marshalls, MCDSME, Osborne and Ramsdens. Further investigation is required to understand the reasons for the higher proportion of lower yielding farms in these subdistricts. Tailored extension plans should be conducted to try and lift the productivity of these farms.

The influence of variety adoption by different farms in the high and low yielding farm clusters was investigated. There were only minor differences in the proportion of new, currently recommended and older varieties between the clusters. The proportion of the three major varieties, Q183, Q208 and KQ228 grown of farms in the high and low yielding clusters was examined. A similar proportion of KQ228 was grown by farms in high yielding clusters 1 and low yielding cluster 2 but cluster 1 had a higher proportion of Q183 and lower proportion of Q208 than cluster 2. These differences may be related to Q208 being more widely grown on the poorer soil types than Q183.

Time of planting has a big influence on yield of the plant crop in the Burdekin. The high yielding farms in cluster 1 had 6% more Early plant (planted before May) than the low yielding farms in cluster 2 and 7% less Late plant (planted after July). Early plant can out yield Late plant by more than 20% and could be a significant contributing factor in the lower yield of cluster 2.

Planting KQ228 after KQ228 was associated with significantly lower $/ha and TCH than if KQ228 was planted after Q183 or Q208 (6.5 and 7% lower $/ha respectively). Planting Q208 after Q208 was associated with significantly lower TCH than if Q208 was planted after Q183 or KQ228 (7 and 5% respectively) but $/ha was not significantly different. Planting Q183 after Q183 was not significantly different to planting after Q208 or KQ228. The differences for KQ228 and Q208 were greater on Delta (non-cracking clay) soils and in the Ayr sub-district than for the whole Burdekin region. These analyses confirm that there is evidence to support the theory that, at least for some varieties, replanting the same variety in a field can lead to significant yield losses. Growers should be encouraged to rotate varieties and to maintain a mix of varieties on their farm. Further research could be conducted to understand the causes of this soil-borne health problem in the Burdekin.

Preliminary analyses to investigate the effect of harvest date in the previous season on yield in the current season in the Burdekin were discussed with industry agronomists and it was decided to extend these analyses. Initially two seasons were included in the analysis, but it was decided to extend this to 10 seasons and to include

$/ha return to growers and tonnes sugar/ha (TSH) in addition to effect on tonnes cane/ha (TCH) and CCS. TCH showed a decline with increasing harvest date in the previous season with the rate of decline increasing for harvest dates after September in the previous year. CCS increased with increasing harvest date in the previous season up until mid-November and then declined rapidly. TSH declines with increasing harvest date in the previous season, with the rate of decline increasing after September. The $/ha return to growers is similar for all blocks harvested before the end of September in the previous year but drops steadily for blocks harvested after September. Blocks harvested after the 23/11 in the previous year return 37% less $/ha and 35% less TSH than blocks harvested before September of the previous year. The potential for increasing industry and grower returns by harvesting a higher proportion of ratoon blocks before September than is currently harvested during this period was modelled. Currently, on average 37% of ratoon crops are harvested before September. The model examined starting harvest in the fortnight ending the 8/6 and increase the harvested area to 55% before September. An estimate was made of the potential increase in returns compared to the existing average harvest pattern. It was estimated that the modified harvest plan could increase total industry returns by $18M and growers would receive on average $202/ha more for ratoon crops. This increase could be achieved within the current capacity of the mills, but the mills would have to reach near maximum capacity within the first 8 to 10 weeks after the start of the season. The benefits would come at no extra cost and would benefit both growers and millers. In the first year of the new harvest model, the benefits of early harvest in the previous year would not be present and some slight losses would occur because of lower CCS for cane harvested early, but these analyses looked at the long-term benefits which would outweigh losses in the first year in the longer term.

Extensive discussions have been held with industry agronomists and the results of the project were presented to approximately 250 growers at a series of shed meetings in Feb-March 2019.

Analysis of productivity and cane quality data – Tully

The long-term average tonnes sugar per ha in the Tully mill area is 10.6 t/ha but yields fluctuate greatly with lower yields associated with above average rainfall and cyclones. Productivity is lower in the high rainfall subdistricts compare with the lower rainfall subdistricts. A combination of factors is likely to be associated with this difference including waterlogging, highly leached soils and lower radiation in the high rainfall subdistricts. Given these environmental constraints to productivity, the Tully industry aims to increase productivity to an average of 90 tonnes cane/ha across the whole district.

Cluster analysis using mill data has been conducted to group growers on farm size and productivity. The analysis has identified groups of growers who could benefit from targeted extension programs to lift their productivity and maximise the impact of extension programs. Tully Productivity Services Limited (TSL), Tully Sugar Limited (TSL) and SRA have used the target groups to conduct extension programs.

Mill data has also been used to investigate effect of variety, crop class and Pachymetra root rot resistance on productivity in the Tully mill area as a whole and in individual subdistricts.

Q208 and Q200 have been the most popular varieties in the Tully mill area for the last 10 years and the analyses support that in most cases these varieties outperformed all other varieties including newer varieties for which data was available. A new method of assessing performance of new varieties, using mill data, by comparing their performance in blocks that have previously grown well established varieties, such as Q208 and Q200, shows promise. Growers have extensive experience with well-established varieties and by comparing yield of new varieties planted into blocks where established varieties were grown in the previous crop, with the yield of established varieties in similar blocks, should provide growers with an accurate comparison of the performance of these varieties. This is an example of using mill data to make better recommendations for varieties based on actual mill data.

Analyses in the Tully district were undertaken to determine if the previous variety planted in a block can affect the performance of the next variety planted. This may be related to the build-up of pathogens such Pachymetra under varieties of different susceptibility to the disease. Crops of Q208 planted following Q200 yielded 3.5% more cane yield than Q208 planted after Q208 but 3% less dollars per hectare. However, the differences were not significant for cane yield or dollars per hectare. Crops of Q200 planted following Q200 yielded 5% more cane yield than Q200 planted after Q208 and 9% more dollars per hectare. These differences were also not significant for cane yield and dollars per hectare.

Tully growers no longer grow Pachymetra susceptible varieties and varieties with intermediate resistance make up a large proportion of the crop. Mill data were used to analyse the effect of continually growing varieties with intermediate Pachymetra resistance compared with rotating intermediate and resistant varieties to reduce the effects of Pachymetra. Data suggested there may be some benefit in rotating intermediate varieties with resistant varieties to reduce the levels of Pachymetra in soils. Growers in Tully have had limited choice of high yielding resistant varieties. The analyses support continued research and breeding to increase the number of high yielding resistant varieties available to growers.

The impacts of severe weather events on farm management can have flow on effects for many years. The impact of above average rainfall during the harvest season in 2010 and cyclone Yasi in 2011 saw a 50% increase in planting in 2012 which flowed through to higher proportions of first, second, third and older ratoons in succeeding years. Yield in Tully decreases on average 6% with each ratoon crop. The highest percentage of older ratoons because of the large planting season in 2012 occurred in 2017 which would have a depressive effect on overall mill productivity. Understanding long-term effects of management decisions using mill data can help mill areas to objectively assess their productivity and plan to moderate these effects where possible.

Tully has largely discontinued the practice of replanting with no fallow, this has benefits for soil health and management of diseases such as RSD which can carryover in volunteers in replant crops. Mill data allows tracking the success of extension programs to improve farm management practices and allows resources used in these programs to be redirected when targets have been achieved.

There are four parameters in the Tully cane quality scheme. These are purity, fibre/CCS ratio, soil and Effective Bulk Density (EBD). There are important limits for cane quality parameters and deliveries are not eligible for premiums when each parameter is above or below a certain value (limits are confidential). The four parameters are combined into a cane quality score. An analysis was undertaken to determine the key drivers of EBD. The study confirms previous research that found that the largest sources of variation in EBD are variety, field conditions, crop presentation and harvesting contractor. There is higher EBD with 5 blades per chopper drum compared to 4 blades. However, there is higher (invisible) sugar loss when number of blades increases. Targeting a high EBD can have a significant impact on yield reduction and cane loss.

An analysis was also undertaken on the four fibre quality traits from 2017-2018 in Tully. This was used to identify patterns in the Tully cane quality data and subsequently characterise the varieties.

Analysis of productivity data – Herbert

This project conducted analyses of mill data from the Herbert River region for the years 2014 to 2019 expanding on analyses conducted in an earlier project, 2014/054. The project analysed mill data to identify groups of farms that are likely to benefit most from extension programs and understand factors that contribute to high and low performance in groups of farms. The objective is to assist the region to progress towards their Target 85 t/ha by addressing issues that the analyses identified as limiting productivity in lower productivity farms.

The Herbert region has been divided into 26 productivity zones and 6 subdistricts based on location and mill management factors. These divisions are not necessarily the optimum groupings for understanding effects of factors contributing to productivity. SRA project 2017/009 analysed the climatic data for the Herbert and assigned farms to 5 climate zones. The climate zones were similar to the previous subdistricts but reduced the number of divisions to 5 from 6. The previous Central and Lower Herbert subdistricts were largely amalgamated into the Central climate zone and some farms from other subdistricts were also added to the Central climate zone making it the largest zone accounting for 43% of the Herbert region. The new climate zones were used in the analyses conducted in this project.

This project examined increases in productivity between the period 2005-2013 and the years 2014-2019. Productivity ($/ha) increased by 0.9% across the whole region which is well below the 8.2% required to lift the average return to the target of $2163/ha. In response to the earlier project, 2014/054, a concerted extension effort was made to increase the productivity of the larger farms with below target productivity. This appears to have been successful with an increase of 1,645 ha in total area above the target despite a net reduction in the number of farms above the target between the two periods. The larger farms that were the focus of the extension effort appear to have benefited, while some smaller farms fell below the target, resulting in a net increase in the total area above the target. The greatest improvement occurred in the poor yielding farms, greater than 25% below the target $/ha return. These farms improved by 20.4% between the two periods. The high yielding farms above the target in 2005-13 yielded 5.5% less in the period 2014-19. An attempt was made to understand the drivers for farms that improved their $/ha returns compared with farms that declined in productivity. The analyses highlighted that farms where the management had changed and/or the manager became full time on the farm had the greatest improvement whereas those where the manager also worked off-farm were over-represented in the farms that went backwards. More than half of the farms that showed the greatest improvement were in the poorest yielding category in 2005-13, greater than 25% below the target yield. This would suggest that there has been some rationalisation in this group with farmers leaving or passing on management of the farm. Further work is required to make progress in improving yields in the region.

A subset of the growers that showed the greatest improvement and the greatest reduction in yield between the two periods were selected for intensive study to try to understand the drivers that resulted in the changes. The primary drivers in the farms that improved the greatest were that the farm manager changed either by acquisition or change of management. This was followed by the manager moving to full time farming. The farms with the largest decline were associated with the age of the grower and moving to part-time farming with off-farm employment and deterioration in farm management. More frequent use of clean seed was associated with the farms that improved the most again reflecting management as a key driver. The enthusiasm and diligence of the farm manager is clearly the greatest factor influencing yields. Promoting greater involvement of younger more enthusiastic managers and motivating managers to be the best they can, will make the greatest impact on overall productivity in the region.

The cluster analysis based on yield and farm size conducted in the earlier project was reanalysed for the period 2014-19. In the current project we focused on $/ha and farm size as the criteria examined. In contrast to the earlier analysis, $/ha was the main factor in most clusters with farm size varying widely in most clusters. Two cluster that fell just below the target $/ha, clusters 4 and 5, were separated by size. Cluster 4 included 17 farms with an average size of 260 ha. This cluster would be an important group of farmers for extension as they control 4,420 ha and most are only just below the target and with a little improvement could be raised above the target. The analysis identified clusters 2 to 5 as those which would have the greatest impact and would benefit most from coordinated extension programs. Because these groups contained both very small and moderately large farms, it was suggested that extension programs for farms with an average harvest area of above 60 ha within these clusters would have the greatest impact on overall regional productivity. The comparison of changes in productivity between the earlier period, 2005-13, and the current period, 2014-19, highlighted that farms that are currently above the target should not be neglected in extension program because if their productivity falls it can cancel any gains in the farms below the target. As farms improve or go backwards over time this analysis should be repeated to identify the farms that would most benefit and would have the greatest impact from extra extension effort.

Some factors associated with higher and lower yielding clusters were investigated. The higher yielding clusters had a higher proportion of the variety Q208 than the lower yielding clusters and the lower yielding clusters had a higher proportion of MQ239. It was also found that the lower performing clusters were much slower at adopting newer varieties. Variety choice is contributing to the differences in yield and reflects general attention to management on the higher yielding farms.

The frequency of obtaining clean seed was also clearly associated with productivity with the higher yielding clusters obtaining clean seed more regularly. Growers closer to the clean seed plots were more likely to obtain clean seed regularly. The projects findings that frequent use of clean seed is associated with higher productivity and the importance of easy access to clean seed has been extended to Herbert Cane Productivity Services Limited (HCPSL) and they have planned to increase clean seed supply and establish a new clean seed plot in an area that previously had difficulty in access to clean seed. HCPSL has recently leased a farm in the Central Herbert region to provide more Approved Clean seed in this area and is also promoting tissue culture plants. The plan is to increase the amount of clean seed sales sufficient to plant 1% of the local mill which is the industry benchmark (SRA 2021).

Younger and older age groups were found to be associated with the lower yielding clusters. Growers in the age range of 40-70 had on average the higher average $/ha returns with growers less than 40 or greater than 70 years of age having on average lower yields. Some factors that could contribute to these differences are motivation, health, experience and conflict of commitment with off-farm employment. Again, management is highlighted as a key driver of productivity. Crop age did not vary significantly between most clusters, but the highest yielding cluster had a higher proportion of old and young ratoons. There was no clear association of row spacing and minimum tillage with the different clusters but there was only a small sample of farms practicing wider row spacing and minimum tillage.

An intensive study was conducted of 6 farms in the Central climate zone that had similar environments but different markedly in yield. The study found that good timing of management practices, good farm hygiene (weed control) and sound nutrition practices were most associated with the higher yielding farms and significantly drove productivity. It also found that an off-farm job had a significant negative impact on productivity because the grower could not attend to issues like farm hygiene in a timely manner.

Mill data can be used to examine variety performance in blocks that have previously grown older well-established varieties. Growers learn where older varieties perform best, so by examining performance of new varieties in blocks that were previously planted to different older varieties, the performance of new varieties can be compared with the existing varieties. This new method of assessing performance of new varieties may improve recommendations and ensure new varieties are planted in the best locations to optimise their potential. An analysis was conducted to compare the performance of 5 newer varieties with this method. The method looks promising and shows that Q208 continues to perform well in all blocks where other varieties were grown and the newer variety Q240 has performed well in blocks where Q200, Q208 and KQ228 have been previously grown but did not perform well where MQ239 was grown previously. Q250 performed well where MQ239 was previously grown but the sample size was small, and more data is required to be confident about this variety’s performance. We recommend that this analysis be undertaken annually as an aid to variety recommendations.

Repeated planting of a single variety of the one species is an extreme example of monoculture and could potentially favour pathogens adapted to that one variety of that species. An analysis was conducted to examine the performance of Q208 when it was planted in blocks where Q208 was planted after Q208, KQ228, MQ239, Q200 and Q183. In all cases, Q208 performed 7-12% higher when it was planted after a different variety compared with planting Q208 after itself. This confirms analyses and observations in other districts. This analysis strongly supports the recommendation to rotate varieties where possible to prevent the detrimental effects of effects of this example of an extreme case of monoculture.

Pachymetra has been a focus of extension in the Herbert and virtually no susceptible varieties are now grown in the region. The majority of varieties grown in the Herbert are intermediate in reaction to Pachymetra. High levels of Pachymetra spores have been recorded in the soil under some intermediate varieties. Analyses were conducted to determine if rotating highly resistant varieties with intermediate varieties is associated with improved yield. There was no consistent effect associated with rotating Pachymetra intermediate and resistant varieties. Some intermediate varieties appeared to perform slightly better after a resistant variety compared with following an intermediate variety but the effect was not consistent. The lower yield potential of the established varieties with Pachymetra resistance is a potentially confounding effect in this analysis and the benefit from resistance in the new varieties such as SRA26 and SRA28 may be more significant.

This project has demonstrated the power of using mill data to identify farms for extension programs that will maximise the impact of the programs on regional productivity. Mill data can also be used to improve variety recommendations and investigate factors associated with improved productivity. This information can be used to improve and support extension messages. The project results have been extensively promoted at meetings with advisors and growers and are already changing the messages promoted by advisory staff.

Adoption of project outputs to aid in industry decision making and improve on-farm profitability

This project has used innovative tools to analyse and summarise mill data within a region to identify those farm production units performing below potential and the factors associated with this. An increased understanding of the factors affecting productivity will broaden the adoption of improved farming practices by working with local industry to enable more appropriate selection of varieties to match field conditions, addressing impediments to farm productivity and Nutrient Management Planning. An improved knowledge of how climatic conditions influence sub-regional productivity performance in Burdekin, Tully and Herbert will assist industry extension programs and on-farm management decisions.

The project has developed a data platform for an Industry Productivity Data Analysis and Reporting Tool (IP-DART) which:

- Created productivity performance groupings based on cane yield, CCS, sugar yield and dollars per hectare to identify opportunities for tailored extension practices in Tully, Burdekin and Herbert. Local extension productivity services can then develop extension programs, based on the factors identified, to show sugarcane growers the potential productivity benefits they could achieve by addressing these factors.
- Extension providers have been able to use the productivity performance groupings to identify opportunities for tailored extension practices by customising variety and on-farm management recommendations for individual growers.
- Compiled farm productivity reporting tool for Tully and Herbert industries which allows growers to benchmark their farm performance relative to all others in their productivity district. Advisory groups in Tully and Herbert are now working one-on-one with individual growers to address productivity drivers.
- Developed a single consistent source of data for all users in Tully and Herbert which was used for to streamline Nutrient Management and Variety Management Plans and available for use in industry reports.

A Pachymetra survey map for all farms in Tully was used to identify hot spots to growers and enabled extension providers to promote the Pachymetra resistant varieties into these areas.

Soil maps were produced for all farms in the Tully mill area. The soils maps have also been widely used by advisors to develop nutrient management plans and in BMP.

One of the datasets produced in this project for the Herbert will be used in an industry led productivity improvement project to identify poor performing growers across productivity zones to target growers who may be potentially looking to transition out of the industry. Further datasets will be used in industry led productivity improvement projects in Tully and Herbert to easily identify growers with below average productivity within their productivity zone and benchmark these farms to demonstrate the potential ‘real’ gains for participating growers.

Ratoon index

In this study, we examined several measures of ratoonability. The proposed ratoonability index combines the economic return of first ratoon crops and the rate of decline of economic returns between first and third ratoon to estimate the number of years until the crop reaches a defined economic threshold for profitability. In our study, we calculated the ratoonability indices for the major varieties grown between 2013 and 2019 in the Herbert. KQ228 and MQ239 had the lowest ratoonability indices across all climate zones in the Herbert and in nearly all of the individual climate zones. This is in good agreement with the $/ha returns across ratoons and the rate of plough out of these varieties. Q200, Q208 and Q232 had higher ratoonability indices across all climate zones, and in individual climate zones, than KQ228 and MQ239. This also agrees well with $/ha returns for these varieties and the rate of plough out of these varieties. Q183 gave the highest ratoonability index across all climate zones and in the Ingham Line and Wet zones. The economic return for Q183 decreased at a slower rate than other varieties between first ratoon and third ratoon across all climate zones. Using our formula for ratoonability this led to this variety obtaining the highest value. However, the rate of plough out of Q183 was similar to or even faster than varieties such as Q200, Q208 and Q232. Our conclusion is that the ratoonability index is a reasonable measure of ratoonability and can identify poor ratooning varieties.

We examined the ratoonability indices of three newer varieties in comparison to four older varieties using data from 2018 and 2019. Q253 gave the highest ratoonability index of all varieties in the Central and Ingham Line zones. Q240 had the highest ratoonability index in the Abergowrie and Stone River zones and was the second highest in the Wet zone. The ratooning performance of these new varieties looks promising.

The percentage of area ploughed out before 3R was significantly related to the ratoonability indices for the major varieties. This is a simple measure of ratoonability and could be an adjunct to the ratoonability index. If growers are taking the hard decision to plough out crops before 3R, the performance of the variety in these blocks must be very poor and is a strong indicator that the variety has a serious overall performance problem.

Development of a decision support tool to predict varietal composition

Using machine learning techniques on Final Assessment Trials (FAT) data across all regions, from 1991 to 2018 a model has been developed to find traits and factors that can be used to predict which varieties go on to become successful commercial varieties in Queensland sugar industry. Data from NSW were excluded as it contains both one- and two-year crops.

The outcome variable was a binary trait of either a variety was commercially successful (1) or not commercially successful (0). A variety was classified as commercially successful if it achieved a Queensland top ten high yield (in tonnes), at least twice within the period of 1991-2019, if not it was deemed not to be commercially successful.

Machine learning classification techniques were used to explore what feature variables are correlated with commercial success of a variety in Queensland. The top 6 traits in order of importance were predicted to be Red Rot (15.8%), Orange Rust (13.6%), Pachymetra (10.2%), Male parent (8.8%), Cane Yield (6.7%) and Fibre (6.4%). Experimental clones may fail due to a large number of traits but only half of these are commercially relevant. Highly successful varieties have been rated intermediate or susceptible to Red Rot (eg Q124, Q232 and Q183), Pachymetra is not an issue for Burdekin or Tablelands production, and the identification of male parentage as a key factor is likely a confounded effect from the underlying data.

There is growing interest in applying artificial intelligence and machine learning approaches to large complex datasets. The analysis conducted in this study demonstrates that models can be developed with high prediction accuracy statistics that still produce uninformative or incorrect predictions. This finding highlights the dependence of these approaches on the underlying datasets and the sensitivity to confounding effects, unbalanced distributions and autocorrelated characteristics. The study highlights that successful use of these approaches requires a strong functional understanding of underlying datasets, ground truthed reference points, and formal prediction validation to minimise the acceptance risk for spurious predictions.

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1. BACKGROUND

1.1 Project rationale

The annual productivity of the Australia sugarcane industry fluctuates significantly across most sugarcane growing regions. Although some of this regional variation can be explained by extreme weather events or disease incursions it is important to identify those causes which can be controlled in order to increase production/profitability for industry. Vast amounts of data are captured annually by each sugarcane mill, however, this significant investment is under-utilised in decision making by the sugar industry value chain. Development of innovative tools to analyse and summarise mill data within a region will be used to identify those farm production units performing below potential and the factors associated with this. Extension and advisory service companies could then design strategic adoption strategies for targeted audiences. This will result in increased production in all regions by optimising extension programs and variety recommendations.

1.2 Previous research

Varieties have played a major role in improving the productivity of the Australian sugarcane industry, however, the productivity potential of a variety can only be realised if growers plant the varieties that are best suited for an individual block or farm (Cox *et al.* 2005). Growers need to consider a wide range of factors when making variety choices, including:

- cane yield;
- sugar content and seasonal sugar profile;
- suitability of the variety to soil type;
- disease resistance;
- germination and ratooning ability;
- reaction to environmental stresses, such as frost, water logging and drought.

When new varieties are released, information on many of these characteristics is limited. The new variety has been tested in SRA selection trials on limited soil types and may not have encountered all of the environmental stresses that it might face when it is grown more widely across a region.

Gathering and disseminating information on new varieties after their release is critical for maximising the potential of the variety, both from an individual grower point of view, and for the overall region. Growers gather this information from a wide range of sources and share experiences with other growers, advisory staff, mill staff and service providers such as planting contractors. Mills provide valuable information on harvest data but these data are limited for a few years after a variety is released and needs careful interpretation because it can be biased by small sample sizes.

In past industry surveys, growers identified variety information as their highest priority for development of web-based information systems. QCANESelect® (Millard *et al*. 2009, Plunkett *et al*. 2014) was developed as a web-based variety information and Decision Support System (DSS) that would provide growers with up-to-date variety information and to assist them to make the complex decisions involved in optimising variety composition on their farm.

When developing any new product, it is important to involve the end user. Lynch *et al.* (2000) suggested that the adoption of new products will be limited, and perhaps the product may ultimately fail, if end users are not consulted early in the development process. An example of the limited success of a DSS is APSIM, which was developed by the Agricultural Production Systems Research Unit (APSRU), in Toowoomba, Queensland. The researchers and developers behind the system were aware of its complexity, and its ease of use was limited for the farming community, so they took the approach of 'co-operative learning', whereby the researchers ran seminars with growers running through various scenarios to help growers gain an understanding of the system. Lynch *et al.* (2000) explains that this was a terminal fault with the system, primarily because it was a complex application, and not user friendly. The co-operative learning being conducted after the development, and not during, combined with the complexity of use of the system led to reduced uptake.

Other adoption issues concerning decision support tools are the relevance of the system and its information. MY Canesim was a DSS for irrigation for the South African sugar industry and was based on computer models and SMS communication with growers. MY Canesim faced technological challenges relating to the speed and relevance of the information supplied via the system. The supply of non-relevant information led to growers abandoning the system. Singels (2007) suggests that growers did not agree with all the information provided and were subsequently not going to use the system long term. The lessons learnt from failures to gain widespread adoption of APSIM and MY Canesim are very relevant to QCANESelect®. The development of QCANESelect focused on direct input and consultation with growers at all stages of the project to ensure the system is easy for growers to use and contains information which is relevant and up-to-date (Millard *et al*. 2009 and Plunkett *et al.* 2014). An independent 2015 survey commissioned by SRA reported that more than 60% of the people surveyed had used QCANESelect® in the last year.

In making enhancements to QCANESelect®, other tools for varietal selection were investigated. In the South African sugar industry, Ramburan *et al.* (2010) recommend that the best approach is to determine the response of varieties to priority factors within homogeneous units. Users can then specify characteristics of their production environment and obtain variety recommendations.

The Australian sugarcane industry has benefited from substantial investment into determining factors contributing to temporal and spatial yield variability. A large amount of information is collected annually by mills at the rake and block level. Mill data have been used by many researchers to identify regional production trends, develop an understanding of the key variables that influence productivity and the importance of obtaining improved predictions of varietal performance across the mill area. Wilson and Leslie (1997) used reference varieties for different time periods to estimate varietal indices. This was a somewhat subjective approach and could not accommodate unbalanced data. Ellis *et al.* (2001) overcame these limitations by developing a methodology based on mixed models (Henderson *et al.* 1959). Laws *et al*. (2004) considered a range of approaches including principal component and cluster analysis to develop an understanding of the key variables that influence productivity at the block level in the Tully mill area. In the Herbert region Garside (2013) recommended that differences in temporal and spatial yield variability be investigated and recognized in varietal selection.

Project 2014/054 was a pilot study to access, analyse and make improved recommendations based on mill data collected over 16 years in the Herbert sugarcane region (Stringer *et al.* 2016 and Stringer *et al.* 2017). Productivity performance groupings were developed from which variety recommendations and adoption strategies can be optimised. Detailed cluster analysis identified adoption of new varieties, whole of farming systems, uptake of clean seed and management of Pachymetra as factors associated with productivity in the Herbert region. This analysis was presented as a report to the Herbert sugarcane industry. Local extension productivity services then developed extension programs, based on the factors identified, to show sugarcane growers the potential productivity benefits they could achieve by addressing these factors. The analyses allowed extension staff to show growers the yield advantage of different practices so that growers with lower yield could be encouraged to change their practices and increase their profitability and productivity for the whole region.

Building on the initial work in the Herbert the current project developed a data platform which automates the statistical analysis and reporting of mill data to aid industry decision making. Currently, the analysis and reporting of industry data is ad-hoc and time consuming. Development of innovative tools to analyse and summarise mill data within a region will be used to identify those farm production units performing below potential and the factors associated with this. Increased understanding of the factors affecting productivity (eg. soil type, variety, crop class, disease) will improve farming practices such as more appropriate selection of varieties to match field conditions, addressing impediments to farm productivity and Nutrient Management Planning.

2. PROJECT OBJECTIVES

There are 7 broad objectives in this project. The first six build on work undertaken in the pilot project 2014/054 based in the Herbert:

1. Automate the data transfer, analysis and reporting of mill data to aid in industry decision making.
2. Identify key drivers of profitability for both growers and millers in additional regions to the Herbert by using analyses of factors affecting mill productivity and cane and sugar quality.
3. Enable the new features such as automated individualised whole farm planning, variety performance by soil type and sub-district and analysis of variety performance across years for the Decision Support System, QCANESelect® (QCS) to optimise variety recommendations in all regions as input data become available.
4. Use objective mill data to design strategic adoption programs to optimise current farm management plans.
5. Promote the new features of QCANESelect® to gain greater adoption in all regions.
6. Develop a ratooning index based on productivity groupings to predict and rate ratooning performance of varieties to tailor variety recommendations.
7. Develop a decision support tool to predict varietal composition and long-term sugar and cane quality parameters to allow mills to plan and implement factory changes that might be required for processing the crop expected in the future.

3. OUTPUTS, OUTCOMES AND IMPLICATIONS

3.1 Outputs

The project generated a number of outputs that appear in the form of knowledge, processes, algorithms and prototype delivery tools. These include:

1. A data reporting and benchmarking tool for Tully that links block level productivity data, block spatial data, soil survey spatial data and variety disease resistance ratings from 2012-2020 for use by the Tully sugar industry. This will enable better industry decision making and streamline variety and nutrient management plans in Tully.
2. Productivity reporting tool for 361 farms in the Tully sugarcane industry to allow growers to benchmark their farm performance relative to all others in their productivity zone.
3. Soil maps for all farms in Tully to support nutrient management planning and streamline the process of soil sampling.
4. A data reporting and benchmarking tool for Herbert that links paddock level productivity data, block spatial data, soil survey spatial data, climate zone spatial data and variety disease resistance ratings from 2005-2020 for use by the Herbert sugar industry. This will enable better industry decision making in the Herbert.
5. Productivity reporting tool for 834 farms in the Herbert sugarcane industry to allow growers to benchmark their farm performance relative to all others in their productivity district.
6. Integration of Herbert climate zones into industry programs and productivity datasets.
7. Improved variety recommendations that examined performance over five climate zones and DPI and CSR soil series in the Herbert.
8. Dataset for Herbert from 2005-2020 to be used in an industry led productivity improvement project to easily identify growers with below average productivity within their productivity zone and benchmark these farms to demonstrate the potential ‘real’ gains for participating growers.
9. Dataset for the Herbert that combines productivity, grower demographic and farming system information from 2014-2020 to be used in an industry led productivity improvement project to identify poor performing growers across productivity zones to target growers who may be potentially looking to transition out of the industry.
10. Dataset for the 2017-2020 seasons to be used in Tully Industry district wide CAPA reporting.
11. Dataset for the 2020 season to be used in Herbert Industry Productivity reporting.
12. A data analysis automation tool that identifies outliers, analyses mill productivity data with a linear mixed model, undertakes clustering and produces graphical output of analyses.
13. An innovative methodology to analyse and summarise productivity data within a mill region to identify those farm production units performing below potential and key factors influencing poor performance.
14. Increased understanding of the factors affecting productivity in Tully, Herbert and Burdekin that will broaden the adoption of improved farming practices by working with local industry to enable more appropriate selection of varieties to match field conditions, addressing impediments to farm productivity and Nutrient Management Planning.
15. Development of a ratoon index for varieties based on number of years to 25% of supply and economic threshold of profitability.
16. Anassessment of machine learning models to predict varietal composition.
17. One ASSCT paper, 1 Milling Matters (Summer 2019) and 1 Cane Connections (Summer 2019) that share new knowledge developed from the project.

3.2 Outcomes and Implications

If adopted and applied to better target extension efforts, the outputs generated from this project will ensure that on-farm profitability in Tully, Burdekin and Herbert mill areas will increase through the adoption of better management practices.

The major outcomes of this project are:

1. More targeted use of varieties
   - Analysis of objective productivity data across years, soil types, sub-districts and crop classes, together with knowledge of field-based experts, will improve the ability to make optimal recommendations on the best varieties for future plantings for the crop-cycle duration.
2. More tonnes of cane delivered to the mill
   - Higher productivity (sugar yield) from better targeted varieties will result in more cane and sugar being produced across all mills. As this is achieved, it will increase over years as more productive and targeted variety selections continue across the crop cycle.
3. Increased on-farm and mill profitability

   - As well as increased profitability from growing the right varieties, additional profitability will accrue if better management practices can be adopted based on the analysis of productivity data and targeted extension.
4. Reduced costs
   - There will be reduced costs to mill and productivity service companies in the annual collation and analysis of data.
5. Need for targeted or tailored extension programs
   - Some of the growers in the 75-85 Target group identified in 2014/054 have shown positive benefits through targeted extension strategies.

There are different key messages for growers, advisors, mills, harvesting contractors and data custodians. These have been grouped into Identification of productivity/cane quality constraints, tailored extension practices and Tool Development.

Identified productivity constraints to increase on-farm profitability in Tully:

- Productivity is lower in the high rainfall subdistricts compare with the lower rainfall subdistricts.
- The northern, wetter climate sub-region yielded less cane and sugar yield than the southern, drier sub-region.
- A high proportion of the small-sized low producing farms for TCH are in the El Arish and Feluga subdistricts which are in the wet climate zone. In contrast, the small-sized high TCH farms are in the dry climate zone and Murray, Kennedy and Riversdale subdistricts.
- Cane and sugar yields were significantly lower in years experiencing high spring-summer rainfall or in the La Niña phase. Yields significantly increased as the amount of spring-summer rainfall decreased.
- Improved knowledge of how climatic conditions influence sub-regional productivity performance will assist industry extension programs and on-farm management decisions.
- Spatial refinements were made to existing 8 subdistricts to better represent productivity performance across the region.
- The two low yielding clusters had 78% and 58% of their Farms in the areas shown to have high Pachymetra soil spore counts in the wet climate zone areas of Feluga and El Arish. The high yielding cluster had just over half of their farms in the drier Murray subdistrict where Pachymetra is less of a problem.
- Rotation of intermediate varieties with resistant varieties will reduce the level and severity of Pachymetra Root Rot.
- Updated Pachymetra survey map which clearly shows where the hot spots are.
- The high yielding cluster had a higher proportion of plant cane than all other clusters and the proportion of old ratoons was lower.
- Q208 and Q200 generally out-performed all other varieties including newer varieties up to SRA7.
- A better understanding of soil type performance and variety x soil type interactions will help improve fertiliser nitrogen use efficiency.
- The impacts of severe weather events on farm management can have flow on effects for many years. The impact of above average rainfall during the harvest season in 2010 and cyclone Yasi in 2011 saw a 50% increase in planting in 2012 which flowed through to higher proportions of first, second, third and older ratoons in succeeding years. Yield in Tully decreases on average 6% with each ratoon crop. The highest percentage of older ratoons as a result of the very large planting season in 2012 occurred in 2017 which would have a depressive effect on mill productivity.
- Discontinued the practice of replanting with no fallow which has benefits for soil health and management of diseases such as RSD which can carryover in volunteers in replant crops.

Identified productivity constraints to increase on-farm profitability in Burdekin:

- Productivity zones with a higher proportion of lower producing farms for TCH, CCS and TSH were identified.
- Time of planting has a big influence on yield of the plant crop.
- Replanting the same variety in a field can lead to significant yield losses. Growers should be encouraged to rotate varieties and to maintain a mix of varieties on their farm.
- Effect of harvest date in the previous season on yield in the current season in the Burdekin demonstrated that blocks harvested after the 23/11 in the previous year return 37% less $/ha and 35% less TSH than blocks harvested before September of the previous year.

Identified productivity constraints to increase on-farm profitability in Herbert:

- Productivity zones with a higher proportion of low producing farms for $/ha were identified.
- Growers who regularly obtained clean seed had 13% higher yields than growers who never or infrequently obtained clean seed.

- Growers in the Bottom 30 farms grew twice as much Q200 and Q174 (smut susceptible) compared to the Top 30 farms.
- Growers in the Top 30 farms grew twice as much Q208 compared to Bottom 30 farms.
- High performing cluster farms had higher % of Q208 compared to low performing clusters.
- Low performing cluster farms had higher % of MQ239 compared to high performing clusters.
- High performing clusters had higher adoption of new varieties (59%) compared to low performing clusters (49%).
- Planting Q208 in blocks that have previously grown Q208 was associated with 7-12% lower $/ha compared with planting Q208 in blocks that had previously grown KQ228, MQ239, Q200 and Q183.
- Timing of operations especially in relation to planting and weed control had an important impact on productivity.
- Off-farm job had a significant negative impact on productivity because the grower could not attend to issues like farm hygiene in a timely manner.

Identified drivers in cane quality parameter Effective Bulk Density (EBD) in Tully:

- Biggest source of variation in EBD are variety, field conditions, crop presentation and harvesting contractor.
- Higher EBD with 5 blades per chopper drum compared to 4 blades. However, there is higher (invisible) sugar loss when number of blades increases.
- Targeting a high EBD can have a significant impact on yield reduction and cane loss.

Identified opportunities for tailored extension practices in Tully, Burdekin and Herbert

- Identified opportunities for advisors to tailor extension practices through creation of productivity performance groupings based on cane yield, CCS, sugar yield and dollars per hectare.

- Development of productivity performance groupings in Tully and Herbert in which variety and management recommendations can be improved by considering the impact of soil type and rainfall on cane yield potential in conjunction with projects 2015/065, 2015/075 and 2017/009.

Development of benchmarking tools for use by growers and aid in industry decision making

- Farm productivity reporting tool for Tully and Herbert industries allows growers to benchmark their farm performance relative to all others in their productivity district.
- Development of data analysis and reporting platform for Tully and Herbert industry which provides a single consistent source of data for all users. This has been used to streamline Nutrient Management and Variety Management Plans.
- Tully sugar industry has requested future tools build on this platform by incorporating semi-automation of nutrient management planning and harvesting decision support tool (2020/003).
- Reporting tool allows variety x soil type x crop class x climates zone performance in Tully and Herbert to be examined. This will allow advisors to have the best possible information to make recommendations on varietal performance over ratoons.

4. INDUSTRY COMMUNICATION AND ENGAGEMENT

4.1 Industry engagement during course of project

The project team established a consultative group at the start of the project. This group included members of the project team and representatives from Productivity Service Companies (PSCs), mills, private extension advisors, CANEGROWERS, growers, harvesting contractors and researchers from SRA, USQ and JCU. Meetings were held on several occasions with the larger group or smaller subset of members to review and discuss project data and outputs.

With the Tully, Burdekin, Plane Creek and Isis mill areas meetings were held with the consultative groups. The purpose of the meetings was to move from gaining support of the project by mill management to actual supply of the required datasets by:

- Presenting the results of project 2014054 based in the Herbert;

- Developing a list of factors which may be driving productivity within each mill area;

- Determining availability of farming practice data from Agdat, Productivity Service Companies or CANEGROWERS;

- Defining industry targets for cane yield, CCS and sugar yield by examining historical mill data;
- Ensuring that data license agreements were in place to cover the legal aspects of the project;
- Determining who the results of the project could be communicated with while maintaining confidentiality of the data.

The methodology used in this project involves seven key steps with the aim to increase productivity/profitability.

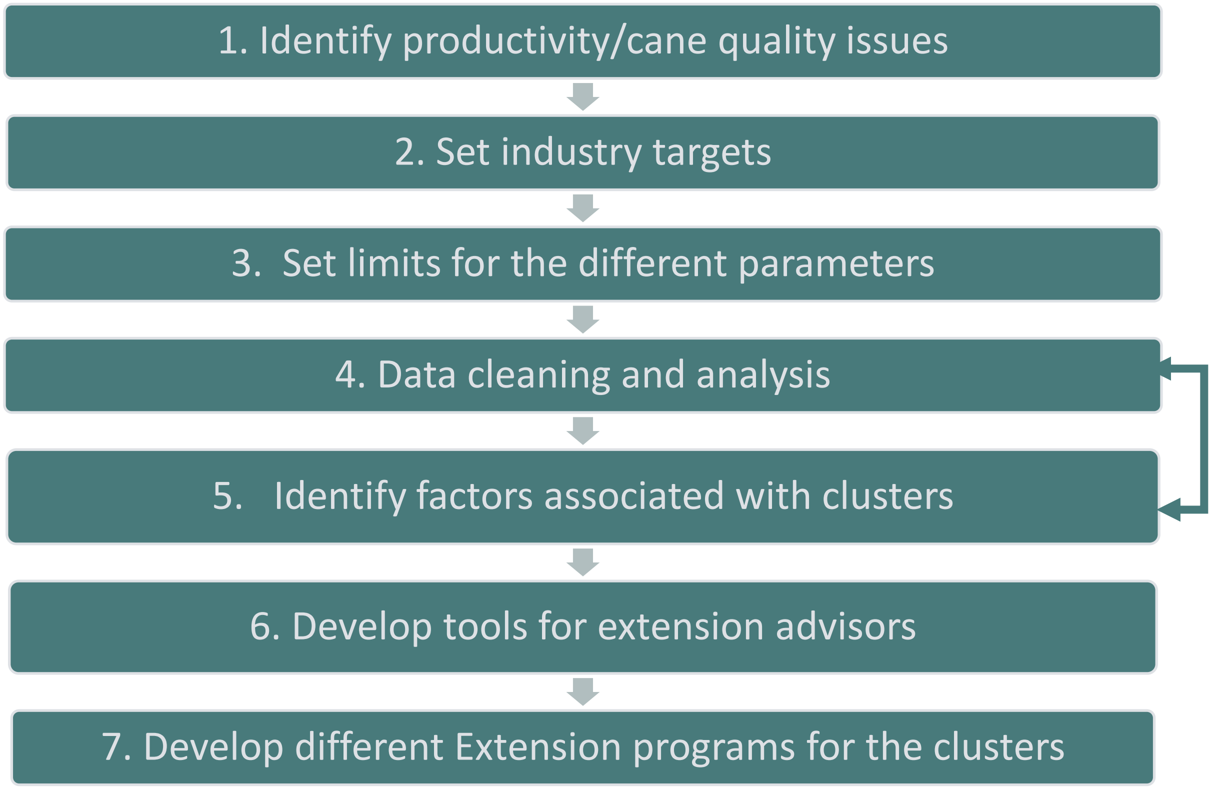

Figure 1: An outline of the methodological approach.

Although the methodology is presented as a linear sequence of steps, a participatory action research approach was undertaken. There is some recycling of steps 4 and 5. At each step of the methodological framework, the project team sought feedback from consultative committee, reflected on their advice and revised the methodology accordingly. Thus, the prototype delivery tool developed in step 6 already incorporates several layers of action learning cycles of continuous improvement.

Through local industry discussions, project 2016/032 will also optimise recommendations for adoption strategies and assist in designing strategic programs for farming enterprises. With the experience of the consultative group coupled with the multidisciplinary expertise housed in the project team, the project team could undertake the next step and initiate action learning processes with industry and extension partners outside the consultative group.

Industry engagement and feedback included:

- Members of the project team prepared oral presentations for delivery at grower shed meetings and stakeholder workshops in Burdekin, Tully, Plane Creek and Isis to promote, communicate and seek feedback on outputs arising from this project.
- Meetings with the Tully Variety Management Group (TVMG) to launch CAPAs and communicate project outputs. Five meetings were held in 2017.
- Meetings were held with the consultative group and stakeholders in the Burdekin. Five meetings were held in 2018.
- Cane quality meeting with TSL, Tully Canegrowers Board, SRA Milling and Harvesting Adoption Teams in December 2019. Two meetings were held during 2019-2020.
- Meetings with 12 HCPSL/SRA extension advisors in December 2020 to communicate outputs on drivers of productivity and variety management in the Herbert region. Three meetings were held in Jan-March 2021. HCPSL conducted 6 shed meetings throughout the Herbert River district between the 15th- 17th of March to launch CAPAs and communicate project outputs. 136

growers attended and this represents 27% of the industry. Each grower attending received a copy of their own individual CAPA report. Growers who did not receive a CAPA report will now be engaged on a one-on-one basis through HCPSL industry led productivity improvement project and through general HCPSL extension activities. Since the shed meetings HCPSL Extension Agronomy staff have had follow ups with growers who are seeking to improve their own farm productivity. A good example was one particular grower where the farm was compared to neighbouring farms for cane yield, CCS and sugar yield. HCPSL are now working with this grower to address productivity drivers like Approved Clean seed adoption, Pachymetra, micro-nutrient deficiencies (especially zinc), crop ripening through the use of Moddus™ to improve early CCS and the use of fallow cover crops.

- Further project outputs in the Herbert will be communicated to HCPSL Board and CANEGROWERS Herbert in July 2021

4.2 Industry communication messages

There are different key messages for growers, advisors, mills, harvesting contractors and data custodians. These have been grouped into Identification of productivity/cane quality constraints, tailored extension practices and Tool Development.

Identified productivity constraints to increase on-farm profitability in Burdekin:

- Productivity zones with a higher proportion of lower producing farms for TCH, CCS and TSH were identified.
- Time of planting has a big influence on yield of the plant crop.
- Replanting the same variety in a field can lead to significant yield losses. Growers should be encouraged to rotate varieties and to maintain a mix of varieties on their farm.
- Effect of harvest date in the previous season on yield in the current season in the Burdekin demonstrated that blocks harvested after the 23/11 in the previous year return 37% less $/ha and 35% less TSH than blocks harvested before September of the previous year.

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- Cane and sugar yields were significantly lower in years experiencing high spring-summer rainfall or in the La Niña phase. Yields significantly increased as the amount of spring-summer rainfall decreased.
- Improved knowledge of how climatic conditions influence sub-regional productivity performance will assist industry extension programs and on-farm management decisions.
- The two low yielding clusters had 78% and 58% of their Farms in the areas shown to have high Pachymetra soil spore counts in the wet climate zone areas of Feluga and El Arish. The high yielding cluster had just over half of their farms in the drier Murray subdistrict where Pachymetra is less of a problem.
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Identified opportunities for tailored extension practices in Tully, Burdekin and Herbert

- Identified opportunities for advisors to tailor extension practices through creation of productivity performance groupings based on cane yield, CCS, sugar yield and dollars per hectare.
- Development of productivity performance groupings in Tully which variety and management recommendations can be improved by considering the impact of soil type and rainfall on cane yield potential in conjunction with projects 2015/075 and 2015/065.

Development of benchmarking tools for use by growers and aid in industry decision making

- Farm productivity reporting tool for Tully and Herbert industries allows growers to benchmark their farm performance relative to all others in their productivity district.
- Development of data analysis and reporting platform for Tully and Herbert industry which provides a single consistent source of data for all users. This has been used to streamline Nutrient Management and Variety Management Plans.
- Tully sugar industry has requested future tools build on this platform by incorporating semi-automation of nutrient management planning and harvesting decision support tool (2020/003).
- Reporting tool allows variety x soil type x crop class x climates zone performance in Tully and Herbert to be examined. This will allow advisors to have the best possible information to make recommendations on varietal performance over ratoons.

5. METHODOLOGY, RESULTS AND DISCUSSION

5.1 Data Analysis and Reporting Tool

Development of data analysis and reporting automation tool

The sugarcane industry is unique with cane consigned to the mills at harvest and data relating to Farm/Block captured and stored. Payment to growers is based on consignment data and while data at farm level is very accurate, at block level it can be less accurate at times. The industry can have a very high level of confidence in farm level data and analysis of data across farms and sub-districts. Consignment errors do exist in the rake data however the data can be filtered, and the poor-quality data can be removed from analyses.

Rake and block level data for Tableland, Mulgrave, South Johnstone, Tully, Herbert, Burdekin, Maryborough, Isis, Condong, Broadwater and Harwood from approximately 5-15 seasons was available for use in this project. Currently, data are manually imported into SPIDNet for display in QCANESelect® using a combination of custom SQL scripts written for each mill's data set, and a general SPIDNet import routine. Custom scripts are necessary because each mill supplies their data in a different format, and each requires different validation and translation of data into a common standardised format to be loaded into temporary staging tables. The subsequent SPIDNet import routine works on the data in those temporary tables applying common validation routine and reports issues to be addressed before data can be moved to the final storage area. Additionally, this stage is used to update any summary data that depends on the newly loaded data.

Summarised data across all mills are available in QCANESelect® under Regional Reporting.

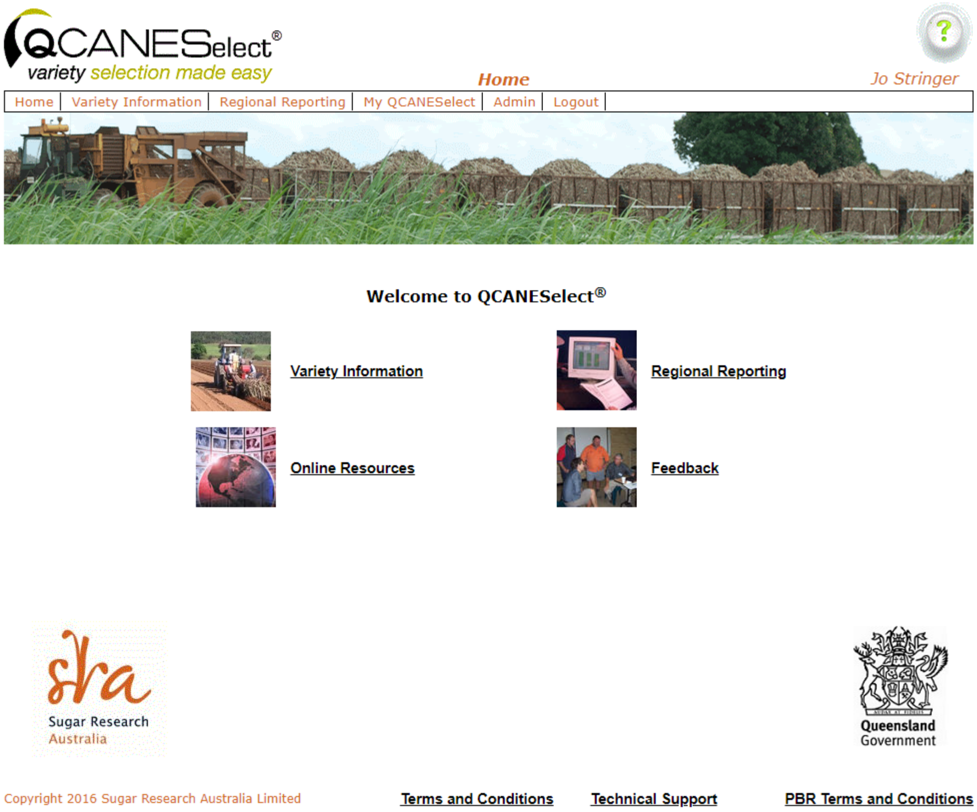


Figure 2: QCANESelect® homepage.

Users have the ability to report on "Tonnes, Hectares, Cane yield, CCS, CCS by week of season, disease, %tonnes, % hectares, $/ha and weekly supply" By "Variety, Region, District, Crop Class and Soil Type. A range of years can be selected. Availability of data differs between those mill that supply rake/block level data and those that only supply whole of mill level data:

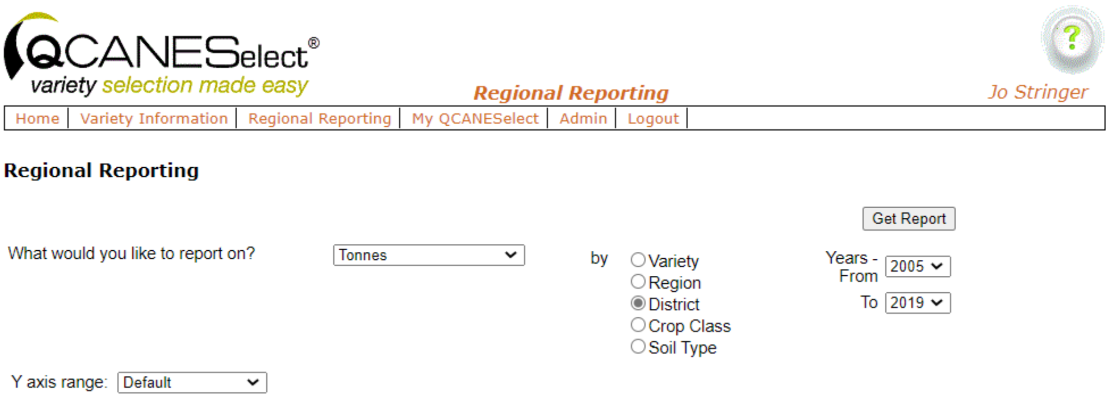


Figure 3: Regional Reporting in QCANESelect®

At the end of December 2018, the "Whole of Farm Planning" and "Block Recommendations" modules in QCANESelect® were disabled as recommendations were based on subjective Yield Scores. Growers and Productivity Service Companies were notified of this decision. Although SRA had budgeted for the rebuild of QCANESelect® in the 19/20 financial year, it was decided that no material progress on redeveloping QCANESelect® could be made until the Spidnet project is complete.

After the decision was made not to progress the redevelopment of QCANESelect®, the user requirements for an Industry Productivity Data Analysis and Reporting Tool (IP-DART) were scoped with a wide cross section of users including researchers, extension advisors and industry personnel in Tully. An on-site design planning workshop was held on the 11 April 2019 in Tully and was attended by staff from TSL (Greg Shannon, Ben Hay), Tully Canegrowers (Peter Lucy), WTSIP (Alex Lindsay), TCPSL (Peter Sutherland), Gerry Borgna (grower, TSL Board and TCPSL Board) and SRA (Danielle Skocaj, Andrew Rigby, Daryl Parker, Jo Stringer). In preparation for the IP-DART, rakes and block level productivity data, spatial layer (block boundaries, fallow information), soils layer, soil tests, Pachymetra surveys and disease ratings from 2012-2018 were joined.

Development of data analysis and reporting tool for Tully

An Individual Cane Area Productivity Analysis (CAPA) Report Data Preparation Model which outlines the procedure to produce the farm productivity reports was developed by Andrew Rigby from SRA. This model together with detailed methodology for the 29 steps was presented at the TCPSL Board meeting on the 13 Dec 2019 to gain approval to develop the tool.

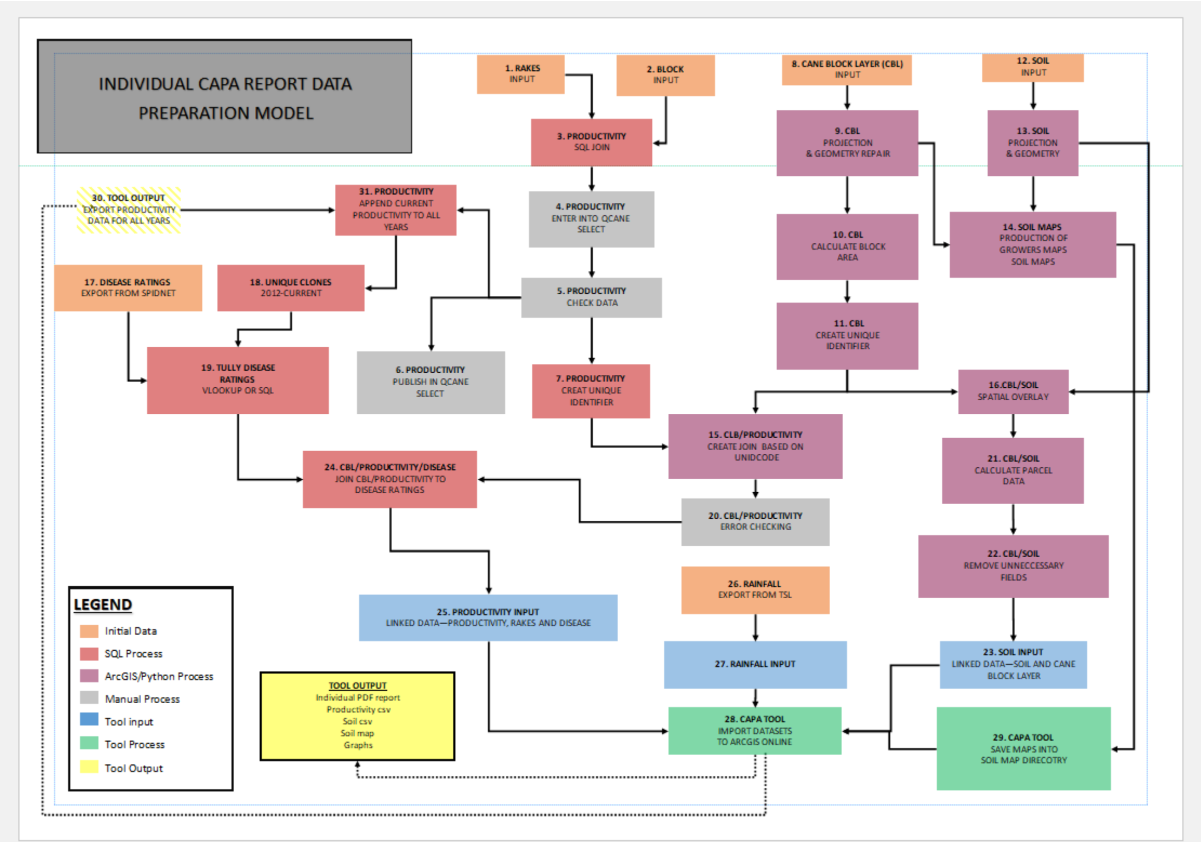


Figure 4: Individual CAPA report data preparation model for Tully.

Since 2019 CAPA reports have been produced for 361 farms in Tully. An example of a CAPA report for F9240 is

F9240_2020.pdf

attached.

Development of data analysis tool and reporting tool for Herbert

A tool has been created by Livia Defeo from SRA and HCPSL, using R programming language to automate the statistical analysis and reporting of mill data in the Herbert region. This tool integrates paddock level data with data ownership (farm name and ABN), productivity district, productivity zone and climate zone data. It enables datasets for the time period of 2005-2013 and another dataset for 2014-2019 to be created and changes in productivity over time to be examined.

The tool comprises eight main steps and these are:

1. Selection of seasons.
    a. 2005-2013
    b. 2014-2019
2. Selection of farms for statistical data analysis.
    a. Farms had to be present in all 6 seasons (2014-2019)
    b. Omit seed cane farms
    c. Same filters apply to seasons 2005-2013
3. Data cleaning.
    a. Filters 99% of the data
        i. Eliminates 0.5% at the bottom and 0.5% at the top
    b. Boxplots for CCS, TCH and TSH
    c. Same filters applied to 2005-2013
4. Calculation of CCS, TCH and TSH at farm level, productivity zone level and mill level.
5. Linear mixed model for prediction of CCS, TCH, TSH and hectares at farm level which removes the effects of seasonality.
    a. Season and Farm as fixed effects, as previously done on the project 2014/054:
        i. TCH and sum of hectares per farm
        ii. CCS and sum of hectares per farm
        iii. TSH and sum of hectares per farm
6. Clustering using K-means method for CCS, TCH, TSH and Dollars per hectare
7. Graphical output of analysis
    a. 10 clusters per pair of variables
    b. Targets indicated for TCH, TSH and Dollars per hectare
    c. Colour coded clusters according to their performance (from red to green)
8. Non graphical output of analysis
    a. Outputs a csv file containing the cleaned raw data used in the data analysis
    b. Outputs a csv file containing the results of the data analysis

Development of Herbert Individual Farm productivity Reporting Tool (CAPA)

A tool was created by Livia Defeo from SRA and HCPSL, to automatically produce individual farm productivity reports for the Herbert region. The tool compares the data from a particular farm to the productivity district that it is located in. The data were supplied by Wilmar Sugar and SRA.

There are twenty-six productivity districts or subdistricts in the Herbert region, and they reflect different productivities.

The CAPA reports contain eight graphs. These are:

1. Tonnes of sugar per hectare at a paddock level
2. Tonnes of sugar per hectare at a farm level
3. Variety by area (ha)
4. Crop Class by area (ha)
5. Pachymetra Resistance Ratings
6. Smut Resistance Ratings
7. Crop Cycle Length
8. Soil maps

In addition, the Herbert district has farms which are located across multiple productivity districts. In this situation, the report presents multiple graphs per graph type. For example, a farm which is across two productivity districts, has two graphs for each graph type in the report and, so on if the farm is across three productivity districts.

As an example, we present the productivity report for the farm 0136A below:

The first graph shows tonnes of sugar per hectare at a paddock level for 0136A. Foresthome is the productivity district this farm is located in. The bars have different colours according to the crop class. There are also values of mill sugar yield and subdistrict sugar yield for comparison purposes.

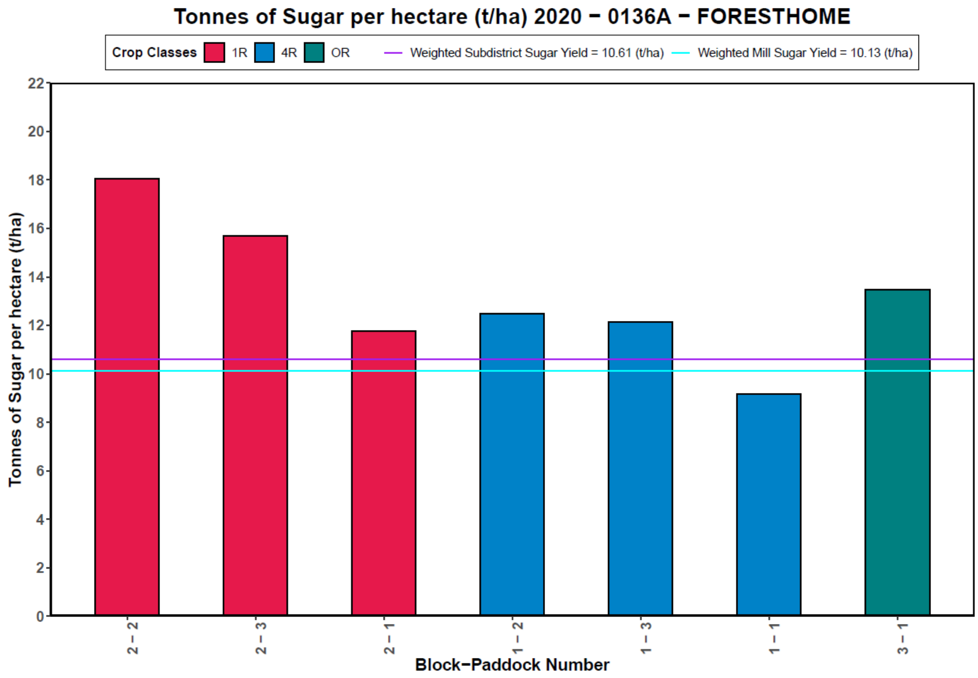


Figure 5: Tonnes of sugar per hectare at a paddock level.

The second graph is tonnes of sugar per hectare at a farm level. The green bar is 0136A and the grey bars are all the other farms in Foresthome. In this case, this farm has the third highest sugar yield in the productivity district. There are also values of mill sugar yield and subdistrict sugar yield for comparison purposes.

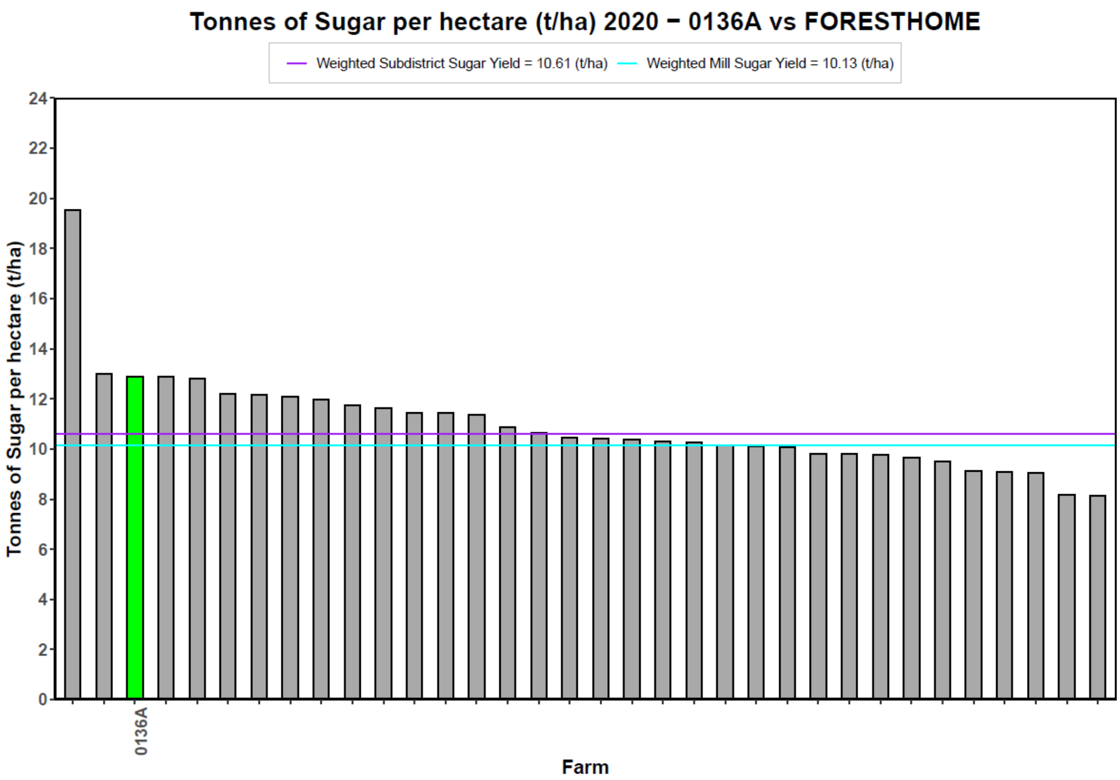


Figure 6: Tonnes of sugar per hectare at a farm level.

The third graph is the comparison between 0136A and Foresthome regarding a Variety of sugarcane by area. On the left-hand side, there are statistics for the farm and on the right-hand side, the statistics of the productivity district. The different colours represent the different varieties. For example, Foresthome has 7% of Q200 whereas 0136A has 24.5% of Q200. The category other is the sum of all varieties which are less than 5%. At the bottom of page, there is a list of the varieties which are under the category Other for both the farm and the productivity district.

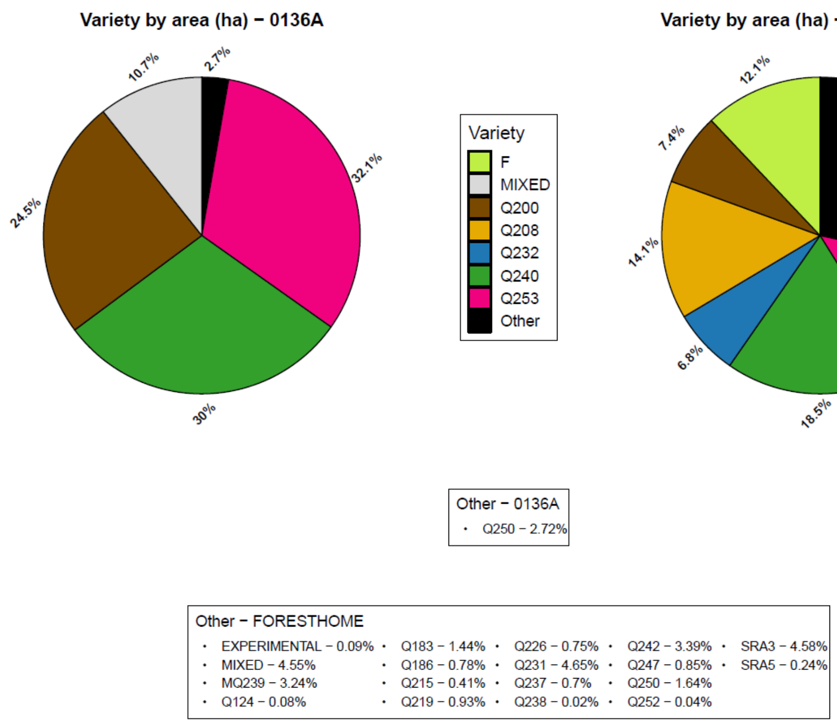


Figure 7: Variety by area.

The fourth graph, Crop Class by area, has a similar comparison but relating to Crop Class instead. The different colours represent the different crop classes. This graph also has a list of crop classes which are less than 5% that are grouped under the category Other.

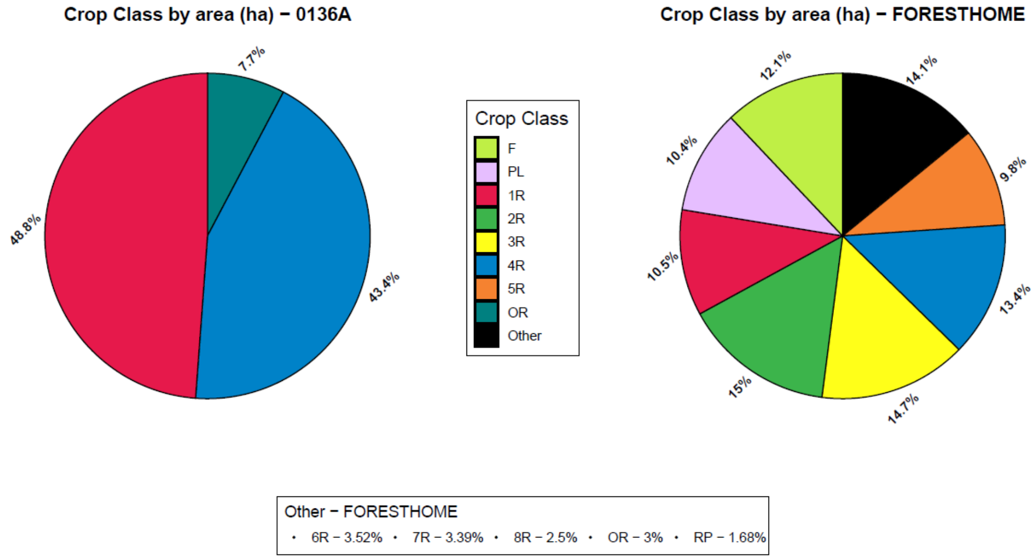


Figure 8: Crop Class by area.

The fifth graph, called Pachymetra Resistance Ratings, is a comparison regarding this disease resistance ratings for farm and productivity district. The disease ratings follow a traffic light system. Susceptible varieties are presented in red, Intermediate-Susceptible in orange, Intermediate in yellow/green, Intermediate-Resistant in light green and Resistant in dark green. For example, 0136A has a higher uptake of pachymetra resistant varieties than the subdistrict of Foresthome (35% for this farm against 30% for Foresthome).

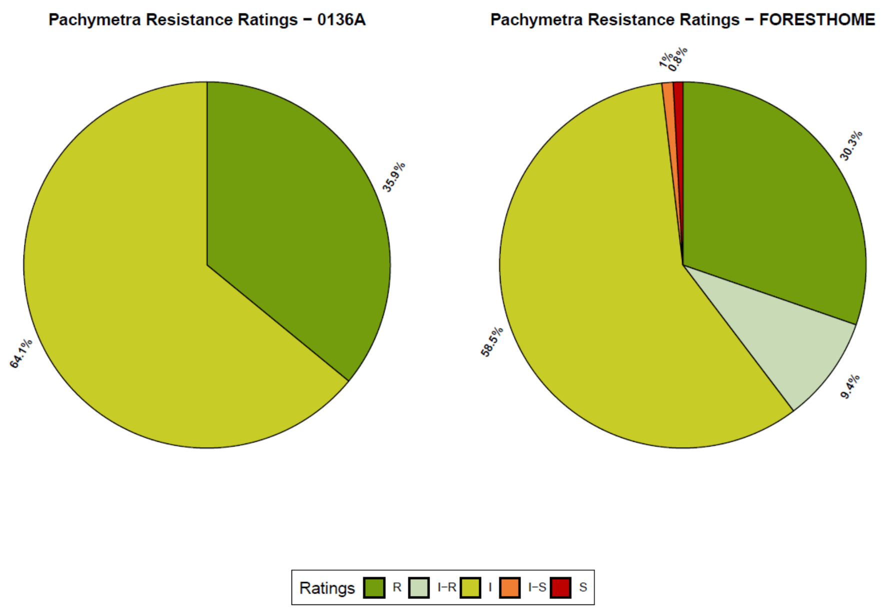


Figure 9: Pachymetra Resistance Ratings.

The sixth graph is a comparison regarding smut resistance ratings between the farm and productivity area. For instance, this farm has 72% smut resistant varieties, whereas, Foresthome only has 52% of smut resistant varieties.

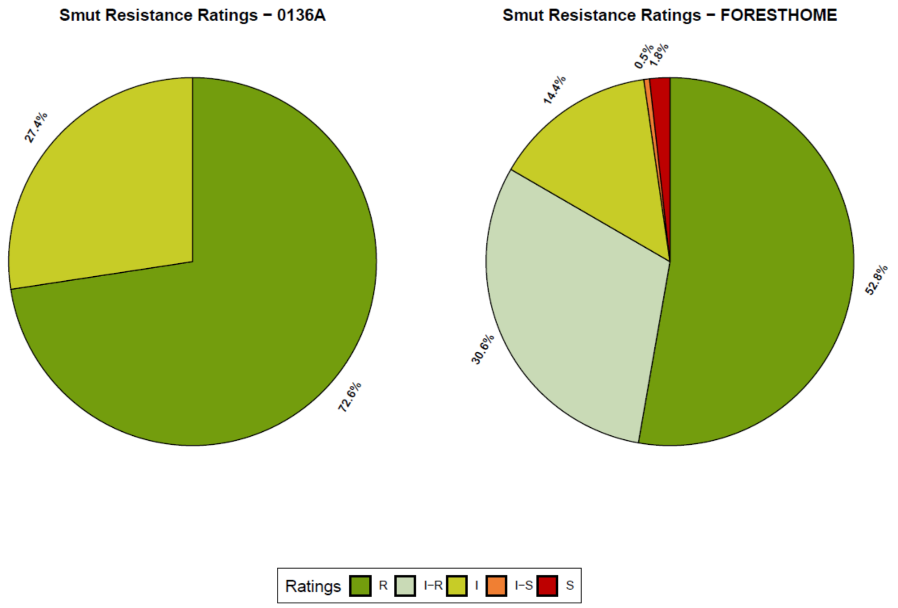


Figure 10: Smut Resistance Ratings.

The seventh graph is a comparison between the farm and productivity area, regarding crop cycle length, which is the average age of all plant and ratoon crops weighted by area.

Crop Cycle Length

3.9 0136A Vs 4.2 FORESTHOME

(Crop Cycle length is the average age of all plant and ratoon crops weighted by area)

Figure 11: Crop Cycle Length.

The last graph contains the soils maps. The classification used is the same soil classes as for 6 easy steps guidelines in the Herbert.

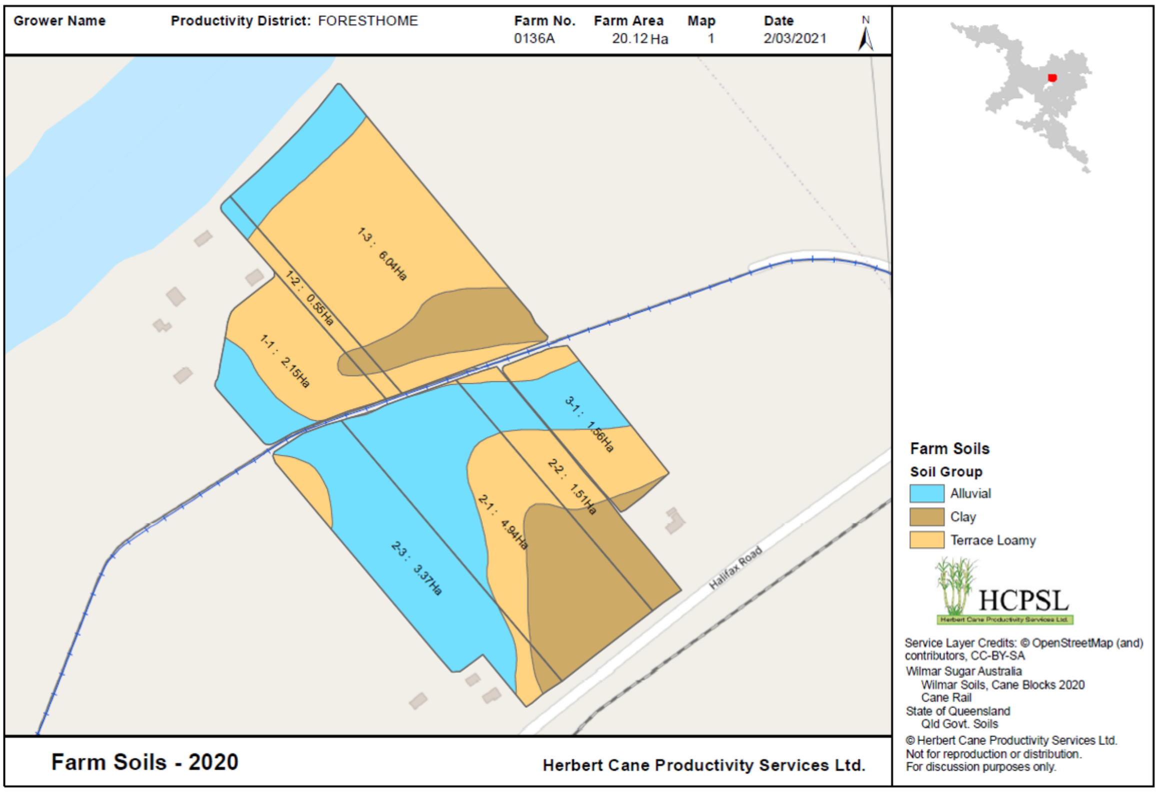


Figure 12: Soil map of 0136A.

In summary, the CAPA reports aim to provide the growers with a “big picture” of their farm. As different productivity districts reflect different productivities, the reports present the data in a manner that the comparisons between farms and/or productivity districts assist advisors in identifying any productivity constraints. It is expected that the reports will assist growers making targeted decisions and therefore, improving on-farm profitability.

5.2 Analysis of mill data to identify key drivers of profitability/productivity

a. Burdekin

Available data

When cane is harvested commercially it is delivered to mills often in bins via cane trains. A collection of bins that is continuously sampled at the weighbridge and given a single reading for sugar content is called a rake. A rake contains 50-250 t of cane.

At a sugar mill juice is extracted to estimate commercial cane sugar (CCS) (BSES 1984). CCS is an empirical formula and estimates the percentage of recoverable sucrose in the cane on a fresh weight basis. Cane farmers are paid on the tonnes of sugar (being sugar yield) supplied to a mill. The growers receive approximately two-thirds of the proceeds and the millers receive approximately one-third of the proceeds when the sugar is sold.

Since cane is automatically consigned to mills they capture huge of amounts of data each year for each grower. Here, we analysed rake data from the Herbert River mills for 2005-2020, Burdekin mills for 2005-2016 and Tully for 2012-2016. Data for each rake consists of farm number, block, paddock, grower name, harvest date, rake number, cultivar, crop class, area harvested, tonnes cane harvested and CCS. Filters were applied to the data to remove outliers that fell outside the range of expected yields for each mill area.

In any given season, cane yield (t/ha) for each farm was calculated as:

(Sum tonnes harvested)/Sum area harvested

Within each season, CCS at a farm level was weighted as:

(Sum(tonnes harvested*CCS))/Sum tonnes harvested

Sugar yield (t/ha) was calculated as 100*(Cane yield*CCS)/100.

Cluster analyses

Prior to any analyses boxplots were used to identify outliers in the Burdekin data. Any paddock level data with cane yield greater than 300 t/ha were omitted from the analyses.

To identify and understand the key factors affecting productivity in Burdekin, an exploratory data mining tool called cluster analysis was used. This method groups a set of objects in such a way that objects in the same group (cluster) are more similar to each other than to those in other groups (Tabachnick and Fidell, 2013). Prior to cluster analyses the effect of season was removed by a fixed effect in the linear mixed model.

Data from 2005-2016 for cane yield (TCH), CCS and sugar yield (TSH) at the farm level were analysed using hierarchical agglomerative clustering using Ward's method and K-means cluster analysis (Ward 1963). These clusters were then analysed to determine factors that may be influencing the yield such as cultivar performance, management and crop class, adoption of new varieties, farming practices such as fallowing and length of crop cycle, row spacing, soil type, climate zone and geographic effect.

Productivity trends

In Figure 13 are the tonnes delivered to the mill and area harvested in the Burdekin from 1990-2016. Production fluctuated from 1990-2003 and peaked at 9.2 Mt in 2011 with 79,700 hectares harvested. From 2003-2010 both the amount of tonnes delivered to the mill and area harvested declined which may have been due to low world sugar prices and associated competition for land from other crops. In 2010, the Burdekin region received 1650mm of rain which is well above the average of 1000mm with unusually high rainfall during the harvest season. This resulted in 31% of the crop being left in the field for harvest as standover in the 2011 season.

Figure 13: Tonnes delivered to the mill and area harvested in the Burdekin from 1990-2016.

Figure 14 contains cane yield, CCS and sugar yield trends for the Burdekin mills from 1990-2016. During this period averages of 114 t/ha cane yield, 14.7 CCS and 16.8 t/ha sugar yield were obtained. Notable events during the period that affected cane yield included cyclone Aivu in 1989 and the high rainfall in 1990 and 1991 which resulted in lower yields in 1990 and 1991. The orange rust epidemic in 2000 and 2001 and high rainfall in 2000 resulted in severe losses in the variety Q124 (11% of the crop) and the subsequent high proportion of plant cane in 2002 and 2003 when Q124 was rapidly replaced. The smut incursion in Queensland in 2006 and its arrival in the Burdekin in 2008 had little effect on the Burdekin crop because it fortunately had a high percentage of intermediate to resistant varieties. The unseasonably high rainfall during the harvest season in 2010 that resulted in 31% of the crop being left unharvested was associated with an increase in average cane yield in that season as growers selectively harvested higher yielding plant and early ratoon crops and stood over older ratoons. CCS was low in 2010 because of the high rainfall during the harvest season and in 2011 because of the poor-quality standover crops. The abnormal years and the flow on effects of the recovery from these years make interpretation of long-term trends difficult. In many of the analyses conducted in this study, we excluded or avoided the abnormal seasons 2010 and 2011 (Figure 15). Since 2013, both cane and sugar yield have increased and this is possibly due the very dry conditions where below average rainfall (1031mm) was obtained (Figure 15). Since 2013 there has been a small decline in CCS which is of concern to many growers.

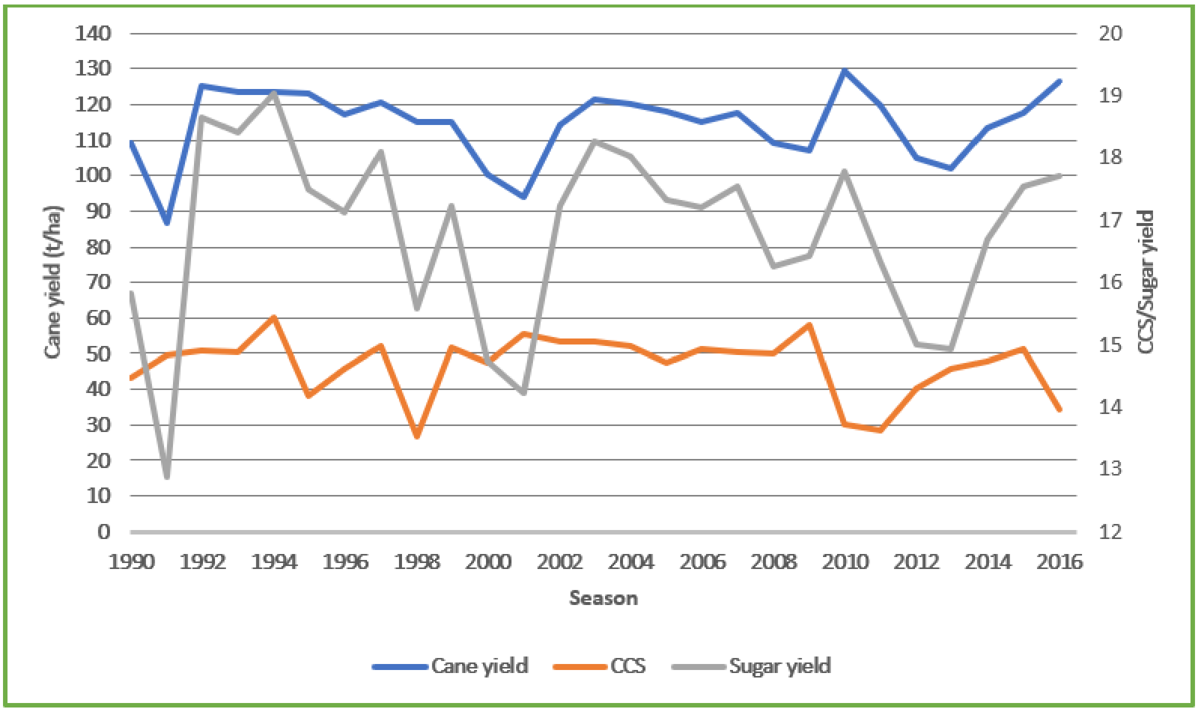


Figure 14: Burdekin cane yield, CCS and sugar yields from 1990-2016.

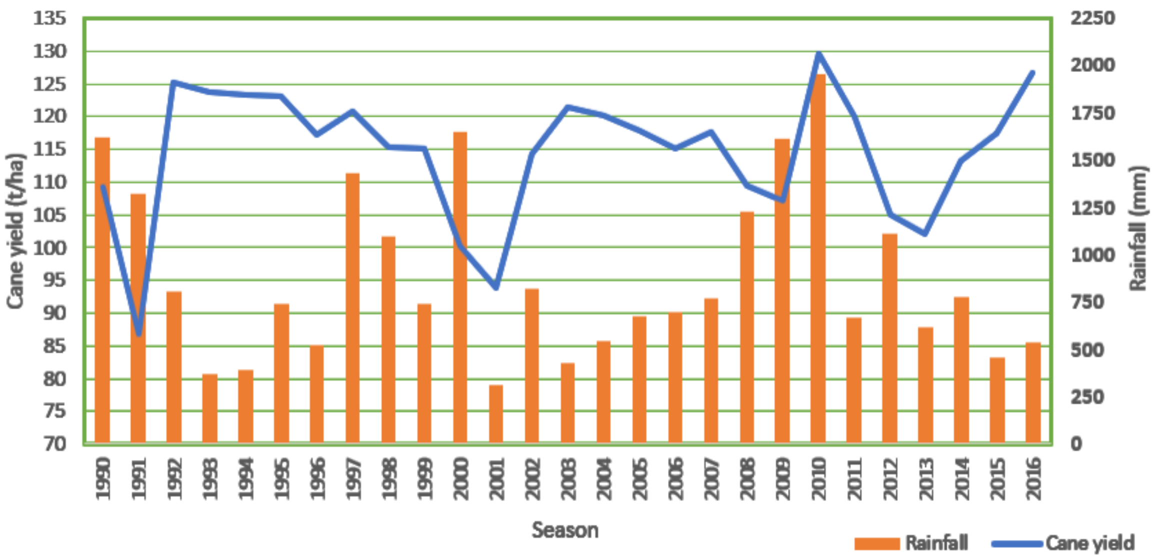


Figure 15: Burdekin cane yield and rainfall from 1990-2016.

Cluster analysis at farm level

TCH

The eight different clusters identified by our analyses are distinguished by different colours and are plotted with Farm size (ha) on the x axis and cane yield (tonnes cane/ha = TCH) on the y axis (Figure 16). Each circle represents a Farm and the industry target is represented by the blue dotted line which is 125 t/ha for TCH. Each colour represents a different cluster, for example the “royal blue” cluster contains the small-sized high producing Farms while the “red” cluster contains the small-sized low producing Farms. To aid in interpretation, the colours for each cluster identified by the analysis of TCH are consistent across the cluster plots (Figure 16).

Small-sized farms in clusters 1 and 2 contain both the highest and lowest yielding farms in the region. The small-sized farms in Cluster 2 which represent 11% of the total area had yields on average 21% lower (100.6 TCH) than the similar sized farms in cluster 1 (127.7 TCH). In Table 1 the average TCH, CCS, TSH, Ha and the number of Farms in each cluster and the percentage area represented by each cluster for clusters based on TCH and size of Farm. Clusters 7 and 8 which included a small number of very large farms have been removed to protect the privacy of the growers.

Cluster 4 (average Farm size 146 ha, average yield 115.3 TCH) had Farms with a wide range of yields from 77 TCH to 149 TCH. Cluster 4 represented 27% of the total area. Cluster 5 (average Farm size 286 ha, 8% of total area) had the second lowest average yield of 106.7 TCH. Cluster 6 (average Farm size 531 ha, 6% of total area) had an average yield of 113.8 TCH. Together these three clusters represent 41% of the total area but only 17% of the number of Farms. Figure 17 shows the distribution of yield classes within these three clusters. Extension to raise the productivity of the below average performing Farms within these clusters may be a better investment in extension because improving yield in a relatively small number of Farms would have a relatively larger impact on productivity in the region.

The industry of 125 TCH would appear ambitious but achievable if specific extension programs for growers, particularly in clusters 2, 4, 5 and 6, can lift their production closer to the growers in cluster 1.

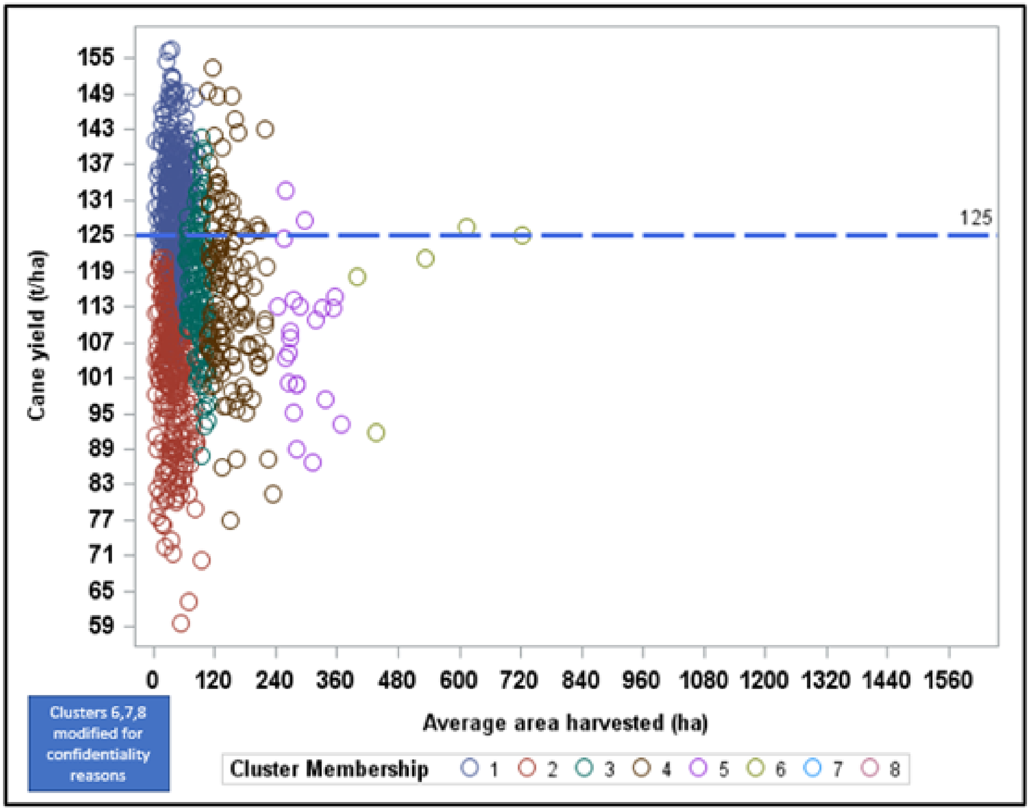


Figure 16: Cluster plot of TCH vs area harvested at the Farm level in Burdekin mill area: 2005-2016. The industry target of 125 t/ha is indicated on the graph.

Table 1: Clusters based on TCH and size of Farm. The average TCH, CCS, TSH, Ha for each cluster is shown and the number of Farms in each cluster and the percentage area represented by each cluster. Clusters 7 and 8 have been removed.

TCH Cluster	Av.TCH	Av.CCS	Av.TSH	Av.Ha	Count Farms	% Total ha

1	127.7	14.3	18.2	41.4	360	23
2	100.6	14.4	14.5	36.8	203	11
3	116.5	14.6	17.0	87.4	139	18
4	115.3	14.6	16.7	146.3	122	27
5	106.7	14.7	15.7	286.1	19	8
6	113.8	14.6	16.6	530.9	8	6
Average All	**117.0**	**14.4**	**16.8**	**77.2**	**854**	**100**

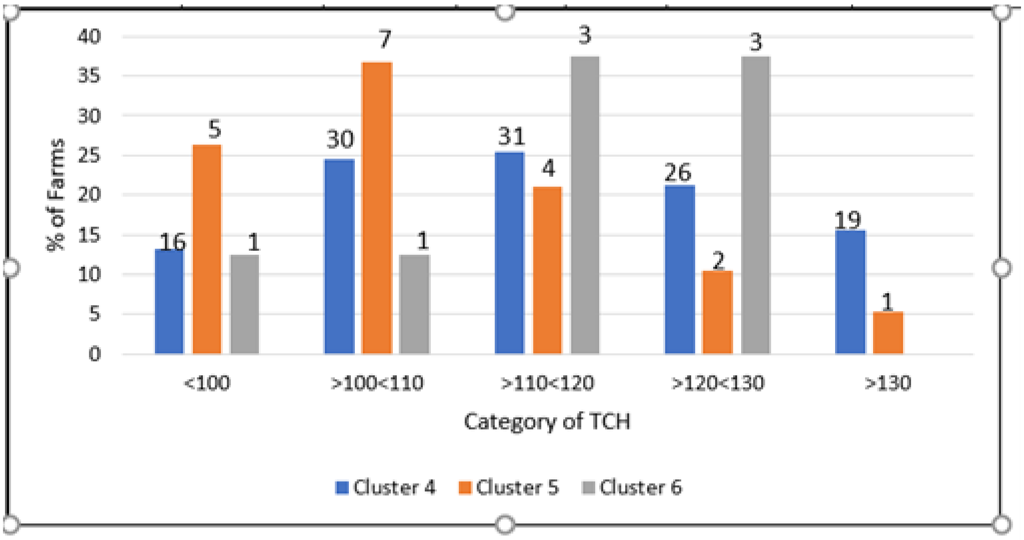


Figure 17: Distribution of yield categories in TCH clusters 4, 5 and 6.

CCS

The cluster analysis for CCS showed that cluster 1 had 7% higher CCS on average than cluster 2 over the period 2005 to 2016 (Table 2). The relative spread of CCS between Farms was not as great as the spread in TCH. The industry target for CCS of 15.5 would appear to be ambitious as only a small number of Farms achieved the target and it would require a significant improvement in nearly all Farms to reach the target.

To aid in interpretation the colours for each cluster undertaken on CCS are consistent across the cluster plot (Figure 18).

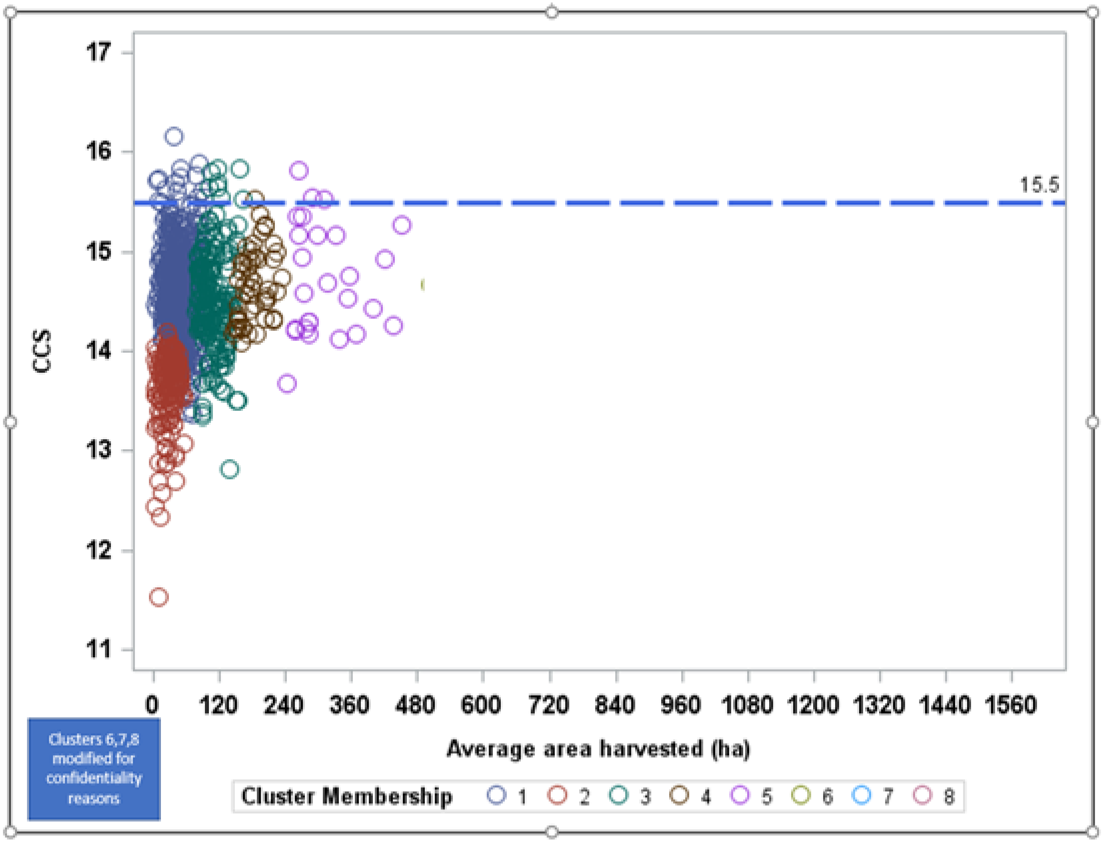


Figure 18: Cluster plot of CCS vs area harvested at the Farm level in Burdekin mill area: 2005-2016. The industry target of 15.5 is indicated on the graph.

Table 2: Clusters based on CCS and size of Farm. The average TCH, CCS, TSH, Ha for each cluster is shown and the number of Farms in each cluster and the percentage area represented by each cluster. Clusters 7 and 8 have been removed.

CCS Cluster	Av.TCH	Av.CCS	Av.TSH	Av.Ha	Count Farms	% Total ha
1	116.6	14.6	17.0	45.9	463	32
2	121.8	13.6	16.6	28.7	139	6
3	116.8	14.5	16.9	107.3	177	29
4	112.3	14.7	16.5	181.1	45	12
5	106.6	14.7	15.6	304.1	22	10
6	118.7	14.7	17.4	598.6	5	5
Average All	**117.0**	**14.4**	**16.8**	**77.2**	**854**	**100**

As shown in Figure 19 the Burdekin has 40 productivity zones and 5 subdistricts.

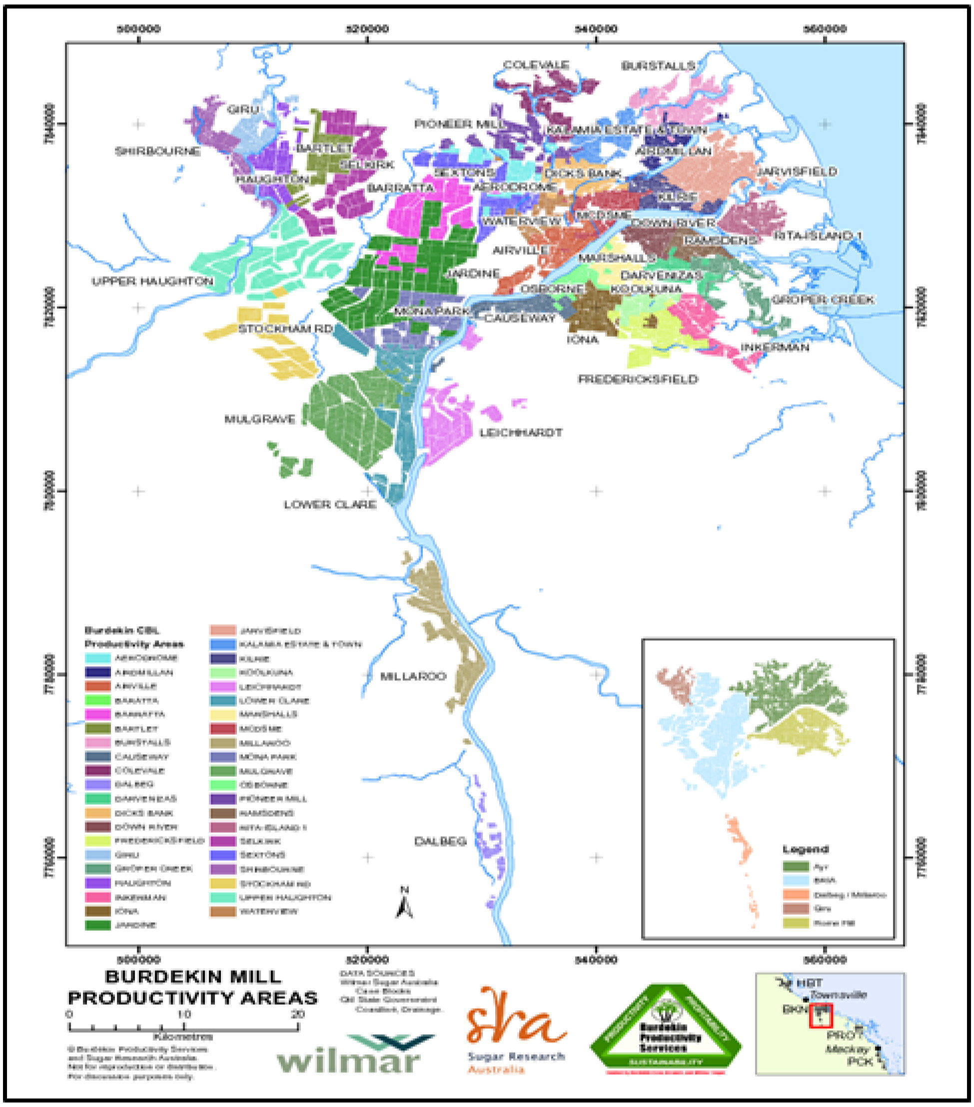


Figure 19: Burdekin productivity zones and subdistricts.

Examination of Figure 19 shows that many of the small-sized low CCS farms are in the Ayr and Home Hill subdistricts particularly along the banks of the Burdekin River. Farms in these localities also have the highest TCH and highly fertile and productive soils. The Giru subdistrict has a higher proportion of low CCS Farms. The BRIA and Dalbeg/Millaroo subdistricts have very few small farms with low CCS and the majority of the Farms in this subdistrict fall within the average to above average CCS categories.

TSH

The cluster analysis for TSH gave a similar spread and distribution plot (Figure 20) to the analysis for TCH. This is not to be unexpected because TCH is one of the components of TSH. The industry target of 19 TSH is on the upper end of the distribution and more than 2/3 of the Farms would need to significantly improve to reach the target.

To aid in interpretation the colours for each cluster undertaken on TSH are consistent across the cluster plot (Figure 20).

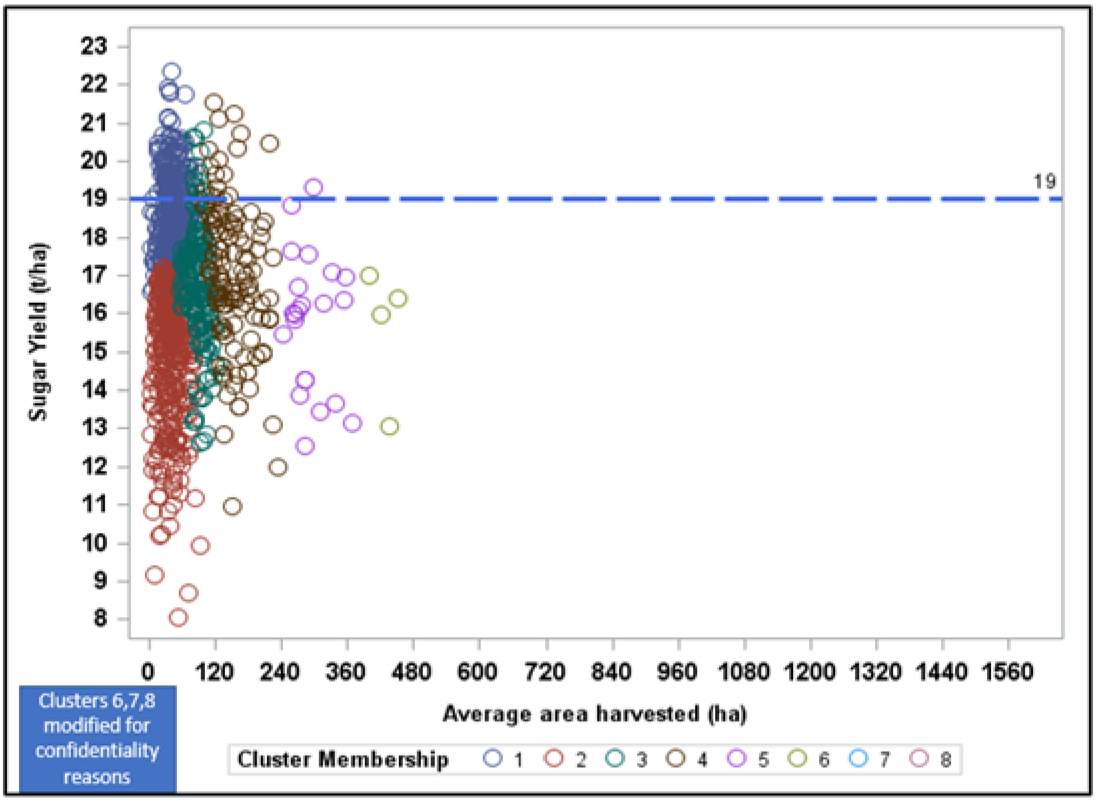


Figure 20: Cluster plot of sugar yield vs area harvested at the Farm level in Burdekin mill area: 2005-2016. The industry target of 19 t/ha is indicated on the graph.

Table 3: Clusters based on TSH and size of Farm. The average TCH, CCS, TSH, Ha for each cluster is shown and the number of Farms in each cluster and the percentage area represented by each cluster. Clusters 7 and 8 have been removed.

CCS Cluster	Av.TCH	Av.CCS	Av.TSH	Av.Ha	Count Farms	% total ha
1	129.8	14.4	18.6	40.9	307	19
2	103.2	14.3	14.7	37.4	248	14
3	115.6	14.6	16.8	88.9	162	22
4	116.8	14.6	17.0	150.6	107	24
5	106.7	14.7	15.7	286.1	19	8
6	113.8	14.6	16.6	530.9	8	6
Average All	**117.0**	**14.4**	**16.8**	**77.2**	**854**	**100**

The distribution of clusters for TSH are like the clusters for TCH with many of the small-sized high producing farms in the Ayr and Home Hill subdistricts.

Clusters 4, 5, 6 and 7 are generally located in the BRIA/Giru/Dalbeg/Millaroo. Giru subdistrict has some small low TSH farms. The BRIA has predominantly average to above average TSH Farms. The below average production areas are predominantly around the outer limits of the production areas which tend to be dominated by poorer soils. The map of Burdekin soil types is shown in Figure 21. Below average production generally occurs on soils classed as sand or loam whereas average to above average TSH is generally associated with sodic clay soils.

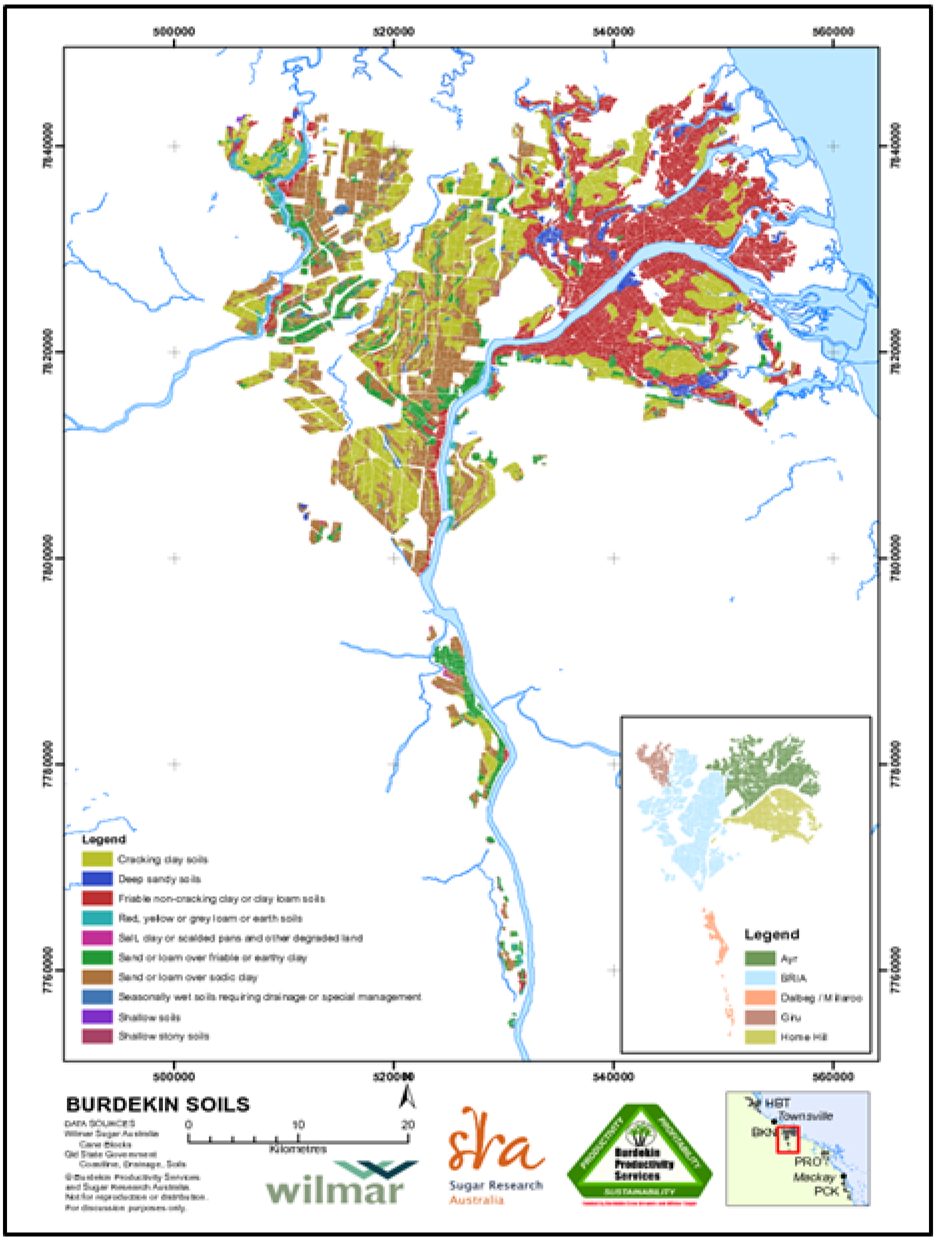


Figure 21: Burdekin soils map.

Table 4 shows the number of Farms in common between each of the eight TCH and CCS clusters. There were 47 Farms (5.5% of total) in clusters 2 for both TCH and CCS. These similar sized farms have lower TCH and CCS. Almost three quarters of Farms in TCH cluster 1 (266 Farms) were also in CCS cluster 1. These Farms are outperforming other Farms for both TCH and CCS. There is no evidence of a negative correlation between TCH and CCS.

Table 4: Number of farms in common between the different clusters obtained from analysis of TCH and CCS at the Farm level.

	CCS clusters							
TCH clusters	1	2	3	4	5	6	7	8
1	266	92	2					
2	154	47	2					
3	43		96					
4			77	45				
5					19			
6					3	5		
7							2	
8								1

Subdistricts and Productivity Zones

Table 5 shows that many of the small-sized high producing farms in terms of cane yields are in the Ayr and Home Hill subdistricts which is also known as the Delta. Further examination of the data reveals that 82 % of the high performing farms for TCH are in the Delta. These subdistricts predominantly have high infiltration soils and are friable non-cracking clay or clay loams (Figure 24). However, some of the soils in the Delta are saline or sodic soils that can restrict cane and sugar yield performance e.g. cluster 2 (red) for cane yield.

Table 5: Percentage membership for clusters 1 and 2 for TCH, CCS and TSH in the Burdekin. Cluster 1 contains the small-sized high producing Farms and Cluster 2 contains the small-sized low producing Farms for TCH.

		Percentage cluster membership by sub-district				
Variable	Cluster	Ayr	BRIA	Dalbeg/Millaroo	Giru	Home Hill
Cane yield (t/ha)	1	41.9	9.8	2.2	1.1	44.9
	2	39.7	16	7.7	5.8	30.8
CCS	1	35.3	17	3.2	1.4	43.1
	2	42.8	7.7	4.1	4.1	41.3
Sugar yield (t/ha)	1	38.7	5.5	1.1	0	54.7
	2	37.9	18.3	6	5.5	32.3

Table 6 gives the average TCH and proportion of Farms in each of the subdistricts for clusters 4-7. The highest proportion of Farms for each of these clusters are located in BRIA subdistrict. In cluster 6, 25% of the Farms are located in the Dalberg/Milaroo subdistrict while clusters 4 and 5 also have some Farms in Giru. These subdistricts generally have yields below the Burdekin average but neighbouring farms with yields at or above the Burdekin average do occur in these subdistricts which shows there is potential for improvement in the below average farms. In the BRIA, many of the soils are cracking clays and are prone to waterlogging. Hence, cane yields are generally lower than in the Delta.

Table 6: Average TCH and proportion of Farms in each of the subdistricts for clusters 4-7.

Cluster	Average TCH	Ayr	BRIA	Dalbeg/Millaroo	Giru	Home Hill
4	115.3	32.8	53.3	0.8	5.7	7.4
5	106.7	21.1	68.4	0.0	5.3	5.3
6	113.8	12.5	62.5	25.0	0.0	0.0
7	102.8	0.0	100.0	0.0	0.0	0.0

The percentage membership for cluster 1 and 2 was compared across productivity zones using different parameters to those reported in milestone 5. Productivity zones which have greater than 5% of their Farms in cluster 1 and 2 for TCH and CCS are shown in Table 7 and Table 8. The negative relationship between TCH and CCS in some productivity zones is shown by Down River and Marshall Productivity zones that have greater than 5% of farms in the high TCH cluster 1 and low CCS cluster 2 and Inkerman and Lower Clare having greater than 5% of farms in the high CCS cluster 1 and low TCH cluster 2. No Productivity zones had greater than 5% of their farms in the high yielding cluster 1 for both TCH and CCS. The Burstall productivity zone had a higher proportion of farms in low-yield cluster 2 for both TCH and CCS.

Further investigation is required to understand the reasons for the higher proportion of lower yielding farms in the subdistricts identified in cluster 2. Tailored extension plans should be conducted to try and lift the productivity of farms in these subdistricts.

Table 7: Productivity zones which have a high proportion (>5%) of their Farms in cluster 1 in the Burdekin. Cluster 1 contains the small-sized high producing Farms.

Productivity zones which have a high % of Farms in cluster 1 for TCH (> 5%)	Productivity zones which have a high % of Farms in cluster 1 for CCS (> 5%)
Down River	Colevale
Marshalls	Darvenizas
	Fredericksfield
	Inkerman
	Iona
	Jarvisfield
	Lower Clare

Table 8: Productivity zones which had have a high proportion (>5%) of their Farms in cluster 2 in the Burdekin. Cluster 2 contains the small-sized low producing Farms.

Productivity zones which have a high % of Farms in cluster 2 for TCH (>5%)	Productivity zones which have a high % of Farms in cluster 2 for CCS (> 5%)
Inkerman	Airville
Lower Clare	Burstalls
Millaroo	Causeway
Burstalls	Down River
	Marshalls
	MCDSME
	Osborne
	Ramsdens

Detailed analyses were conducted for each Productivity Zone to look for trends over years in average TCH, CCS and TSH (Appendix 1,2 and 3).

Appendix 1.pdf Appendix 2.pdf Appendix 3.pdf

There were no obvious trends for TCH but a few Productivity zones had possible downward trends for CCS and TSH. However, the downward trends were confused by the low CCS and TSH in 2010 and 2011, associated with above average rainfall and standover crops. CCS and TSH in these Productivity zones should be watched over coming seasons to see if this is a consistent trend or an anomaly caused by seasonal variation.

Comparison of adoption of “new” vs “old” varieties

A detailed analysis was conducted of the adoption of new varieties in each of the TCH clusters (Table 9). The proportion of each of the major varieties grown within clusters 1 and 2 was also examined (Figure 22). New varieties were defined as varieties that were released within the last 5 years, current varieties were varieties currently on the recommended variety list that have been grown for more than 5 years and old varieties were not currently recommended. Varieties consigned as Other, Mixed or had very low tonnes were omitted. There were no obvious differences between TCH clusters in the proportion of new, current and old varieties. Cluster 2 (small - low TCH) had 4% more current varieties and 4% less old varieties than cluster 1 (small – high TCH) but this difference is relatively small. The dominance of the three major varieties, Q183, Q208 and KQ228, masked any differences in the other categories.

Table 9: Comparison of new, current and old varieties for TCH clusters 1 to 6 in the Burdekin.

TCH Cluster	New	Current	Old
1	2	83.9	14.1
2	1.8	87.9	10.3
3	1.9	85.5	12.6
4	2.2	88.5	9.3
5	1.9	88	10.1
6	2.2	89.7	8.2

The proportion of the three major varieties, Q183, Q208 and KQ228 in TCH clusters 1 and 2 was examined (Figure 22). A similar proportion of KQ228 was grown by farms in clusters 1 and 2 but cluster 1 had a higher proportion of Q183 and lower proportion of Q208 than cluster 2. These differences may be related to Q208 being more widely grown on the poorer soil types than Q183.

Figure 22: Proportion of the three major varieties grown by farms in TCH clusters 1 (small- sized high TCH) and 2 (small-sized low TCH).

Crop ratoon age

Clusters 1 and 2 for TCH were also compared in terms of age of their ratoon crops (Table 10). Young crops were defined as any crop class up to 3R and included 3R plough-out replant. Old crops were defined as any crop class 3R or older. Standover cane was not included. There was very little difference in the proportion of young or old crops between the clusters 1 and 2 for TCH (Table 10).

Table 10: Comparison of young and old crops for TCH clusters 1 and 2. Cluster 1 contains the small-sized high producing Farms and Cluster 2 contains the small-sized low producing Farms.

Cluster No	Proportion of young crops (%)	Proportion of old crops (%)
1	66.6	33.4
2	65.9	34.1

Planting time

In the Burdekin, planting extends from February-March through to September-October. Early plant is defined as blocks planted before May, Plant is defined as blocks planted between May and July and Late plant is defined as blocks planted after July. Cluster 1 had 6% more Early plant than cluster 2 and 7% less Late plant (Figure 23). Early plant can out yield Late plant by more than 20% and could be a significant contributing factor in the lower yield of cluster 2. The reason why cluster 2 has more late plant and less early plant should be further investigated.

Figure 23: Proportion of the three planting times for farms in TCH clusters 1 (small-sized high TCH) and 2 (small-sized low TCH) in the Burdekin.

Climate Zones

Climatic conditions are known to impact sugarcane yields differently from region to region within Australia. Recent research has focused on identifying sub-regional 'climate zones' to help improve nitrogen fertilizer recommendations within Australia (Sexton *et al*. 2017). The objective of this study was to identify sub-regions within the Burdekin mill area based on climatological attributes and to use this information for variety recommendations. Daily rainfall, radiation and temperature data were obtained on a 0.05 by 0.05 decimal degree grid (approximately 5 km by 5 km) for sugarcane-growing areas within the Burdekin mill region. For each grid cell, seasonal and annual mean temperature (maximum and minimum) and radiation were calculated using data from the period 1975 to 2017. Mean total seasonal and annual rainfall were also calculated for each grid cell. A K-means clustering algorithm was then used to cluster these grid cells into distinct sub-regions based on seasonal or annual climate data.

In the Burdekin region, spatial patterns of temperature and rainfall are also relatively stable between seasons, exhibiting a north-south gradient. Radiation tends to have a more east-west gradient with higher radiation to the east during spring and summer and higher radiation to the west during autumn and winter.

Two distinct sub-regions were identified based on all seasonal rainfall totals and seasonal average daily radiation and temperature data (Figure 24). These sub-regions were identified as:

1. The North-Eastern sub-region (green shading in map)
2. The South-Western sub-region (red shading in map)

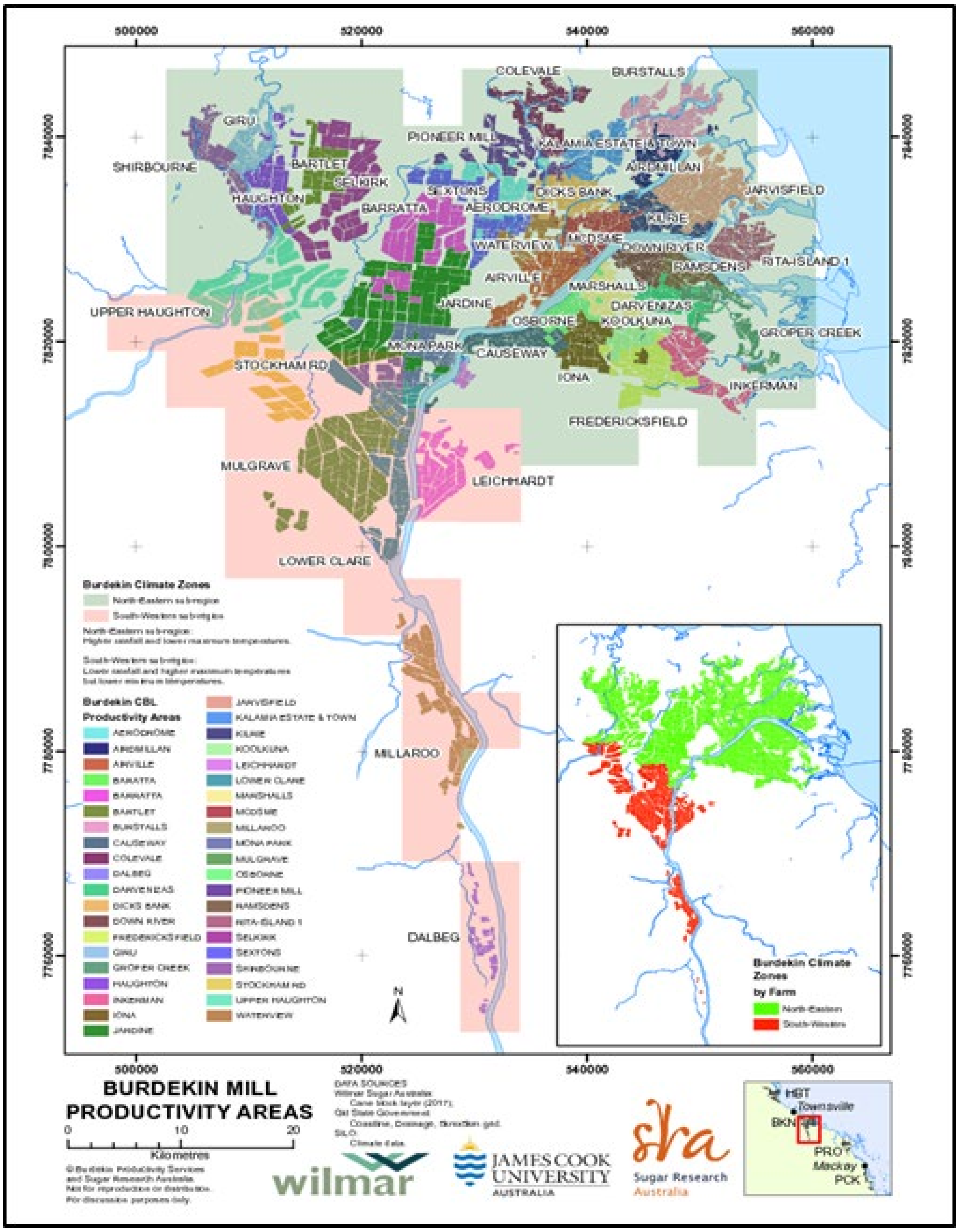


Figure 24: A map of the Burdekin mill area with sub-regional climate zones. The North-Eastern sub-region (green) tended towards higher rainfall and lower maximum temperatures. The South-Western (red) sub-region tended toward lower rainfall and higher maximum temperatures but lower minimum temperatures. Radiation did not vary greatly between sub-regions.

The objective of this study was to identify climatological zones or sub-regions within the Burdekin milling region. Two sub-regions were identified. In contrast to previous research in the Tully region and Herbert region, the climatic sub-regions were not as clearly determined by rainfall and radiation data. Discussions were held with variety and agronomy staff in SRA and other industry agronomists to determine if the sub-regions could be used to tailor management or variety decisions.

Soil Health

Percent of one variety

Planting a mix of varieties is a policy to restrict build-up of pathogens or diseases that become adapted to one variety. It is also probably an indicator of progressive growers who manage varieties actively on their farms. To determine whether planting a mix of varieties is associated with higher yields on farms, the period 2012 to 2017 was studied and the maximum percent of any one variety on each Farm in each year and the average maximum percent for the Farms over the period were calculated. The average maximum percent of any one variety was related to the average TCH for each Farm (Figure 25 and Figure 26).

There was a trend for average TCH to reduce as maximum percent of any one variety increased. The difference was about 7 TCH between Farms with less than 40% of any one variety and Farms with >80% of any one variety. There was obviously wide variation about this general trend but the data would support maintaining a mix of varieties on a farm.

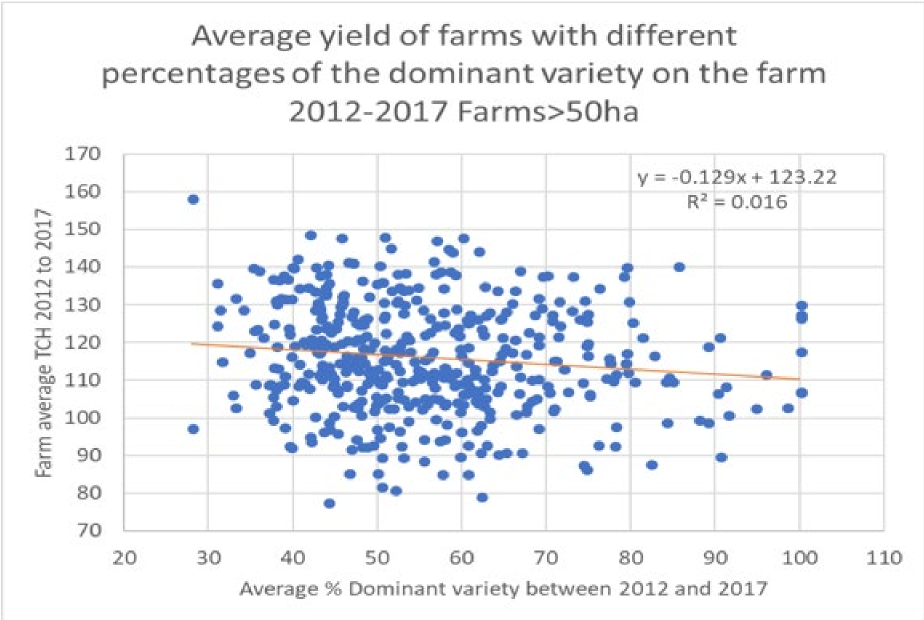


Figure 25: Relationship between Farm average TCH for the years 2012 to 2017 and average maximum percent of any one variety over the same period for each Farm.

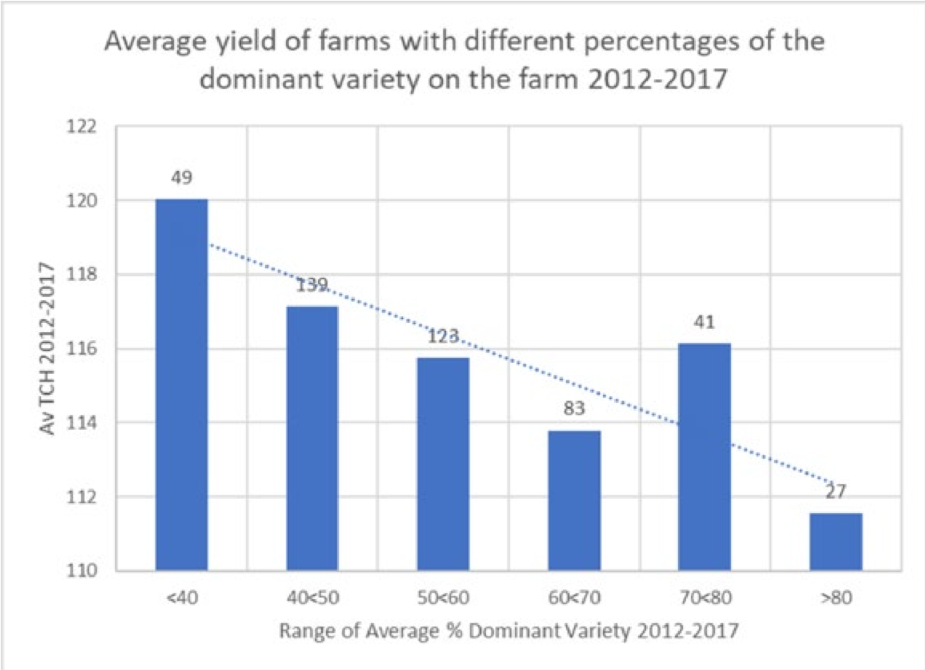


Figure 26: Relationship between Farm average TCH for the years 2012 to 2017 and average maximum percent of any one variety grouped in ranges from 40% to >80% over the same period for each Farm.

Effect of previous variety on current crop

Sugarcane in most areas of Australia is grown as monoculture (continual cultivation of the same crop species) with only short breaks every 4-6 years. Monoculture is associated with a build of soil-borne pathogens that leads to reduced yields in nearly all crops. The traditional method to reduce the effects of monoculture is to rotate different species or fallow fields for extended periods. Repeated planting of a single variety of the one species is an extreme example of monoculture and could potentially favour pathogens adapt to that one variety of that species. In other sugarcane districts in Australia, Pachymetra root rot has been shown to build up under susceptible and some intermediate resistant varieties and is associated with reduced yields if the susceptible or intermediate resistant varieties are continuously grown (Magarey *et al.,* 2003). Pachymetra is currently not widespread in the Burdekin but the same phenomenon seen with Pachymetra could apply to other soil-borne pathogens if single varieties are continuously grown. The potential for reduced yield with continual cultivation in a block of a single variety was investigated and preliminary results were presented to industry groups. They requested that this analysis be extended and that the effect be examined for subdistrict and soil types. The average $/ha for plant blocks in a given year were followed across plant and first ratoon crops for the four years from 2013 to 2016. Blocks were grouped on the combinations of previous variety planted in each block and the current variety in the block. Only the three major varieties, Q183, Q208 and KQ228 were included. The difference between means were statistically analysed with a t-test for groups with uneven variances. Comparisons were simplified for presentation to growers.

Two methods were examined:

- Method 1. Average TCH for all plant blocks in a given year were followed across a crop cycle and paddocks were grouped on the combinations of previous variety planted in each paddock and the current variety in the paddock. Only the three major varieties, Q183, Q208 and KQ228 were included.
- Method 2. Average TCH for all paddocks in one year were examined and the variety planted in the previous crop cycle and the current variety were recorded by looking back over previous years.

Two years were analysed with method 1, 2013 and 2014. The plant crops in these years were followed through to harvests in 2016 and 2017, respectively. The results were averaged for the two sets of analyses and are contained in Figure 27.

With method 1, all varieties appeared to perform better if they were planted after Q183 than if they were planted after KQ228 or Q208. Q208 and KQ228 performed worse if they were planted after themselves compared with when they were planted after another variety.

Three years were examined with method 2, 2013, 2016 and 2017. The results were average for the three sets of data. The responses were similar but the benefit of planting after Q183 was not as great as with method 1 (Figure

28). Q208 and KQ228 were worse if they were planted after themselves than if they were planted after another variety.

This data would support the recommendation that it is better to rotate varieties to minimise build-up of soil pathogens and other diseases adapted to individual varieties. Sugarcane is grown basically as a monoculture which is ideal for build-up of soil pathogens. Planting the same variety is monoculture of a single genetic entity which is an extreme case of monoculture. Rotating varieties with different genetic backgrounds is recommended to partially alleviate the build-up of pathogens.

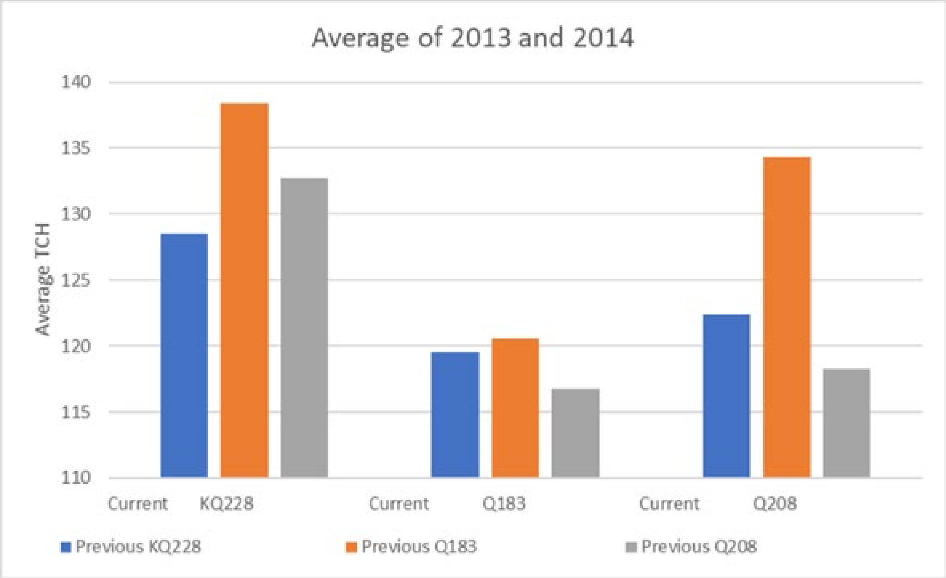


Figure 27: Method 1. Effect of previous variety on crops of the current variety for paddocks planted in 2013 and 2014.

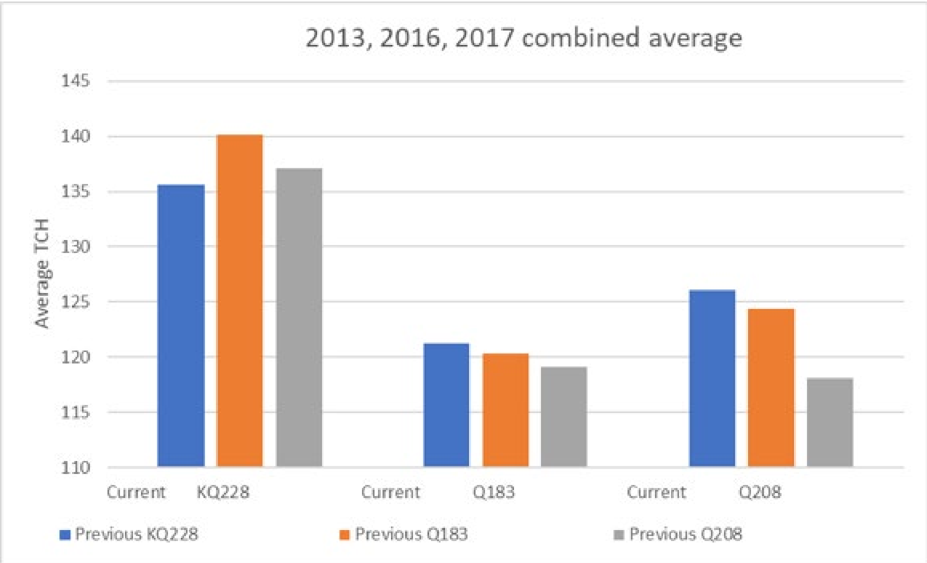


Figure 28: Method 2. Effect of previous variety on crops of the current variety for paddocks planted in 2013, 2016 and 2017.

Fallow versus replant

Two methods were used to investigate the effect of fallow plant versus replant on TCH throughout a crop cycle. The methods were:

- Method 1. Examine the TCH of individual paddocks planted after a fallow period compared to paddocks planted with no fallow (Replant) from plant crop to third ratoon.
- Method 2. Examine the TCH of all paddocks harvested in one year and determine their history by looking back to whether they were originally planted after a fallow or replant and averaging the yield of the paddocks in the different crop classes for each category.

The average TCH for crops planted after a fallow and re-planted with no fallow for the 2013 and 2014 planting seasons are shown in Figure 29 (Method 1). Planting after a fallow has a significant advantage in the plant crop because fallow planting is usually conducted in the autumn whereas re-plant can only be done in the spring. Fallow planted crops had a small advantage in first ratoon and second 2 ratoon crops but no advantage by third ratoon. All fallow planted blocks were still present as third ratoon but 12% of re-plant paddocks were not harvested as third ratoon (ploughed out).

Comparison of fallow and re-plant with method 2 showed a similar advantage for fallow plant over re-planting in the plant crop but no advantage in first, second or third ratoon (Figure 30).

In the short term, fallowing does not appear to have a significant advantage over re-planting in the Burdekin. Longer term studies would be required to determine if fallow has a benefit.

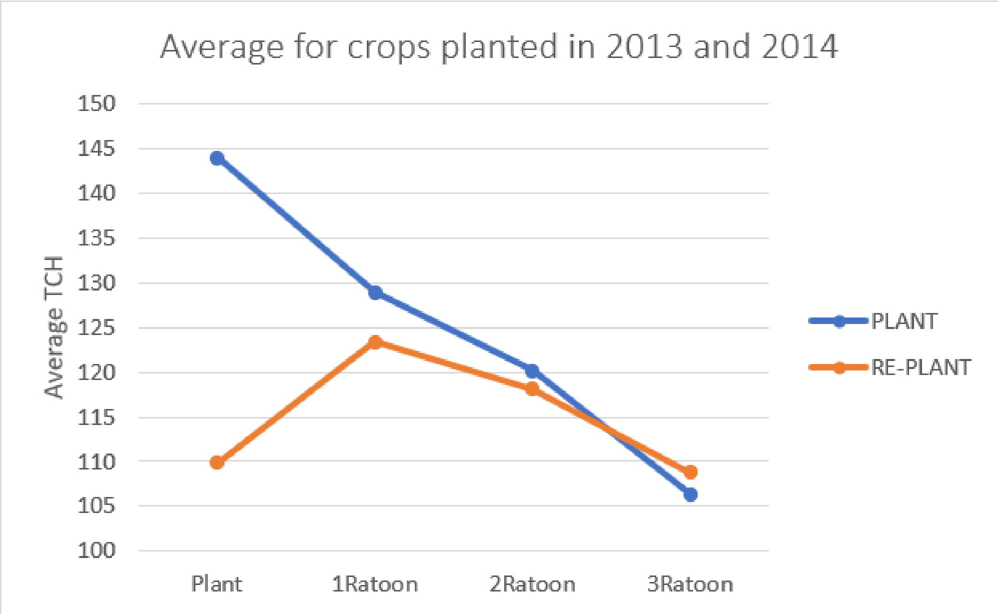


Figure 29: Method 1. Average TCH for crops planted in 2013 and 2014 after a fallow or re-planted with no fallow period.

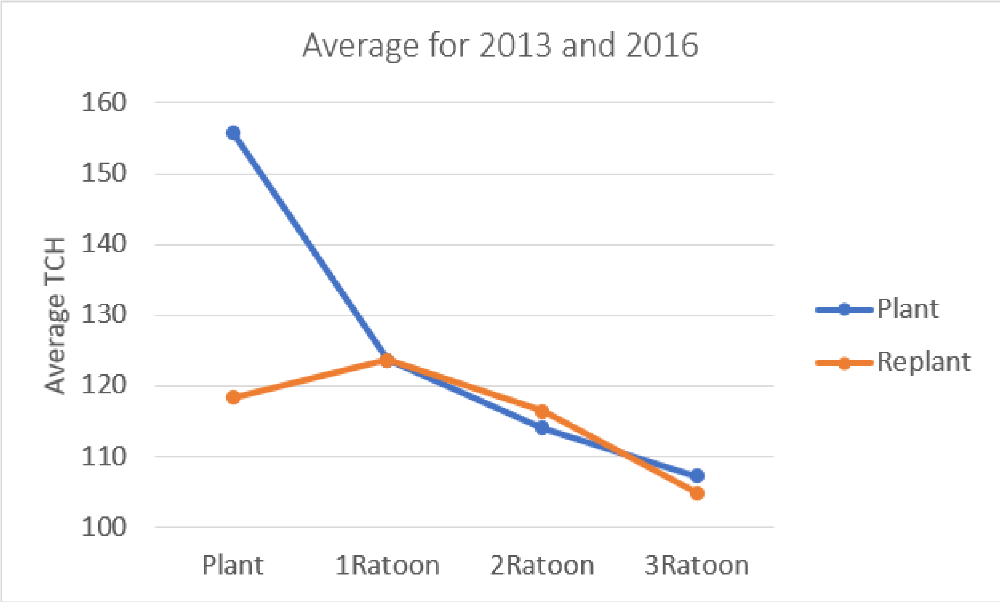


Figure 30: Method 2. Average TCH for crops in 2013 and 2016 that were planted after a fallow or were re-planted with no fallow period.

Harvester contract size

Data on size of harvesting contractors were analysed to determine if there is a relationship between size of contract and TCH. Harvesting contractors were grouped into four categories depending on size:

- Small– less than 80,000 t
- Medium: > 80,000t and < 100,000 t
- Big: > 100,000t and < 120,000 t
- Very big: > 120,000 t

The proportion of Farms in each category from 2005-2017 is given in Figure 31.

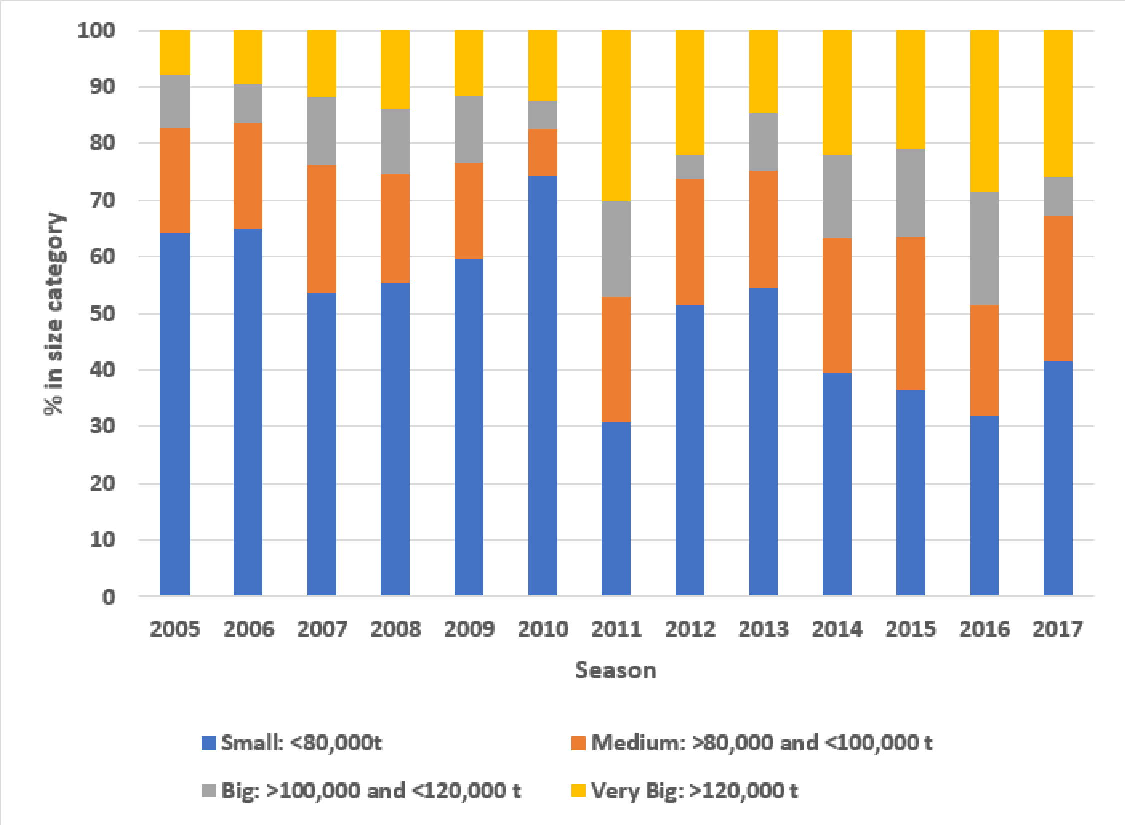
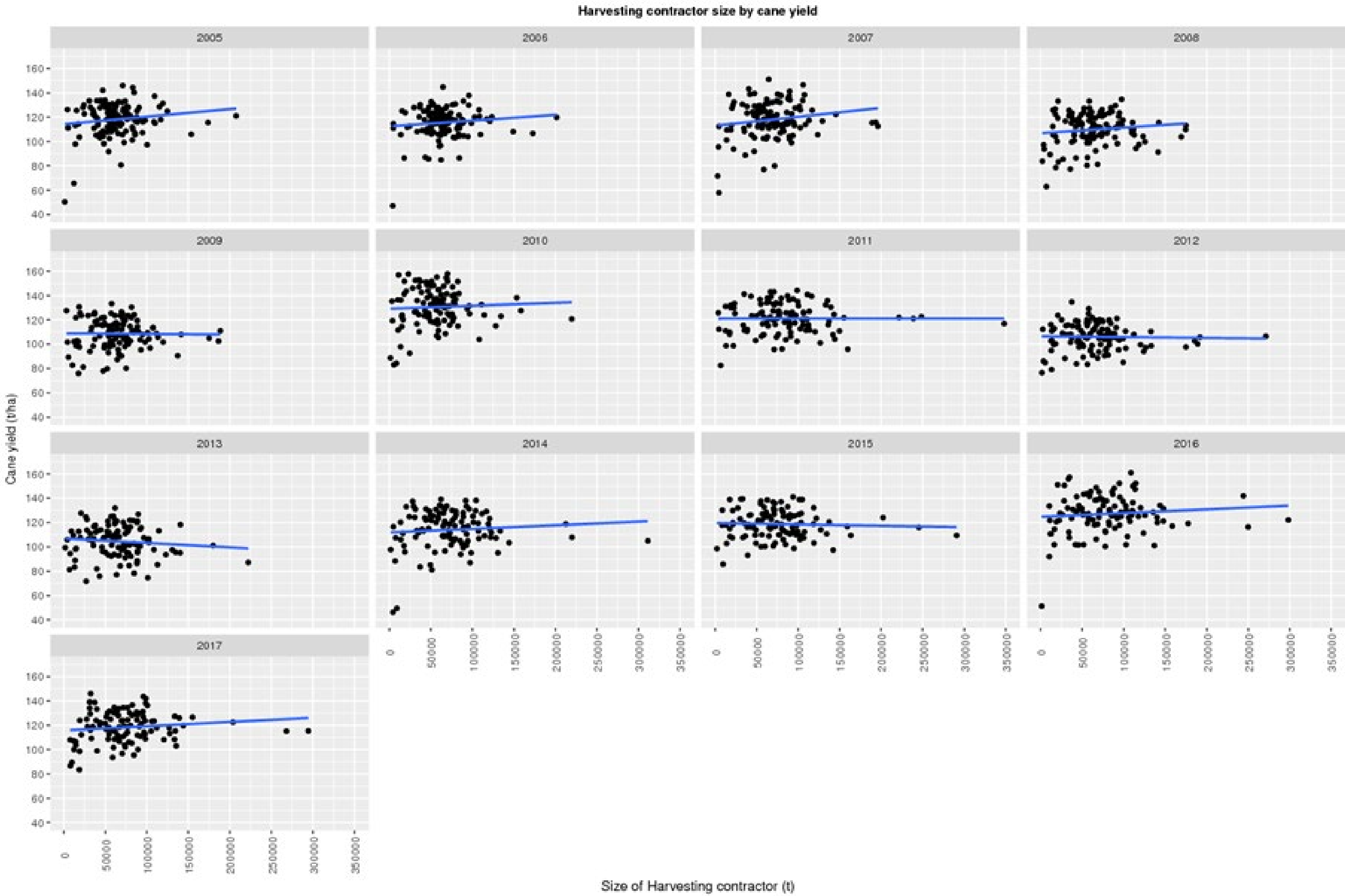


Figure 31: The proportion of Small, Medium, Big and Very Big harvesting contractors based on tonnes harvested from 2005-2017 in the Burdekin.

In 2005 there were 134 harvesting contractors in the Burdekin and by 2017 this had decreased to 109. During the same period the number of small-sized harvesting contractors decreased from 64% to 42% while there was an increase in the very big sized group from 8-26%.

An analysis was conducted to examine if there was any relationship between harvester contract size and TCH. For each season from 2005-2017 the average TCH was plotted against the harvester contract size. There was no obvious relationship between contractor size and cane yield (Figure 32).



Harvesting contractor size by cane yield
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Cane yield (t/ha)
Size of Harvesting contractor (t)

Ratoon Index

A ratoon index based on hectares harvested in ratoons was calculated for each Productivity Zone from 2005-2017 (Figure 33). In this period the mean ratoon index was 2.4 while the median which represents 50% of the values is 2.3. The following Productivity Zones had average number of ratoons greater than 2.5: Bartlett, Selkirk, Sextons, Upper Haughton, Kalamia Estate and Town, Lower Clare, Jardine, Dicks Bank and Dalbeg while Ramsdens, Leichardt and Frederickfield had an average of only 2.2 number of ratoons.

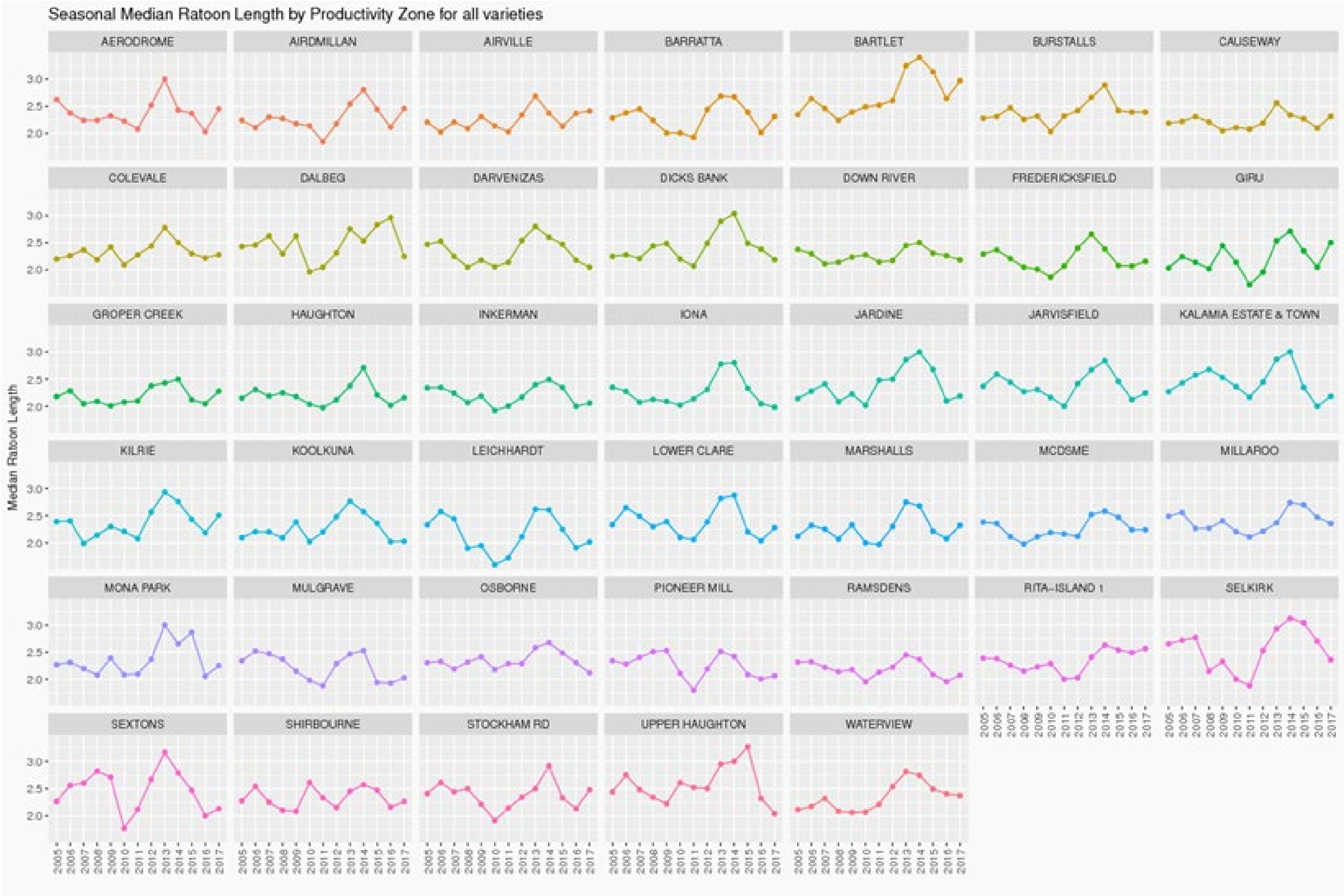


Figure 33: Seasonal Median Ratoon Length by Productivity zone for all varieties.

CCS Variation

To examine CCS variation at the Farm level, all data from 2005 to 2017 was used except for where a rake had a CCS < 8. For each season all the PayCCS records within a Farm were used to calculate the coefficient of variation:

Coefficient of variation (CV) = 100* Standard deviation / mean.

The coefficients were summarised by grouping:

- Season and CCS Clusters for the mean coefficients, coefficients at 25% or 75% percentile.
- Season, similar to above however no cluster was considered.

The results for each season are contained in Figure 34.

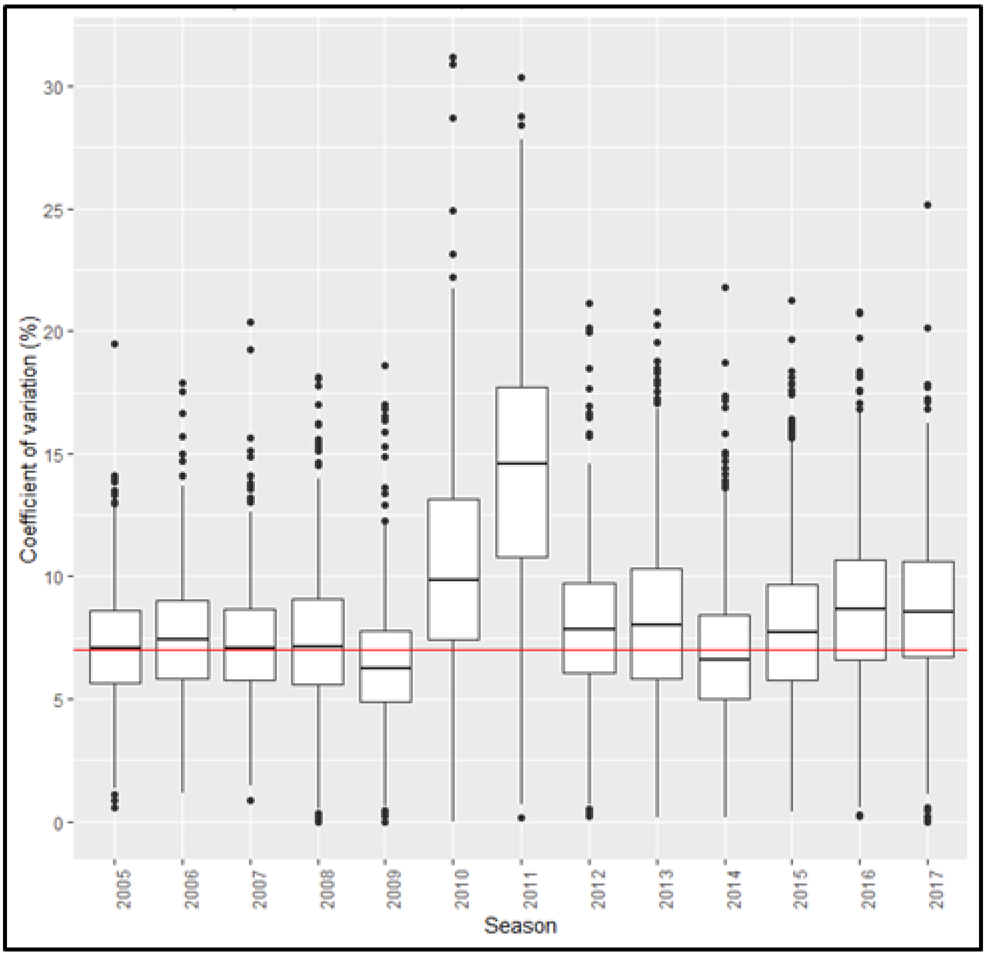


Figure 34: Variation in PayCCS within a Farm from 2005-2017 in the Burdekin.

In 2005 the CV was 7% while in 2017 it was 8.5%. In 2010, 1956mm of rain were received in the Burdekin which resulted in a large standover crop in 2011. The CVs for PayCCS in these two seasons are particularly high with values of 10 and 14% being recorded (Table 11). If we look at the 75% percentile the CV has increased much more from 8.5% in 2005 to 10.6% in 2017.

Table 11: The number of Farms, mean coefficient of variation and 75% percentile coefficient of variation for PayCCS at Farm level from 2005-2017 in the Burdekin.

Season	No of Farms	Mean CV	75% percentile CV
2005	944	7.0	8.5
2006	925	7.4	8.9

2007	921	7.2	8.6
2008	909	7.4	9.1
2009	898	6.4	7.8
2010	894	10.2	13.1
2011	917	14.1	17.6
2012	904	7.9	9.8
2013	915	8.1	10.3
2014	909	6.8	8.4
2015	904	7.8	9.7
2016	887	8.7	10.6
2017	883	8.5	10.6

Effect of harvest date in previous season on yield in the following season

There is a real need to recognise that we are not dealing with an annual crop and management one year will affect productivity in ensuing years as shown in a number of studies in the Herbert Region (McDonald and Wood, 2001; Di Bella *et al.*, 2008). All of these studies showed that late harvesting (November/December) had a major negative effect on cane yield in the following ratoon and can result in reducing the number of ratoons in a cycle.

In this study, we examined the yield of individual blocks harvested at different dates in one season and their yield in the following season. Initial analyses for two years were presented to growers at shed meetings. After discussions with industry agronomists the analyses have been extended to include 10 years of data and, in addition to TCH and CCS, analyses were conducted for $/ha and tonnes sugar/ha (TSH). In previous analyses, the first date of harvest of a block was used as the harvest date. This is not an accurate representation of harvest date for blocks that are harvested over an extended period. To better represent harvest date, the weighted average harvest date was calculated. The weighted average harvest date is:

$$\textit{Weighted average harvest date} = (D_1{*}T_1/T_{1+2+n}) + (D_2{*}T_2/\ T_{1+2+n}) + \ldots..(D_n{*}T_n/\ T_{1+2+n})$$

Where D is the day number in year and T is the tonnes of cane harvested on that day.

A simple model was used to estimate the benefits to growers and industry of varying the tonnage harvested at different periods during a season.

The influence of harvest date in the previous season on yield of ratoon blocks in the current season was examined for the years 2006 to 2009 and 2013 to 2018. The years 2010 to 2012 were excluded because of the disruption in 2010 when persistent rain during the harvest resulted in 30% of the crop being stood-over to 2011. The disruption this caused had flow on effects into 2012. The data for the 10 years of the study were combined and average yields were calculated for blocks grouped by the different fortnights when the blocks were harvested in the previous year.

The concept of the effect of harvest date in the previous season has been difficult to explain because it looks at yield in the current season for dates of harvest in the previous year. When presenting this concept to industry staff, we found that the graph of yield of blocks in the current season for blocks harvested in different fortnights in the previous season was helpful. An example for TCH is presented in Figure 35. Figure 35 also shows the effect of age of harvest of blocks within in group. Blocks harvested in the fortnight ending the 7/12 in the previous season and before September in the following year are only 7 to 9 months of age at harvest and, because their growing season is short, their TCH is low. If harvested in the fortnight ending the 7/12 in the following year, they would be approximately 12 months of age and their yield has improved but is still well below blocks harvested earlier in the previous year. The average TCH for all blocks in the current season that were harvested in the fortnight ending the 22/6 in the previous season is shown in the legend of the graph. This figure, along with the averages for all blocks harvested in each of the other fortnight periods in the previous year, is plotted in Figure 35.

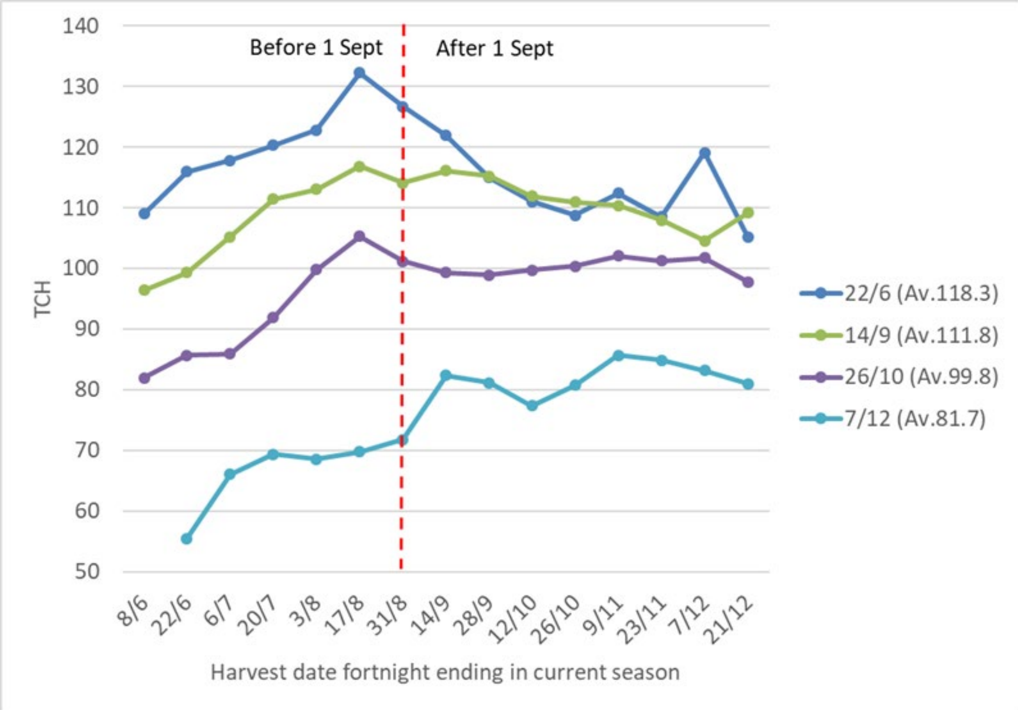


Figure 35: Average TCH in the current season for blocks harvested in fortnights ending the 22/6, 14/9, 26/10 and 7/12 in the previous season for the 10 years 2006-2009 and 2013-2018. The average of all blocks in each fortnight is shown in brackets next to the legend.

The TCH and CCS of blocks harvested in different fortnights in the previous season for the 10 years of the study are shown in Figure 36. TCH showed a decline with increasing harvest date in the previous season with the rate of decline increasing after September. CCS increased with increasing harvest date in the previous season up until mid-November and then declined rapidly. The patterns for TCH and CCS with harvest date in the previous season were very similar to that reported in the initial study of two years.

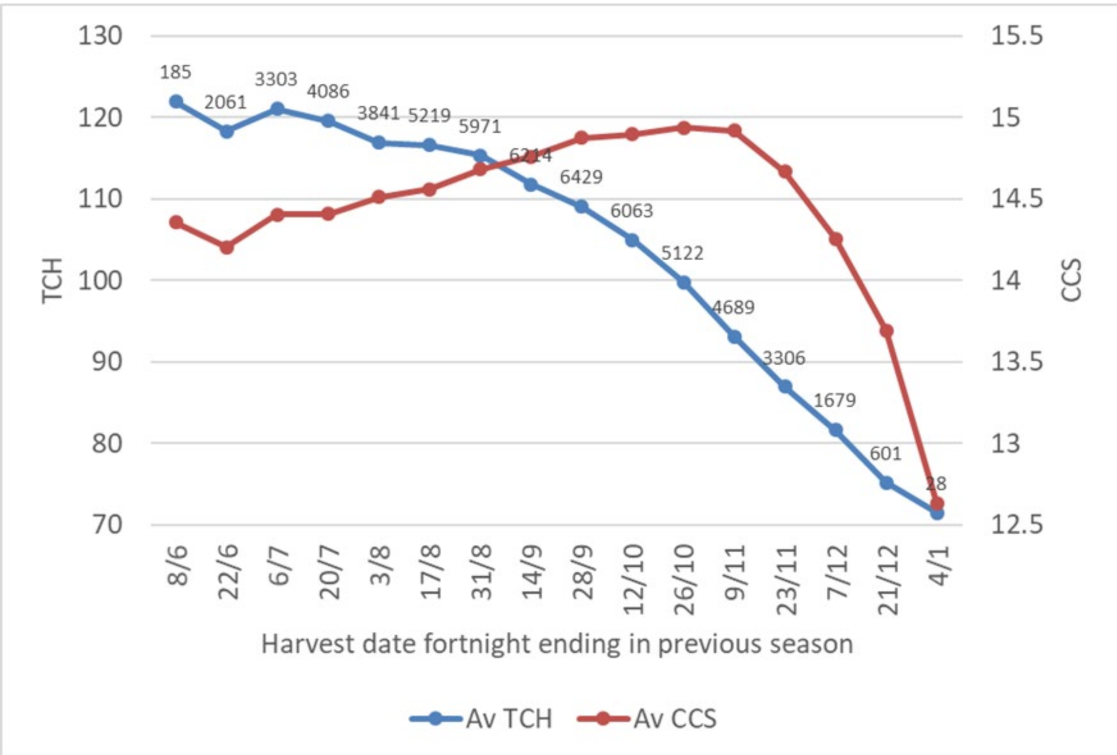


Figure 36: Average TCH and CCS in the current season for blocks harvested in different fortnights in the previous season for the 10 years 2006-2009 and 2013-2018. Number of blocks in each fortnight is shown.

The effect of harvest date in the previous season on tonnes sugar/ha (TSH) and $/ha return for growers were examined (Figure 37). The formula for $/ha in the Burdekin is:

*$/ha = ((((Sugar price * 0.009 * (CCS-4)) + Price Adjustment) *TCH)-(TCH*(Harvest costs + levies)))*

Where:

Sugar Price is $420/t, Price Adjustment is $0.662 and Harvest Costs and Levies is $7.50. The price adjustment is a mill supplied incentive payment based on historical Cane Supply Agreements.

TSH declines with increasing harvest date in the previous season, with the rate of decline increasing after September (Figure 37). The $/ha return to growers is similar for all blocks harvested before the end of September in the previous year but drops steadily for blocks harvested after September. Blocks harvested after the 23/11 in the previous year return 37% less $/ha and 35% less TSH than blocks harvested before September of the previous year. This analysis quantifies the impact of late harvest in the Burdekin.

Analyses based on Figure 37 were used to examine the potential for increasing industry and grower returns by harvesting a higher proportion of ratoon blocks before September than is currently harvested during this period. Currently, on average 37% of ratoon crops are harvested before September. The scenario examined was to start harvest in the fortnight ending the 8/6 (during the 10 years of the study harvest commenced in fortnight ending 8/6 in 4/10 years) and increase the harvested area to 55% before September (Figure 38). An estimate was made of the potential increase in returns compared to the existing average harvest pattern. It was estimated that the modified harvest pattern could increase total industry returns by $18M and growers would receive on average $202/ha more for ratoon crops. This increase could be achieved within the current capacity of the mills but the mills would have to reach near maximum capacity within the first 8 to 10 weeks after the start of the season. The benefits would come at no extra cost and would benefit both growers and millers. There may be some losses in the first year the new plan is instigated because the disadvantage of lower CCS early in the season would not be offset by the benefits of earlier harvest in the previous year in the first year of the revised harvest plan. This scenario should be viewed as a target and does not make allowances for factors such as weather and mill breakdowns that may restrict the proportion of crop harvested at different times during the season.

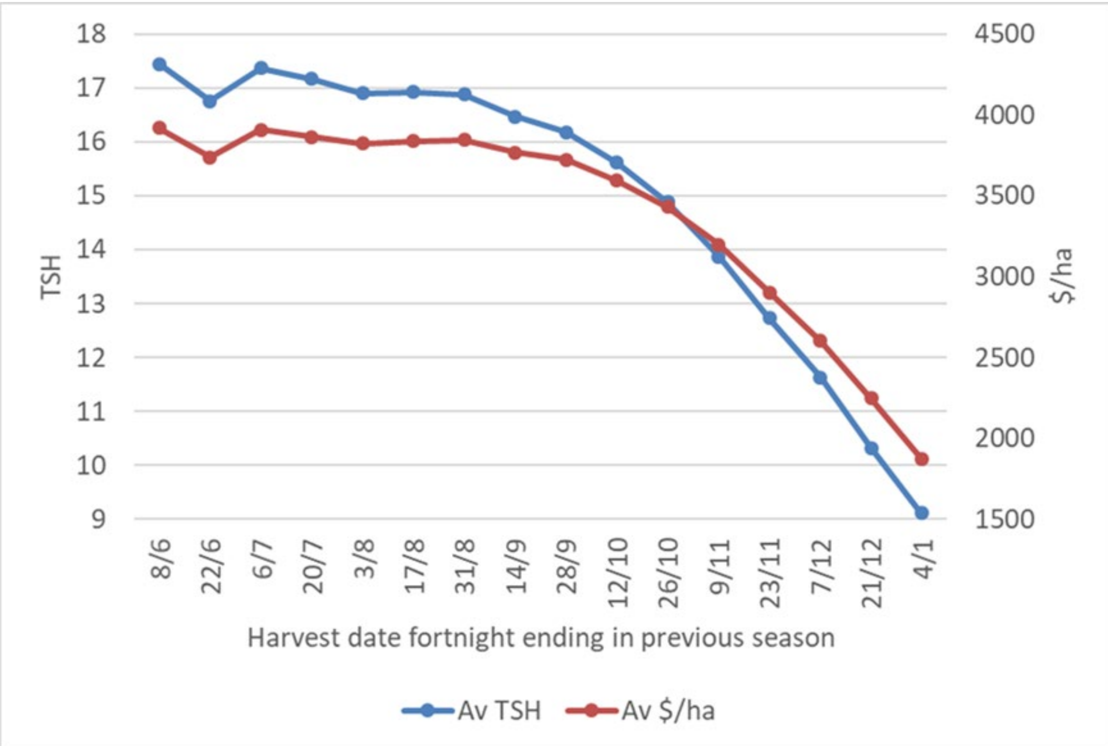


Figure 37: Average TSH and $/ha in the current season for blocks harvested in different fortnights in the previous season for the 10 years 2006-2009 and 2013-2018.

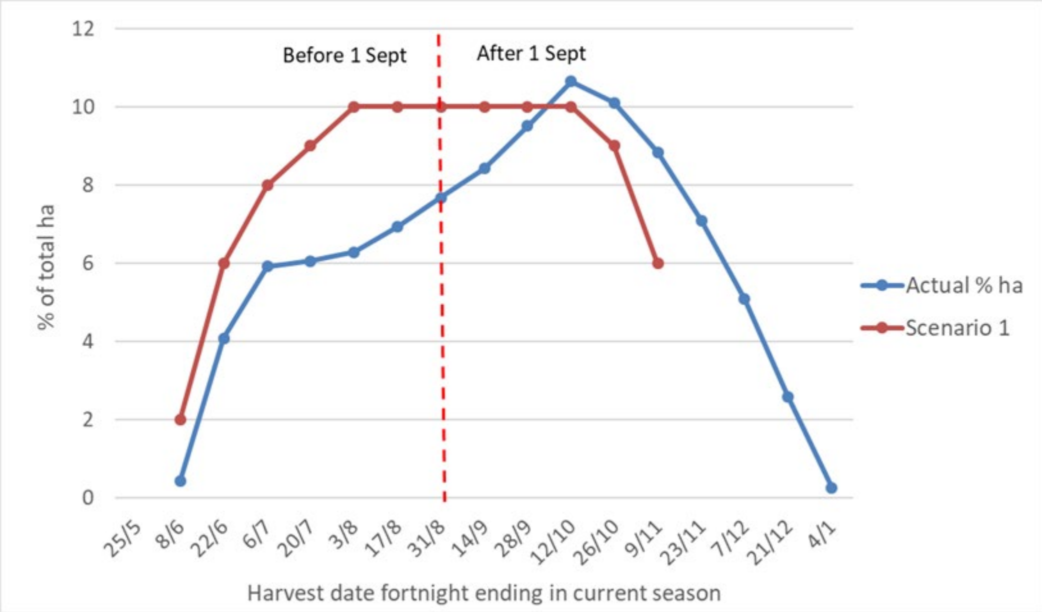


Figure 38: Percentage area harvested on average of the 10 years 2006-2009 and 2013-2018 for each fortnight and a proposed scenario where this area is increased so that 55% of the crop harvested before September.

To confirm the earlier finding that the relationship between harvest date in the previous season and yield in the current season is independent of several potential compounding factors, these analyses were repeated with the larger sample of years. The relationship between TCH and harvest date in the previous season was similar for 12-month-old crops to that found for all crops (Figure 39). CCS of 12-month-old crops followed the seasonal CCS curve for the current year until late in the season when crops harvested late in the previous season had lower CCS than the season average for that time of the year (Figure 40). This shows that late harvest in the previous season affects CCS in the current season for late harvested blocks.

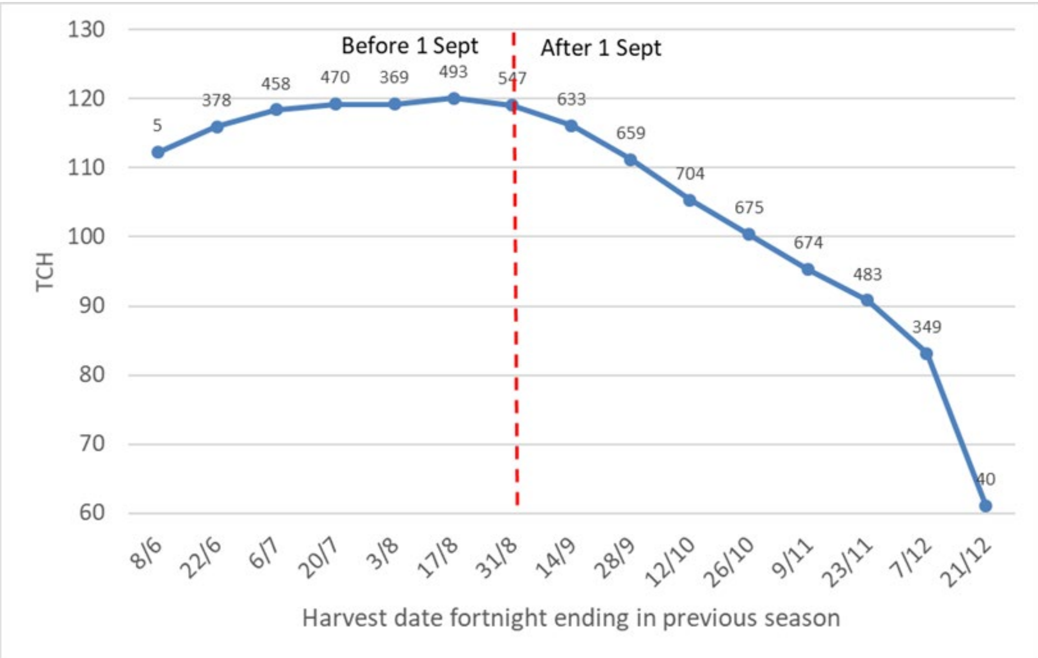


Figure 39: Average TCH in the current season for blocks harvested in the same fortnight in the previous and in the current season (crop 12 months of age). Number of blocks in each fortnight is shown.

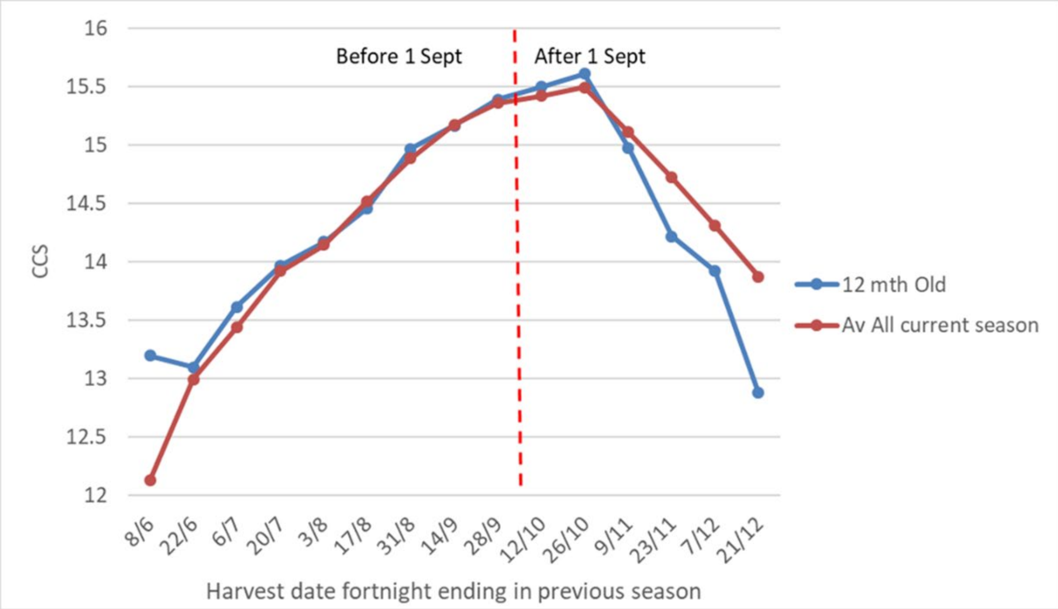


Figure 40: Average CCS in the current season for blocks harvested in the same fortnight in the previous and current season (crop 12 months of age). The current season CCS curve is shown for comparison.

The relationship between harvest date in the previous season and TCH was similar for first, second and third ratoons (Figure 41). One concern was that a higher proportion of older ratoons are harvested late and that the observed drop in yield from blocks harvested late in the previous year was just a result of a higher proportion of older crop classes being harvested late in both years. This analysis clearly shows that the effect of harvest date in the previous season is independent of crop class.

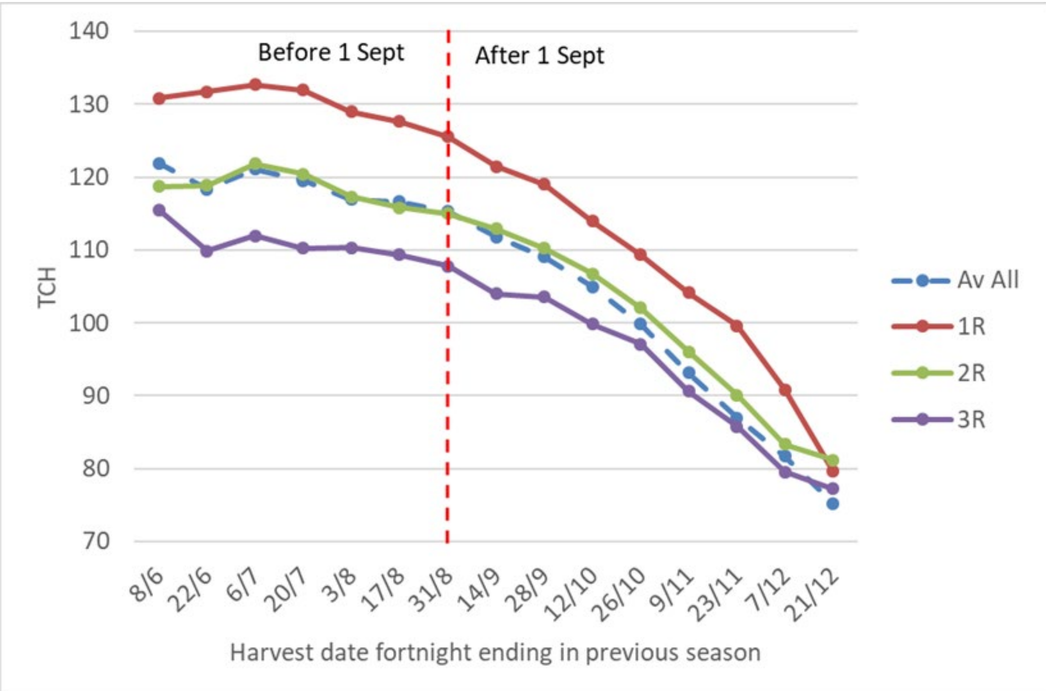


Figure 41: Average TCH for first (1R), second (2R) and third (3R) in the current season for blocks harvested in different fortnights in the previous and in the current season (crop 12 months of age).

The proportions of blocks harvested in different fortnights in the current season from a selection of fortnights in the previous season are shown in Figure 42. A higher proportion of blocks harvested early in one season are also harvested early in the next season and vice versa, blocks harvested late in one season are harvested late in the next season.

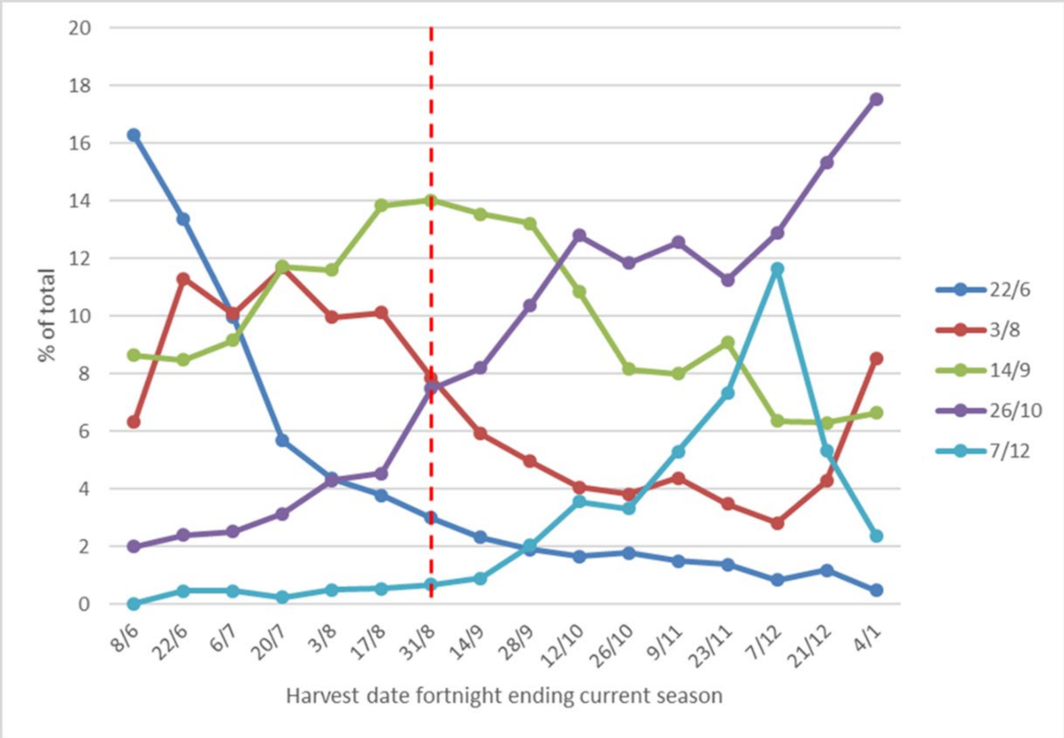


Figure 42: Percentage of blocks harvested in each fortnight in the current season from a selection of fortnights harvested in the previous season.

b. Tully

Productivity trends

The Tully region experiences extreme climate variability and has a long-term average annual rainfall of 4,075mm. The tonnes delivered to Tully mill increased from 1M t in 1990 to approximately 2.5 M t in 2005 mainly due to expansion of the area planted to cane. During this period, excessive rainfall in some years, for example 7,800mm in 1990/1991, and cyclones have had a dramatic effect on tonnes delivered to the mill (Figure 43).

The hectares harvested increased to 25,000 in 2005 and then there was a decline in hectares harvested until 2009 when a lot of cane land was planted to trees as part of managed investment schemes. In 2010 and 2011 Tully mill area suffered major disruptions to its operations due to weather events (Figure 45). In 2010, excessive rain during the harvest period meant that 14% of the crop could not be harvested and was stood-over for harvest in 2011 and in 2011 cyclone Yasi caused widespread damage.

Since 2012 there has been an expansion of 8,000 ha in southern subdistricts of Tully to areas that have not been under cane before and are on marginal soils.

The average TCH from 1990-2017 has been 84 t/ha and the average CCS, 12.6, combining to give an average sugar yield of 10.6 t/ha (Figure 44). The dramatic effects of excessive rainfall and cyclones can be seen in Figure 44 and Figure 45. Excessive rainfall often led to lower yields in the following year due to harvester damage to crops from wet harvest in the previous year. The lowest average TCH occurring in 2011 following the high rainfall and disrupted harvest in 2010 which was compounded by cyclone Yasi in early February 2011. In years of below average rainfall, for example 2002-2005 and 1992-1997, TCH and TSH have exceeded the long term average.

In 2015 and 2016, the tonnes delivered to the mill was approximately M2.9 t and this is close to the current capacity of the mill.

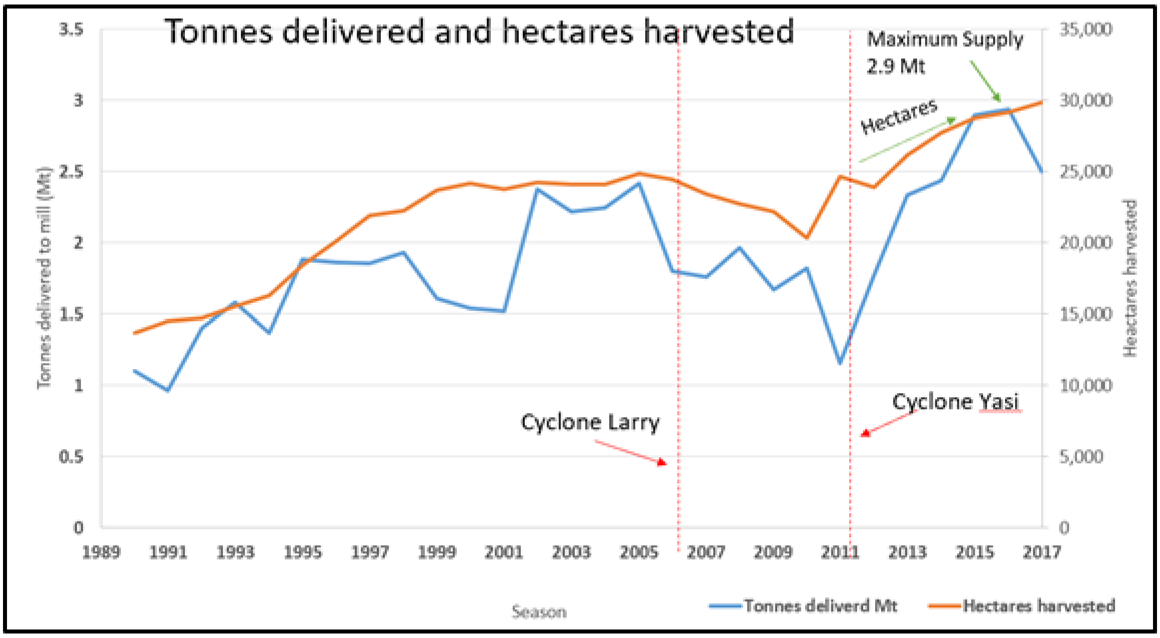


Figure 43: Tonnes delivered and area harvested for Tully mill area from 1990-2017.

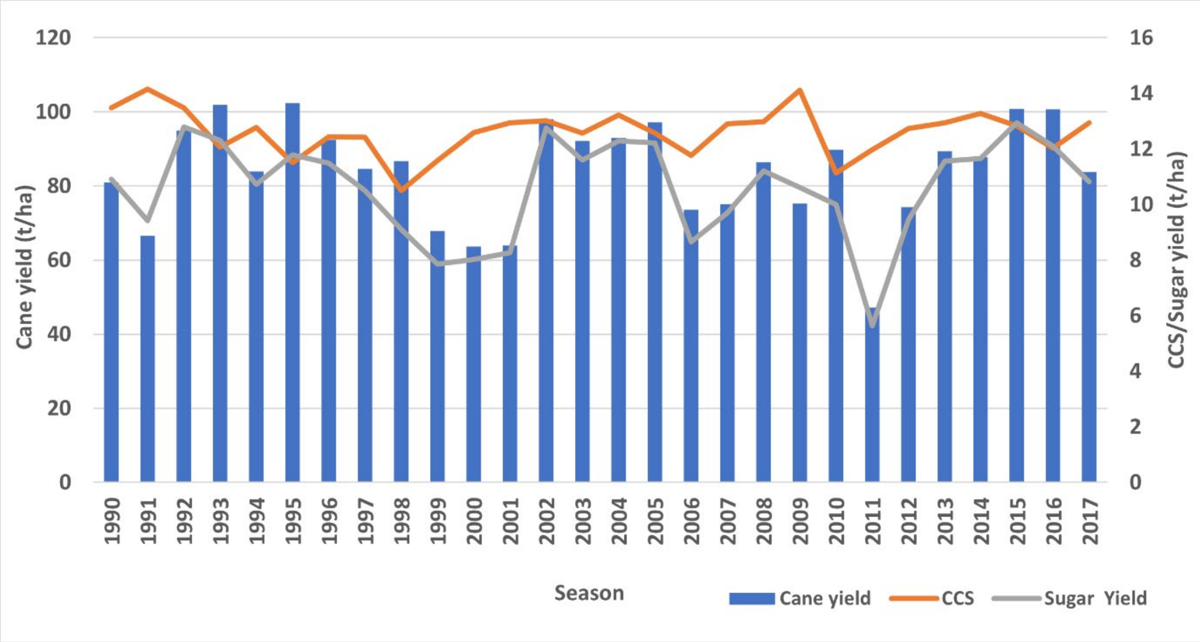


Figure 44: Tully cane yield, CCS and sugar yields from 1990-2017.

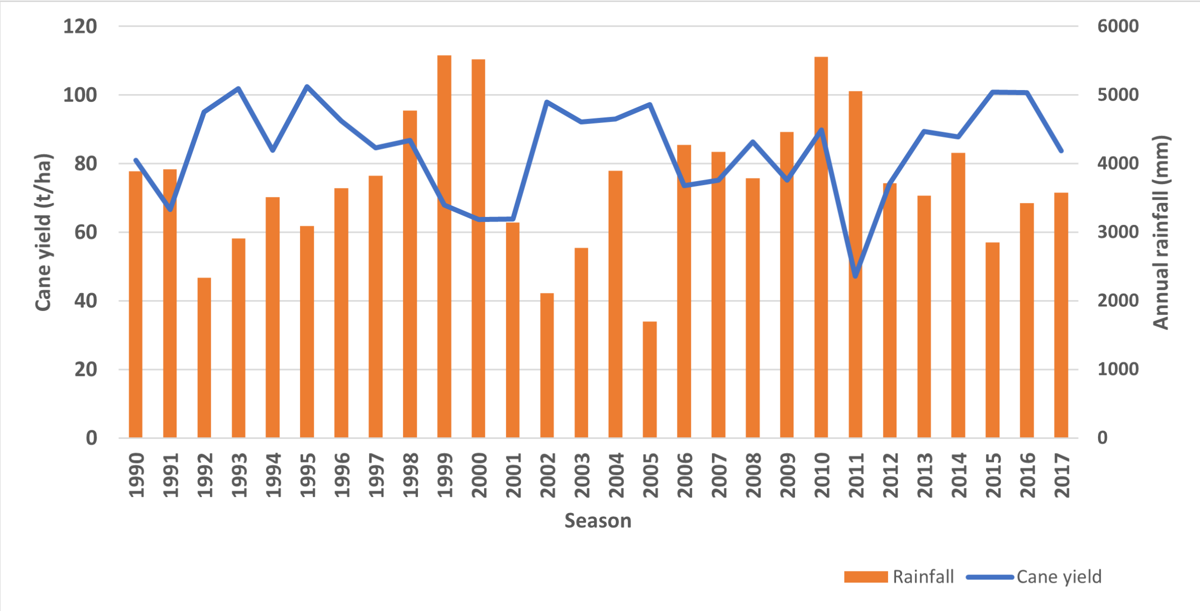


Figure 45: Tully cane yield and rainfall from 1990-2017.

Subdistricts

In the Tully Mill area there are eight subdistricts. These subdistricts are shown in Figure 46 and are known as El Arish, Feluga, Lower Tully, Syndicate, Murray, Kennedy, Euramo and Riversdale. These subdistricts vary in productivity, climate, soils and how cane is supplied to the mill *i.e.* road or rail transport.

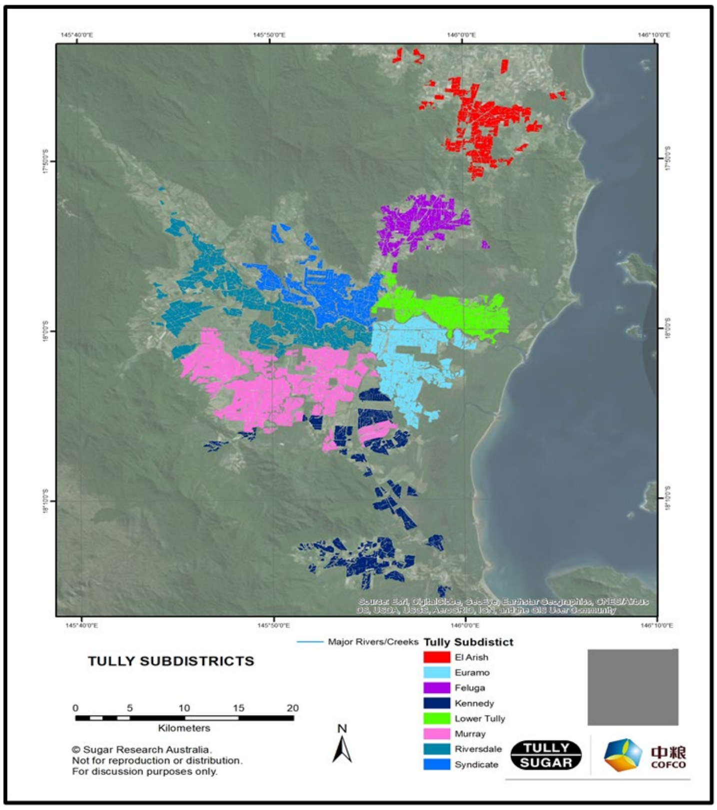


Figure 46: Subdistricts within the Tully mill area.

Table 12 contains the average cane yield, CCS and sugar yield for each of the 8 subdistricts from 2012-2016. The Kennedy subdistrict only has data from 2011 onwards. Prior to this Kennedy supplied cane to South Johnstone mill.

Table 12: Long term averages for cane yield, CCS and sugar yield for the 8 subdistricts zones in the Tully mill area from 2012-2016.

Subdistrict	Name	Cane yield (t/ha)	CCS	Sugar Yield (t/ha)
1	El Arish	76.4	12.2	9.3
2	Murray	97.9	13.0	12.7
3	Feluga	73.9	11.9	8.8
4	Kennedy	87.9	13.3	11.7
5	Lower Tully	89.4	12.7	11.3
7	Euramo	94.2	12.9	12.1
8	Riversdale	92.9	12.3	11.3
9	Syndicate	89.4	12.5	11.2
Mill average		87.1	12.6	11.0

Climate Zones

Recent research by Sexton *et al*. (2017) used seasonal and annual climate data from 1975-2017 to determine sub-regional climatological differences in the Tully mill area. This resulted in the identification of two sub-regions which are labelled as the *southern Dry* and *northern Wet* climate zones and are roughly separated by the Tully River. The wet climate zone has lower radiation, lower temperatures and higher rainfall than the southern climate zone. However, although the dry zone has lower rainfall and more sunlight than the wet zone the amount of rainfall is generally not limiting to cane growth.

Using the 2018 Tully Sugar spatial layer (known as F18), the 221 farms were allocated to the Wet or Dry climate zones (Figure 47). Using F18 to allocate farms to climate zones according to their spatial location instead of simply allocating farms based on productivity subdistricts, (*e.g.* the Wet climate zone containing El Arish, Feluga, Syndicate and Lower Tully vs the Dry climate zone containing Riversdale, Euramo and Murray) resulted in the omission of another 15 farms from the analysis. These 15 farms had area in both climate zones and these were omitted from Figure 47.

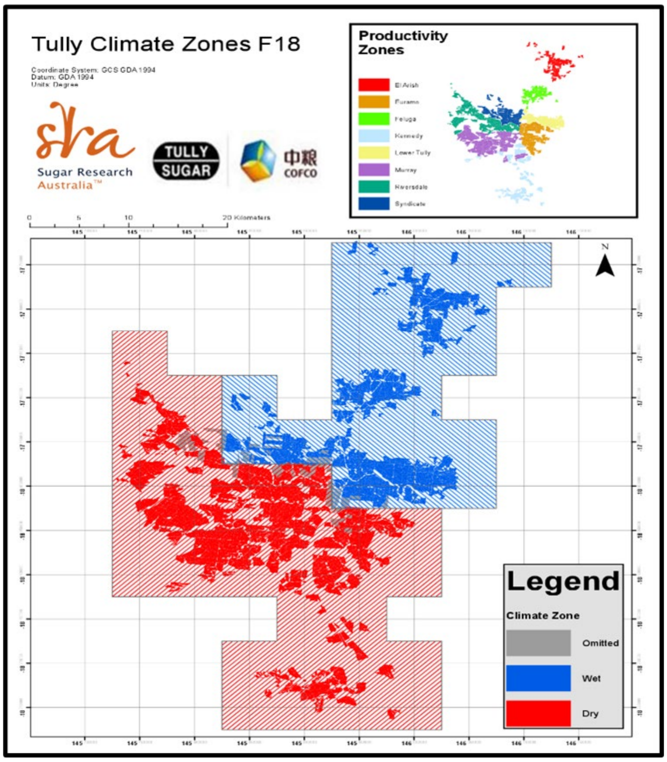


Figure 47: Climate zones in the Tully mill area.

Mean cane and sugar yields were analysed for the two climate sub-regions using block productivity data obtained from Tully Sugar Limited for 2000 to 2017 (Stringer *et al*. 2017). After excluding 2011 (Tropical Cyclone Yasi), only farms with 15 or more years of data were included. The impact of spring-summer (SONDJF) rainfall and El Niño Southern Oscillation (ENSO) phases on cane and sugar yields in the two climate sub-regions was also analysed. On average, the northern, wetter climate sub-region yielded less cane and sugar yield than the southern, drier sub-region. There were significant differences between SONDJF rainfall terciles (dry, normal and wet) and ENSO phases (El Niño, Neutral and La Niña) for cane and sugar yields in the two climate sub-regions. Cane and sugar yields were significantly lower in years experiencing high SONDJF rainfall or in the La Niña phase. This analysis validates the results of the analyses used to derive the two climatological sub-regions in Tully.

As the Kennedy subdistrict only supplied cane to Tully from 2011 this presents challenges in the analyses. We examined three sets of data to examine the effects of different parameters on productivity:

1. 1994-2016 data for cane yield, CCS, sugar yield and area harvested at the Farm and farming enterprise level excluding Kennedy.
2. 2012-2016 data for cane yield, CCS, sugar yield and area harvested at the Farm level Farm and farming enterprise level for Kennedy only.
3. 2012-2016 data for cane yield, CCS, sugar yield and area harvested at the Farm level Farm and farming enterprise level across all subdistricts.

Only the last set of analyses will be discussed.

Prior to any analyses, boxplots were used to identify outliers in the Tully data. Any block level data with cane yield greater than 250 t/ha and sugar yield greater than 30 t/ha were omitted from the analyses.

For each subdistrict in the Tully mill area, the dollars per hectare were calculated using the following formula:

*Dollars/ha = ((((Sugar price * 0.009 * (CCS-4)) + Price Adjustment) *TCH)-(TCH*(Harvest costs + levies)))*

Where:

Sugar Price is $385/t, Price Adjustment is $1.60 and Harvest Costs and Levies is $9.29. The price adjustment is a mill supplied incentive payment based on historical Cane Supply Agreements.

Table 13 contains the numbers of farms, area harvested, dollars/ha, relative dollars per hectare and climate zone for the 8 subdistricts.

Table 13: The number of farms, area harvested, dollars per hectare, relative dollars per hectare and climate zone for the Tully subdistricts.

Subdistrict	Number of farms in subdistrict	% Area	$/ha	$/ha relative to Tully average $/ha	Climate zone
1-El Arish	72	11.9	1588.7	0.82	Wet
2-Murray	63	22.7	2302.7	1.19	Dry
3-Feluga	52	6.3	1465.2	0.76	Wet
4-Kennedy	39	11.9	2159.5	1.12	Dry
5-Lower Tully	49	9.0	1993.2	1.03	Wet
7-Euramo	47	12.2	2184.0	1.13	Dry
8-Riversdale	37	16.1	1925.2	1.00	Dry
9-Syndicate	42	9.9	1942.6	1.01	Wet
Total	**401**		**1.00**	**1.00**	

In the dataset from 2012-2016, there were 401 farms spread across 8 subdistricts which vary in size and in dollars per hectare return. The average dollars per hectare for the Tully mill area is $1,945. The Murray and Riversdale subdistricts are the largest subdistricts and account for 39% of the area harvested. These subdistricts have above average dollars per hectare which can largely be attributed to being in the Dry climate zone. El Arish and Feluga are the two most northern subdistricts and are in the Wet climate zone. They have below average dollars per hectare.

We undertook a combination of hierarchical agglomerative clustering using Ward’s method and K-means cluster analysis on rake data from 2012-2016 to determine groups of like-yielding/like-sized production units.

The eight different clusters distinguished by different colours are plotted with Farm size (ha) on the x axis and cane yield (TCH) on the y axis (Figure 48). Each circle represents a farm and the industry target is represented by the green dotted line which is 90 t/ha for TCH. Each colour represents a different cluster, for example the “orange” cluster 5 contains the small-sized high producing Farms while the “red” and “blue” clusters 1 and 2 contain the small-sized low producing Farms.

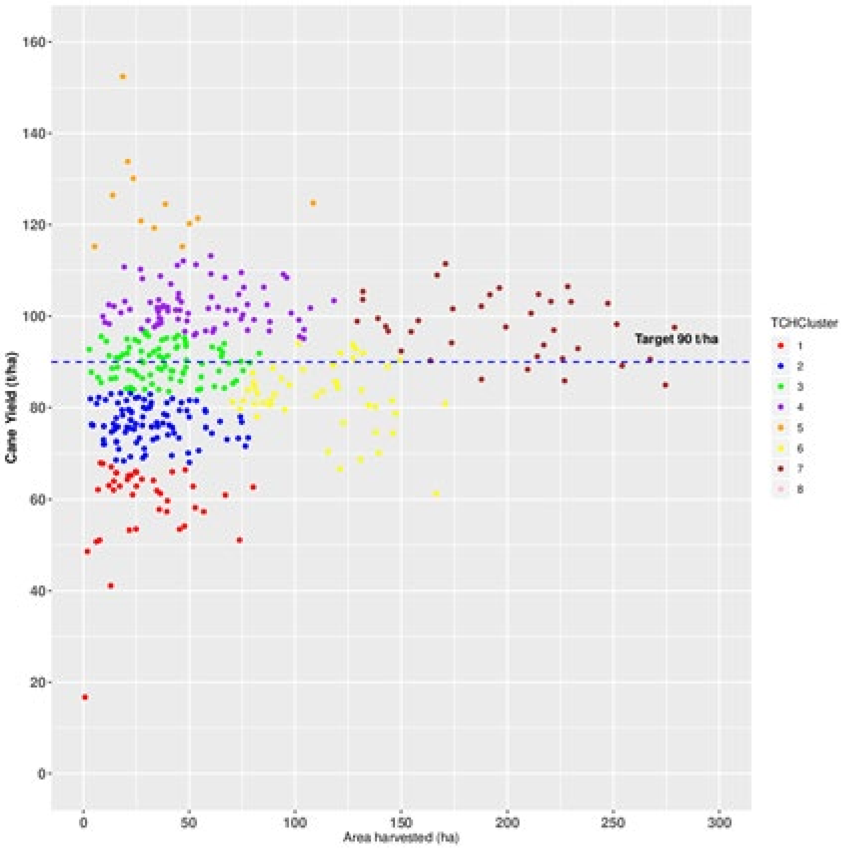


Figure 48: Cluster plot of cane yield vs total area harvested at the Farm level in Tully mill area: 2012-2016. Cluster 8 had been hidden to protect the identity of the large farms. The industry target of 90 t/ha is indicated on the graph.

The number of farms and average cane yields for each cluster are given in Table 14. Clusters 1 and 2 (red and blue, small-sized low producing farms) contain 41 and 91 farms respectively and have cane yields of 59.4 t/ha and 76.6 t/ha. Within Cluster 5 (orange) there are 5 farms that average above 120 t/ha.

The Target for Tully is 90 TCH. In Figure 48, most of the farms in clusters 1-3 and 6 are below the Target. Cluster 1 is well below the Target. The target groups for extension programs should be clusters 3 and 6 where many of the farms sit less than 10 t/ha under the industry target. These clusters represent a significant proportion of the harvested area and extension efforts are likely to provide the greatest return on investment. With tailored extension practises their cane yields should be able to be increased to 90 t/ha.

Table 14: Number of farms and average cane yield per cluster for Tully mill data: 2012-2016.

Cane yield cluster	Number of farms	Average farm size (ha)	Average cane yield (t/ha)
1	41	28.8	59.4
2	91	31.8	76.6
3	83	38.0	89.9
4	79	53.8	102.1
5	12	36.8	125.4
6	47	112.6	82.4
7	37	197.9	97.7

8	11	382.3	91.9
Total/Average	**401**		**87.1**

Table 15 contains the percentage cluster membership for cane yield by subdistrict based on data from 2012-2016. A high proportion of the small-sized low producing farms (clusters 1 and 2) for TCH are in the El Arish and Feluga subdistricts which are in the wet climate zone. In contrast, the small-sized high TCH farms (cluster 5 - orange) are in the dry climate zone and Murray, Kennedy and Riversdale subdistricts.

Table 15: Percentage cluster membership for cane yield by subdistrict for 2012-2016 in the Tully mill area.

	Percentage cluster membership for cane yield in each subdistrict							
Cane yield cluster	**El Arish**	**Murray**	**Feluga**	**Kenned y**	**Lower Tully**	**Euram o**	**Riversda le**	**Syndicate**
1	46	2	32	7	10	2	0	0
2	29	5	29	12	9	8	1	8
3	14	11	10	4	20	13	7	20
4	8	23	1	10	15	22	10	11
5	0	58	0	17	0	8	17	0
6	17	17	9	11	6	2	26	13
7	0	32	0	16	14	22	8	8
8	9	27	0	9	0	9	45	0

Variety management and soil health on cane yield clusters

Disease scores

For each farm a disease score for Pachymetra was calculated as follows:

*Disease score per variety per farm = (Disease rating * hectares harvested)/total hectares*

Where:

Disease rating is on a 1-9 scale for each variety in a block obtained from SRA,

Hectares harvested is the amount of hectares harvested of a variety per block,

Total hectares is the total hectares harvested per farm.

For each Farm in the different cane yield clusters, a Pachymetra score was calculated. The colours in Figure 49 match the cluster plot in Figure 48. For example, Red is cluster 1 – small-sized low yielding, Blue, is small-sized low yielding and Orange is cluster 5 which is small-sized high yielding.

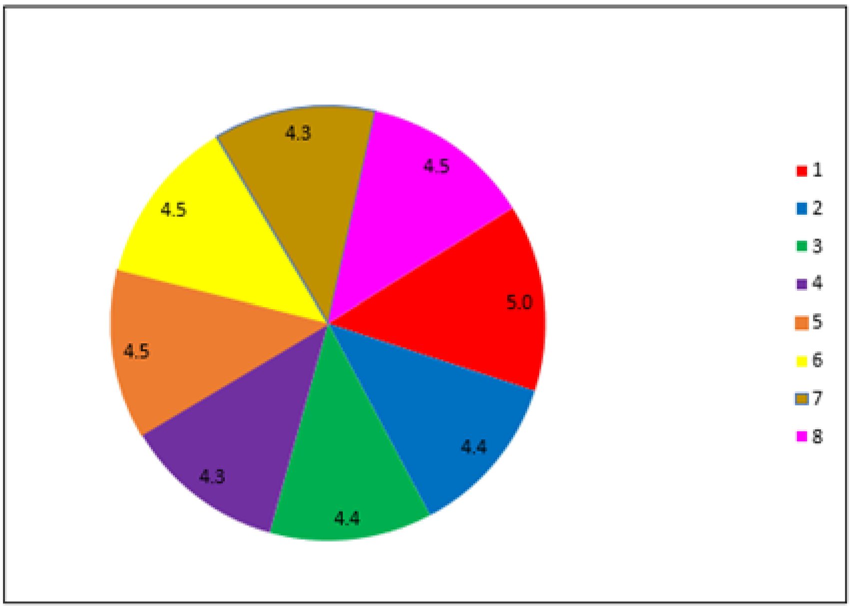


Figure 49: Pachymetra score by cane yield cluster for Tully data 2012-2016.

For all clusters, the Pachymetra scores were between 4 and 5 which is in the intermediate range. During the period 2012-2016, KQ228, Q200, and Q208 dominated the cane supply. These three varieties were 70%, 73% and 85% for clusters 1,2 and 5 respectively and all are rated intermediate to Pachymetra. High Pachymetra soil spore counts have been associated with varieties with intermediate resistance in some subdistricts (Shannon *et al.*, 2019). Clusters 1 and 2 had 78% and 58% of their Farms in the areas shown to have high Pachymetra soil spore counts in the wet climate zone areas of Feluga and El Arish. In contrast, cluster 5 had just over half of their farms in the drier Murray subdistrict where Pachymetra is less of a problem.

In the 2017-2018 seasons the proportions of KQ228, Q200 and Q208 were 68% and 64% of the total cane supply. The Pachymetra resistant variety Q241 decreased to only 1% of the crop in 2018 as it has sugar quality and milling problems. Pachymetra resistant Q231 increased in cane supply to 6% of the crop in 2018. However, it is not well liked by many growers as it has a lot of thin stalks and has lower Effective Bulk Density (EBD) compared to the three major varieties. Recently, EBD has been added to the cane quality scheme used by TSL and larger plantings of Q231 may not occur. Q183 is also a Pachymetra resistant variety but has not been grown widely (1% in 2018). Newer Pachymetra resistant varieties, such as SRA6, are not grown widely yet in Tully and only account for 0.1% of the cane supply.

Crop Class

Tully mill area suffered major disruptions to its operations in 2010 and 2011 due to weather events. In 2010, excessive rain during the harvest period meant that 14% of the crop could not be harvested and was stood-over for harvest in 2011 (Figure 50). Often the crops that are stood-over are crops that would normally be ploughed out and replanted in the following year. Being forced to stand-over crops, disrupts the normal cropping cycle on farms. Unfortunately, the situation was compounded by cyclone Yasi which devastated the Tully region in early February 2011. The damage caused to crops during these two exceptional years required a large replanting program in 2012 which can be seen by well above average percentage of plant crop harvested in 2013. The large planting program in 2012 has flowed on to above average proportions of the crop harvested as first ratoon in 2014, second ratoon in 2015, third ratoon in 2016 and older ratoons in 2017. In 2017, the proportion of the crop harvested as older ratoons increased well above normal levels and the proportion of plant cane decreased significantly. The reason for the increase in older ratoons can partially be explained from the flow on from the large planting in 2012 but probably also reflects the gloomy forecast for sugar prices in 2016 to 2017. During periods of downturn in sugar price, growers try to reduce costs and the easiest way to reduce costs is to reduce planting and extend the ratoon period.

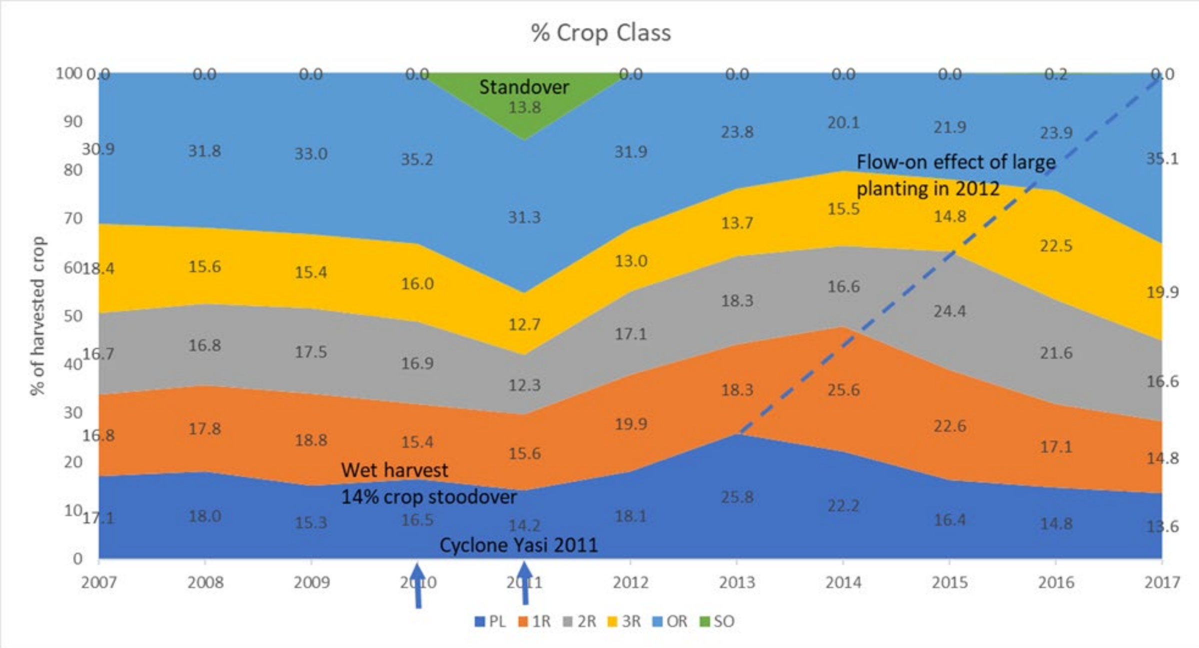


Figure 50: Proportion of the crop harvested as different crop classes from 2007 to 2017 in Tully mill area.

The area derived from blocks replanted with no fallow (includes all crop classes classified as from replant) decreased from 20% in 2012 to less than 10% in 2017 (Figure 51). The area harvested from blocks replanted in the previous year fell from 3.4% in 2012 to 0.6% in 2017. Replanting should not be a major factor affecting yield in future years if it stays at this low level.

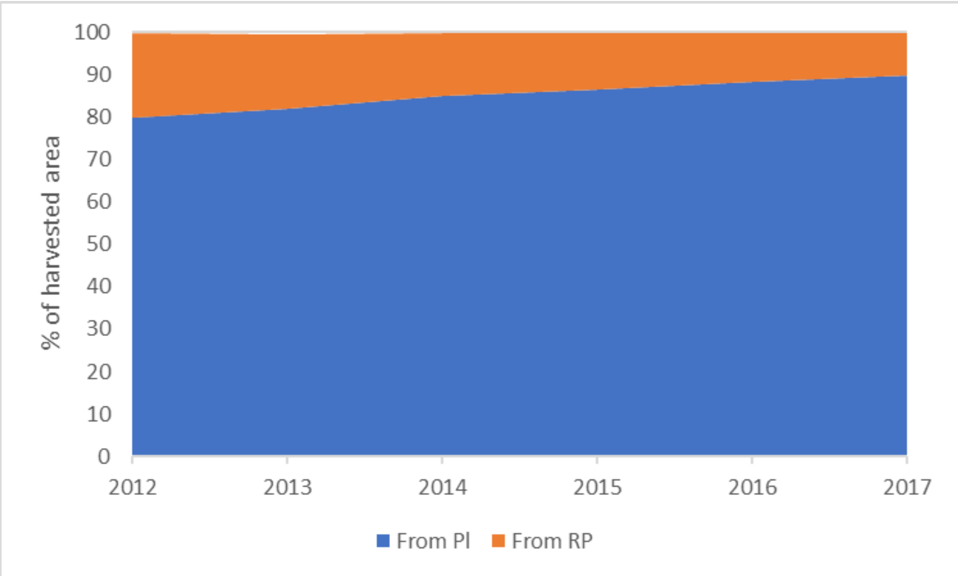


Figure 51: Proportion of the crop harvested from crop classes classified as having derived from replant (RP) versus crops derived from fallow plant (Pl) 2007 to 2017 in Tully mill area.

The proportion of older crop classes has an obvious effect on the overall yield of the mill area. The average decline in yield with crop class for the years 2012 to 2017 in Tully is shown in Figure 52. Crops planted after a fallow are separated from replant crops (RP). The percent reduction in TCH with each crop class from plant to fourth ratoon for fallow planted crops is approximately 6% per crop class. Replant crops suffer a similar reduction after first ratoon. Yield of the plant crop of replant crops is well below that of fallow plant crops which reflects both the advantage of a break from sugarcane and the difference in crop age between fallow and replant crops. Replant crops are planted towards the end of the season, whereas fallow plant crops are generally planted much earlier in the year.

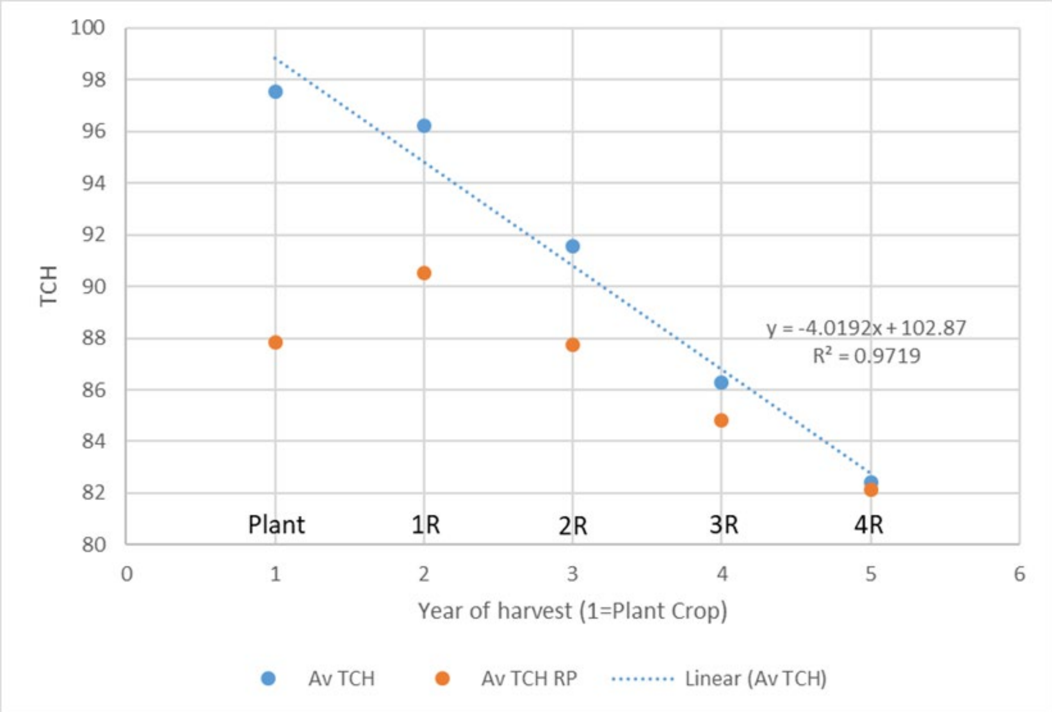


Figure 52: Relationship between crop class and tonnes cane/ha (TCH), average of all blocks 2012 to 2017 in Tully mill area. Blue are fallow plant crops and orange are replant.

To examine whether the performance of different cane yield clusters and subdistricts could be explained by the proportions of crop classes in each group, the average proportion of crop classes for 2012 to 2017 were calculated for each group.

The cane yield clusters 1 to 4 (small farms) had only minor differences in the proportion of the different crop classes (Figure 53). Differences in the proportion of crop class is unlikely to explain the differences in performance of these clusters. The very high yielding Cluster 5, which is a small group of only 12 farms, had a higher proportion of plant cane than all other clusters and the proportion of old ratoons was lower. Combined these differences in crop classes could partially explain the higher yield of cluster 5. Clusters 6 and 7 had a similar proportion of the different crop classes. Cluster 8 had a lower proportion of older ratoons than other clusters, except cluster 5.

El Arish and Feluga are the two lowest yielding subdistricts. El Arish had a moderately high proportion of older ratoons compared with the other subdistricts but Feluga has one of the lowest proportions of older ratoons (Figure 54). The low proportion of older ratoons in Feluga could be due to the harsher environment leading to early plough out of blocks. Lower Tully and Murray have over 30% older ratoons. These subdistricts have relatively high yields, but their yield could be increased further if they reduced the proportion of older ratoons.

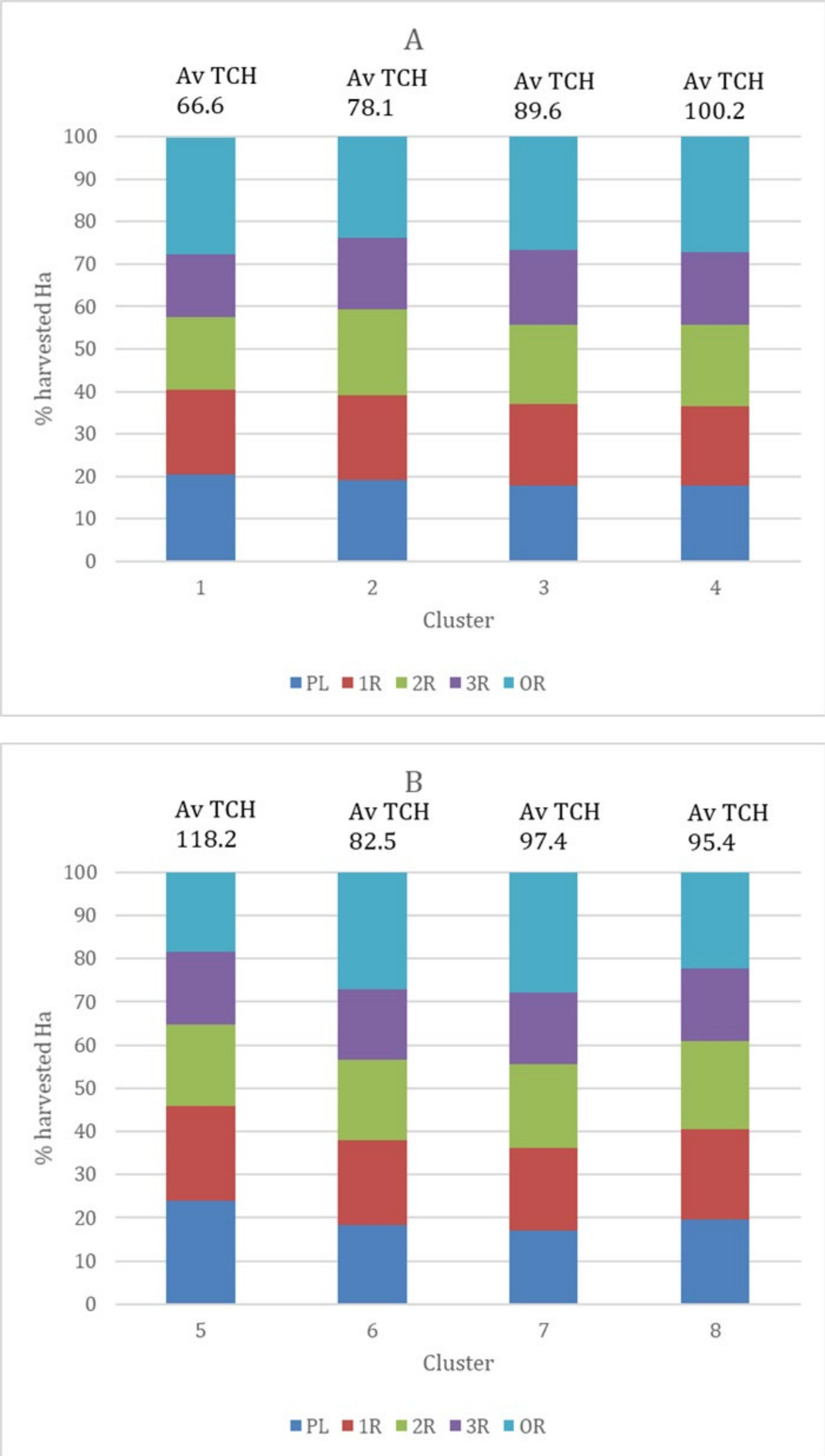


Figure 53: Proportion of the crop harvested as different crop classes from 2012 to 2017 for cluster groups 1 to 4 (A) and 5 to 8 (B) in the Tully mill area. Old ratoons (OR) are ratoons 4 or greater. Crop classes from fallow and replant combined. Average TCH for each cluster is shown (pnly blocks with >30 and <250 TCH included in average).

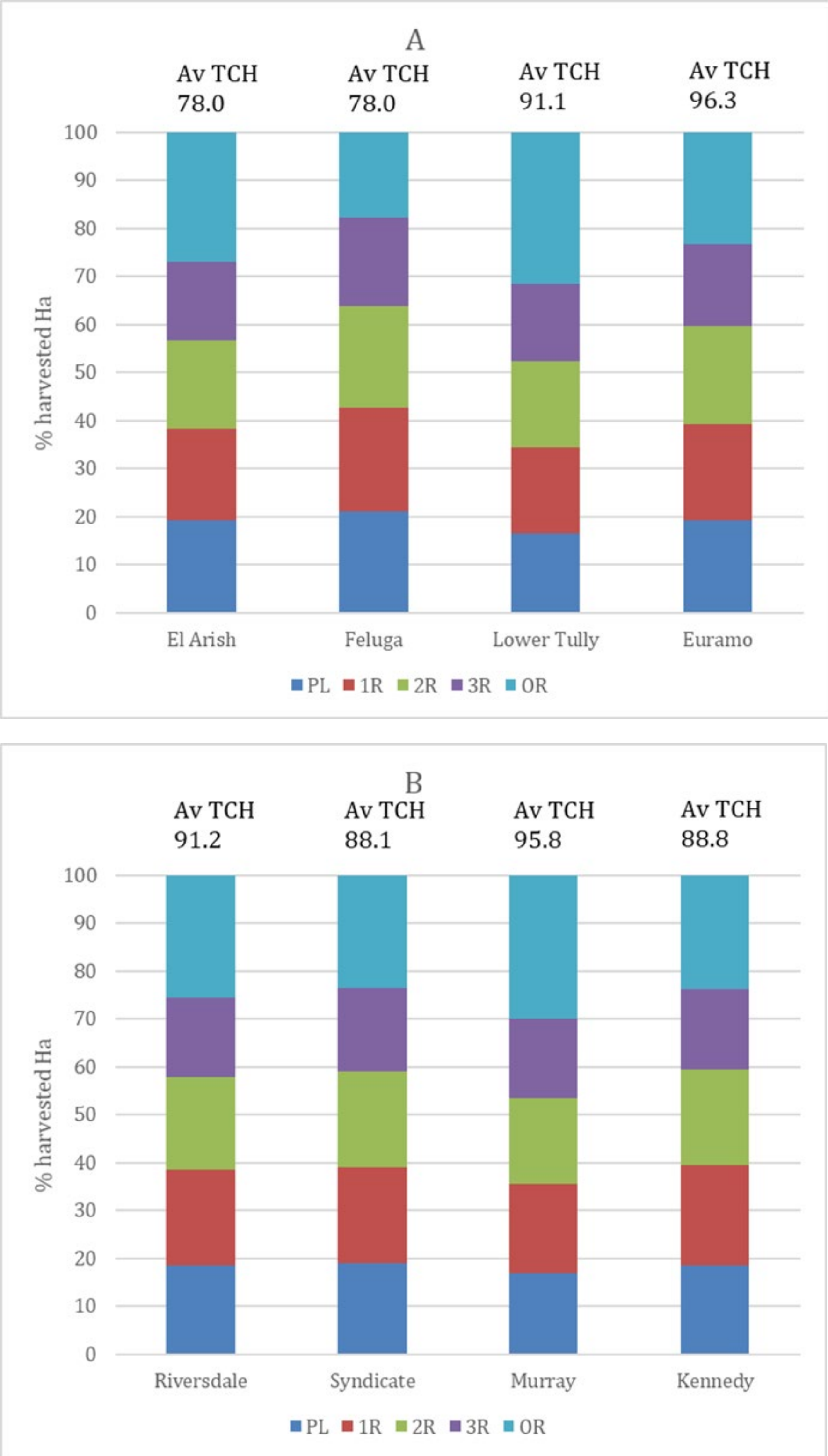


Figure 54: Proportion of the crop harvested as different crop classes from 2012 to 2017 for the 8 subdistricts in the Tully mill area. Old ratoons (OR) are ratoons 4 or greater. Crop classes from fallow and replant combined. Average TCH for each subdistrict is shown (only blocks with >30 and <250 TCH included in average).

The relationship between percentage of old ratoons and yield for the El Arish and Feluga subdistricts was examined. The average percentage of old ratoons over the years 2012 to 2017 was calculated for each farm and plotted against the average yield of the farm over the same period (Figure 55). Although there is a trend for decreasing yield with increasing percentage of old ratoons, the relationship is not strong. There are many very small farms in these subdistricts which can cause some distortion of the percentages of crop class.

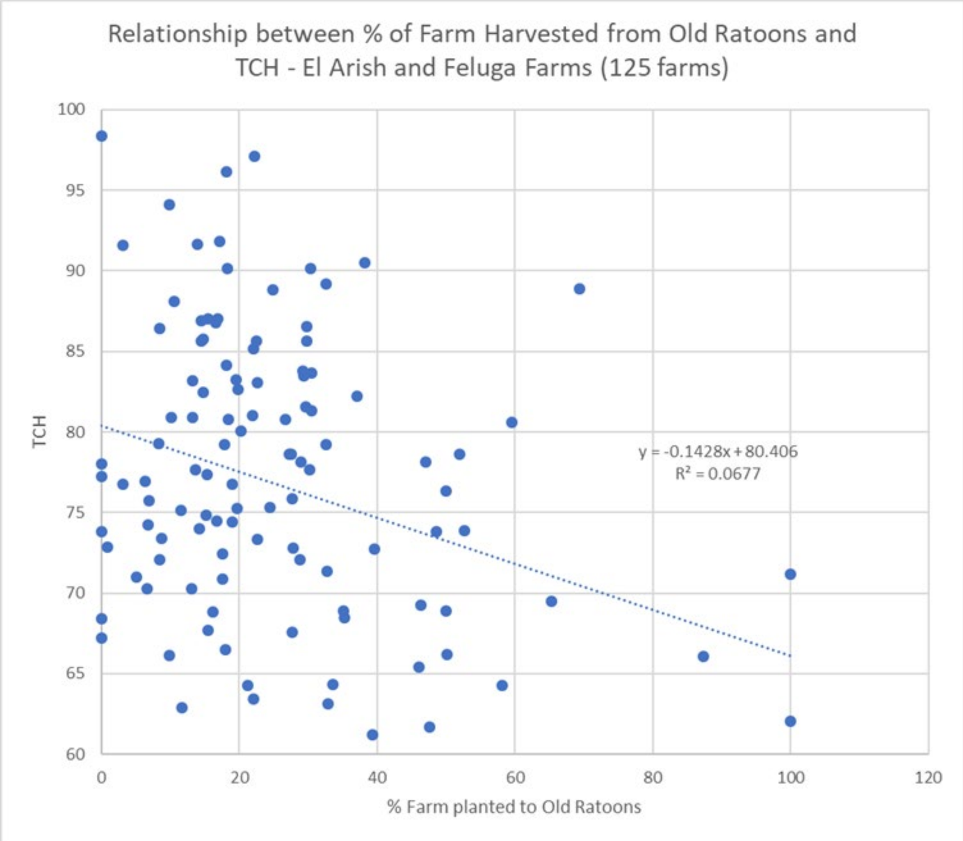
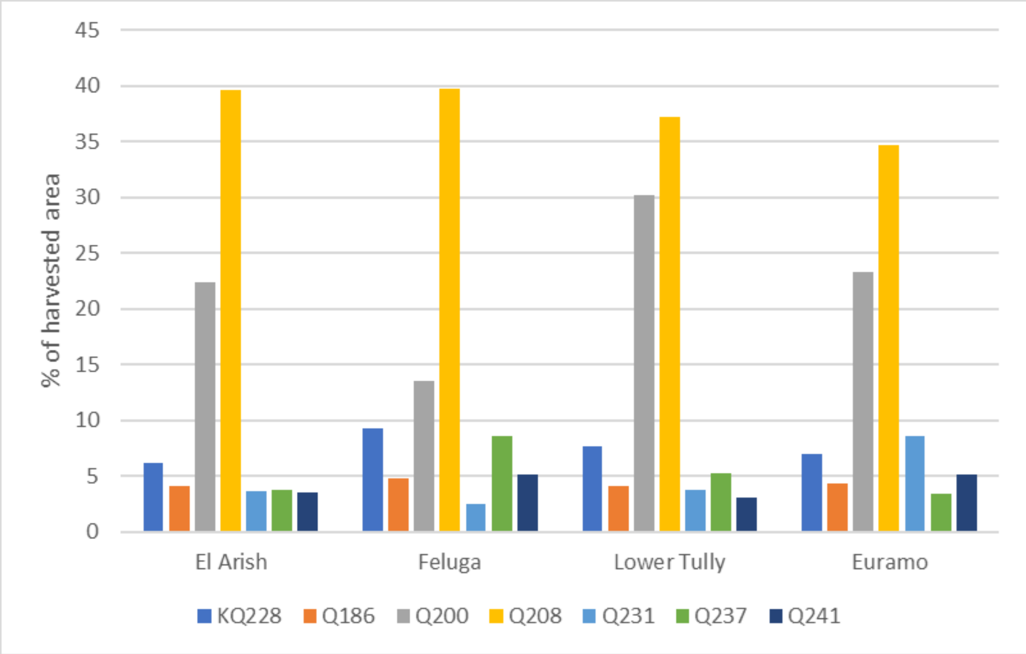


Figure 55: Relationship between TCH and percent of old ratoons for farms greater than 30 ha in size 2012 to 2017 for El Arish and Feluga subdistricts in the Tully mill area. Old ratoons (OR) are ratoons 4 or greater.

Variety Adoption

Differences in rates of adoption of higher yielding varieties on farms is a factor that could account for the differences in yield of clusters and subdistricts. The proportion of the subdistricts planted to the top 7 varieties is shown in Figure 56. Q208 and Q200 were the top varieties in all subdistricts, with the proportion of these two varieties varying slightly between subdistricts.



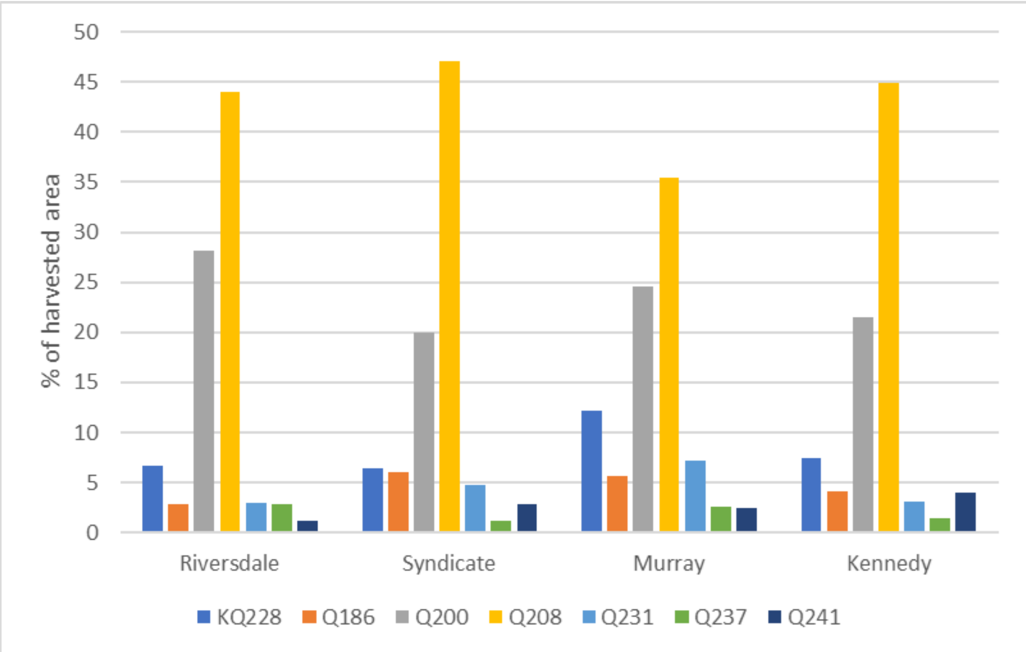
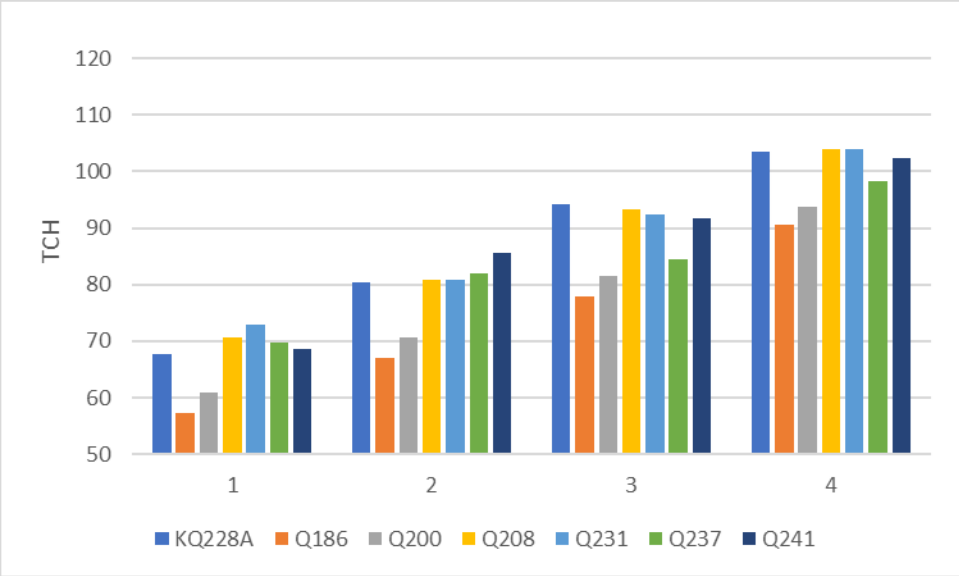


Figure 56: The percentage of the area planted to the top 7 varieties in the 8 subdistricts, 2012 to 2017 in the Tully mill area.

The average cane yield for 2012 to 2017 of the top 7 varieties in clusters 1 to 8 are shown in Figure 57. Q208 was close to the best performing variety in all clusters. KQ228 performed well in all clusters except cluster 6. Q200 performed poorly relatively to most other varieties in all clusters based on TCH but had higher CCS than the other varieties and consequently it had $/ha close to or higher than the other varieties (data not shown).



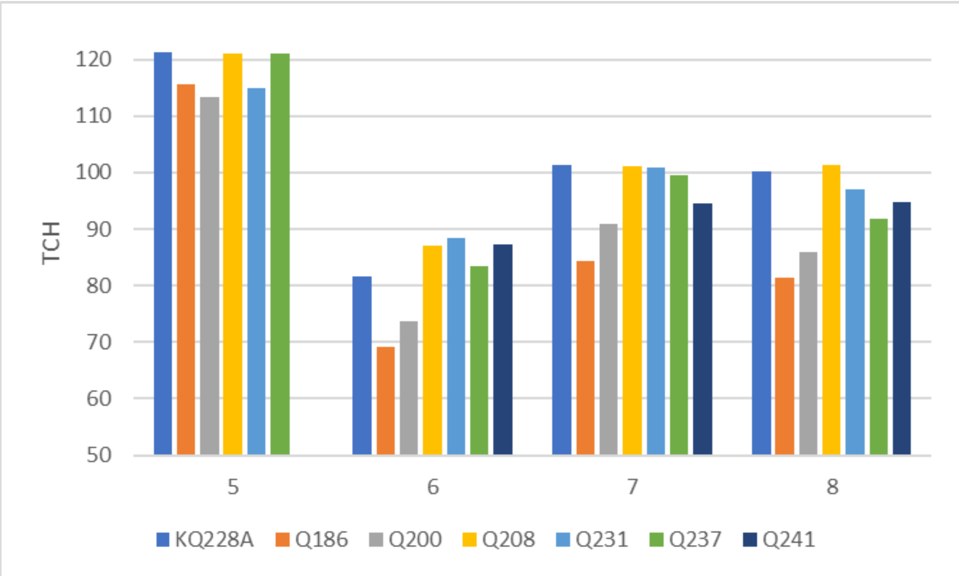


Figure 57: The average cane yield (TCH) of the top 7 varieties in clusters 1 to 8, 2012 to 2017 in the Tully mill area.

The proportion of the clusters planted to the top 7 varieties is shown in Figure 58. Q208 and Q200 accounted for between 58 and 65% of all clusters, with the proportion of these two varieties varying slightly between clusters. The percentage of Q208 was slightly higher in clusters 2 and 3 compared with cluster 1 and Q200 was slightly lower. Some varieties that performed well in clusters 1 to 4, for example KQ228, Q231 and Q241, only made up a small percentage of the harvested area. Q241 has a quality issue and has not been recommended, which could explain the reluctance of growers to plant this variety. KQ228 performed well in clusters 7 and 8 and could be more widely planted in these clusters.

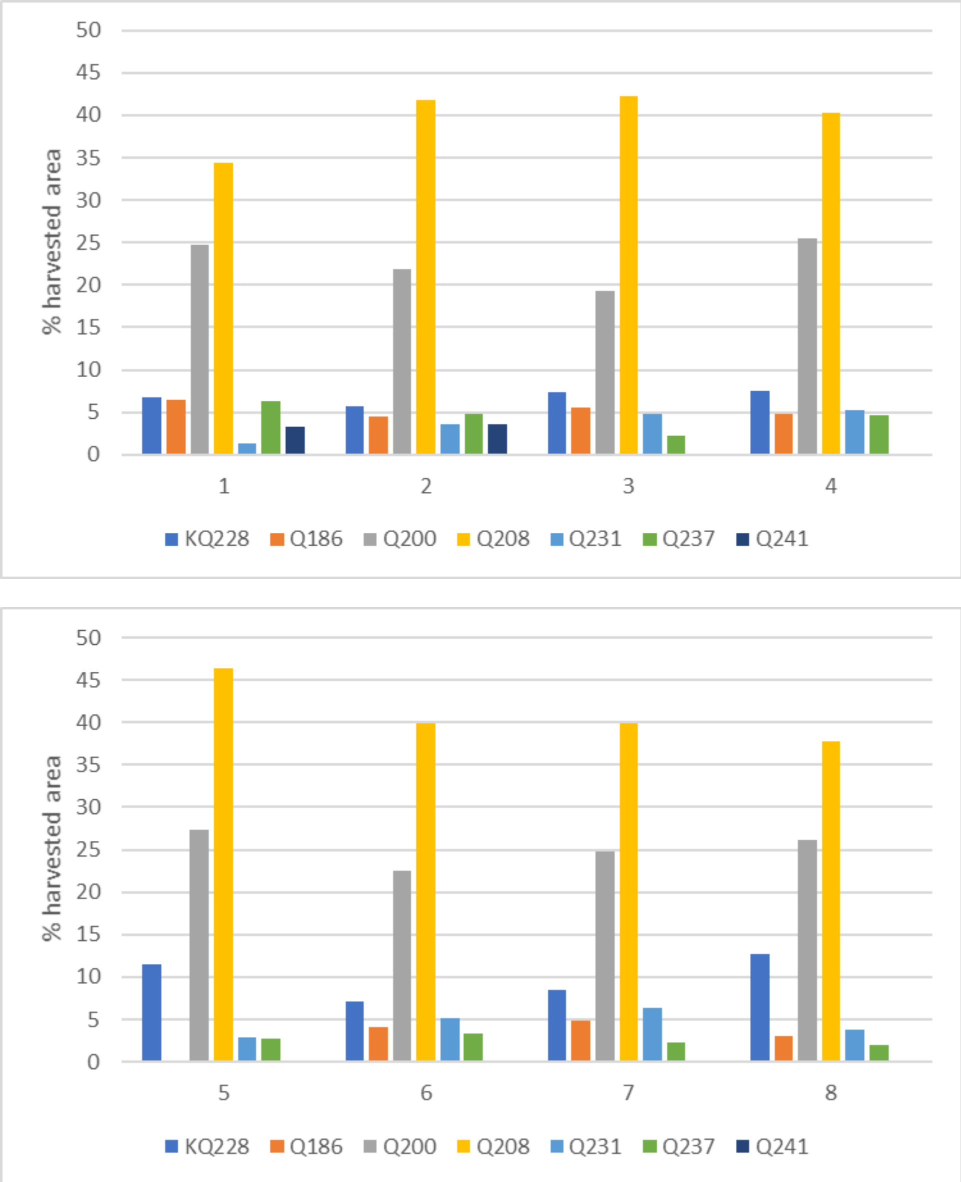
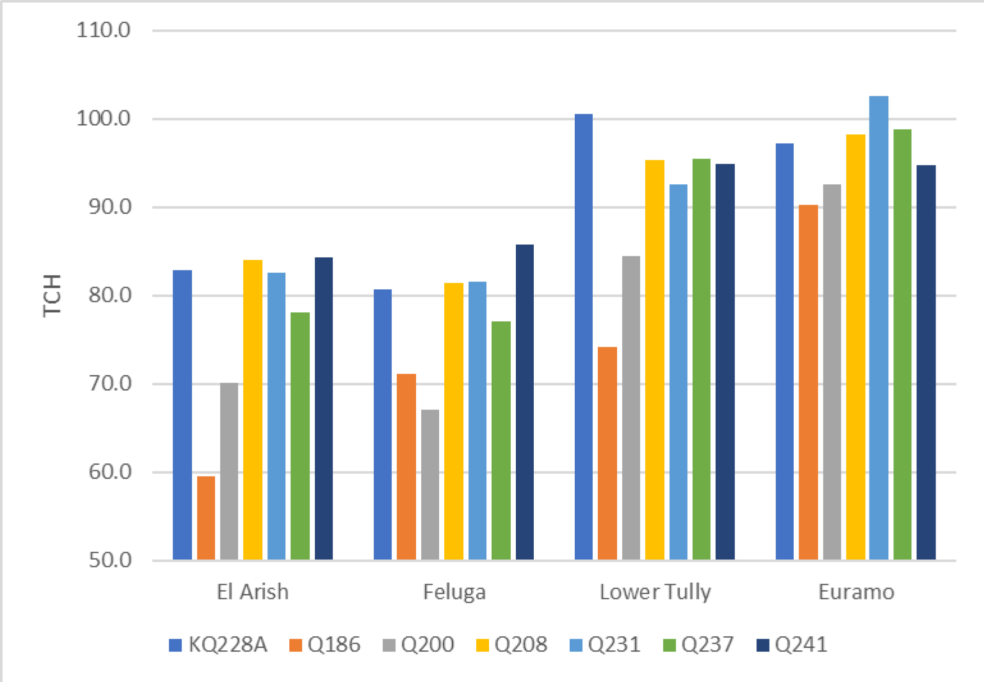


Figure 58: The percentage of the area planted to the top 7 varieties in cane yield clusters 1 to 8, 2012 to 2017 in the Tully mill area.

The cane yield performance of varieties in the 8 subdistricts are shown in Figure 59. The highest performing varieties in all districts were KQ228, Q208, Q231, Q237 and Q241. Q186 performed poorly relative to the other varieties in all districts. Q200 had lower cane yield but its' high CCS and $/ha accounts for its continued popularity (an example of the effect of Q200's high CCS on $/ha return is shown in Figure 67 and Figure 69). The variety Q241 has sugar quality issues which has restricted its wider adoption. In retrospect, the yield of the mill area could have been improved in the period if the area planted less Q186. Q208 and Q200 gave growers the highest $/ha returns during the period and were the most widely grown varieties.



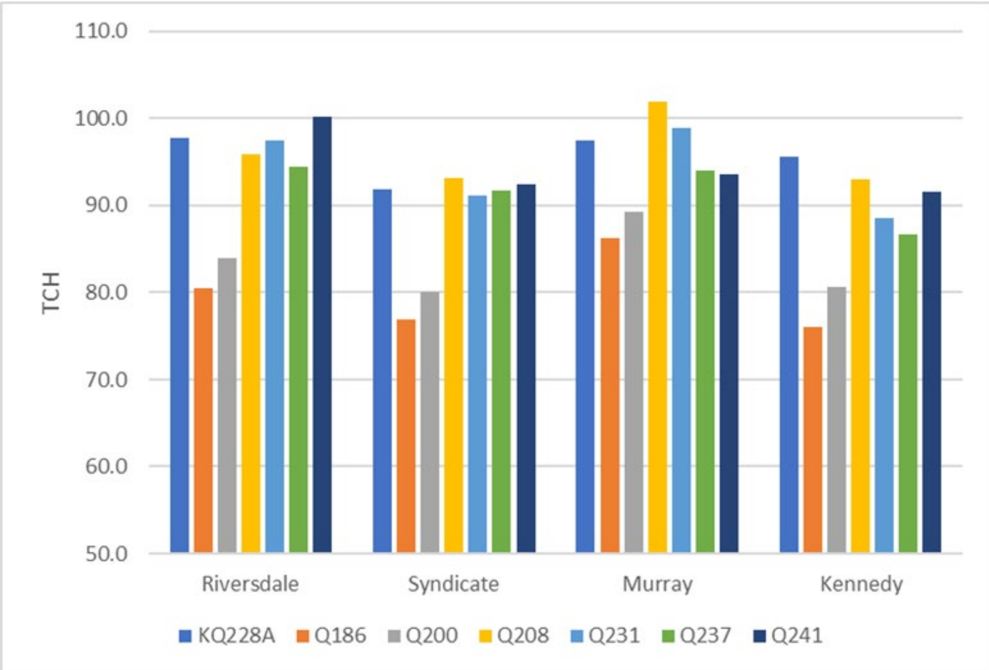
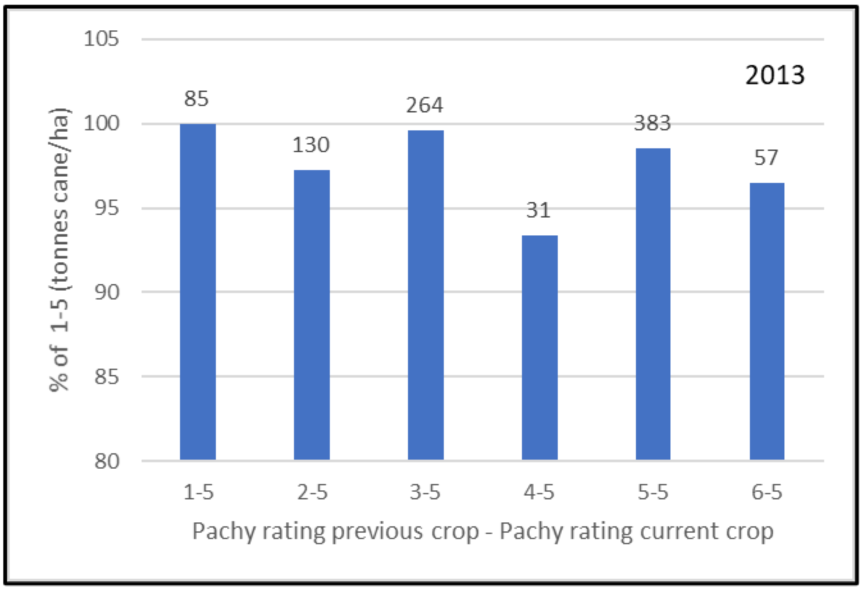


Figure 59: The average cane yield (TCH) of the top 7 varieties in the 8 subdistricts, 2012 to 2017 in the Tully mill area.

Pachymetra resistance of previous variety on yield in current crop

Previous analyses conducted on mill data from the Herbert had shown that the Pachymetra resistance of the previous variety in a crop cycle significantly affected the yield of the current crop planted in the block (Stringer et. al 2016). This confirmed research conducted by Rob Magarey and strengthened the extension message that varieties that are intermediate to Pachymetra should be rotated with resistant varieties especially if high Pachymetra oospore counts are found in fields after growing a crop of intermediate variety.

Similar analyses were conducted for Tully mill area for the years 2013 and 2015 but because Pachymetra susceptible varieties have not been grown in Tully for many years, comparisons were only made between varieties rated 1 to 6 for Pachymetra resistance (disease resistance scale of 1-9 where 1 is highly resistant and 9 is highly susceptible). Subdistricts where Pachymetra was reported to be low were excluded from the analyses. The yield of varieties rated 5 (intermediate) and 6 (intermediate to susceptible) were compared when planted in blocks previously planted to varieties with ratings 1 to 6 (Figure 60 and Figure 61). Although there was a trend for the varieties rated 5 and 6 to yield better when planted after varieties rated 1 (highly resistant) than after varieties rated 4-6 (intermediate) the effect was not consistent in all cases and varied between years.



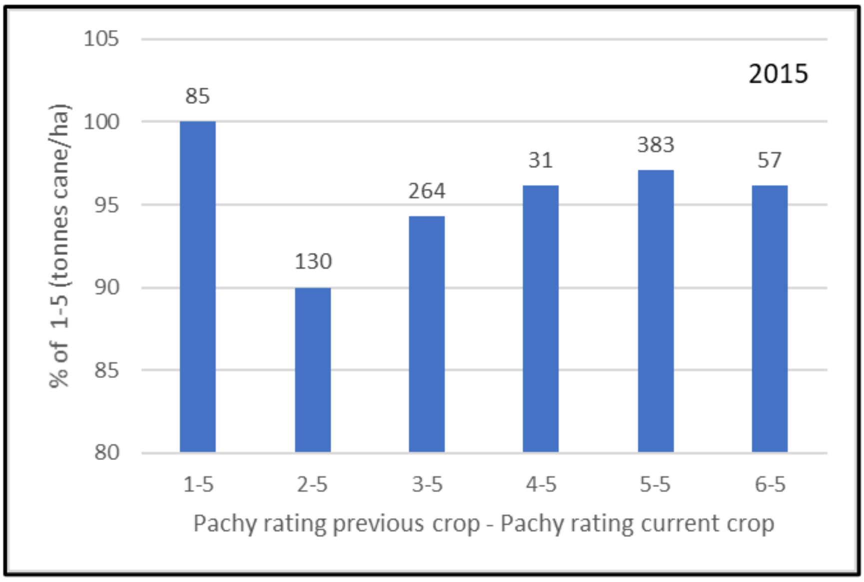
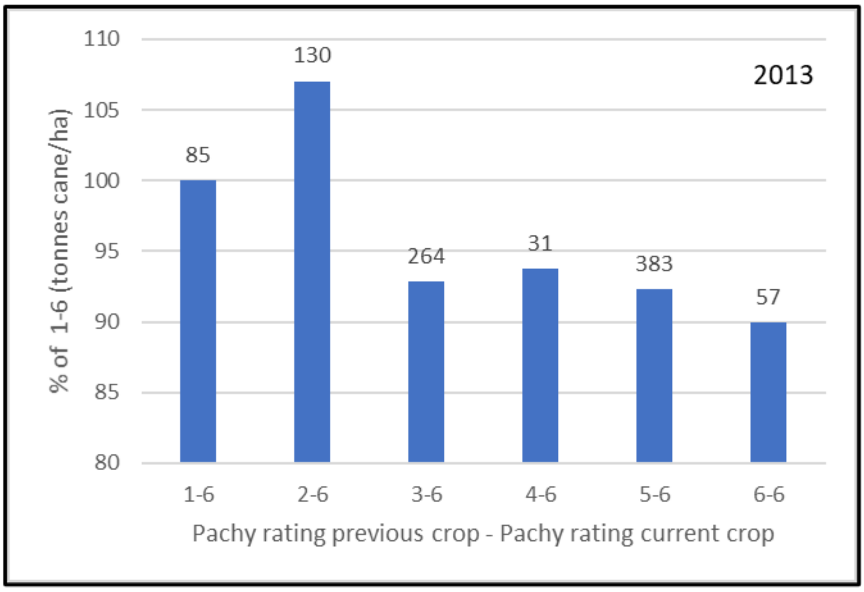


Figure 60: Yield of blocks of varieties rated 5 (intermediate) in 2013 and 2015 previously planted to varieties rated 1 (highly resistant) to 6 (intermediate to susceptible) to Pachymetra relative to blocks planted to varieties rated 1 (highly resistant) equal to 100%. Number of blocks shown above bars.



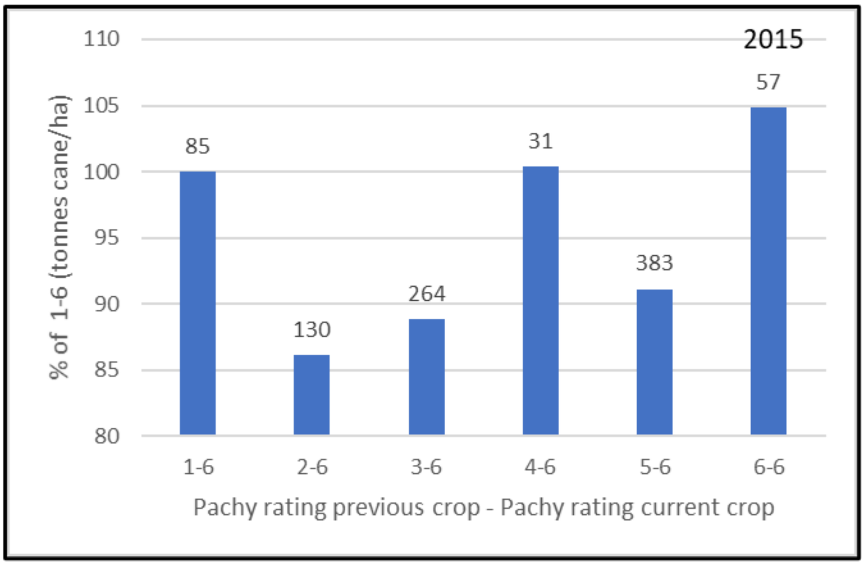


Figure 61: Yield of blocks of varieties rated 6 (intermediate to susceptible) in 2013 and 2015 previously planted to varieties rated 1 (highly resistant) to 6 (intermediate to susceptible) for Pachymetra resistance relative to blocks planted to varieties rated 1 (highly resistant) equal to 100%. Number of blocks shown above bars.

Effect of previous variety on current crop

Analyses in the Burdekin district have shown that the previous variety planted in a block can affect the performance of the next variety planted. In some districts, this may be related to the build-up of pathogens such Pachymetra under varieties of different susceptibility to the disease. However, differences in performance were observed in data from the Burdekin district where Pachymetra is not a major problem. It is postulated that planting a single variety of the one species is an extreme example of monoculture and could potentially favour pathogens to adapt to that one variety of that species. The potential for reduced yield with continual cultivation in a block of a single variety was investigated for data from the Tully mill area.

When the Tully data were examined, only blocks that had previously grown Q200 and Q208 had enough blocks for meaningful analyses. Blocks planted in 2015 and 2016 and harvested as plant crops in 2016 and 2017 were selected for analysis. When the distribution of the selected blocks was examined, blocks previously planted to Q200 and Q208 were not evenly distributed between subdistricts (Figure 62). Q200 is only recommended for good soils and it had a higher percentage of blocks than Q208 in the Euramo, Murray and Riversdale subdistricts, which have above average productivity, and a lower percentage of blocks in lower producing Feluga and El Arish subdistricts. The Kennedy, Lower Tully and Syndicate subdistricts which have average productivity also had a higher percentage of Q200 than Q208 compared with El Arish and Feluga but the difference was not as great as for the above average productivity subdistricts. The distribution of blocks previously planted to these varieties will bias the results of the analyses.

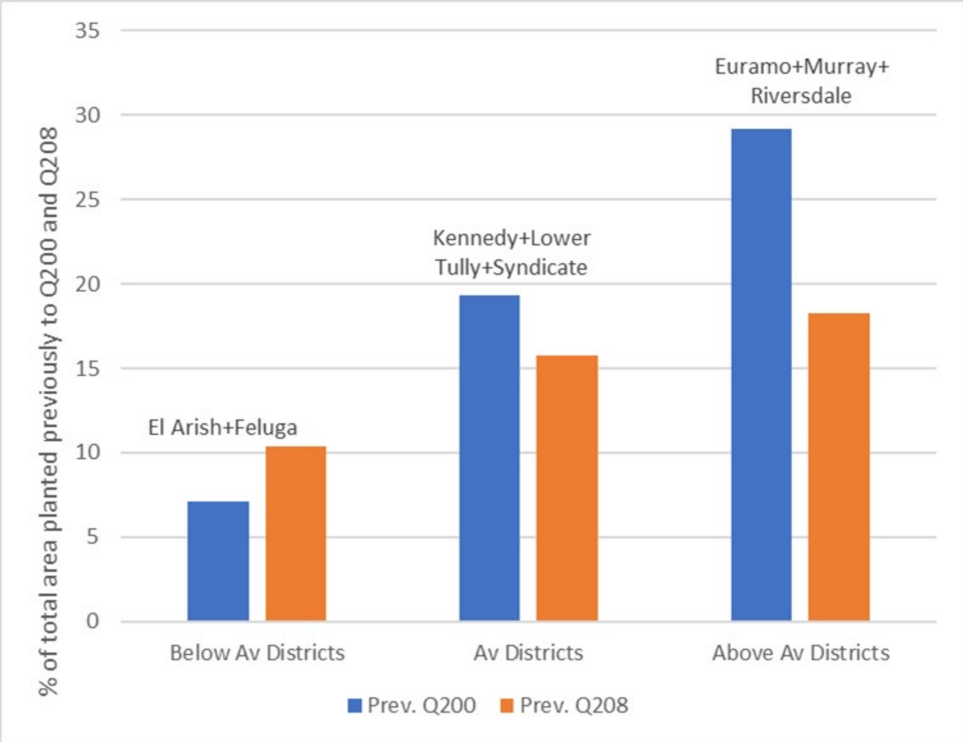


Figure 62: Percentage of blocks previously planted to Q200 and Q208 in the below, average and above average yielding subdistricts of the Tully mill area.

Crops of Q208 planted following Q200 yielded 3.5% more TCH than Q208 planted after Q208 but 3% less \$/ha (Figure 63 and Figure 65). The differences were not significant for TCH or \$/ha (T-test $p > 0.05$).

Crops of Q200 planted following Q200 yielded 5% more TCH than Q200 planted after Q208 and 9% more \$/ha (Figure 64 and Figure 66). The differences were not significant for TCH or \$/ha.

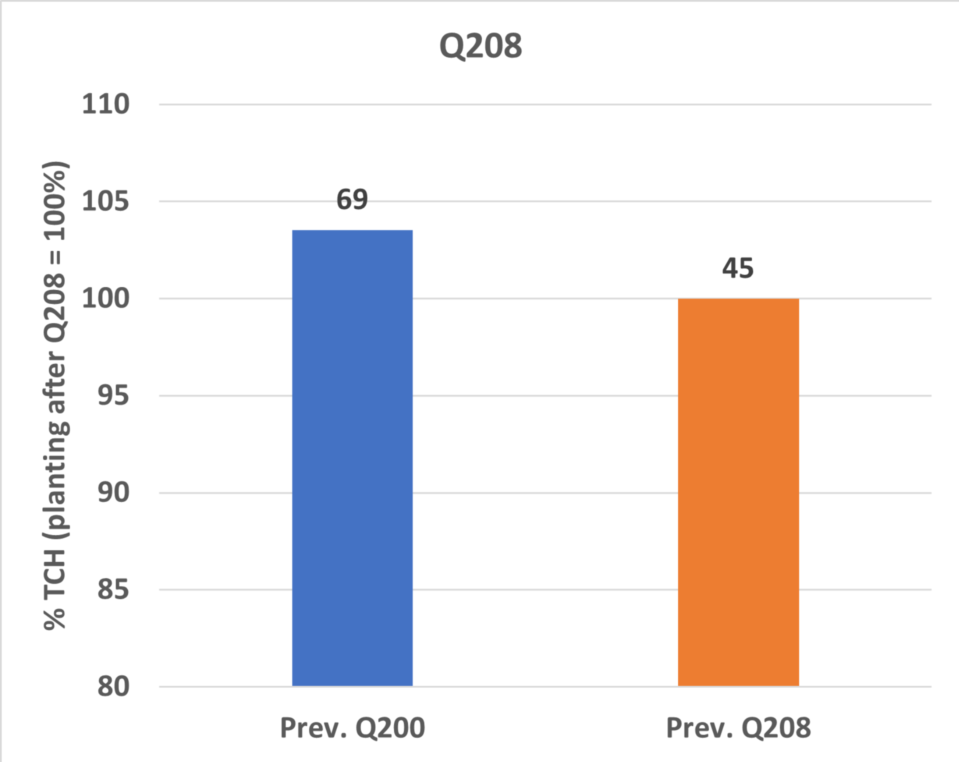


Figure 63: Average TCH expressed as a percentage of the Q208 following Q208 of plant and first ratoon crops of Q208 planted after previous crops of Q200 and Q208. Number of blocks are shown above each column.

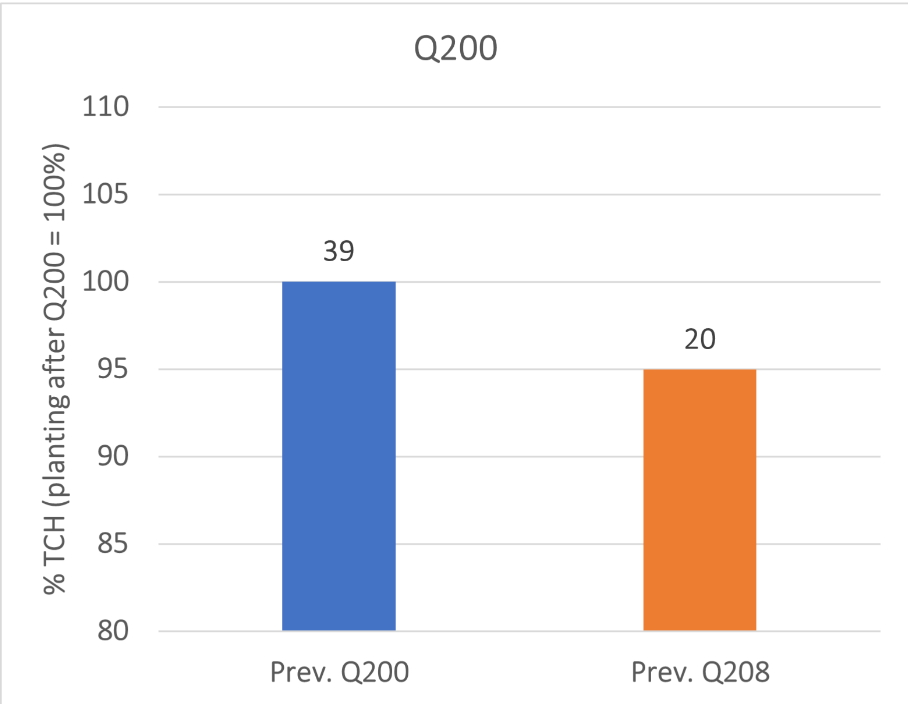


Figure 64: Average TCH expressed as a percentage of the Q200 following Q200 of plant and first ratoon crops of Q200 planted after previous crops of Q200 and Q208. Number of blocks are shown above each column.

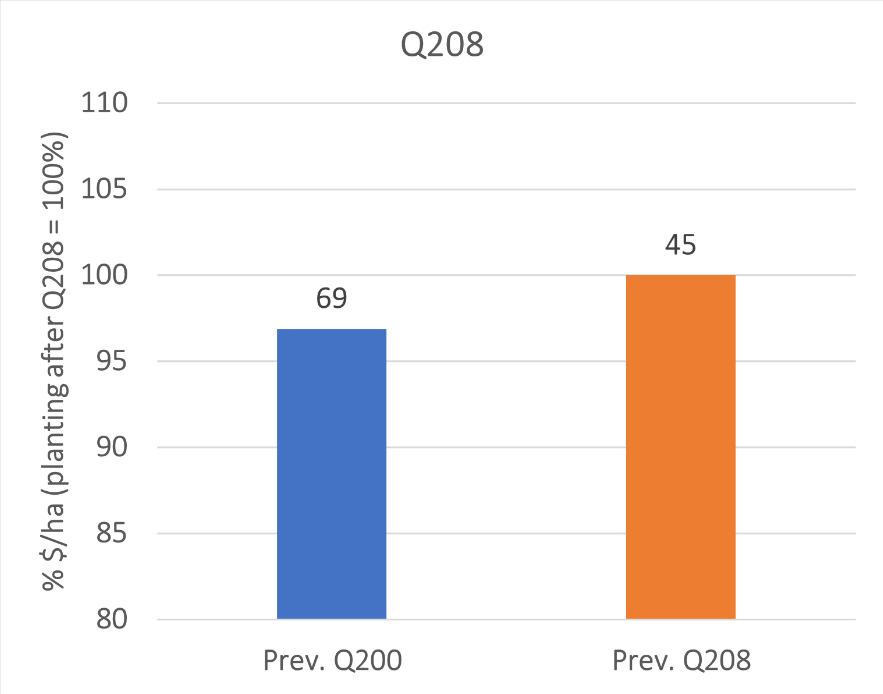


Figure 65: Average $/ha expressed as a percentage of the Q208 following Q208 of plant and first ratoon crops of Q208 planted after previous crops of Q200 and Q208. Number of blocks are shown above each column.

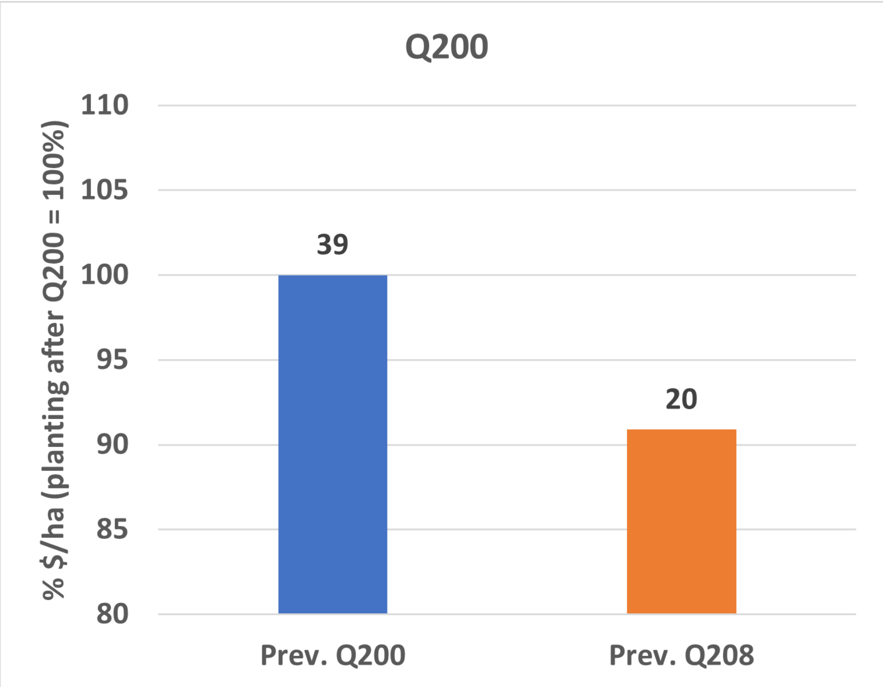


Figure 66: Average $/ha expressed as a percentage of the Q200 following Q200 of plant and first ratoon crops of Q200 planted after previous crops of Q200 and Q208. Number of blocks are shown above each column.

Although the differences are not statistically significant, the trend is that Q200 provides the best $/ha returns to growers on blocks that previously grew Q200 and Q208 provides the best return on blocks that have previously grown Q208. These two varieties have been grown for more than 10 years in the Tully mill area and growers have a good knowledge of their performance and are likely to plant them in the areas that suit them best. The difference in adaption of these varieties to different soil type/environmental conditions means that any effect of build-up of pathogens in the soil under the varieties is masked by the different properties of the soils and environments where the varieties are grown. No conclusions can be made about rotating varieties from this data.

A new way of examining new varieties

An idea suggested by the data was that the performance of new varieties on blocks where the established Q200 and Q208 were previously grown may provide a different way of assessing the new varieties relative to the well-established varieties. Recommendations could be based on planting the new varieties where Q200 or Q208 have been grown and performed well in the past.

The TCH and $/ha of blocks planted to Q231, Q240, Q250 and Q251 were compared to blocks planted to Q200 and Q208 on blocks that had previously grown Q200 or Q208 (Figure 67, Figure 68,Figure 69 and Figure 70).

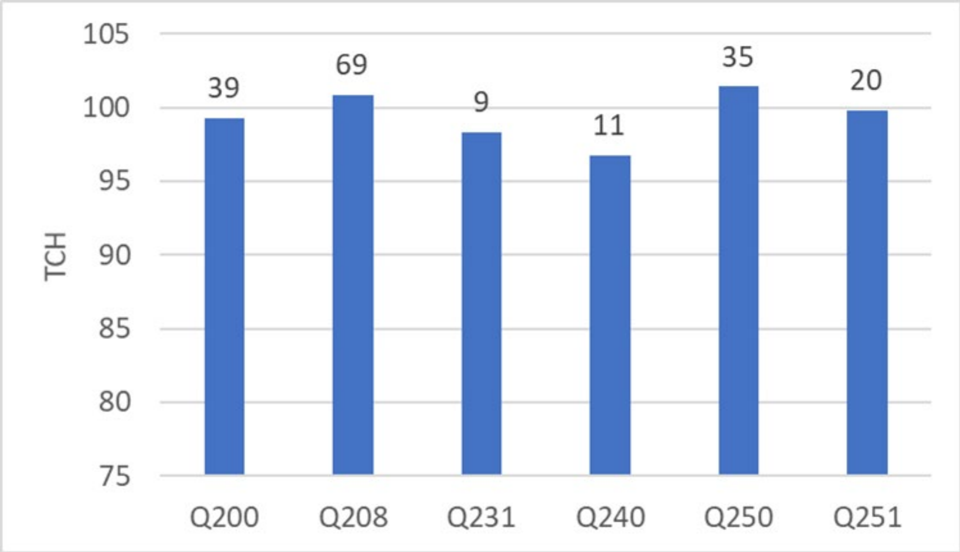


Figure 67: Average TCH of Q200, Q208, Q231, Q240, Q250 and Q251 planted after previous crops of Q200. Number of blocks are shown above each column.

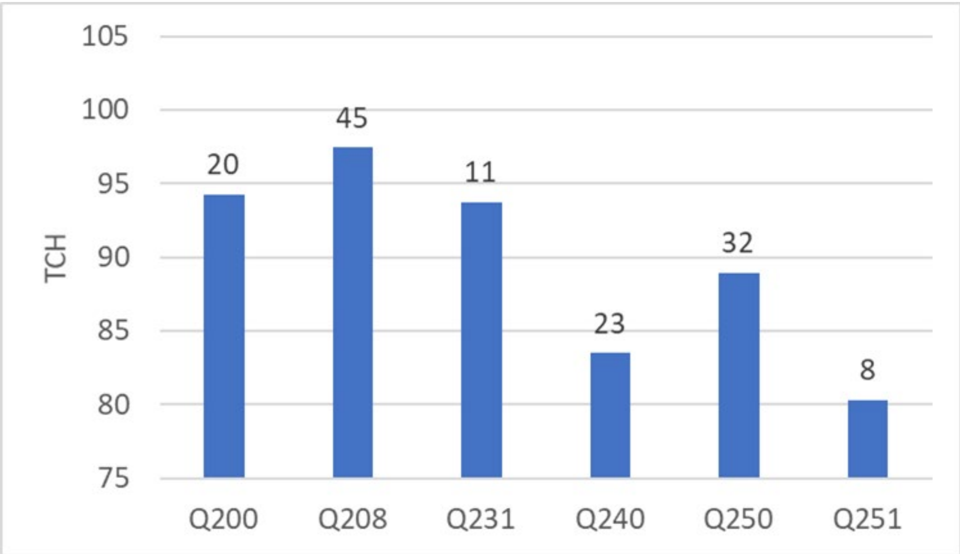


Figure 68: Average TCH of Q200, Q208, Q231, Q240, Q250 and Q251 planted after previous crops of Q208. Number of blocks are shown above each column.

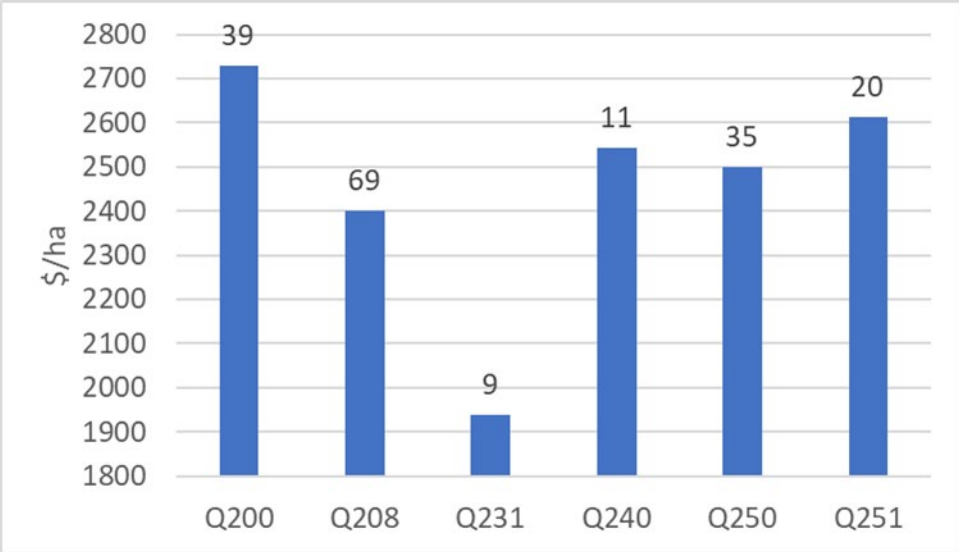


Figure 69: Average $/ha of Q200, Q208, Q231, Q240, Q250 and Q251 planted after previous crops of Q200. Number of blocks are shown above each column.

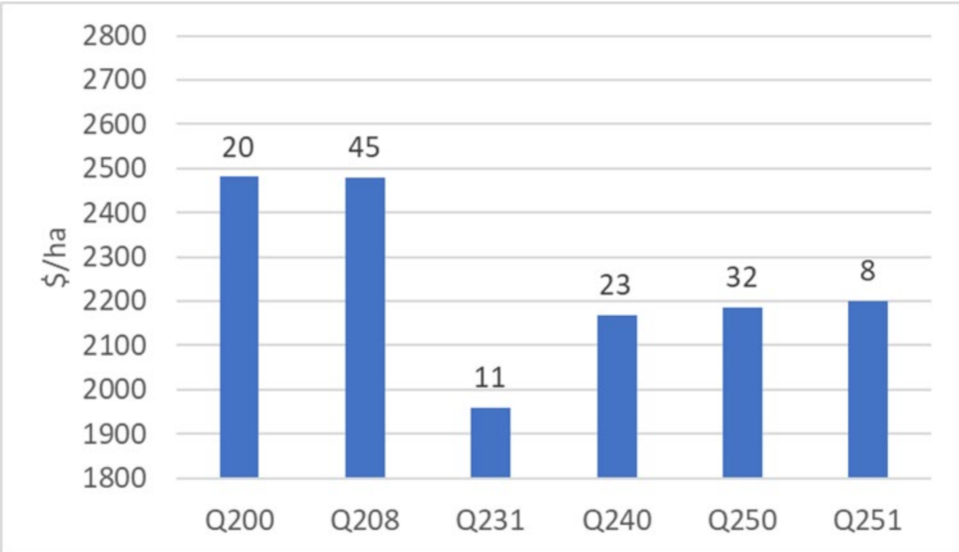


Figure 70: Average $/ha of Q200, Q208, Q231, Q240, Q250 and Q251 planted after previous crops of Q208. Number of blocks are shown above each column.

The best $/ha return to growers on blocks that have previously grown Q200 was still provided by Q200 followed by Q251 and Q240. On blocks that have previously grown Q208, the best varieties were Q208 and Q200 with a similar $/ha return. The next best varieties were Q252, Q250 and Q240. These analyses only included plant and first ratoon crops and therefore the influence of ratooning ability over a full crop cycle is not considered. Limited ratoon data are available for the newer varieties.

Variety composition and performance in the Feluga and El Arish Subdistricts

Feluga and El Arish are the lowest yielding subdistricts in the Tully mill area. The variety composition in these subdistricts was compared to the variety composition in other subdistricts to see if variety choices by growers could partially explain the poor performance in these areas. Data from 2012-2018 was used.

The variety composition in the poor yielding Feluga and El Arish subdistricts combined compared to combined variety composition for subdistricts which have average yield (Kennedy, Lower Tully and Syndicate) and the above average yield (Euramo, Murray and Riversdale) is shown in Figure 71. The differences in variety composition were minimal between the three groups of subdistricts. Q200 is lower in the Feluga and El Arish subdistricts than in average and above average yielding subdistricts. Minor varieties which have been grouped in the "other" category were much higher in the Feluga and El Arish subdistricts. The proportion of soil types suited to different varieties is different between these subdistricts and would be expected to influence variety composition.

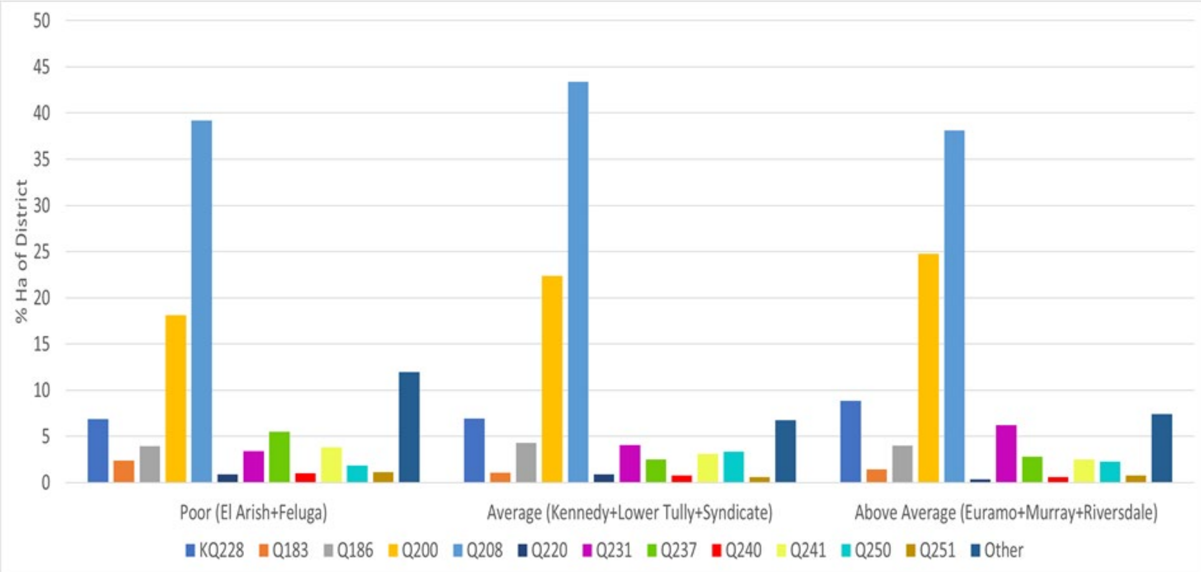


Figure 71: Variety composition in poor yielding subdistricts (Feluga and El Arish), average yielding subdistricts (Kennedy, Lower Tully and Syndicate) and above average yielding subdistricts (Euramo, Murray and Riversdale) in the Tully mill area for the years 2012 to 2018.

The variety performance ($/ha) in the Feluga and El Arish subdistricts for varieties that were grown in all years from 2012 to 2018 is shown in Figure 72. Q183 had the highest $/ha return but made up only 2% of the subdistricts and the small sample size probably suggests caution when making conclusions about its performance more widely in the subdistricts. Q208 (39 % of subdistricts, $1663/ha) and Q200 (18 % of subdistricts, $1661) were the next best varieties. The performance of Q200 and Q208 was similar which is surprising considering Q208 is recommended for poor, average and good soils. The average return for all varieties, other than Q200 and Q208, was $1556 or approximately $46/ha less than Q200 and Q208. If Q208 was planted at 70% instead of only 39% of the area in Feluga and El Arish, the average return to growers could have potentially been approximately $197,000/year greater. This analysis highlights the impact of choice of varieties on growers returns.

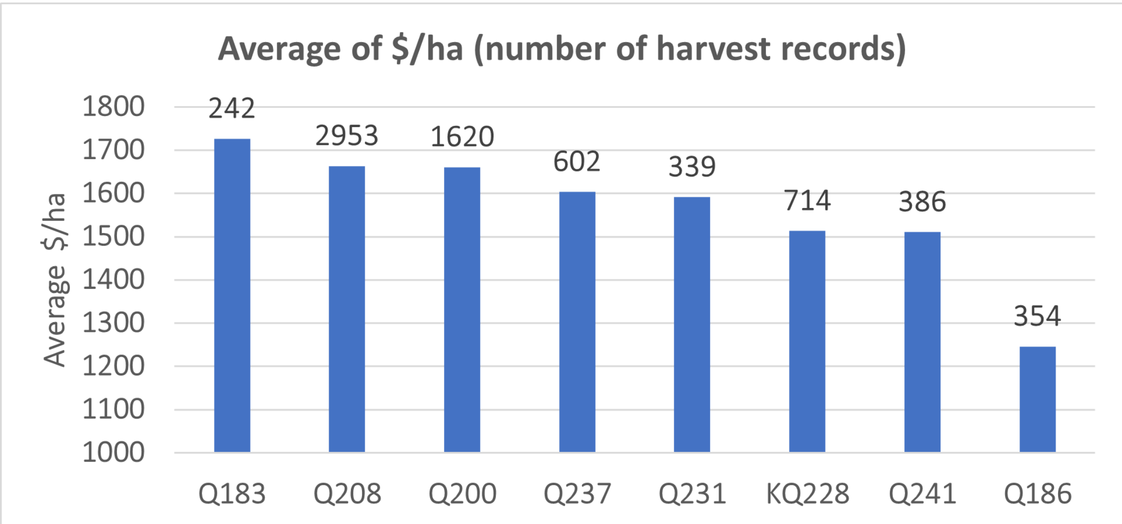


Figure 72: Variety performance ($/ha) of varieties grown in all years from 2012-2018 in the Feluga and El Arish subdistricts.

We examined if mill data can assist growers to make better variety choices in the future in Feluga and El Arish subdistricts. New varieties have limited data and if care is not taken the analysis of mill data for new varieties can be distorted by small sample size and the higher proportion of plant and early ratoon crop classes of new varieties compared to established varieties. An analysis was performed for three relatively new varieties for the

Feluga and El Arish subdistricts, Q240, Q250 and Q251, compared to Q200 and Q208. Data were restricted to first ratoon crops to remove bias due to differing proportions of crop classes. Figure 73 shows the average $/ha of first ratoon crops of the three new varieties and Q200 and Q208 for the years 2016 to 2018. Q200 and Q240 are both only recommended for good soils. Q200 gave 5% higher returns than Q240 in the first ratoon crops in the years examined. Q251 and Q250 are recommended for average to good soils and Q208 is recommended for poor, average and good soils. Q251 averaged 10% higher $/ha returns than Q208. Q208 is widely grown on all soil types and the advantage Q251 shows in these figures may be inflated because Q208 is probably grown on a higher percentage of poorer soil types than Q251. However, Q251 has performed well and, if its performance continues to impress in coming years, growers should continue to plant more of this variety. Q250 did not perform as well as Q251 or Q208. These results are only for first ratoon crops and do not consider long term ratooning potential which is another important consideration when choosing varieties. As more data becomes available, the ratoon performance of these new varieties should be reviewed.

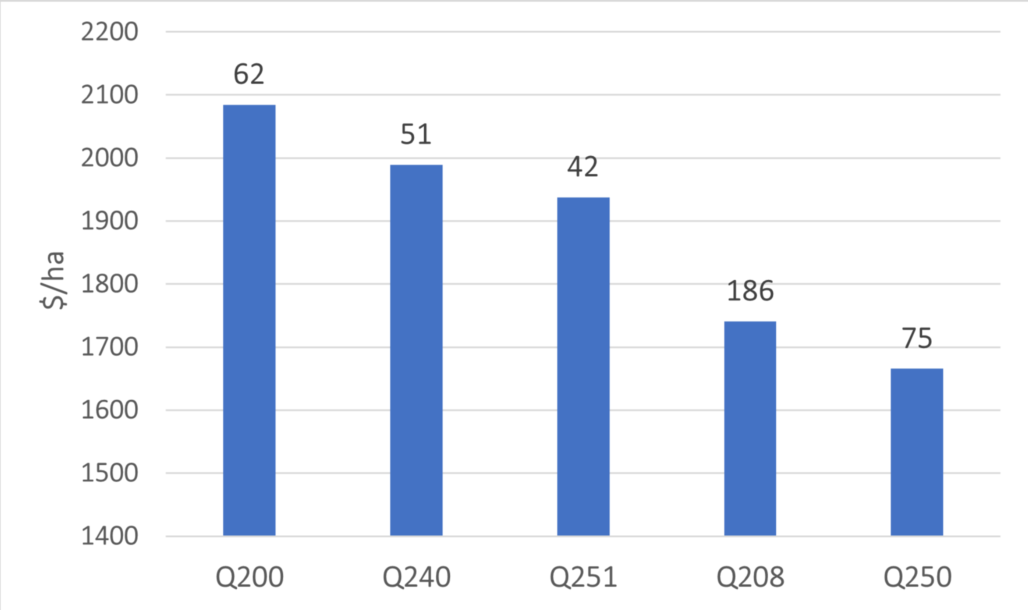


Figure 73: Variety performance ($/ha) of first ratoon crops of three new varieties compared with Q200 and Q208 in the years from 2016-2018 in the Feluga and El Arish subdistricts in the Tully mill area.

Farm size

Farm size affects the management decisions of growers. The data obtained from the mill gives farm number, this often hides groups of farms managed as one by a grower. However, many small farms could affect the efficiency of farm management if they are managed independently. The average tonnes cane per ha for farms of different sizes are shown in Figure 74. Small farms are clearly lower yielding than larger farms. Obviously, there is a bias in the data because many of the larger farms are in the more productive regions such as the Murray subdistrict (Figure 75), however relatively small farms occur in all regions except the Murray. Amalgamation of smaller farms is likely to improve the productivity in the mill area.

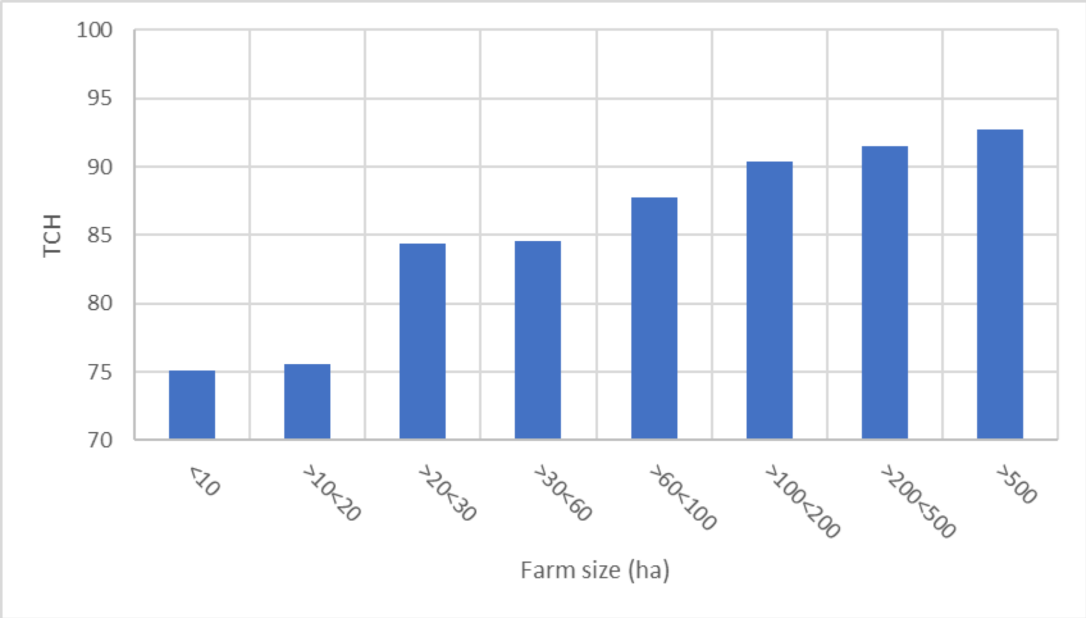
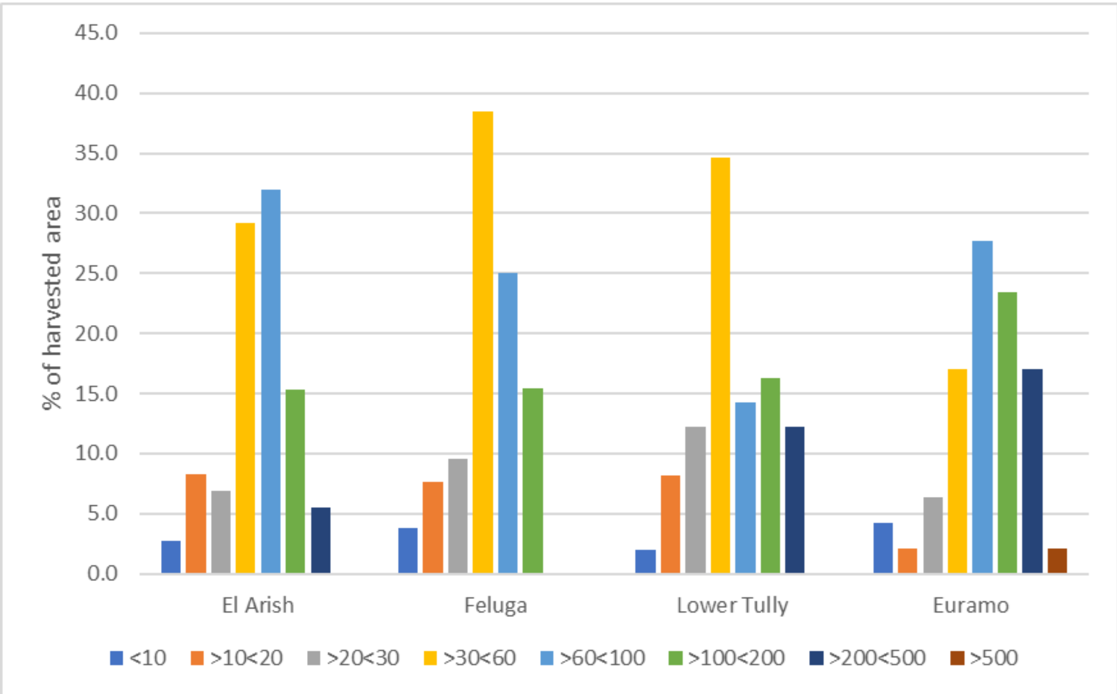


Figure 74: The average yield of farms of different size, 2012 to 2017 in the Tully mill area.



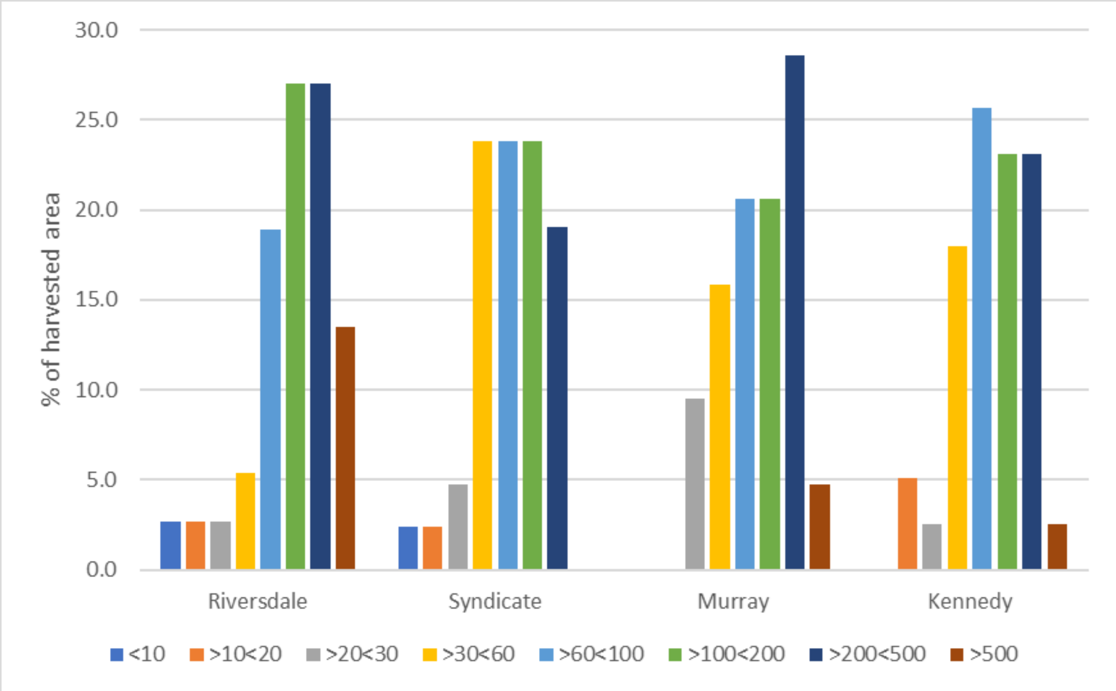


Figure 75: The percentage of farms of different size (harvested ha) for the 8 different subdistricts, 2012 to 2017 in the Tully mill area.

Conclusions

The long-term average tonnes sugar per ha in the Tully mill area is 10.6 t/ha but yields fluctuate greatly with lower yields associated with above average rainfall and cyclones. Productivity is lower in the high rainfall subdistricts compare with the lower rainfall subdistricts. A combination of factors is likely to be associated with this difference including waterlogging, highly leached soils and lower radiation in the high rainfall subdistricts. Given these environmental constraints to productivity, the Tully industry aims to increase productivity to an average of 90 tonnes cane/ha across the whole district.

Cluster analysis using mill data has been conducted to group growers on farm size and productivity. The analysis has identified groups of growers who could benefit from targeted extension programs to lift their productivity and maximise the impact of extension programs. Tully Productivity Service, Tully Sugar and SRA have used the target groups to conduct extension programs.

Mill data has also been used to investigate effect of variety, crop class and Pachymetra root rot resistance on productivity in the Tully mill area as a whole and in individual subdistricts.

Q208 and Q200 have been the most popular varieties in the Tully mill area for the last 10 years and the analyses support that in most cases these varieties outperformed all other varieties including newer varieties for which data was available. A new method of assessing performance of new varieties, using mill data, by comparing their performance in blocks that have previously grown well established varieties, such as Q208 and Q200, shows promise. Growers have extensive experience with well-established varieties and by comparing yield of new varieties planted into blocks where established varieties were grown in the previous crop, with the yield of established varieties in similar blocks, should provide growers with an accurate comparison of the performance of these varieties. This is an example of using mill data to make better recommendations for varieties based on actual mill data.

The impacts of severe weather events on farm management can have flow on effects for many years. The impact of above average rainfall during the harvest season in 2010 and cyclone Yasi in 2011 saw a 50% increase in planting in 2012 which flowed through to higher proportions of first, second, third and older ratoons in succeeding years. Yield in Tully decreases on average 6% with each ratoon crop. The highest percentage of older ratoons because of the large planting season in 2012 occurred in 2017 which would have a depressive effect on overall mill productivity. Understanding long-term effects of management decisions using mill data can help mill areas to objectively assess their productivity and plan to moderate these effects where possible.

Tully has largely discontinued the practice of replanting with no fallow, this has benefits for soil health and management of diseases such as RSD which can carryover in volunteers in replant crops. Mill data allows tracking the success of extension programs to improve farm management practices and allows resources used in these programs to be redirected when targets have been achieved.

Tully growers no longer grow Pachymetra susceptible varieties and varieties with intermediate resistance make up a large proportion of the crop. Mill data was used to analyse the effect of continually growing varieties with intermediate Pachymetra resistance compared with rotating intermediate and resistant varieties to reduce the effects of Pachymetra. Data suggested there may be some benefit in rotating intermediate varieties with resistant varieties to reduce the levels of Pachymetra in soils. Growers in Tully have had limited choice of high yielding resistant varieties. The analyses support continued research and breeding to increase the number of high yielding resistant varieties available to growers.

Analysis of cane quality data

Tully mill is unique in that it is at capacity with approximately 3M tonnes supplied per annum. As such, it is required to place a greater emphasis on cane quality. This includes purity, fibre/CCS ratio, soil and Effective Bulk Density (EBD). EBD is a transport metric based on bin weights and is adjusted for the three different bins sizes in Tully cane supply. It was added to the Tully cane quality scheme in 2016.

There are important limits for cane quality parameters and deliveries are not eligible for premiums when each parameter is above or below a certain value (limits are confidential). The four parameters are combined into a cane quality score. An analysis was undertaken to determine the key drivers of cane quality and in particular EBD. Previous research by Vitale et *al.* (1997) and Norris (pers comm) have shown that the biggest factors affecting EBD in order of importance are billet diameter (function of variety), EM level (function of variety and equipment operation) and billet length (function of equipment and number of blades per drum).

Tully industry were also interested to determine how elevator pour rate and any characteristics of the harvesting contractors could be related to differences in cane quality.

Datasets

There were two datasets available for the study provided by Tully Sugar Limited (TSL):

2017-2018 season “Cane Quality” data at block level which contained cane quality parameters (purity, soil, CCS/Fibre Ratio and EBD), bin capacity, harvester speed, tonnes harvested, area harvested and cane yield. There were also 1,000 samples of EM but these data were not used. Fibre/CCS is an indicator for EM levels in delivered cane. It is used in placed of mill EM sampling due to the low frequency of the latter.

2015-2018 season “Siding” data by sample by week which contained the 4 cane quality parameters. This dataset contained block level data for Farm, block, variety, crop class, contractor, first cut date, last cut date, siding number, siding characteristics, capacity of siding, fill from both left and right, and distance to the mill. As the Tully industry was particularly interested in determining key drivers of EBD it was the only parameter used in this dataset.

The datasets could not be matched.

The elevator pour rate for each record in the cane quality data was calculated as:

*Elevator pour rate = Cane yield * harvester speed x row spacing/10*

Although the exact row spacing of each farm was not known the data were categoried as “Conventional” row spacing = 1.52m, “Intermediate” row spacing = 1.75m and “Control traffic” row spacing = 1.8m. If a row spacing was not known it was assumed to be 1.52m.

Outliers in the cane quality data were removed prior to analysis. Bin capacity < 80%, purity < 40% and cane yield < 30 t/ha and > 250 t/ha were removed. Mixed and experimental varieties together with harvesting contractor 7 (SRA) were removed.

The siding data was also cleaned before analysis. The varieties Mixed and Experimental together with Contractor 7 (SRA) were deleted. If the first cut date and last cut date for a block were greater than 6 weeks apart the records were deleted. As described in the section on analysis of the productivity data, in Tully there are 8 subdistricts and these are El Arish, Murray, Feluga, Kennedy, Lower Tully, Euramo, Riversdale and Syndicate. The first two digits of a siding are subdistrict except for siding 07STP which is Kennedy cane supplied to Euramo.

There are 31 harvesting contractors in Tully. These were characterized in terms of harvester make and model, primary extractor details, type of drum (factory fitted or after market), number of blades per drum (3,4 or 5), feedtrain optimization and fan speed. There was limited understanding by dealers and operators of machine specifications. Only the type of drum and number of blades per drum for each harvester make and model were accurate and included in the study.

The cane quality data were analysed using a linear mixed model with Subdistrict, Crop Class, Contractor, Variety and Week of season as random effects and Season, Type of drum and Number of blades per drum as random effects.

The siding cane quality data were also analysed using a linear mixed model with Subdistrict, Crop Class, Contractor, Variety and Week of season as random effects and Season, Type of drum and Number of blades per drum as random effects. Distance from the siding to the mill was taken into account as a covariate.

In both analyses the different contractors may have a different error and this was taken into account in the linear mixed model.

Cluster analyses at the farm level were undertaken on the cane quality dataset for:

- EBD vs bin capacity
- EBD vs Fibre/CCS ratio
- EBD vs elevator pour rate

All mixed model analyses were undertaken using Asreml R (Butler, 2019). Cluster analyses were undertaken using R (R Core team 2020).

Results

Table 16 contains the variance components from the analysis of cane quality data in Tully. The variance components given represent the amount of variation accounted for by each effect and can be compared. The largest source of variation for EBD were “Contractor” and “Variety” and these were approximately of equal importance.

Table 16: Analysis of random effect parameters for EBD from the Tully cane quality dataset: 2017-2018.

Effect	Variance components for EBD	Significance
Subdistrict	6	NS
Crop class	17.6	NS
Contractor	177.8	*
Variety	161.6	*
Week	63.6	NS
Error	451.2	

Table 17 contains the results of testing the fixed effects in the cane quality dataset. For EBD none of the effects were significant although the Number of blades per drum approached significance ($p = 0.07$).

Table 17: Analysis of fixed effect parameters for EBD from the Tully cane quality dataset: 2017-2018.

Effect	Purity	Fibre/CCS Ratio	Soil	EBD
Season	*	*	*	NS
Type of Drum	*	NS	NS	NS
Number of blades per drum	NS	NS	NS	NS

Note: * denotes significance at p = 0.05, NS is not significant at p=0.05.

Table 18 contains the variance components from the analysis of siding dataset in Tully. The Siding District is not significant although the different Sidings within Siding District are significant. As was found with the cane quality data, the effects that had most impact on EBD were “Contractor” and “Variety”.

Table 18: Analysis of random effect parameters for EBD from the Tully siding quality dataset: 2015-2018.

Parameter	Variance component	Significant
Siding District	2.8	NS
Contractor	230.7	*
Variety	189.2	*
Sidings within Siding District	54.7	*
Error	634.8	

Note: NS denotes not significantly different (p>0.05), * denotes significantly different (p<0.05).

Table 19 contains the results of testing the fixed effects for EBD in the siding dataset. Distance from the siding to the mill and Type of drum were not significant (p > 0.05). However, the number of blades per drum was significant (p < 0.05).

Table 19: Analysis of fixed effect parameters for EBD from the Tully siding quality dataset: 2015-2018.

Effect	Significant
Distance from Siding to Mill	NS
Season	*
Type of Drum	NS
Number of blades per drum	*

Note: NS denotes not significantly different (p>0.05), * denotes significantly different (p<0.05).

In Table 20 there was no significant difference between Factory Fitted or After Market drums (p>0.05). As there was a significant difference between number of blades per drum the LSD multiple comparison test was undertaken (Table 20). Three blades per drum had a significantly lower EBD than 4 and 5 blades per drum (p<0.05). However, only 1.3% of the crop harvested in 2015-2018 was for 3 blades per drum which is from 1 harvesting contractor. There was no significant difference in EBD between 4 and 5 blades per drum (p>0.05).

Table 20: Comparison of 3,4, and 5 blades per drum for EBD in Tully: 2015-2018.

Number of blades per drum	Mean EBD	Multiple comparison test	% of crop harvested in 2015-2018
3	318	A	1.3
4	352	B	77.5
5	363	B	21.2

In Table 21 is the average EBD and bin capacity of the major varieties in Tully relative to the mill average. The varieties are ranked in descending order for percentage of the crop in 2017-2018. All major varieties have high bin capacity. Q208 which was the most widely grown variety at the time had below average EBD while Q200 was 3.3 units above average. Similarly, Q231 was 3.1 units below average for EBD while the newer variety Q240 was 2.7 units above.

Table 21: EBD and bin capacity for the major varieties in Tully cane supply: 2017-2018.

Major Variety	Average EBD	Relative EBD to mill average	Average bin capacity	Relative bin capacity to mill average	% of Crop
Q208	347	-1.6	99	0	42.0
Q200	352	3.3	99.2	0.1	17.2
KQ228	350	1	99	-0.1	7.2
Q231	346	-3.1	99.1	0	6.5
Q250	350	1.3	99.2	0.1	6.4
Q240	351	2.7	99.6	0.5	2.4
Average All	**348**		**99.1**		**83.5**

In Figure 76 is the EBD for varieties in the SRA variety guide for 2017-2018, including the major varieties listed in Table 21. The average EBD of 348 kg/cubic meter is indicated in the graph and allows low, average and high EBD varieties to be easily identified. Q219, Q231, Q232, Q241, Q242 have low EBD, KQ228, Q208 and Q237 have average EBD and Q200, Q240, Q249, Q250, Q251, Q252 and Q253 have high EBD.

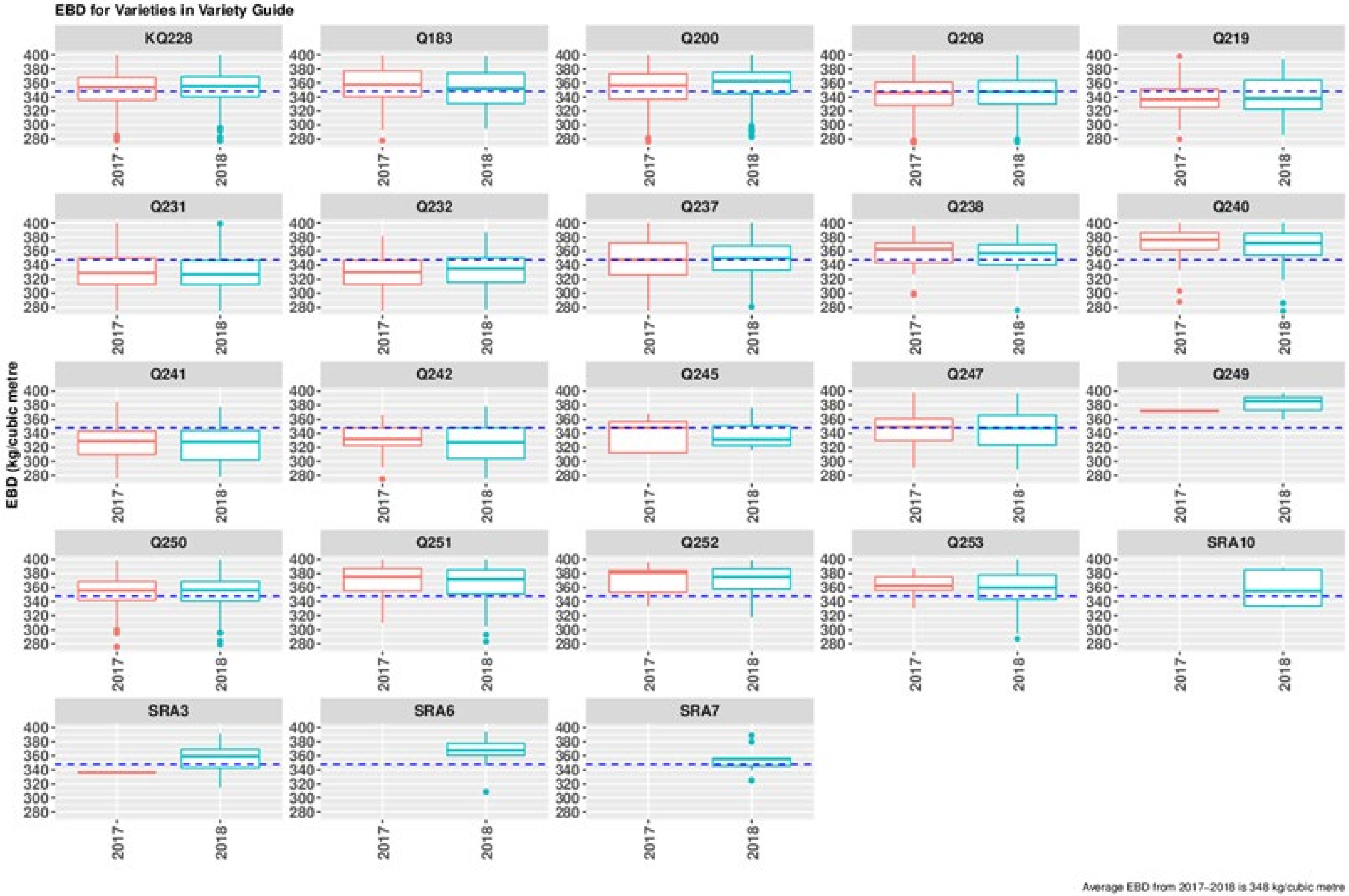


Figure 76: EBD for varieties in the SRA variety guide for 2019. The average EBD of 348 kg/cubic metre is indicated on the graph.

The relationship between EBD and crop class is given in Figure 77: Relationship of EBD vs crop class in Tully: 2017-2018.Figure 77. From 1R to 5R EBD declines with a slope of -0.6.

Figure 77: Relationship of EBD vs crop class in Tully: 2017-2018.

The EBD and bin capacity for each of the eight subdistricts is given in Figure 78. The EBD data are shown in increasing order by subdistrict. Kennedy and El Arish have low EBD and bin capacity. While EBD is a function of the variety and contractor bin capacity is a function of the bin filling (operator) and distance from the mill. Kennedy cane is transloaded to a siding at Euramo before going on the mill so it is not surprising it has lower bin capacity compared to the other subdistricts. Syndicate has low EBD and high capacity. This may be due to high EM. Euramo has the highest EBD of all the subdistricts. Feluga which is the wet climate zone in Tully has above average EBD and bin capacity which is optimal.

To maintain confidentiality of the 31 contractors in Tully the cluster Membership of EBD and Bin Capacity by Subdistrict cannot be discussed in this report. SRA harvesting Team lead by Phil Patane is working closely with harvesting contractors in Tully.

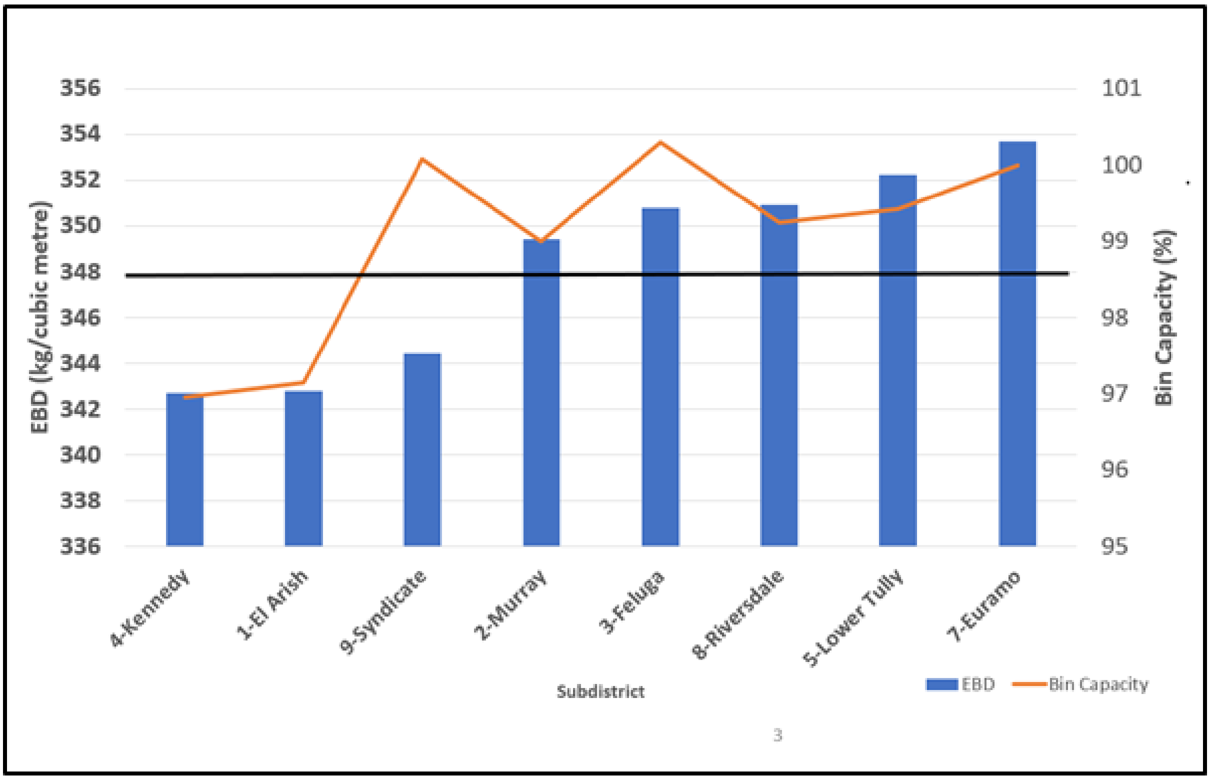


Figure 78: EBD and bin capacity for the 8 subdistricts in the Tully mill area: 2017-2018. The average EBD for 2017-2018 of 348 kg/cubic metre is indicated on the graph.

The relationship between bin capacity and EBD is given in Figure 79. The low and high EM zones together with low and high bin mass are indicated on the graph. There is a strong correlation between capacity and EBD. As EBD increases and capacity decreases this results in a lower EM and higher bin mass. Similarly, when EBD decreases and capacity increases this results in a higher EM and lower bin mass.

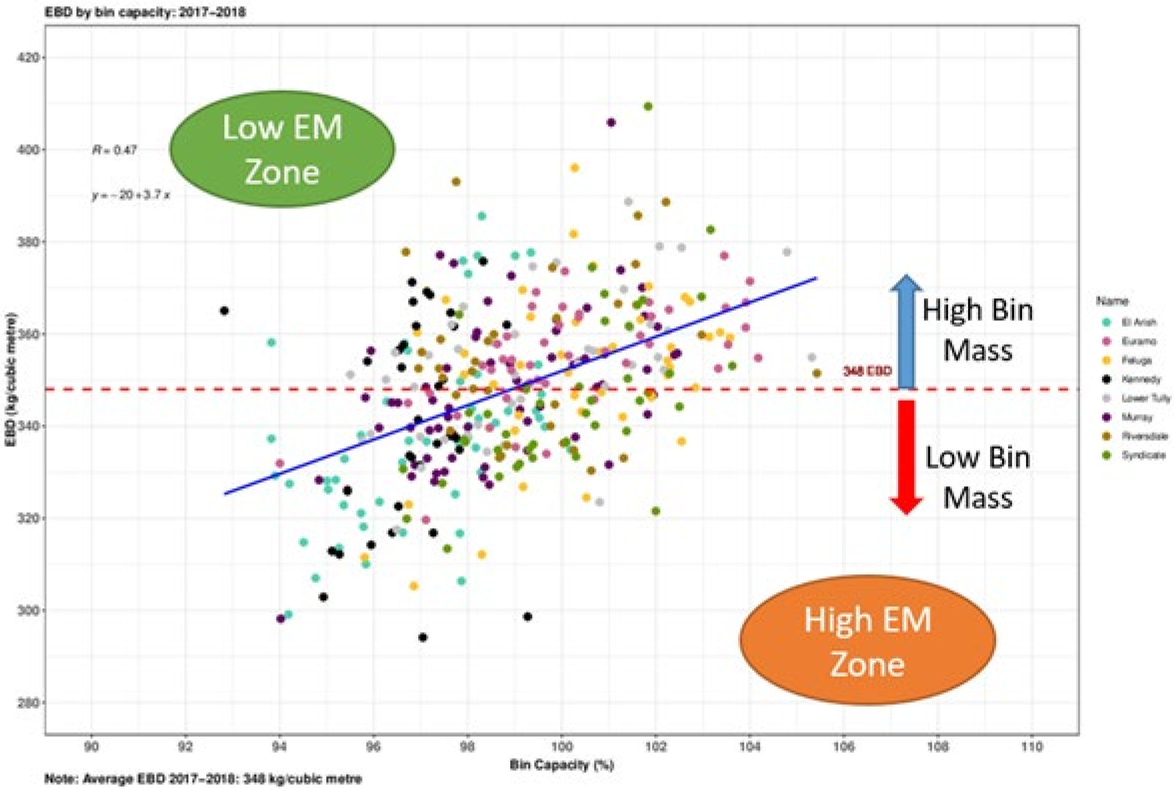


Figure 79: Scatterplot of bin capacity vs EBD in Tully: 2017-2018. The average EBD for 2017-2018 of 348 kg/cubic metre is indicated on the graph.

The results of clustering bin capacity and EBD is contained in Figure 80. The eight different clusters distinguished by different colours are plotted with bin capacity (%) on the x axis and EBD (kg/cubic meter on the y axis. Each circle represents a farm and the industry target is represented by the red dotted line which is 348 kg/cubic meter for EBD. Each colour represents a different cluster, for example the “orange” cluster 6 contains the farms that have high bin capacity and high EBD while the “light blue” clusters 7 contains farms that are low bin capacity and low EBD. The “bad zone” contains farms that have low EBD and high capacity. In this zone there is the potential risk of excessively high pour rates which drive an increase in EM. In the “High EBD and low capacity zone” there is the potential high risk of increased cane loss through aggressive fan speeds.

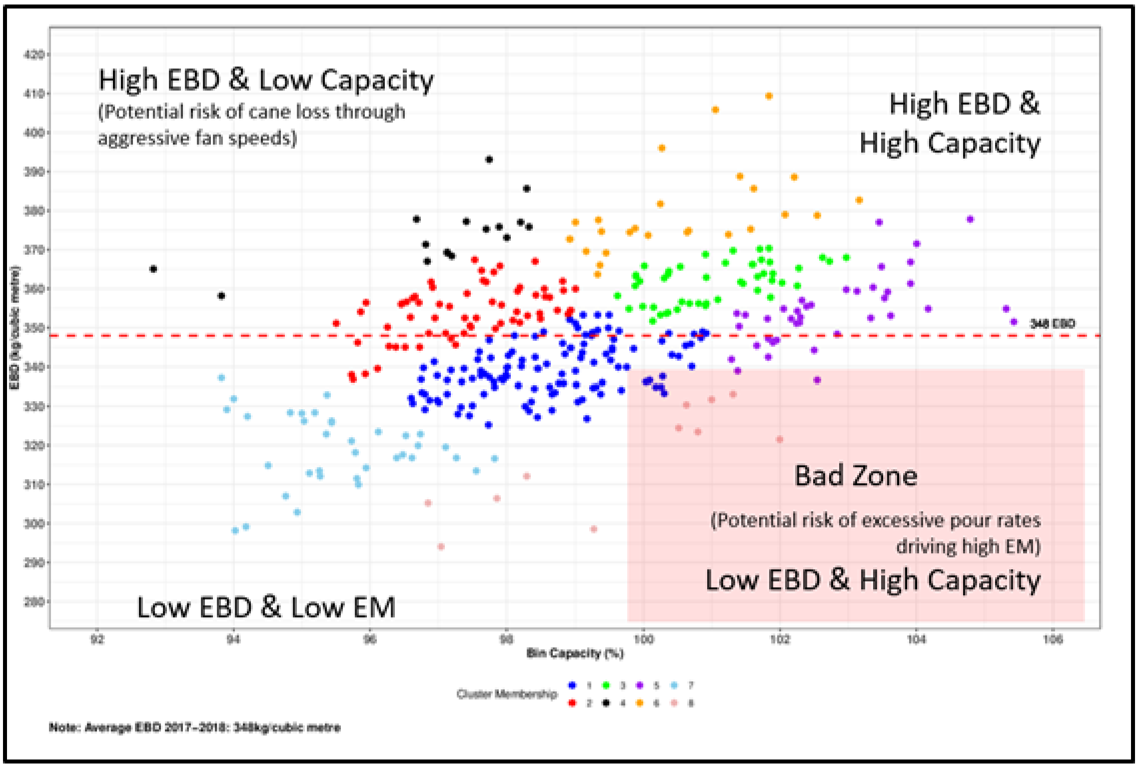


Figure 80: Cluster plot of bin capacity vs EBD in Tully: 2017-2018. The average EBD for 2017-2018 of 348 kg/cubic metre is indicated on the graph.

In Figure 81 contractors coloured in red have the lowest EBD and also the lowest Capacity while the contractors coloured in green have the highest EBD with varying levels of Capacity.

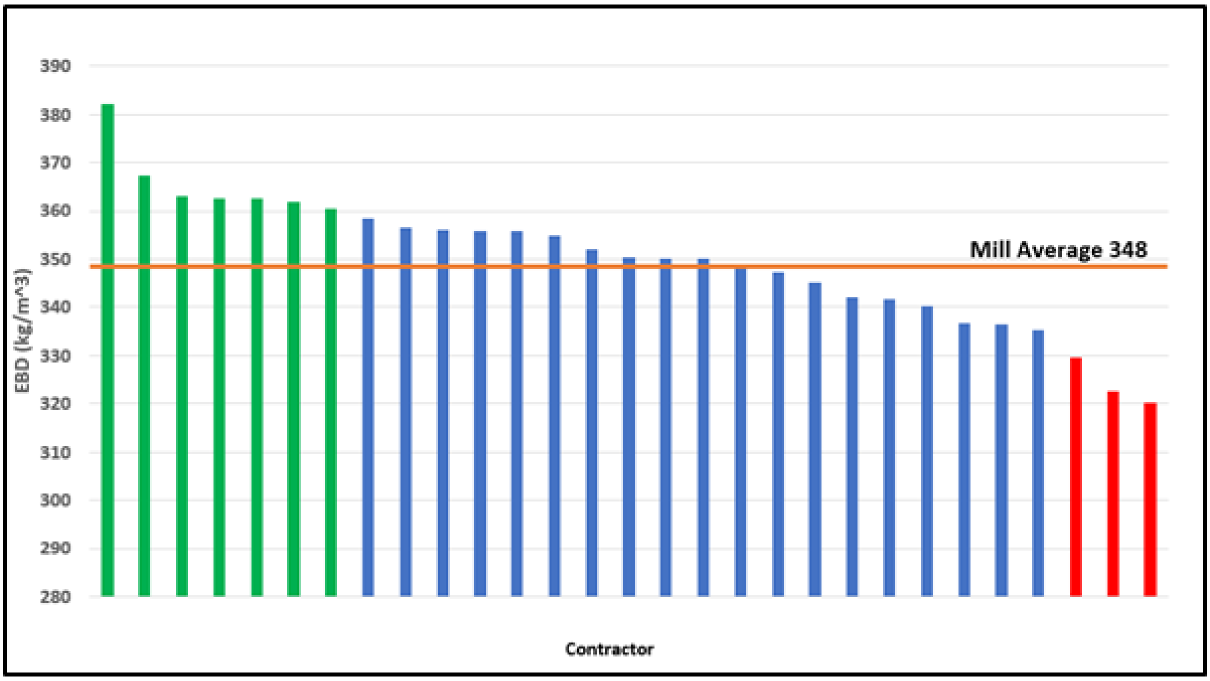


Figure 81: EBD for each contractor in the Tully mill area: 2017-2018. The average EBD for 2017-2018 of 348 kg/cubic metre is indicated on the graph.

Percentage cluster membership by major variety is given in Table 22.

Cluster 6 which has high EBD has twice the proportion of (high EBD) Q200 compared to clusters 7 and 8. Clusters 7 and 8 which have low EBD have 20% more (average EBD) Q208 compared to cluster 6.

Table 22: Percentage membership of the clusters from capacity and EBD by major variety in Tully: 2017-2018.

	% Cluster membership								
Major variety	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**% of crop**
KQ228	7	8	8.5	11.4	7.3	9.1	5.9	10.1	7.1
Q200	17	25	24	18.7	22.3	32.6	16.8	17.3	17.6
Q208	50.3	49	42	43.6	47.9	38.1	57.6	56.3	41.2
Q231	11.6	7	9.9	3	6.9	5.5	10.3	8.7	6.4
Q240	4.1	3	5.1	7.4	7.6	4.9	2.2	1.8	3.1
Q250	10	8	11	15.9	8	9.8	7.3	5.9	8.1

The relationship between fibre/CCS ratio and EBD is given in Figure 82. We have used fibre/CCS ratio as an indicator for EM levels in delivered cane. The low and high EM zones together with low and high EBD are indicated on the graph. There is a moderate negative correlation between fibre/CCS ratio and EBD. As EBD increases and EM decreases there is the potential of significant cane loss through aggressive fan speeds. In the "bad zone" where we have low EBD and high EM there is the potential risk of excessive elevator pour rates which increases EM.

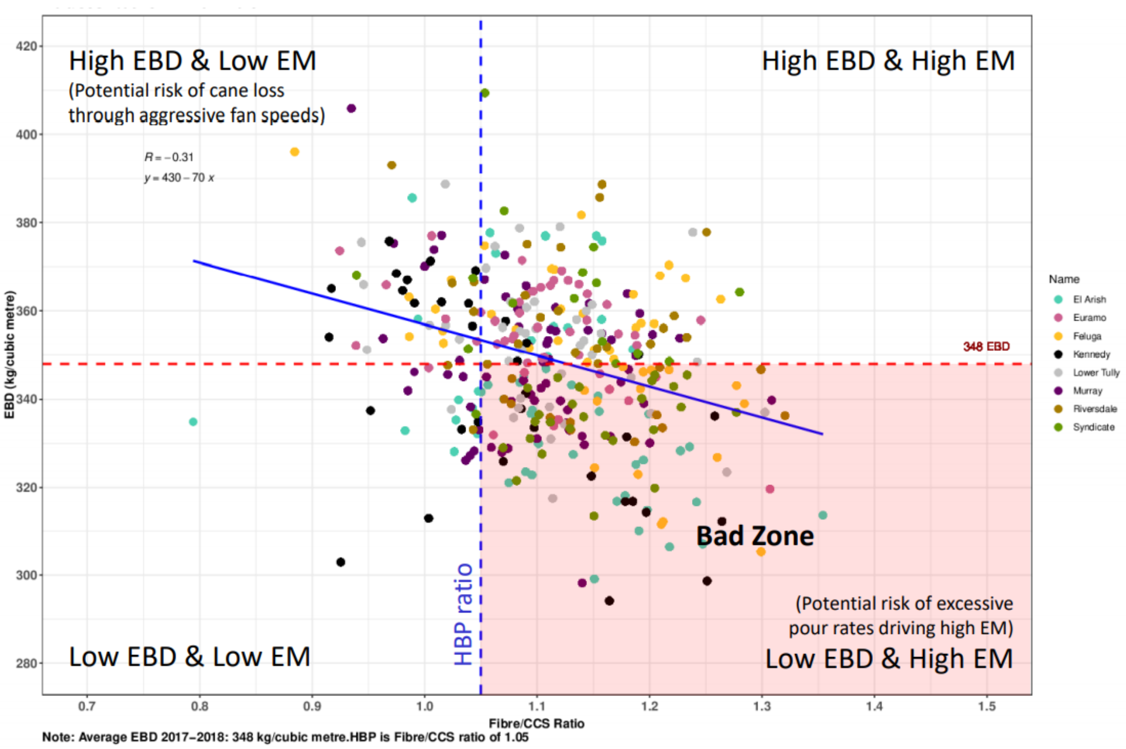


Figure 82: Scatterplot of fibre/CCS ratio vs EBD in Tully: 2017-2018. The average EBD for 2017-2018 of 348 kg/cubic metre and HBP ratio of 1.05 are indicated on the graph.

The fibre/CCS ratio vs EBD by variety relationships are given in Figure 83. The average EBD for 2017-2018 of 348 kg/cubic metre and HBP ratio of 1.05 are indicated on the graph. There are no notable trends. Most varieties are delivered with a fair proportion of elevated EM levels. This could be masking impact of variety on EBD in this circumstance.

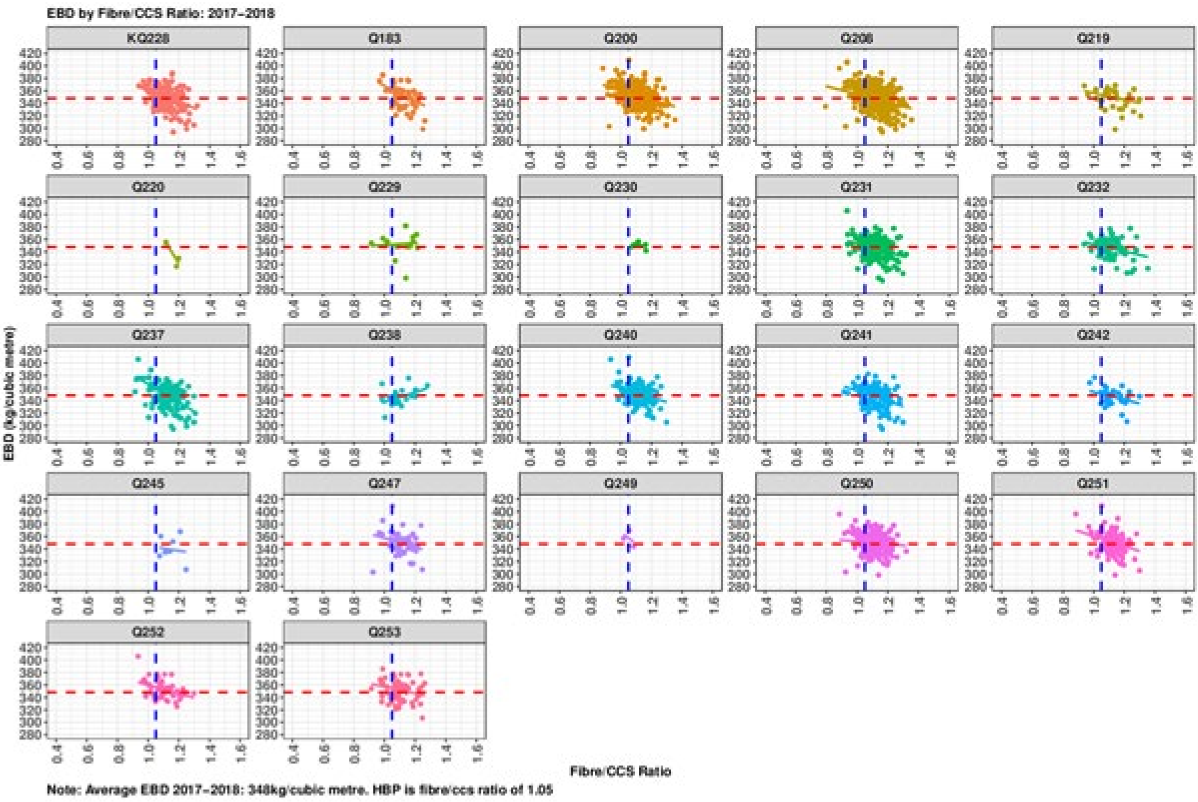


Figure 83: Fibre/CCS ratio vs EBD by variety in Tully: 2017-2018. The average EBD for 2017-2018 of 348 kg/cubic metre and HBP ratio of 1.05 are indicated on the graph.

The fibre/CCS ratio for the 31 harvesting contractors in Tully for 2017-2018 together with HBP target of 1.05 is given in Figure 84. The identity of the contractors is hidden. The HBP Target was estimated from all trials in Australia (Patane 2020). Fibre/CCS ≥ 1.1 have elevated EM levels which drives lower EBD. All of the harvesting contractors except 2 have levels of EM above HBP.

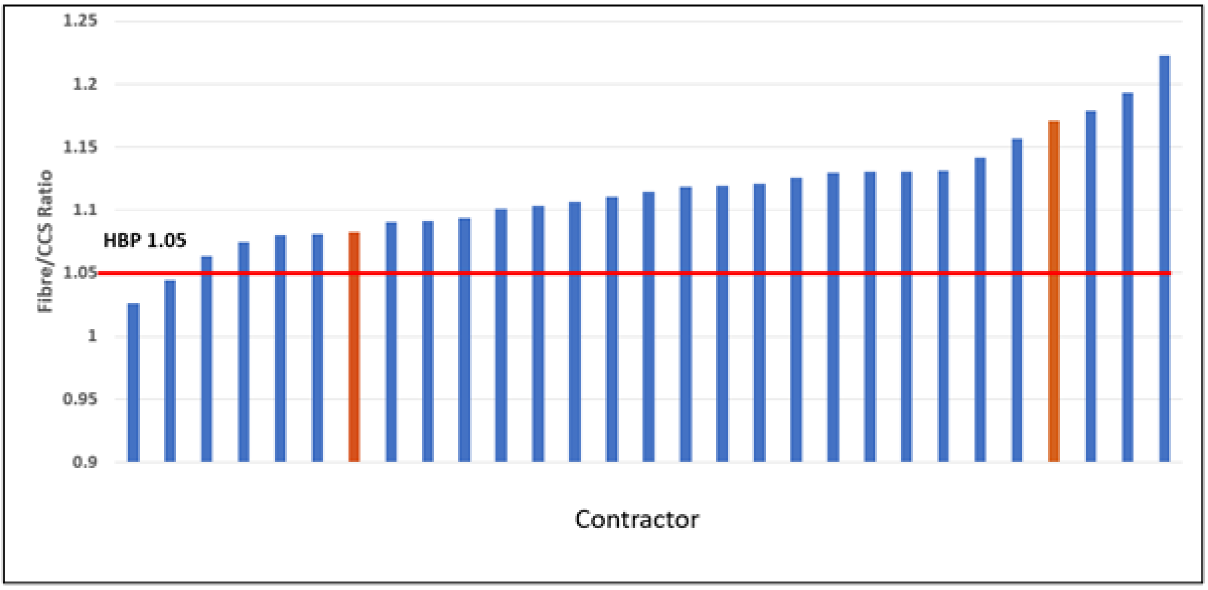


Figure 84: Fibre/CCS ratio of the 31 harvesting contractors in Tully: 2017-2018. The identity of the contractors is hidden.

The average fibre/CCS ratio by subdistrict is given in Figure 85. The average fibre/CCS ratio for all subdistricts is above HBP of 1.05.

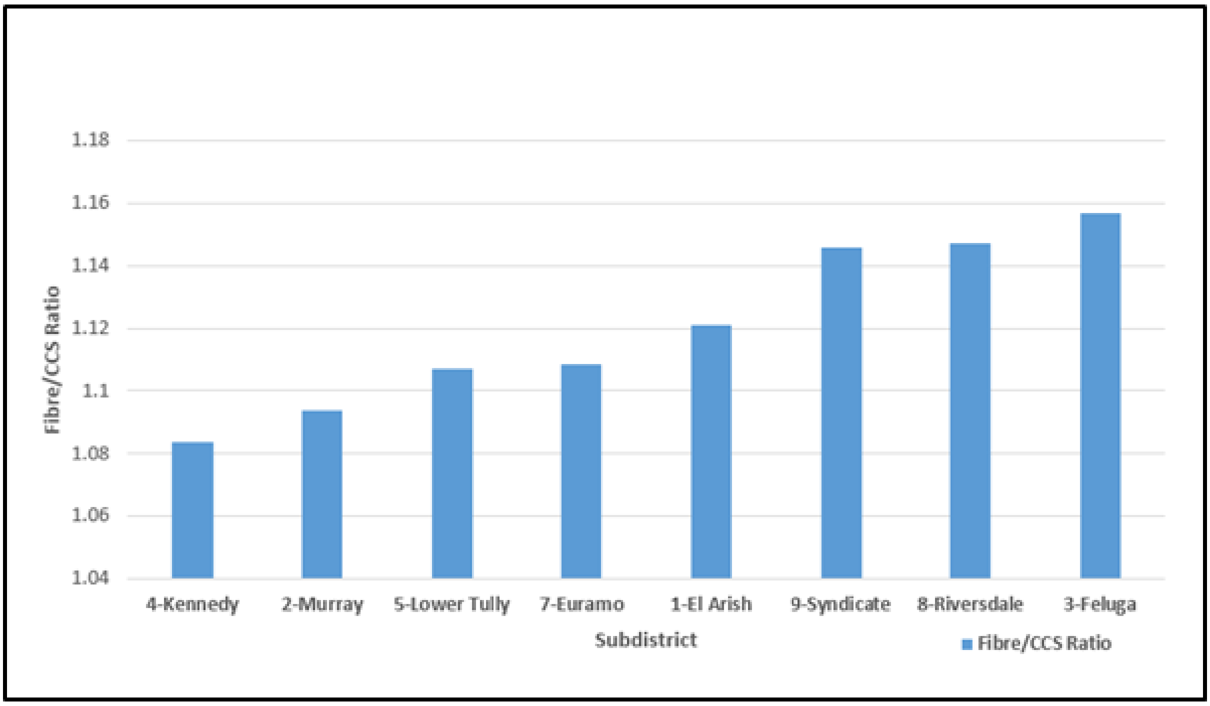


Figure 85: Fibre/CCS ratio by subdistrict in Tully: 2018-2019.

The results of clustering fibre/CCS ratio and EBD is contained in Figure 86. The eight different clusters distinguished by different colours are plotted with fibre/CCS ratio on the x axis and EBD (kg/cubic meter) on the y axis. Each circle represents a farm and the industry targets are represented by the red dotted line which is 348 kg/cubic meter for EBD and 1.05 for HBP fibre/CCS ratio. Each colour represents a different cluster, for example the “orange” cluster 6 contains the farms that have high fibre/CCS ratio and low EBD while the “black” cluster 7 contains farms that are low fibre/CCS ratio and high EBD. The “bad zone” contains farms that have low EBD and high fibre/CCS ratio. In this zone there is the potential risk of excessively high pour rates which drive and increase in EM.

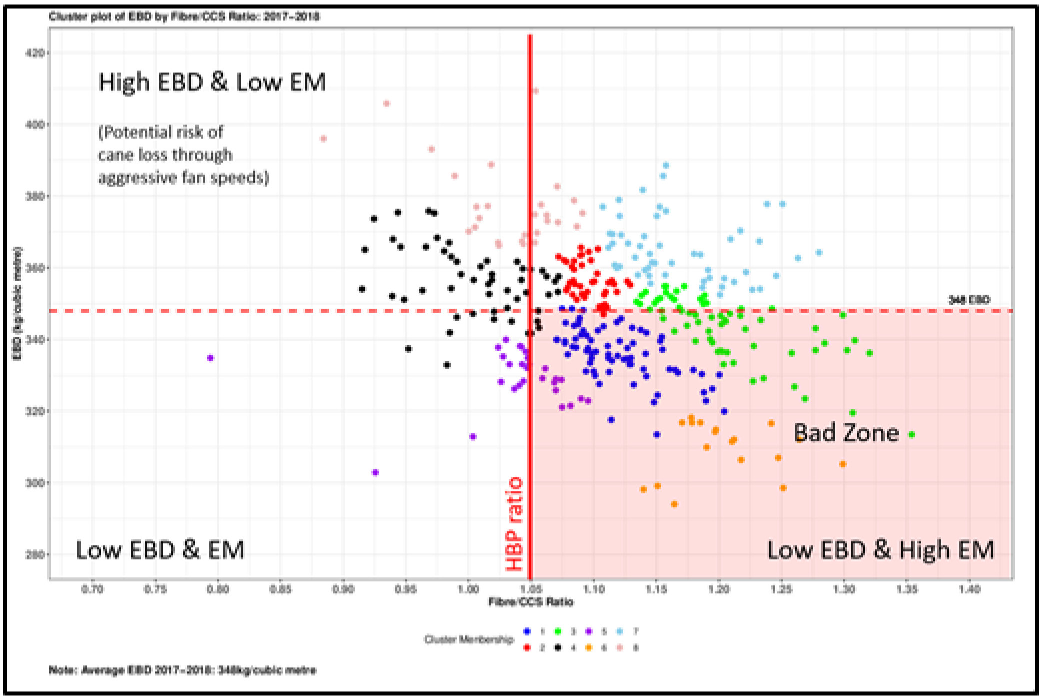


Figure 86: Cluster plot of fibre/CCS ratio vs EBD in Tully: 2017-2018. The average EBD for 2017-2018 of 348 kg/cubic metre and HBP ratio of 1.05 are indicated on the graph.

The results of the clustering of elevator pour rate vs EBD in Tully from 2017-2018 is given in Figure 87. The average EBD for 2017-2018 of 348 kg/cubic metre and HBP range for elevator pour rate are indicated on the graph. The eight different clusters distinguished by different colours are plotted with elevator pour rate on the x axis and EBD (kg/cubic meter) on the y axis. Each circle represents a farm and the industry targets are represented by the red dotted line which is 348 kg/cubic meter for EBD and green shaded box of 65-80 t/hr for pour rate. Each colour represents a different cluster, for example the "black" cluster 4 contains the farms that have low elevator pour rate and low EBD while the "pale blue" cluster 7 contains farms that are low pour rate and high EBD. All of cluster 2 are in the "bad zone". Farms in this zone have elevator pour rate > 90 t/hr and EBD higher than 384 kg/cubic meter. There is potentially a high risk of increased cane loss in this zone. This is due to the cleaning chamber being saturated and not efficiently separating cane from EM causing an increase in total material being extracted. Clusters 1 and 8 appear to be operating in the HBP pour rate range with good EBD. Clusters 4 and 5 appear to be operating in the HBP pour rate range or lower which suggests they may have contractors with smaller allocations or dominated by low EBD varieties this includes the impact of stalk diameter on EBD and sub-region climatic conditions. Cluster 3 and 6 have high pour rates exceeding the HBP range with average EBD. This suggests the groups have contractors with large allocations and so they need high pour rates to cover the hectares and tonnes.

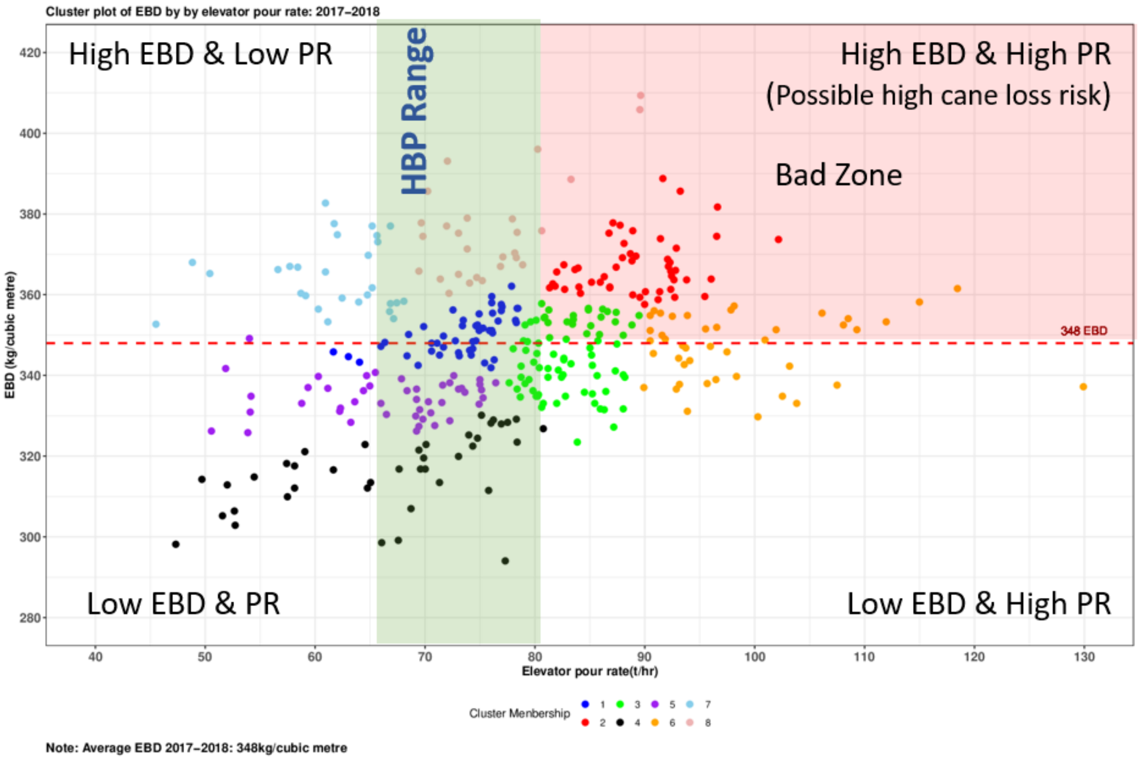


Figure 87: Cluster plot of elevator pour rate vs EBD in Tully: 2017-2018. The average EBD for 2017-2018 of 348 kg/cubic metre and HBP range for elevator pour rate are indicated on the graph.

Conclusions

The Tully industry place a large emphasis on EBD in the cane quality scheme. The relationship between EBD and various other cane quality parameters was investigated. In this study we found higher EBD with 5 blades per drum compared to 4. However, it must be remembered there is higher (invisible) sugar loss when number of blades increases. Research conducted by Norris et al. (2017) in the Tully region identified a mean yield decrease of 9.6 tonnes per hectare from 8 blade chop to 10 blade chop. Norris et al. (2017) also identified a significant relationship between reducing billet length and increased sugar loss in the field. This was also observed in the Isis region where an increase in yield loss of 4.8% from 8 blade chop to 10 blade chop.

The biggest sources of variation in EBD are due to variety, field conditions, crop presentation and harvesting contractor. Varieties such as Q219, Q231, Q232, Q241, Q242 have low EBD, KQ228, Q208 and Q237 have average EBD and Q200, Q240, Q249, Q250, Q251, Q252 and Q253 have high EBD. In ratoons EBD decreases from 1R to 5R EBD with a slope of -0.6.

Trashiness of variety impacts the relationship between effective cane cleaning and cane loss in the harvester. Higher trashing varieties will have an increase in poor cane quality impacting EBD and increased loss. Billet diameter impacts EBD, the thicker the variety the higher EBD. Billet diameter also impacts cane loss thicker with thicker varieties harder to extract with moderate fan speeds in the cleaning chamber. Crop conditions also impacts EBD with heavily lodged crops having a higher level of EM then erect standing crops. Wet conditions impact trash separation in the cleaning chamber causing a reduction in EBD.

Targeting a high EBD can have significant impact on yield reduction and cane loss. With a number of factors (listed above) impacting on EBD in the field, changing harvesting practice to increase EBD will cause a detrimental effect on yield and sugar.

Principal component analysis of Tully Cane Quality Data

Tully mill is unique in that it is at capacity with approximately 3M tonnes supplied per annum. As such, it is required to place a greater emphasis on cane quality. This includes purity, fibre/CCS ratio, soil and Effective Bulk Density (EBD). EBD is a transport metric based on bin weights and is adjusted for the different size bins. It was added to the Tully cane quality scheme in 2016.

A Principal Component Analysis (PCA) was conducted on the four cane quality traits from 2017-2018. Although PCA is primarily a dimension-reduction tool that can be used to reduce a large set of correlated variables to a smaller set of linearly uncorrelated principal components, it was still used here to identify patterns in the Tully cane quality data. The aim of this analysis is to reduce these four traits into one or two dimensions (principal components) that can be used to characterise the varieties.

The PCA analysis was only undertaken on the major varieties in the Tully cane supply from 2017-2018. The major varieties and percentage of each based on tonnes harvested are given in Table 23.

Table 23: Percentage of crop in 2017-2018 based on tonnes harvested by variety in Tully.

Variety	% of crop in 2017-2018 (based on tonnes harvested)
Q208	42.9
Q200	17.7
KQ228	7.4
Q250	6.9
Q231	6.6
Q237	3.1
Q240	2.6
Q251	2.1
Q186	1.8
Q241	1.8
Q183	1.4
Q232	1.4
Q253	1.0
Q219	0.9

In Table 24 is a summary of the analysis. This displays the eigenvalues in units of standard deviation. These are also expressed as a percentage and cumulative percentage. We use the eigenvalues to determine how many principal components should be considered. In our analysis, the first principal component explains about 85% of the variation and cumulatively the first two principal components explained 93%.

Table 24: Importance of components in analysis of Tully cane quality data: 2017-2018.

	Component 1	Component 2	Component 3	Component 4
Standard deviation	1.84	0.57	0.46	0.24
Proportion of Variance	0.85	0.08	0.05	0.01
Cumulative Proportion	0.85	0.93	0.99	1

To interpret each component, we computed the correlations between the original data and each principal component (loadings). The loadings or eigenvectors indicate the degree of correlation between the original variables and the new principle components. In this way they indicate how much each of the original variables contribute to the new variables (components). In Table 25 principal component 1 (PCA1) is made up of fairly uniform contributions from all of the original variables, while soil and EBD are more strongly correlated to principal component 2 (PCA2).

Table 25: PCA Loadings of Tully cane quality data – 2017-2018.

	Component 1	Component 2	Component 3	Component 4
Purity	-0.512	-0.308	0.499	-0.627
Fibre/CCS Ratio	0.516	-0.237	-0.467	-0.677
Soil	0.486	0.613	0.575	-0.24
EBD	-0.484	0.688	-0.449	-0.30

The sign of an eigenvector indicates the polarity of the correlation between the original variable and the new variable. Soil and EBD are the major contributors to principle component 2, while Purity and Fibre/CCS Ratio are major contributors to principle component 4.

A biplot from the PCA of the Tully cane quality data from 2017-2018 is given in Figure 88. The biplot aims to represent both the observations and variables of a matrix of multivariate data on the same plot. It allows us to visualize how the samples relate to one another in our PCA (which observations are similar, and which are different) and will simultaneously reveal how each variable contributes to each principal component. The overlayed eigenvectors associated with each of the principle components featured on the PCA plot, are typically represented by arrows. The arrows originate at the origin (0,0) and extend out to the eigenvector values for each principle component. Positive correlated variables point to the same side of the plot. Negative correlated variables point to opposite sides of the graph.

The arrow lengths are generally scaled to fit within the bounds of the limits defined by the axes scores, and they provide a relative indication of the strength and polarity of the associations. EBD and Purity are positively correlated with each other but negatively correlated with Soil and Fibre/CCS Ratio.

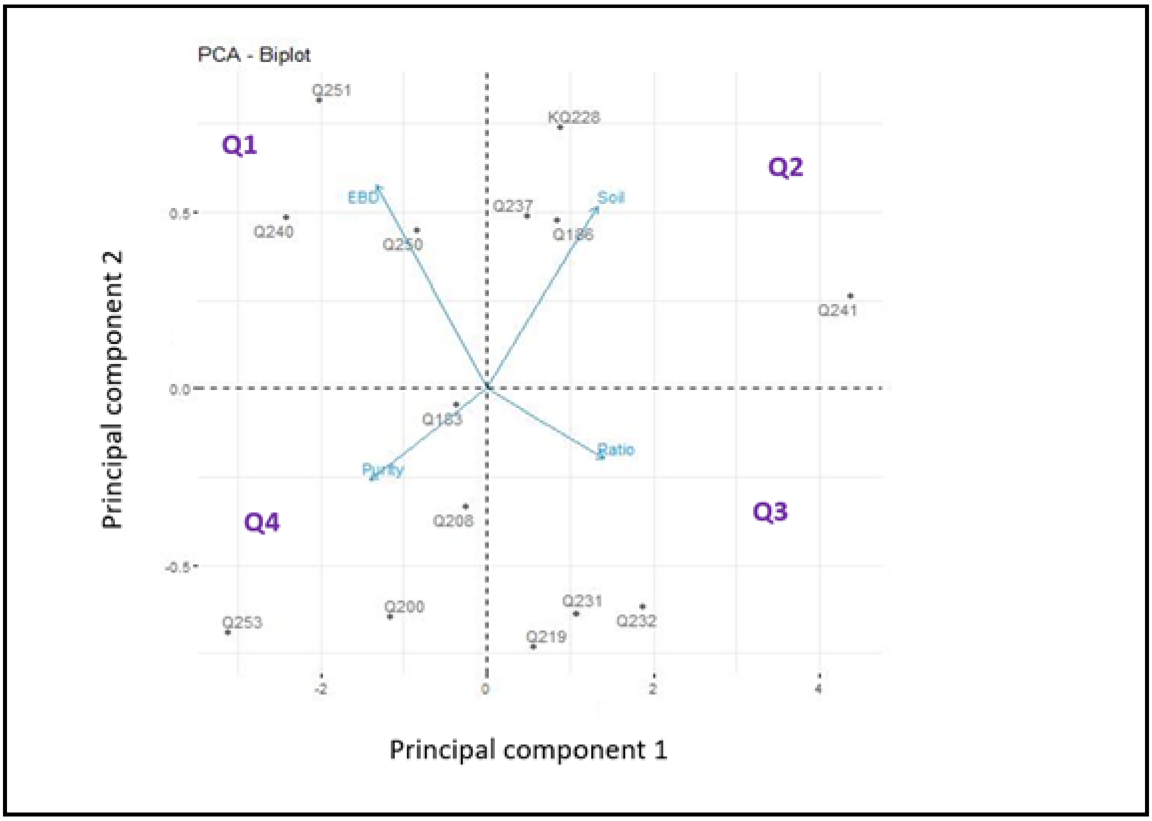


Figure 88: Biplot of Tully cane quality data: 2017-2018. The four quadrants of the biplot indicated by Q1, Q2, Q3 and Q4 are indicated.

Each variable that went into the PCA has an associated arrow in Figure 88. Arrows for each variable in a quadrant (Q1-Q4) point in the direction of increasing values of that variable. In Q4 the 'Purity' arrow points towards low values of PC1 so we know the lower the value of PC1, the higher the Purity. In Q1 the 'EBD' arrow also points towards low values of PC1. Hence, the lower the value of PC1, the higher the EBD. In Q2 the 'Soil' arrow points to high values of PC2 and so the higher the value of PC2 the higher the soil. In Q3 the 'fibre/ccs ratio' arrow points to high values of PC1 and low value of PC2. This means that varieties in Q3 have high fibre/ccs ratio and low EBD.

PC1 is lower if a variety has lower soil content and high EBD and higher if a variety is high soil content and low EBD. It is negatively associated with EBD and Purity (the signs of the eigenvectors are negative) and therefore we would expect low values of PC1 to be associated with high values of EBD and Purity. Principal component 2 (PC2) is strongly positively associated with EBD and soil and to a lesser extent negatively associated with purity and fibre/ccs ratio.

There are 4 key points from this analysis:

1. Varieties that have low values of PC1 have high purity and high EBD, low soil or low fibre/CCS ratio e.g.
2. Varieties that have high values of PC2 have high EBD and high soil, lower purity and lower fibre/CCS ratio
3. The varieties that are closer together in each quadrant are more similar than those in other quadrant *e.g.* Q208 and Q183 are close together
4. Within each quadrant the extreme varieties are very different:
    - Q251 – high EBD, high purity, low soil and low fibre/CCS ratio
    - Q241 – high value of PC1 and moderate value of PC2 - low purity, low EBD, moderate soil
    - Q253 – low value of PC1 and PC2 - high purity, high EBD, low soil

The varieties in the Tully cane supply were characterised by plant breeding staff in Meringa and these characteristics were related to cane quality traits. Varieties in Q1 and Q4 are all either free trashing or loose trashing varieties, whereas varieties in Q2 and Q3 are all moderate to tight trashing varieties. These varieties also have more compact stool habits. This partly explains the higher fibre/CCS ratio of varieties Q231 and Q232, compared to the looser trashing varieties which are easier to clean at harvest. Varieties in Q1 with higher EBD have stalks that are both average to thick in diameter and have free-loose trashing habits. The characteristics of the varieties presented in the biplot confirm the work undertaken by Vitale et. al (1997). They found that billet length and billet diameter are two of the most important variables affecting bin weights (EBD). They also found that if a variety has loose trashing habit then you would expect lower extraneous matter (EM).

c. Herbert

Background

Production peaked in the Herbert River mills in 2005 but since then productivity has declined. Detailed analysis of 16 years of mill data in project 2014/054 in the Herbert successfully identified groups of farms and farming enterprises with similar productivity over time and the major factors associated with these groupings. Detailed cluster analysis identified adoption of new varieties, whole of farming systems, uptake of clean seed and management of Pachymetra as factors associated with productivity in the Herbert region (Stringer, et *al*. 2016, Stringer et *al*. 2017). This analysis was presented as a report to the Herbert sugarcane industry. Local extension productivity services then developed extension programs, based on the factors identified, to show growers the potential productivity benefits they could achieve by addressing these factors. This would increase their profitability and productivity for the whole region. Building on the initial work in the Herbert further analyses have been undertaken to measure the level of adoption of project outputs from 2014/054 and if this has contributed to the increased dollars per hectare over time.

Cluster analysis

Prior to any statistical analysis the 99% quantiles were calculated on cane yield, CCS and sugar yield. As there were some obvious outliers that reflected consignment errors for cane yield the 0.5% lower values and the 0.5% top values were removed prior to analyses.

Rake data from 2005-2019 for the Herbert River mills from Wilmar Sugar Australia was available for this study. For each Farm in the Herbert the dollars per hectare were calculated using the following formula:

*Dollars/ha = ((((Sugar price * 0.009 * (CCS-4)) + Price Adjustment) *TCH)-(TCH*(Harvest costs + levies)))*

Where:

Sugar Price is $400/t, TCH is cane yield, Price Adjustment is $0.635 and Harvest Costs and Levies were $8.50 and $0.518, respectively. The price adjustment is a mill supplied incentive payment based on historical Cane Supply Agreements.

Cane yield (TCH), CCS, sugar yield (TSH) and dollars per hectare ($/ha) at the farm level were analysed using hierarchical agglomerative clustering using Ward's method and K-means cluster analysis. These clusters were then analysed to determine factors that may be influencing the yield such as cultivar performance, management and crop class, adoption of new varieties, farming practices such as fallowing and length of crop cycle, row spacing, soil type, climate zone and geographic effect.

Analyses in project 2014/054 were undertaken on 2005-2013. To examine the changes in productivity of individual farms since 2013 two sets of analyses at the Farm level were undertaken to examine the effects of different parameters:

1. Change in productivity ($/ha) between the period 2005-13 and 2014-19.
2. Analysis of all farms for $/ha for 2014-2019

Rake data from 2014-2019 contained 920 farms. In the analyses, a farm must have data across all years to enable the major trends to be identified. For 2005-2013 only the farms that were in all years for 2014-2019 were included. Also, some farms only had plant and first ratoon data in 2005-2013. These were removed prior to analyses. This reduced dataset contained 768 farms.

A technique commonly used in psychology (Toledo Piza et *al.* 2014) is to characterize contrasting groups and then apply the results to target groups. For analysis 1, 30 of the high-producing farming group and 30 of the low-producing farming group were characterised according to the following factors:

- Climate zone
- Age of manager making the business decisions on the farm. HCPSL has a database which contains the age of the farm owner and manager. Age of the manager is categoried as <40, 40-50, 50-60, 60-70, > 70 years old.
- Clean seed usage - Regular is at least 6 years out of 7, Frequent is 4 or 5 years out of 7, Infrequent is 1,2 or 3 years out of 7, Never is 0 out of 7 years.
- Ratoon age
- Ratoon Age = (Plant ha x 0) + (1R ha x 1) + (2R ha x 2) + (3R ha x 3) + (4R ha x 4) + (5R ha x 5) + …/total area harvested-Plant crop
- Row spacing: Below conventional < 1.625m, Conventional as 1.625-1.75, Controlled traffic system > 1.8m.
- Varietal disease ratings for Pachymetra and smut. Varieties are assigned ratings R (Resistant), I-R (Intermediate-Resistant), I (Intermediate), I-S (Intermediate-Susceptible) and S (Susceptible). The tonnes harvested for each Variety in the Smut and Pachymetra resistance categories was calculated.
- Varietal composition based on area harvested.

Productivity trends

Production peaked in the Herbert River mills in 2005 at 5.5 Mt but since then this has declined to 4.1 Mt in 2019 (Figure 89). Long-term average cane and sugar yields in Herbert River mill area are 80 and 11 t/ha, respectively (Garside 2013). Cane and sugar yields during this period have also been below average, particularly in 2011, and some land has gone from growing cane to other uses (Figure 90). Although some of this regional variation can be explained by extreme rainfall events such as in 2010 and 2011 when more than double the annual rainfall of 1,287 mm was received or disease incursions, it is important to identify those causes that can be controlled in order to increase production/profitability for industry (Figure 91). As part of this process, the Herbert Cane Productivity Services Limited (HCPSL) launched an initiative to increase productivity to 85 t/ha (Target 85) in 2014.

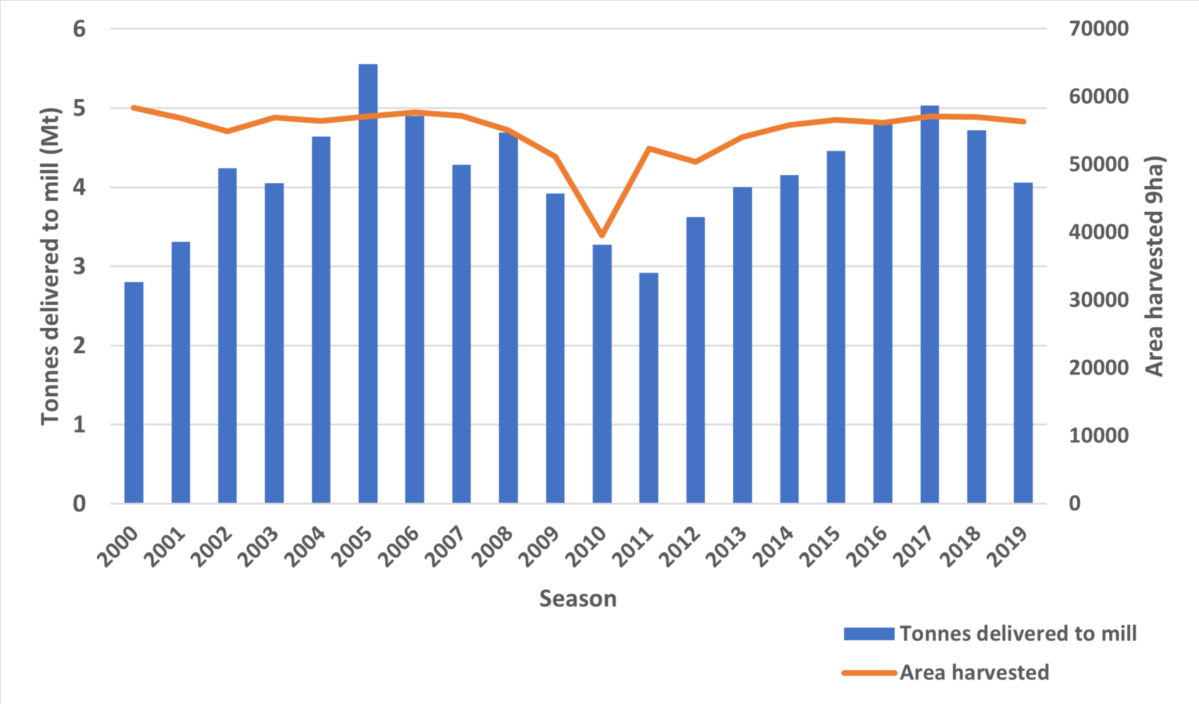


Figure 89: Tonnes delivered to the mill and area harvested in the Herbert from 2000-2019.

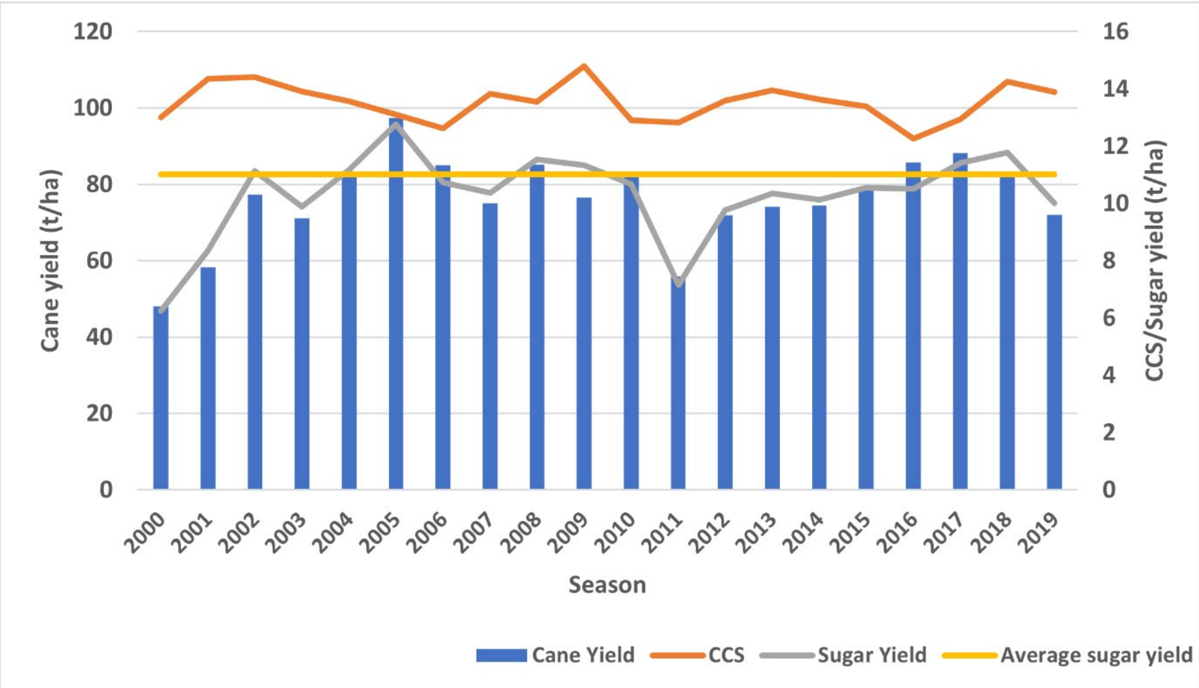


Figure 90: TCH, CCS and TSH in the Herbert from 2000-2019. The long-term average sugar yield of 11t/ha is indicated on the graph.

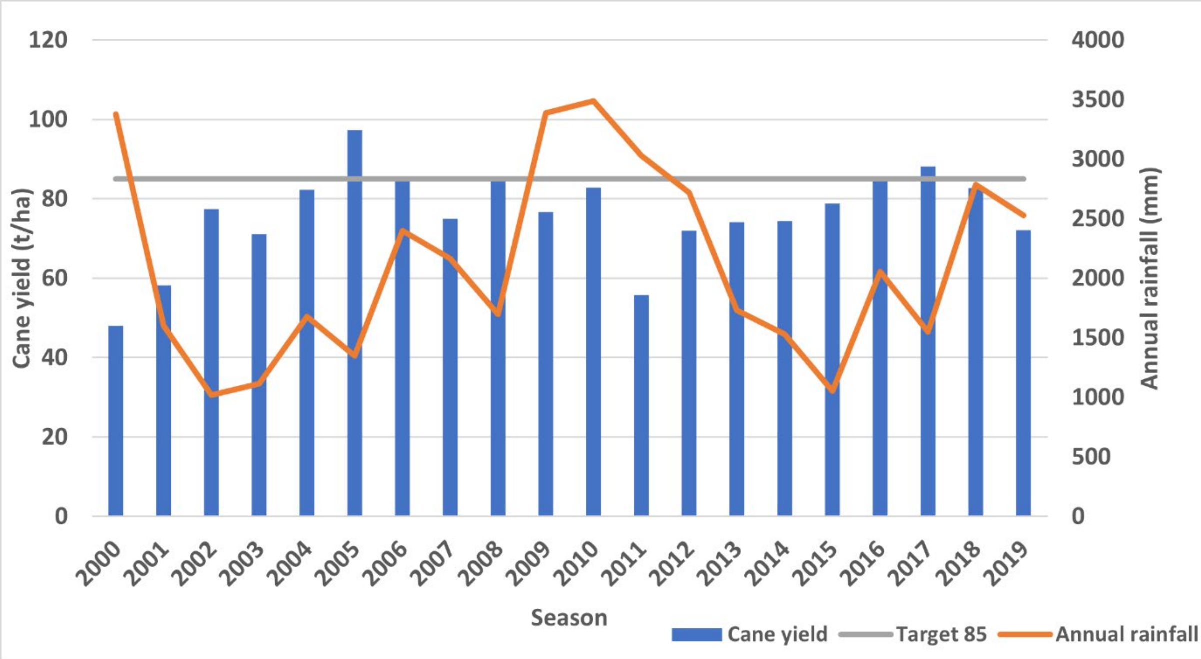


Figure 91: TCH and annual rainfall in the Herbert from 2000-2019. Target 85 is indicated on the graph.

Climate zones

In the Herbert there are 26 productivity zones and 6 subdistricts (Figure 92). These productivity zones and subdistricts vary in productivity, climate and soil types. Recent research in 2017/009 used annual climate data from 1975-2016 to determine sub-regional climatological differences with the Herbert River mill area.

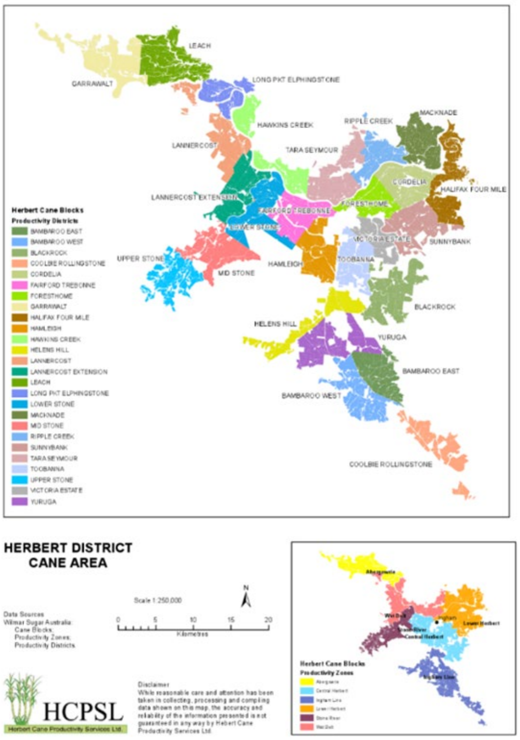


Figure 92: Productivity zones and subdistricts with the Herbert River mill area.

Daily rainfall, radiation and temperature data were obtained on a 0.05 by 0.05 decimal degree grid (approximately 5 km by 5 km) for sugarcane-growing areas within the Herbert mill region. For each grid cell, seasonal (summer, autumn, winter and spring) and annual mean temperature (maximum and minimum) and radiation were calculated using data from the period 1975 to 2016. Total seasonal and annual rainfall were also calculated for each grid cell. The temporal median of temperature, radiation and rainfall data was then calculated for each grid cell. A K-means clustering algorithm was used to cluster these grid cells into five distinct sub-regions based on seasonal (summer, autumn, winter and spring) rainfall and radiation data (Figure 93).

Five climate zones were identified which can be described geographically as:

1. Wet Zone (dark blue): This zone includes part of the Wet belt and northern reaches of the Lower Herbert productivity region.
2. Abergowrie Zone (red): This zone mainly consists of the Abergowrie productivity zone. This zone also contains a single pixel (5km X 5km square) of the Stone River area.
3. Stone River Zone (orange): This zone includes the Stone River productivity region and the area around Helens Hill that is considered part of the Ingham Line.
4. Ingham Line Zone (grey): This includes the Ingham Line productivity region as well as the southern parts of the central productivity region.
5. Central Zone (light blue): This includes parts of every productivity zone but the majority of the Central and Lower Herbert productivity zones.

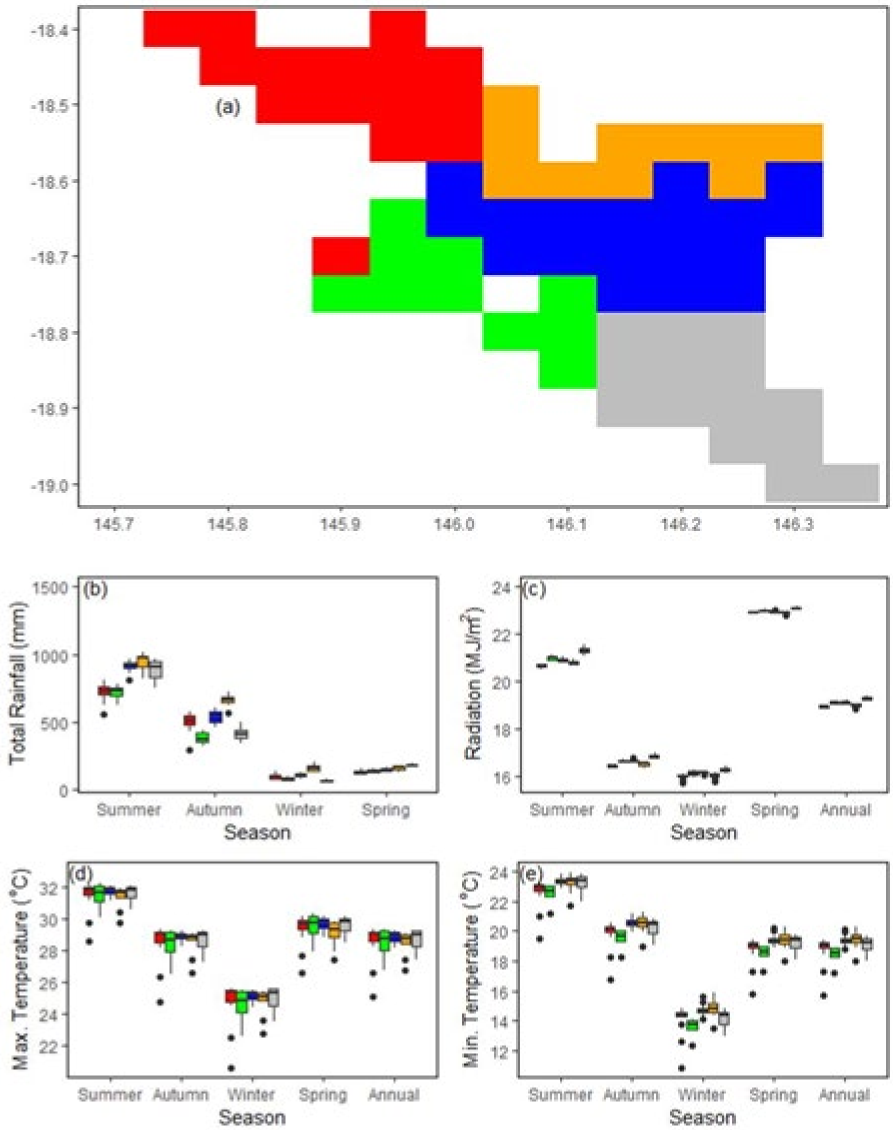


Figure 93: Five climatic sub-regions in the Herbert mill area using all seasonal rainfall and radiation climate data. (a) Spatial plot showing the Eastern (blue), Western (red) and Southern (green) sub-regions. Figures (b) to (e) contain boxplots of median (1970: 2016) annual climate variables for all 0.5 by 0.5 decimal degree pixels in the western (red), eastern (blue) and southern (green) sub-regions. Boxplots

show: (b) Total rainfall, (c) average daily radiation (d) average daily minimum temperature and (e) average daily minimum temperature for each season.

The Wet zone had the highest rainfall in summer, autumn and winter (Figure 93b). The Abergowrie and Stone River zones have the lowest spring and summer rainfall. However, the Stone River and Ingham Lines zones had the lowest autumn and winter rainfall, with the Abergowrie zone having higher rainfall than either. This difference in rainfall in autumn is one of the main reasons for differentiating the Abergowrie and Stone River zones. Summer rainfall in the Central zone is more similar to the Wet and Ingham Line zones than the low summer rainfall associated with the Abergowrie and Stone River zones.

The spatial variation in radiation was lower than the spatial variation in rainfall both within and between climate zones. The most evident difference was high radiation in the Ingham Line zone in each season and the low solar radiation in the Abergowrie zone in summer (Figure 93c).

There were little obvious differences between the climate zones when the maximum daily temperature was considered (Figure 93d). However, the Abergowrie and Stone River zones had the lowest maximum daily temperatures (Figure 93e).

The five climate zones in the Herbert together with the 26 subdistricts are contained in Figure 94.

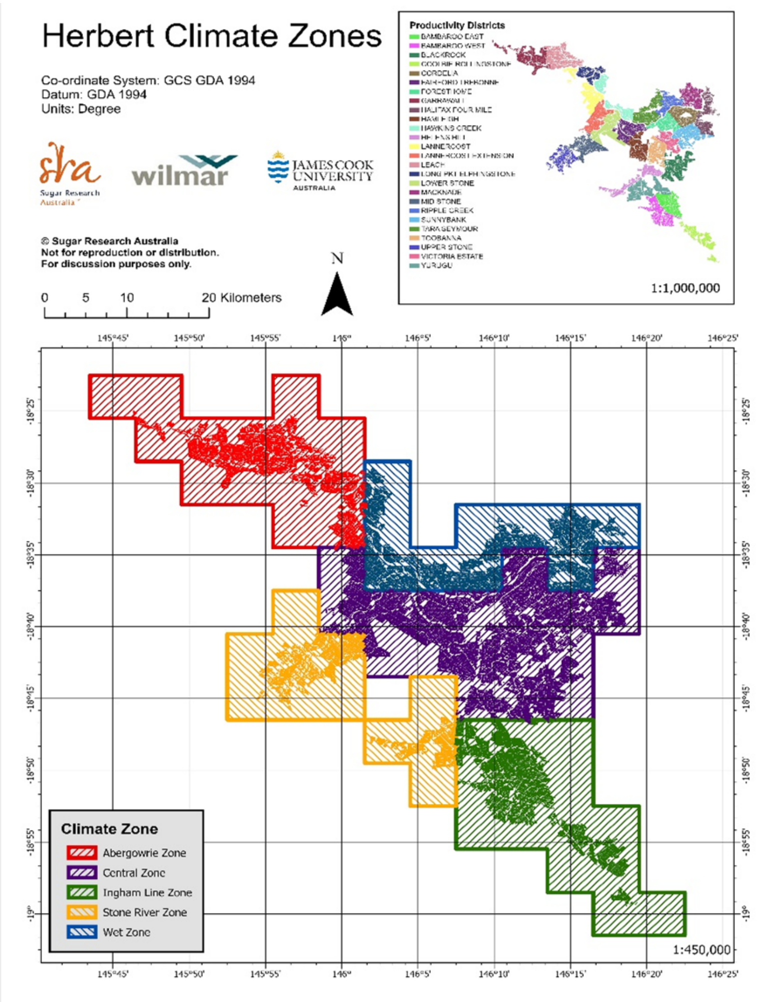


Figure 94: Climate zones in the Herbert region in relation to productivity zones.

The climate zones vary in size with Stone River zone having 63 farms and only occupying 8% of the area harvested based on the 2019 crop (Table 26). The largest climate zone is Central zone which has 331 farms and occupies nearly half (43.2%) of the area harvested in the Herbert.

Table 26: Number of farms, size and percentage area harvested for the 5 climate zones in the Herbert.

Climate Zone	Number of farms	Area harvested (ha)	% Area harvested

Abergowrie zone	129	8,471	16.3
Wet zone	165	9,761	18.8
Central zone	331	22,443	43.2
Stone River zone	63	4,166	8.0
Ingham Line zone	80	7,111	13.7
Total All	768	51,952	

In Table 27 are the average Farm TCH, average CCS, minimum, maximum and average $/ha for the 5 climate zones from 2014-2019. Ingham Line zone had the highest radiation of all the climate zones which resulted in the highest CCS and, although its' TCH was the second lowest, it had the highest $/ha. The Wet zone had the lowest cane yield and CCS, so it was not surprising that it had the lowest $/ha of all climate zones with a value of $1,868. There is a large range in the $/ha for the 5 climate zones. The lowest $/ha of $1,023 was in the Central zone while the highest of $3,047 was in Ingham Line zone.

Table 27: Average TCH, CCS, minimum, maximum and $/ha for the 5 climate zones in the Herbert: 2014-2019.

Climate zone	Avg TCH	Avg CCS	Min of $/ha	Max of $/ha	Avg $/ha
Abergowrie Zone	84.2	13.2	1,420	2,844	2,081
Wet Zone	76.6	13.1	1,178	2,568	1,868
Central Zone	79.2	13.3	1,023	2,661	2,000
Stone River Zone	80.8	13.9	1,533	3,032	2,191
Ingham Line Zone	77.8	14.2	1,574	3,047	2,202
Average	79.5	13.4	1,023	3,047	2,022

Change in productivity ($/ha) between the period 2005-13 and 2014-19.

A comparison of the number of farms above and below the target $/ha (target $2,163 calculated from target of 85 TCH and the long-term average CCS using formula for $/ha returns above) in the periods 2005-13 and 2014-19 is shown in Table 28. There was a net decrease of 4 farms from above the target to below the target but the total area of farms above the target increased by 1,645 ha. Twenty-two farms moved up from greater than 25% below the target group to between the target and 25% below the target and 4 farms moved up from greater than 25% below the target to above the target (30.6% reduction in number of farms in the >25% below the target group). The net increase in farms between the target and 25% below the target was 30 farms (6.8% increase). In response to the earlier project, 2014/054, a concerted extension effort was made to increase the productivity of the larger farms with below target productivity. This appears to have been successful with an increase of 1,645 ha in total area above the target despite a net reduction in the number of 4 farms above the target between the two periods. The larger farms that were the focus of the extension effort appear to have benefited, while some smaller farms fell below the target, resulting in a net increase in the total area above the target.

The improvement in $/ha returns for the farms assigned to the different groups in 2005-13 is shown in Table 29. Over the whole region the $/ha returns increased by 0.9% between the two periods which is disappointing considering an increase of 8.1% would have been required to lift the region up to the target $2,163/ha. The group that was above the target in 2005-13 fell by 5.5% in the 2014-19 period while the group that was below the target improved by 4.6%. The group that had the greatest improvement was the group that was 25% below the target in 2005-13, improving by 20.4%. The fall in the number of very low yielding farms probably means that there has been some rationalization with these farms being acquired by better or managers or there has been a change in management within the family owning the farms.

Table 28: Comparison of number of farms and total hectares for groups of farms above and below the target $/ha for the region (target $2,163 calculated from target of 85 TCH and the long-term average CCS using formula for $/ha returns above).

Target group	2005-2013	2014-2019	Difference 14-19 to 05-13

	No. Farms	Total Ha	No. Farms	Total Ha	No. Farms	Total Ha
Below Target	512	33810	516	32165	4	-1645
>25%Below Target	85	4002	59	3110	-26	-892
0-25% Below Target	427	29808	457	29055	30	-753
Above Target	235	15602	231	17248	-4	1645
All Farms	747	49412	747	49412		

Table 29: Comparison of $/ha for farms for groups of farms above and below the target $/ha for the region (target $2163 calculated from target of 85 TCH and the long term average CCS using formula for $/ha returns above). The $/ha for the group of farms in each category in 2005-2013 was calculated for the same farms in 2014-2019.

	$/ha			
Target group	**2005-2013**	**2014-2019**	**Difference 14-19 to 05-13**	**% change $/ha**
Below Target	1,842	1,926	84	4.6
>25%Below Target	1,414	1,703	289	20.4
0-25% Below Target	1,928	1,971	44	2.3
Above Target	2,347	2,219	-128	-5.5
All Farms	2,001	2,019	17	0.9

In an attempt to understand the drivers that caused farms to improve or to go backwards for $/ha, we examined the top 30 improvers (biggest increase in $/ha) and the bottom 30 farms that went backwards (biggest decrease in $/ha) between the years 2005-2013 and 2014-2019. The average farm size, average $/ha for 2005-2013, average $/ha for 2014-2019 and average difference in productivity for each group between the two time periods is given in Table 30. The average change in $/ha for the Bottom 30 group over the two time periods decreased by $549/ha while for the Top 30 improvers the average increased by $673/ha.

The industry needs to seriously consider various options to transition the very low productivity farmers out of the industry if productivity advantages are to be achieved; this approach will be discussed further in this paper.

Extension programs are usually ineffective with the very low productivity growers because the desire to change is limited (due to various factors like farmer age, health issues or available finance) or there is a total lack of interest in progressing further. Extension programs should focus on those farmers who have the desire, capacity and willingness to make productivity and business improvements.

Table 30: Average farm size, average $/ha for 2005-2013 and 2014-2019 and average difference in productivity.

Comparison	Avg Ha	Avg $/ha 2005-2013	Avg $/ha 2014-2019	Avg Difference
Bottom 30	45	2,322	1,773	-549
Top 30	37	1,601	2,273	673

In Table 31 is the proportion of bottom 30 and top 30 farms in each climate zone. Approximately, 83.3% of the Bottom 30 farms are in the Central zone. The composition of the Top 30 farms is more evenly spread over the 5 climate zones, although the Central zone also has the highest proportion of Top 30 farms.

Table 31: Proportion of Bottom 30 and Top 30 farms based on $/ha in each climate zone in the Herbert.

	Proportion in climate zone	
Climate Zone	**Bottom 30 farms**	**Top 30 Farms**
Abergowrie zone	3.3	23.3
Wet Zone	13.3	6.7
Central zone	83.3	30
Stone River zone	0	20
Ingham Line zone	0	20

In Table 32 is the proportion of clean seed usage for the Bottom 30 and Top 30 farms. Approximately, 63% of the Bottom 30 infrequently or never use clean seed. This can be contrasted with 67% of Top 30 are frequent or regular users of clean seed.

Table 32: Proportion of Bottom 30 and Top 30 farms in each clean seed usage group in the Herbert.

	Proportion in clean seed usage group	
Usage of clean seed	**Bottom 30**	**Top 30**
Never	20	23.3
Infrequent	43.3	10
Frequent	23.3	30
Regular	13.3	36.7

There was only a small difference in the average ratoon age of 3.3 for the Bottom 30 farms compared to 2.9 for the Top 30 farms.

In Table 33 are the counts of the Bottom 30 and Top 30 Farms practicing Below Conventional, Conventional and Controlled Traffic row spacing. Conventional row spacing is by far the most common practice in both groups. Due to the low numbers in Below Conventional and Control Traffic no conclusions can be drawn from this.

Table 33: Proportion of Bottom 30 and Top 30 farms in each row spacing group in the Herbert.

Row spacing	**Counts in Bottom 30 farms**	**Counts in Top 30 farms**
Below conventional	1	2
Conventional	26	26
Control traffic	3	2
Grand Total	30	30

The varietal composition of the Bottom 30 farms and Top 30 farms were compared (Figure 95). There are three major differences. There was twice as much Q200 in the Bottom 30 farms (28%) compared to the Top 30 farms (15%). Q200 does not perform well in dry environments and is therefore more widely planted in the lower yielding Wet zone. In contrast, there was twice as much Q208 in the Top 30 farms compared to the to the Bottom 30 farms. Both Q200 and Q208 are rated I to Pachymetra. In the Bottom 30 farms there was 11% of the smut susceptible variety Q174 compared to 3% in the Top 30 farms. Smut would have caused significant losses in

Q174 during the period of the study and would have contributed to the lower yields in the Bottom 30 farms. The slow replacement of smut susceptible varieties by the Bottom 30 farms reflects their slow adoption of new varieties.

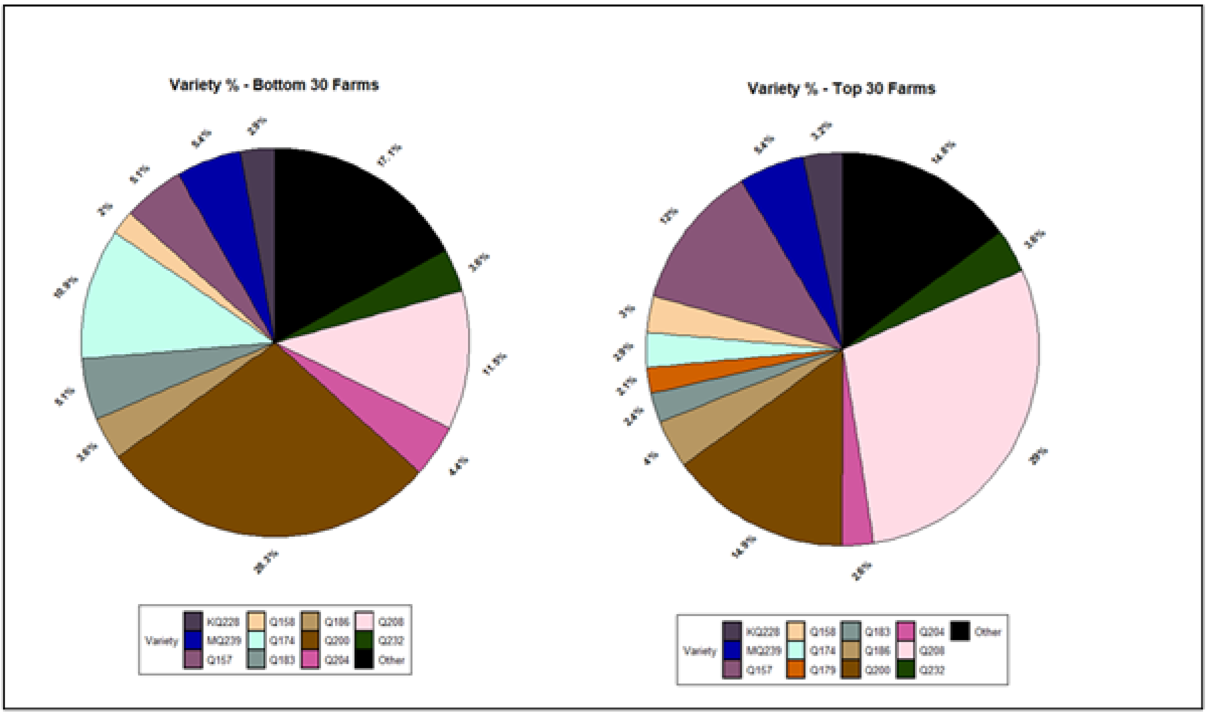


Figure 95: Proportion of tonnes harvested for each variety for the Bottom 30 and Top 30 farms in the Herbert.

The proportion of tonnes harvested for the five Pachymetra and smut resistance categories for the Bottom 30 and Top 30 farms are given in Figure 96 and Figure 97. For Pachymetra, there is a much higher proportion of I-S (12.6%) in the Bottom 30 farms compared to the Top 30 farms (4.3%). However, there was a higher proportion of S in the Top 30 farms. Q208 and Q200 are both rated I and they were the major contributors to the approximately 50% of this class in both groups. It is unlikely that the relatively small differences in proportions of Pachymetra resistant varieties between the two groups would contribute significantly to the differences in $/ha.

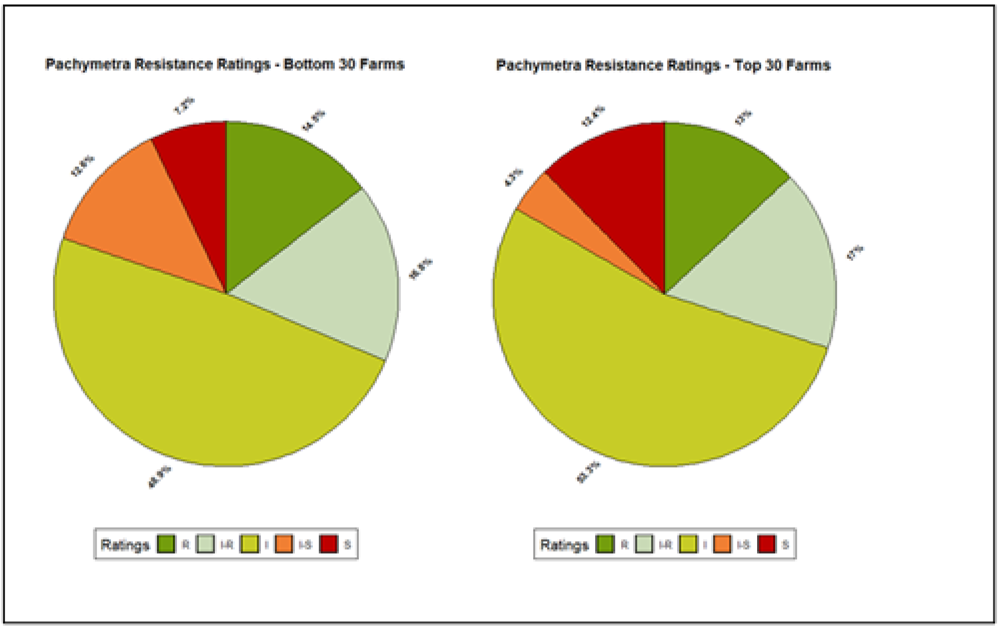


Figure 96: Proportion of tonnes harvested for Pachymetra resistance ratings for Bottom 30 and Top 30 farms in the Herbert. Varieties are rated R (Resistant), I-R (Intermediate-Resistant), I (Intermediate), I-S (Intermediate-Susceptible) and S (Susceptible).

For smut there is a much higher proportion of I-R in the Top 30 farms than in the Bottom 30 (Figure 97) and a lower percentage of varieties rated intermediate.

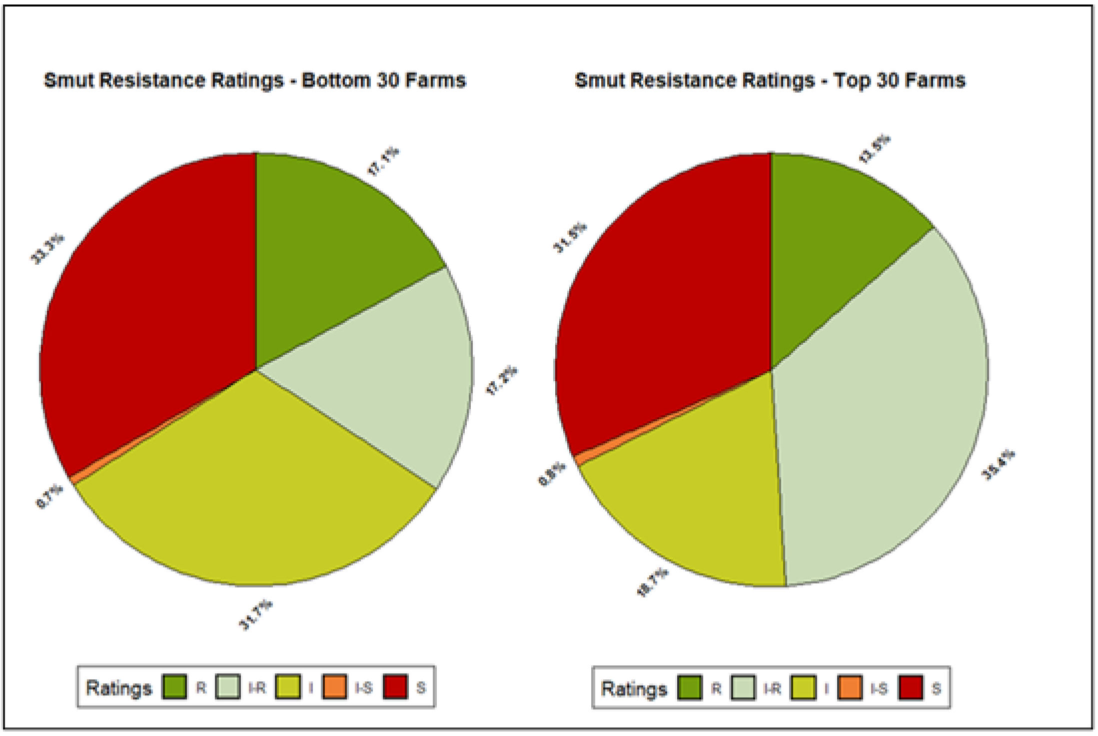


Figure 97: Proportion of tonnes harvested for Smut resistance ratings for Bottom 30 and Top 30 farms in the Herbert. Varieties are rated R (Resistant), I-R (Intermediate-Resistant), I (Intermediate), I-S (Intermediate-Susceptible) and S (Susceptible).

Data containing Farm number, area harvested, TCH, CCS, TSH, $/ha, productivity zone and climate zone were given to local HCPSL Extension Agronomy staff and the Bottom 30 and Top 30 farms were assessed to determine productivity drivers. To assist in interpretation of results of the clustering the 60 farms were also mapped for each climate zone. These maps are not presented here to maintain confidentiality under the Privacy Act.

The project team undertook a study of the Bottom 30 and Top 30 farms to determine the main productivity drivers. The following activities were assessed:

- Age of manager
- Farm management
- Introduction of irrigation to the farm
- Left full time job to farm full-time
- Off farm income
- Purchased rundown farm
- Small farm and/or plants infrequently
- Took farm over from family/acquired the farm
- Unknown reason
- Young crop age

Table 34: Percentage of Bottom 30 and Top 30 farms in each activity affecting productivity in the Herbert.

Activity	% of farms in Bottom 30	% of farms in Top 30
Age of manager	53	0
Farm management	13	0
Introduction of irrigation to the farm	0	3

Left full time job to farm full time	0	10
Off farm income	30	0
Purchased rundown farm	3	0
Small farm and/or plants infrequently	0	7
Took farm over from family or acquired the farm	0	63
Unknown reason	0	10
Young crop age	0	7

In the Bottom 30 farms, the top 3 factors associated with low productivity were Age of manager making the business decisions on the farm, Off-farm income and Farm management. Older managers were over-represented in the Bottom 30 farms. When growers have substantial off farm income this can lead to poor timing of farm operations such as planting, weeding, harvesting. In the Top 30 farms by far the biggest driver was Taking over the farm /acquiring the farm followed by Full Time farming and Unknown reasons.

The impact of YCS appears to be greatest in the Kingsbury Creek, Ripple Creek, Palm Creek and along parts of the Herbert River when comparing the change in productivity between the period 2005-13 and 2014-19. There is an underlying farm management trend in some cases, however some of the better farmers in especially the Central Herbert area have been impacted. The 2019 and 2020 data (which are low YCS years) will hopefully allow us to see some further trends to a return in productivity in these areas.

Analysis of all farms for $/ha 2014-2019

Farm level data for $/ha and area harvested from 2014-2019 were analysed with cluster analysis. Eight clusters gave poor differentiation between groups. The clustering was repeated with 10 clusters which allowed clear differentiation between clusters. The ten different clusters identified are distinguished by different colours and are plotted with Farm size (ha) on the x axis and $/ha on the y axis (Figure 98). Each circle represents an individual farm and the industry target of $2,163 dollars per hectare is indicated by the black dotted line. This was calculated based on Target 85 and average CCS from 2014-2019 of 13.4 (Figure 35). To maintain confidentiality for the small number of growers with farms >400 ha (cluster 7 and one farm in cluster 4), their performance has been hidden in Figure 98.

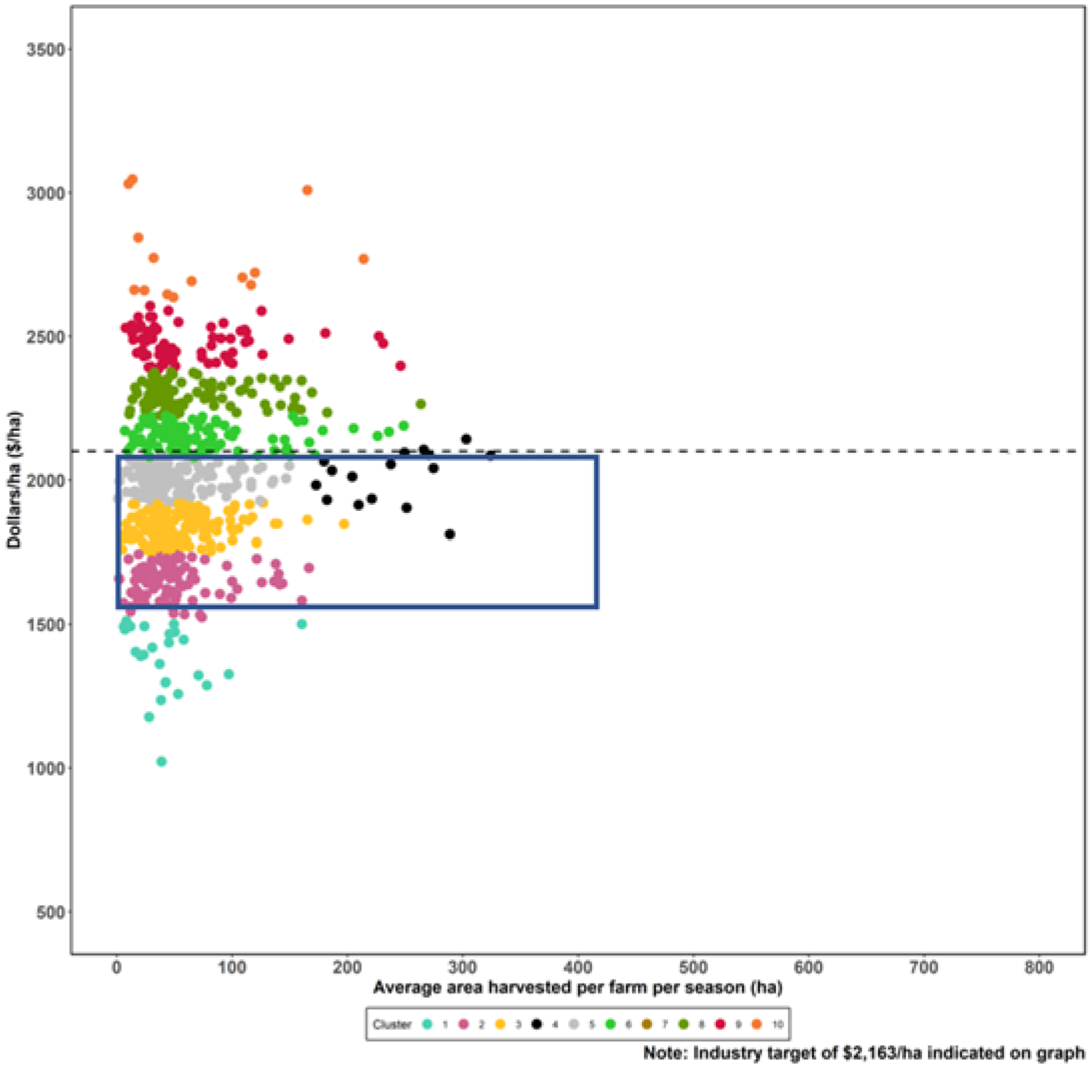


Figure 98: Cluster plot for dollars per hectare in the Herbert: 2014-2019. Farms greater than 400ha have been hidden for privacy reasons. The industry target dollars per hectare of $2,163 is indicated by the black dotted line on the graph. The Target farms for focus of extension programs are indicated by the blue box.

In this analysis, the primary factor separating most groups was $/ha and within groups Farm size varied significantly (Figure 98). Clusters 1-3 are the low-performing Farms and contained 25, 101 and 165 farms, respectively. Clusters 6, 8, 9 and 10 were the high-performing Farms and contain 117, 100, 71 and 14 farms, respectively. Clusters 4 and 5 have similar $/ha but have been separated on Farm size with cluster 4 having larger average farm size than cluster 5.

Table 35: Clusters based on $/ha and size of Farm. The average TCH, CCS, TSH, Ha for each cluster is shown and the number of Farms in each cluster and the percentage area represented by each cluster. Cluster 7 is omitted to protect the identity of farms > 400 ha in size.

Dollar cluster	Avg TCH	Avg CCS	Avg TSH	Avg Dollars	Avg Ha	Count of farms	%Total area
1	59.2	12.8	7.6	1,380	43	25	2
2	67.9	13.2	8.9	1,650	50	101	10
3	75.6	13.1	9.9	1,839	54	165	17
4	78.8	13.4	10.5	1,990	260	17	9

5	78.8	13.4	10.5	2,003	50	149	14
6	84.3	13.5	11.3	2,152	68	117	15
8	86.3	13.8	11.8	2,297	66	100	13
9	91.7	13.9	12.6	2,475	64	71	9
10	97	14.3	13.8	2,777	71	14	2
Average All	**79.5**	**13.4**	**10.6**	**2,022**	**68**	**768**	**100**

Cluster 10 contains the highest yielding Farms and includes both very small Farms and Farms up to 200 ha in size (Table 35). Clusters 1 and 2, the lowest yielding groups, contain both very small Farms and Farms up to approximately 160 to 170 ha in size respectively. Grouping the clusters 1 and 2 together represents 12% of the total area and had TCH on average 32% lower (63.5 TCH) than the similar sized farms in clusters 9 and 10 (94.4 TCH). Comparing the $/ha, clusters 1 and 2 had 42% lower $/ha than similar sized farms in clusters 9 and 10.

Cluster 3 had Farm sizes ranging from very small to 200 ha and below average $/ha. Clusters 4 and 5 had similar TCH, CCS and $/ha but varied in size with cluster 4 containing much larger farms (averaging 260 ha) compared to cluster 5 (averaging 50 ha). This appears to be the only two groups that were separately primarily on Farm size.

Clusters 3, 4 and 5 account for 40% of the harvested area in the Herbert. Clusters 3 and 5 contain farms ranging from very small to up to 200 ha and the average $/ha range from $1,839 to $2,003. Cluster 4 contains much larger farms with an average farm size and $/ha of 260ha and $1,990, respectively.

The Target for the Herbert is $2,163 dollars per hectare. This was calculated based on Target 85 and average CCS from 2014-2019 of 13.4 (Table 35). In Figure 98, most of the farms in clusters 1-5 are below the Target. Cluster 1 is well below the Target. The suggested group of farms to focus extension and technical services provision activities is indicated by the blue box in Figure 98. The median farm size in the Herbert is approximately 60 ha. Within the box, the Herbert industry should focus extension efforts on or above 60ha and farms in the range from $1,500/ha to the Target of $2,163/ha. This includes most farms in clusters 2-5 and represented 31% of the harvested area in the Herbert. Investment in extension for these farms could have a high impact on productivity for the Herbert region.

Clusters 6 and 8 contain 217 farms and represent 28% of the harvested area in the Herbert. The Herbert industry has set a target to increase average yields to 85 TCH. TCH in clusters 6 and 8 are approximately at the Target 85 for cane yield. Both clusters have above average CCS and $/ha.

Table 36 contains the major varieties in the Herbert cane supply from 2014-2019. The cane supply was dominated Q208, Q200 and MQ239.

Table 36: Percentage hectares of the major varieties in the Herbert cane supply 2014-2019. Varieties greater than 1% of the cane supply are given.

Variety	% hectares of cane supply 2014-2019
Q208	34.3
Q200	16.3
MQ239	13.4
Q232	7.1
Q183	3.9
KQ228	3.3
Q240	3.1
Q253	2.9

Q242	2.5
SRA3	1.4
Q250	1.3
Q226	1.0

The clusters were compared in terms of the proportion of major varieties (Figure 99 and Figure 100). Differences were found when comparing the proportion of Q208, Q200, MQ239 and Q183 across low performing clusters 1 and 2 and high performing clusters 9 and 10. Clusters 9 and 10 had a much higher proportion of Q208 compared to clusters 1 and 2. In contrast, low performing clusters had a much higher proportion of MQ239. MQ239 is recommended for soils prone to waterlogging, flooding or have low soil fertility and this would account for the higher proportion of this variety in low yielding Clusters 1 and 2. Q208 is also recommended for poorer soil types. Clusters 3, 4 and 5 also had more MQ239 than clusters 9 and 10 (compare Figure 99 and Figure 100) but did not show significant differences between the proportions of the varieties within clusters 3, 4 and 5. MQ239 consistently performed poorly relative to Q208 and the Herbert could have increased overall productivity by replacing this variety.

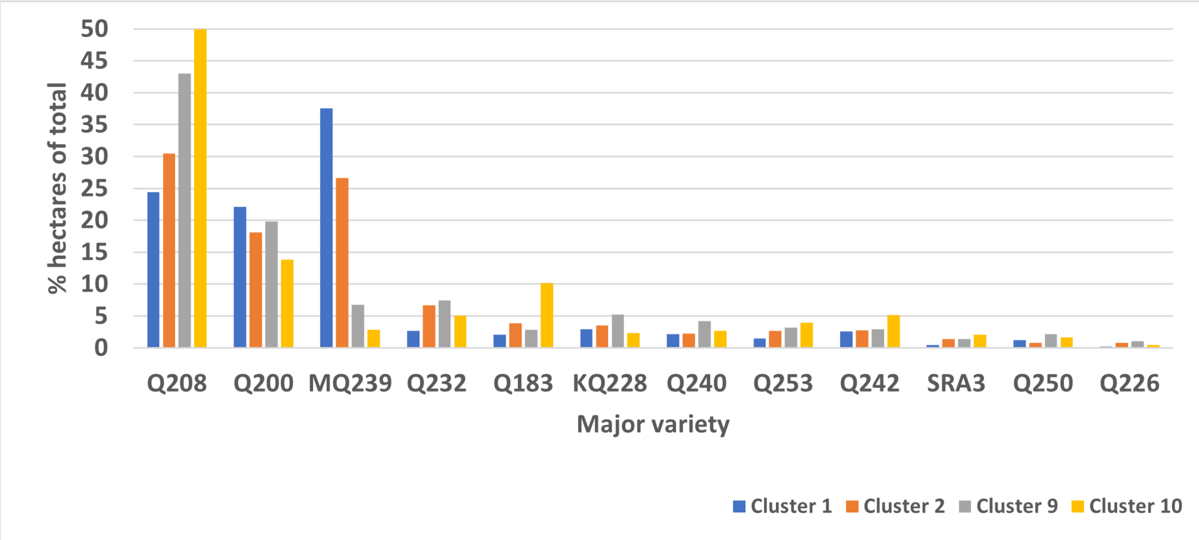


Figure 99: Proportion of major varieties for low (clusters 1 and 2) and high (clusters 9 and 10) performing clusters for dollars per hectare.

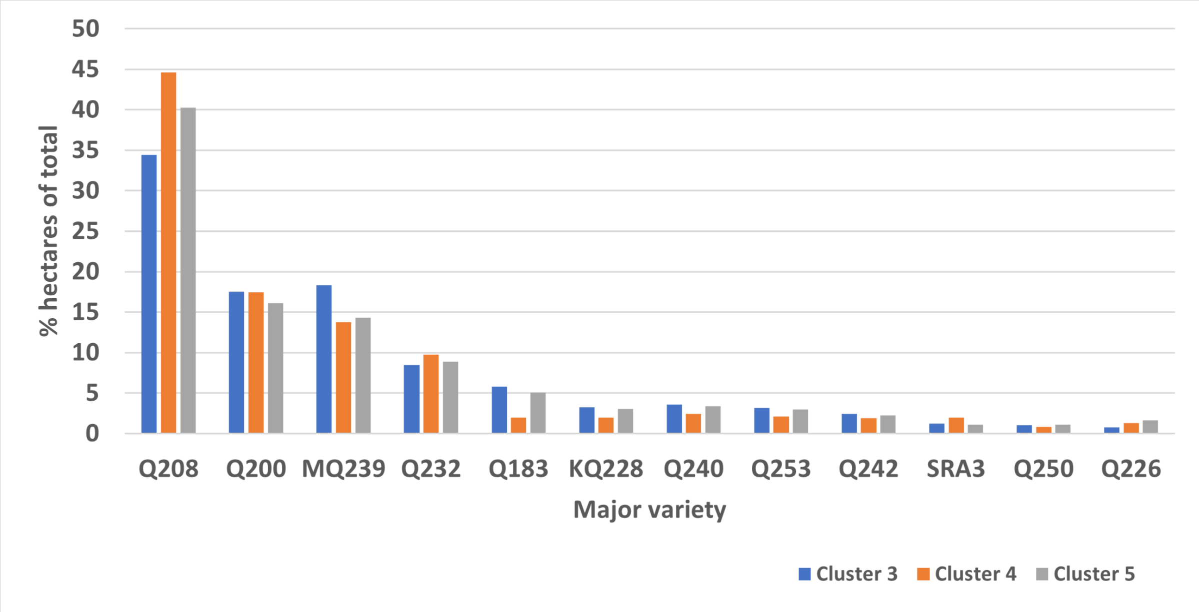


Figure 100: Proportion of major varieties for target clusters (clusters 3,4 and 5) for dollars per hectare.

The length of the crop cycle was calculated for all clusters. All clusters except cluster 10 had an average crop cycle length of 4 which means an average of plant and 3 ratoons (data no shown). For cluster 10 the average crop cycle length was 3. The higher proportion of younger ratoons would significantly contribute to the higher productivity of this cluster.

The proportions of % plant, % young crops, % old crops, % new varieties and % old varieties were compared for the low productivity clusters 1 and 2 vs high productivity clusters 9 and 10. Plant crops included plant and plough out replant. Young crops were defined as plant, plough out replant, 1R and 2R. Old crops were those 3R and older. A variety was defined as being “new” if it was released since 2011. There were no differences among % plant, % young crops and % old crops. However, the low and high performing groups varied significantly in terms of new varieties, suggesting that the low performing group were not adopting the new, more productive varieties to the same extent as the high performing group.

Table 37: Proportion of % plant, % young crops, % old crops, % new varieties and % old varieties were compared for the low productivity clusters 1 and 2 vs high productivity clusters 9 and 10.

Cluster comparison	% plant crop	% young crops	% old crops	% new varieties	% old varieties
Low yielding clusters 1 and 2	15.6	51.1	48.8	10.2	89.8
High yielding clusters 9 and 10	15.9	51.0	48.9	16.3	83.7

The percentage of farms in each climate zone within each cluster is given in Figure 101. Ingham Line zone had 73% farms in higher $/ha Clusters 6-10 and only 7% in the lower $/ha Clusters 1-3. Stone River zone had approximately 51% of their farms in high yielding groups compared to only 12% in low yielding clusters 1-3 In Abergowrie zone, the high yielding cluster 6 has the highest proportion (22%) although it still has 18% of the low performing farms in cluster 3. Of all climate zones the Wet zone had the highest proportion of low yielding clusters 1-3. The Central zone represents 43% of the harvested area in the Herbert and the highest proportion of farms in this zone occurred in clusters 3 and 5 and the next highest proportions occur in Clusters 2 and 6. Clusters 2, 3 and 5 are all below the Target $/ha for the mill area and represent 60% of farms in the Central zone. In a later section, there will be further analysis of several farms from the Central zone.

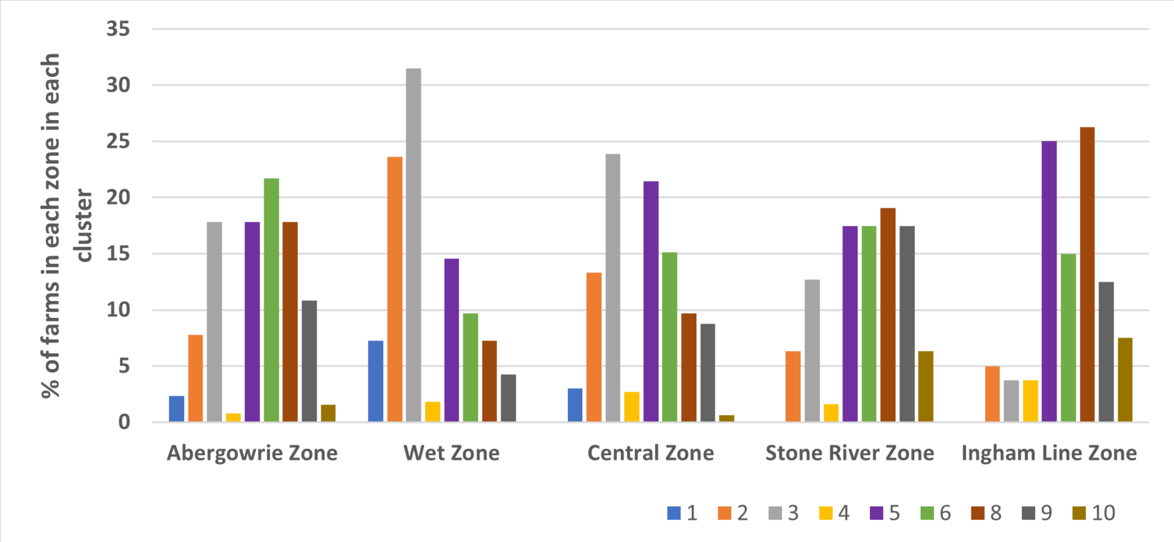


Figure 101: Percentage of farms in each $/ha cluster by climate zone. Cluster 7 is omitted to protect the identity of farms > 400ha in size.

The usage of clean seed was compared across the different clusters (Table 38). Only 10% of clusters 1 and 2 use clean seed frequently/regularly compared with 43% in the high performing clusters 9 and 10. Similarly, 40% of farms in low performing clusters use clean seed infrequently/not all at versus only 7% for high performing groups. This highlights the benefit of clean seed and should encourage the Herbert to place more emphasis on promoting clean seed especially with growers in the lower performing clusters.

Table 38: Clean seed usage as a proportion of $/ha clusters in the Herbert: 2014-2019. Cluster 7 is omitted to protect the identity of farms > 400ha in size.

	% usage of clean seed			
Cluster No	**Never**	**Infrequent**	**Frequent**	**Regular**
1	48	48	0	4
2	35	29	26	11
3	21	23	32	25
4	6	12	41	41
5	17	33	28	22
6	8	28	38	26
8	12	20	36	32
9	10	6	42	42
10	14	0	29	57

The dollars per hectare for the 4 different clean seed usage categories were compared by using a one-way ANOVA and displayed in Figure 102. The dollars per hectare for “Never” and “Infrequent” clean seed categories were not significantly different ($p > 0.05$). The dollars per hectare for “Regular” usage of clean seed was significantly greater than “Frequent” and “Infrequent” and “Never”. Up to a 13% increase in dollars per hectare could be obtained by Regularly using clean seed.

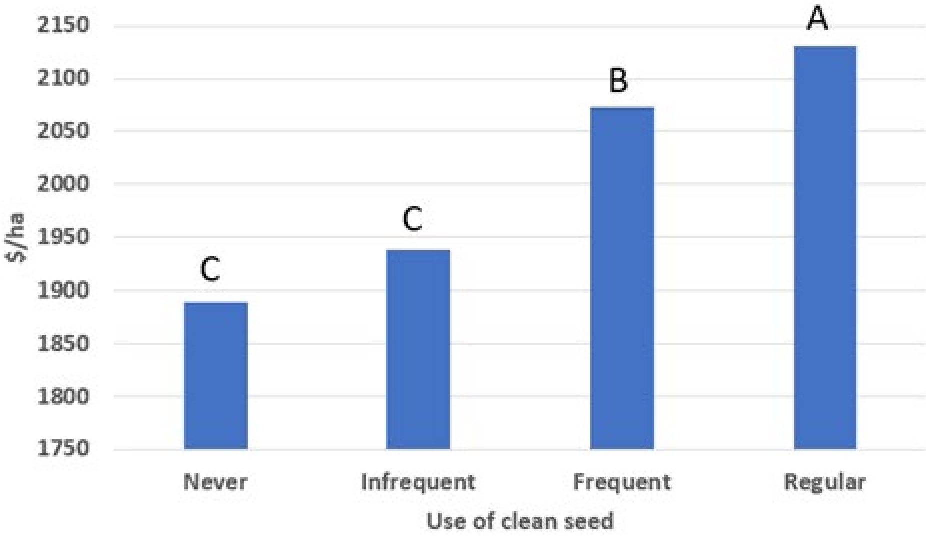


Figure 102: $/ha by clean seed usage categories in the Herbert: 2013-2019. Means followed by the same letter are not significantly different (p> 0.05).

Clean seed usage by climate zone is given in Table 39. There is a high uptake of clean seed in Ingham Line, Stone River and Wet zones. In the Central zone clean seed uptake is split approximately 50:50. In Abergowrie there is poor uptake.

Table 39: Clean seed usage by climate zone in Herbert: 2013-2019.

	% usage of clean seed				
Category	**Abergowrie Zone**	**Central Zone**	**Ingham Line Zone**	**Stone River Zone**	**Wet Zone**
Never/Infrequent	57	45	23	32	39
Frequent/Regular	43	55	78	68	61

The relationship of clean seed use to proximity to the clean seed plots was examined (data not shown because of privacy). It appears that growers will not travel more than 10kms to a Clean Seed plot. Also, the Bruce Highway where there is limited auxiliary roads for growers to travel is also a barrier to obtaining Clean Seed from plots. There is a general relationship of lower use as distance to a HCPSL Approved Clean seed plot increases but some farms with infrequent use are close to the clean seed plots. Given the results of this project HCPSL has recently leased a farm in the Central Herbert region to provide more Approved Clean seed in this area. HCPSL is also investigating other options in parts of the district to provide Approved Clean Seed cane to farmers, one of the options being promoted is the use of plant tissue culture plants.

The $/ha for farms in each manager age group were compared in Figure 103. There was a significant difference among the age groups ($p < 0.05$) although there is no clear increasing or decreasing trend between age of manager and productivity. Higher productivity was found in 50-60 and 60-70 age group compared to <40 and > 70 years old ($p < 0.05$). There was no significant difference in productivity between 40-50, 50-60 and 60-70 age groups. HCPSL will use this information to design different extension strategies for the different age groups and different farmer needs.

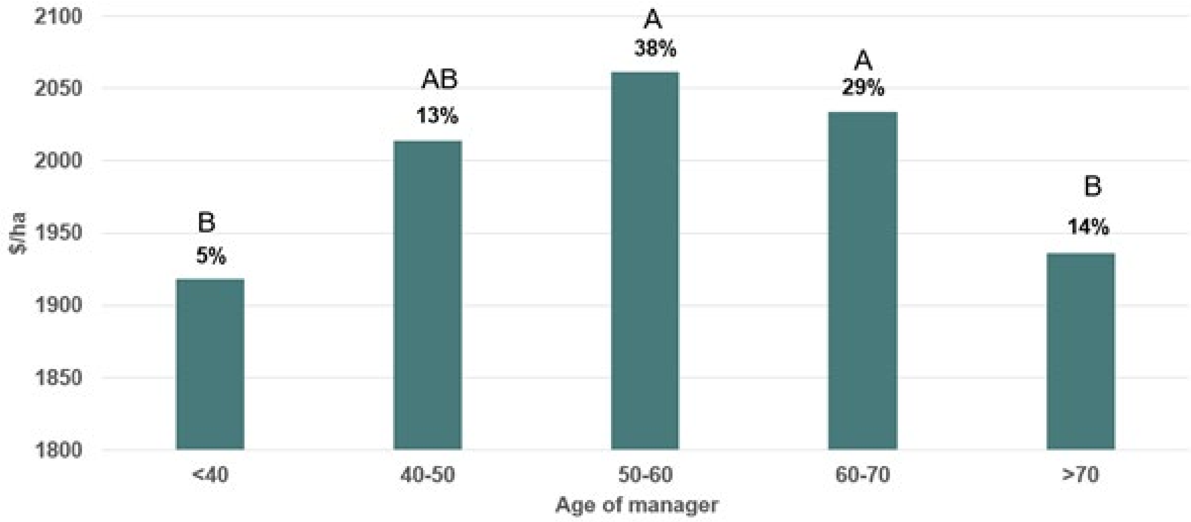


Figure 103: Dollars per hectare for each manager age group in the Herbert. The proportion of farms in each age group is indicated above the bars. Mean followed by the same letter are not significantly different (p>0.05).

In Table 40 are the counts and average dollars per hectare for all 768 farms practicing Below Conventional, Conventional and Control Traffic row spacing. Conventional row spacing is by far the most common practice with 82% of the farms in this category. An ANOVA was undertaken on the data and there were no significant differences in dollars per hectare between the row spacing categories. Due to the low numbers in Below Conventional and Control Traffic no further examination of the data by climate zone could be undertaken.

Table 40: Number of farms and average dollars per hectare for each row spacing category in Herbert: 2014-2019.

Row spacing	Count of farms	Average dollars per hectare
Below conventional	52	1,951
Conventional	631	2,028
Control traffic	85	2,022
Total	**768**	

Case study in Central Climate Zone

The Central climate zone occupies 43% of the harvested area in the Herbert. It contains both low and high productivity farms. The project team undertook a study to compare 6 adjacent growers in the Central Climate zone on the same soil type to investigate what were the main productivity drivers. The 6 farms were on clay and clay loams soils. The following activities were assessed:

Codes Drivers of productivity

- D Demographics (Age of manager)
- T Timing (All operations: planting, harvesting, weeds)
- O Off farming job (Substantial)
- F Farm Hygiene (Pest, Weeds, Disease)
- N Nutrition
- HM Harvesting Management - able to shift harvesting machinery between subdistricts when fields are too wet to harvest.
- HB Harvesting Best Practices
- C Changed Owner

The proportion of major varieties, crop age and crop cycle length were also calculated for the 6 farms.

The $/ha from 2014-2019 for the 6 farms were ranked in order from highest to lowest and plotted in Figure 104. The farm numbers have been coded as A-F to protect the privacy of the growers involved in study.

Farmer A has excellent timing, farm hygiene, nutrition, owns his own harvester and operates his harvester at HBP. Farmer B has excellent timing, farm hygiene and nutrition. Farmer C has excellent timing, farm hygiene and nutrition but is older than 70 years. Farmer D has off farm job, poor hygiene and nutritional deficiencies on his farm which negatively impact on productivity. Both Famers E and F have off farm jobs and have poor harvest management which often means they have to harvest in wet conditions which decreases their productivity.

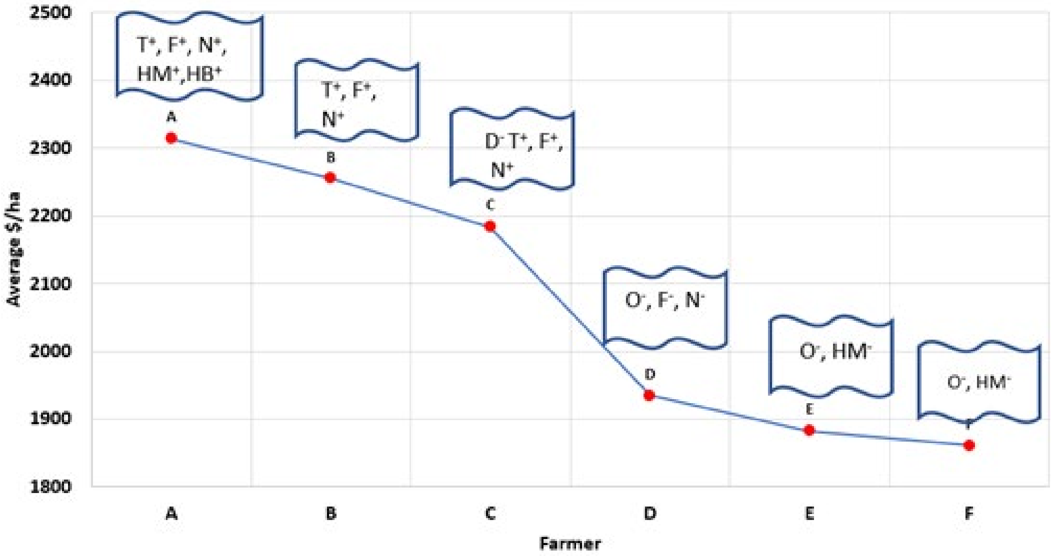


Figure 104: The $/ha for 6 adjacent farms in the Central climate zone on the same soil type. The $/ha have been ranked in order from highest to lowest. D – Demographics, T – Timing, O-Off farm job, F – Farm hygiene, N – Nutrition, HM – Harvest Management, HB – Harvesting Best Practices. A + and – indicate an increase or decrease on productivity.

The study clearly highlighted that good timing (T), good farm hygiene (F) and sound nutrition practices (N) were most commonly associated with the higher yielding farms and significantly drove productivity. It also found that an off-farm job had a significant negative impact on productivity because the grower could not attend to issues like farm hygiene in a timely manner.

Figure 105 shows the proportion of different crop classes for the 6 farms. There were relatively small differences and no clear relationship between the proportion of crop classes and average $/ha of the farms.

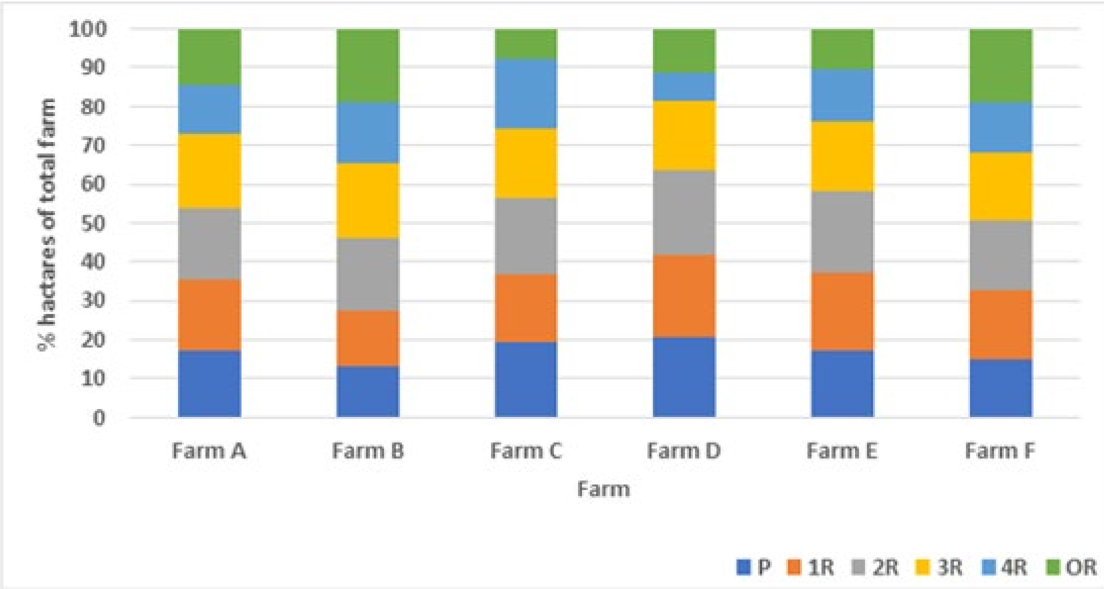


Figure 105: Crop age for 6 farms in the Central climate zone. The farms have been ranked in order from highest to lowest productivity.

The crop cycle length for the 6 farms was also calculated but again there was no clear relationship with average $/ha.

Table 41: Crop cycle length for 6 farms in the Central climate zone: 2014-2019.

Farm	Crop cycle length
A	4
B	4
C	3
D	3
E	3
F	4

In Figure 106 the proportion of different varieties grown on the 6 farms is compared. There was no clear pattern in variety composition and average $/ha of the 6 farms.

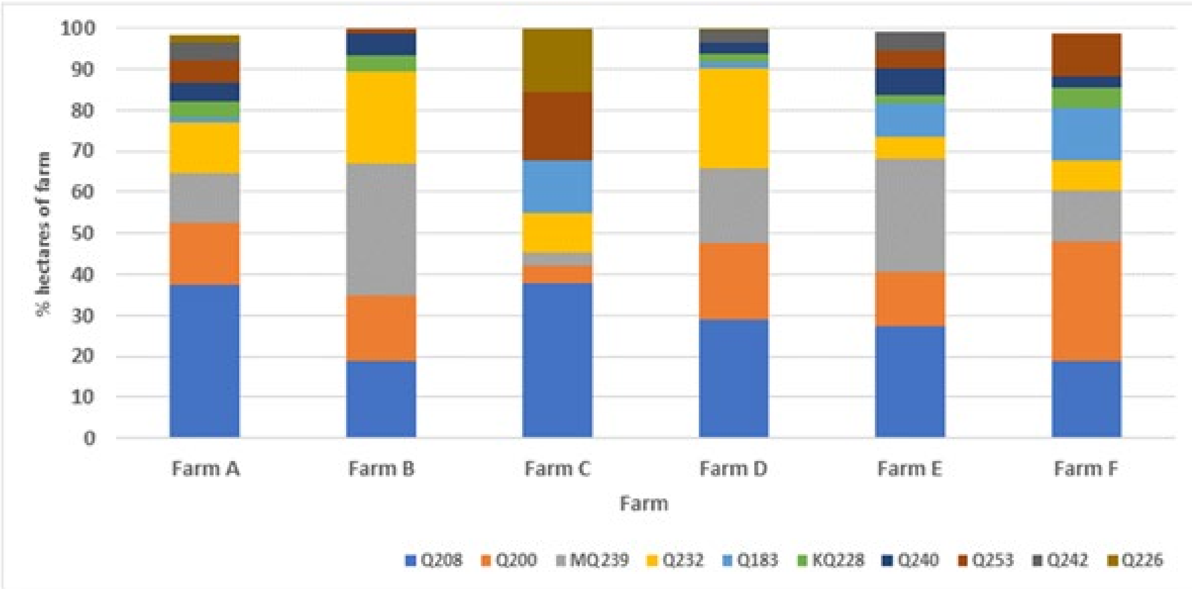


Figure 106: Percentage of major variety composition for 6 farms in the Central climate zone. The farms have been ranked in order from highest to lowest productivity.

There were no large differences found between the 6 growers for crop age, crop cycle length or variety percentage.

Variety performance where older variety were previously grown

An examination of new varieties on blocks where the established varieties have been previously planted may provide a useful method of assessing the performance of the new varieties and provide good recommendations for where to plant the new varieties. Farmers have had many years' experience with older major varieties like KQ228, MQ239, Q200 and Q208 and know which blocks suit these.

Two methods were examined:

- Method 1: The variety planted in a block in the previous crop cycle was identified. The $/ha averaged across P-1R for each individual block, for blocks harvested as plant crops in 2017 and 2018 and 1R in 2018 and 2019 was calculated. Then the $/ha averaged for each combination of previous and current variety, *e.g.* previous Q208-current Q208, previous Q200-current Q208 was obtained.
- Method 2: The variety planted in a block in the previous crop cycle was identified for blocks of P-3R in each year from 2017-2019. The average $/ha for crop classes P-3R for each combination of previous and current variety was calculated *e.g.* previous Q208-current Q253 was calculated.

For both methods blocks <0.25 ha and TCH <20 or >160 TCH were excluded.

The results for method 1 are given in Figure 107. On the x axis is the previous variety and the different coloured bars are the current variety *e.g.* if the previous variety was KQ228 and the current variety is now Q208 (blue) the $/ha was about 2850.

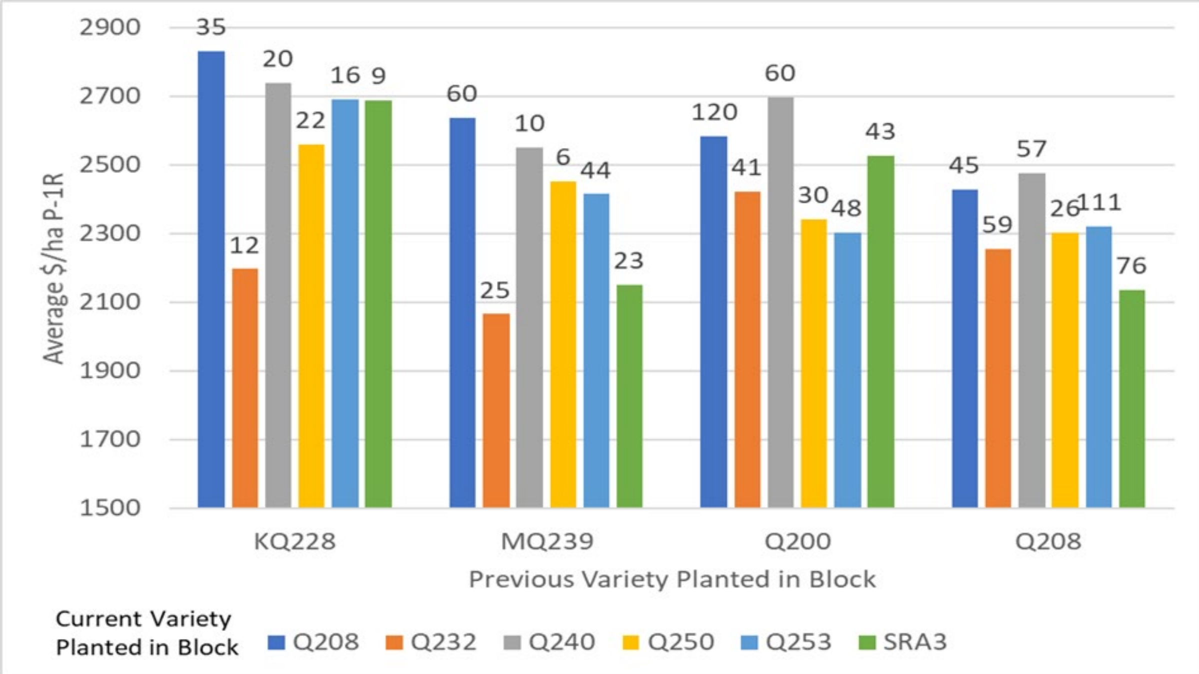
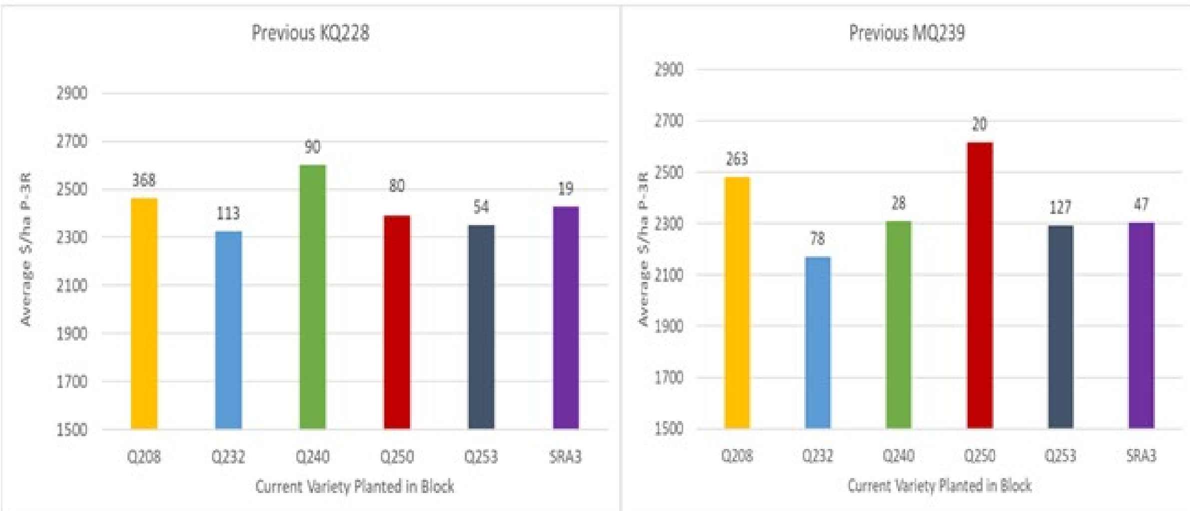


Figure 107: The average dollars per hectare for previous variety in block followed by current variety in block: P-1R from 2017-2019: Method 1. The numbers above each bar indicate the number of blocks.

Q240 was best variety where Q200 and Q208 were grown previously and 2nd best where KQ228 and MQ239 were grown previously. Q208 was the best variety where KQ228 and MQ239 were previously grown and 2nd best where Q200 and Q208 were previously grown. However, this method has some limitations in that it only considers P to 1R for blocks planted in 2017-2018 and no older ratoons. There are small number of blocks so caution should be taken when making conclusions from these results.

The results for method 2 are given in Figure 108. In this case we given a separated graph for each group of blocks that were previously planted to the different varieties and the current variety is shown by different colours.



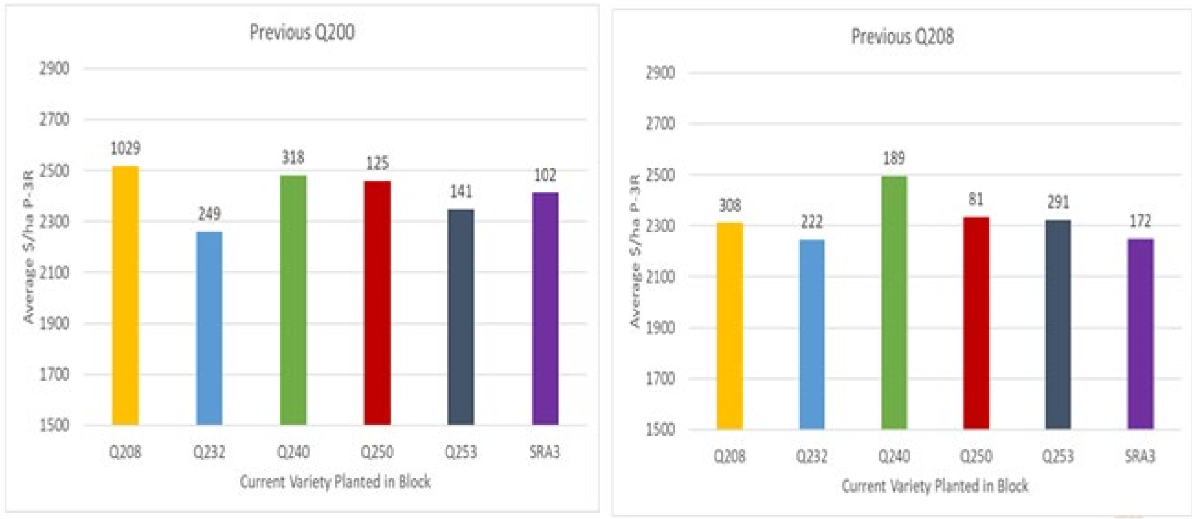


Figure 108: The average dollars per hectare for previous variety in block followed by current variety in block: P-3R from 2017-2019: Method 2. The numbers above each bar indicate the number of blocks.

Q240 was best performing variety in blocks that had previously grown KQ228 followed by Q208. Q208 was the best performing variety in blocks that had previously grown MQ239. Q250 had better performance for blocks that had previously grown MQ239 but there were only a small number of blocks and no 3R data so the result was considered unreliable. Q208 was the best performing varieties in blocks that had previously grown Q200 followed by Q240 and Q250. Q240 was the best performing variety in blocks that had previously grown Q208 followed by Q250, Q253 and Q208.

Both methods 1 and 2 gave similar results. Q208 and/or Q240 were identified as the best performing varieties in most comparisons. There was insufficient data for some of the newer varieties in some combinations to make fair comparisons. These analyses would support further planting of Q240 and continued planting of Q208. These analyses need to be repeated in future years as more data becomes available for the newer varieties.

Effect of planting Q208 in blocks that had previously grown Q208

Sugarcane in most areas of Australia is grown as monoculture (continual cultivation of the same crop species) with only short breaks every 4-6 years. Monoculture is associated with a build of soil-borne pathogens that leads to reduced yields in nearly all crops. The traditional method to reduce the effects of monoculture is to rotate different species or fallow fields for extended periods. Repeated planting of a single variety of the one species is an extreme example of monoculture and could potentially favour pathogens adapted to that one variety of that species. In the Herbert River district, Pachymetra root rot has been shown to build up under susceptible and some intermediate resistant varieties and is associated with reduced yields if the susceptible or intermediate resistant varieties are continuously grown (Magarey *et al.,* 2003). Planting Q208 in blocks that have previously grown Q208 has been shown to lead to poor performance of Q208 in other regions.

As outlined in the description of Method 2 above, the variety planted in a block in the previous crop cycle was identified for blocks of P-3R in each year from 2017-2019. The average $/ha for crop classes P-3R for each combination of previous and current variety was calculated. In this study we examined Q208, KQ228, MQ239, Q200 and Q183 in the previous crop cycle and Q208 in the current crop cycle to determine the percentage $/ha relative to Q208 (Figure 109).

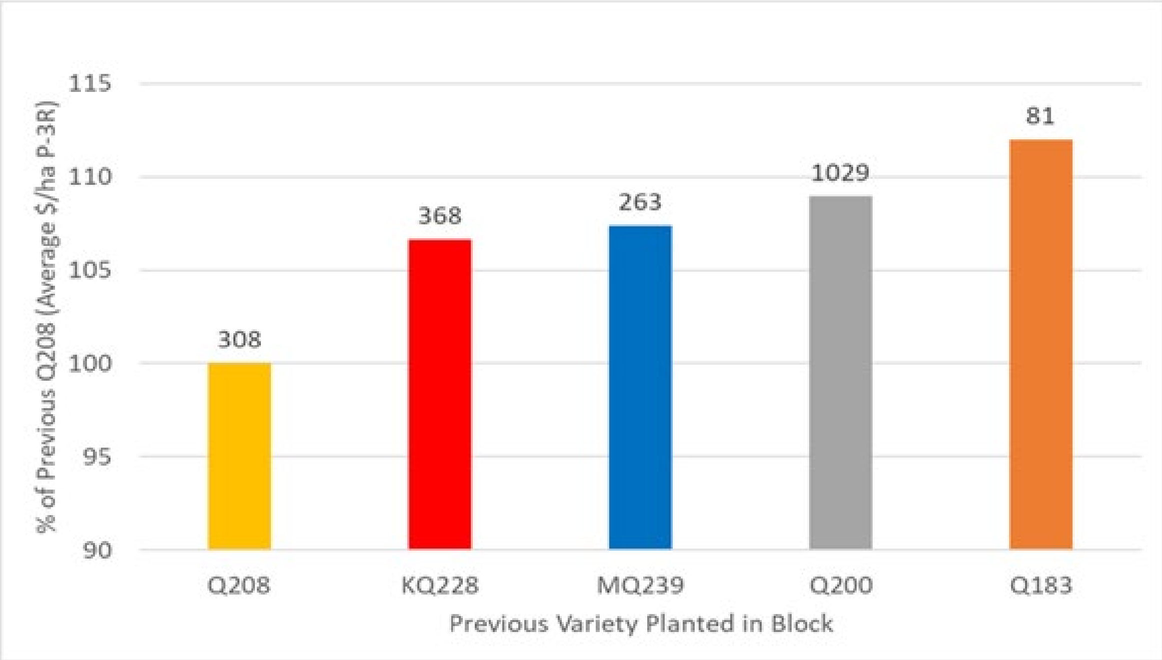


Figure 109: Previous variety in block followed by Q208 as current variety in block.

Planting Q208 in blocks that have previously grown Q208 was associated with 7-12% lower $/ha compared with planting Q208 in blocks that had previously grown KQ228, MQ239, Q200 and Q183 (Figure 109). Q208 performed approximately 12% better in blocks that had previously grown Q183 compared to blocks that had previously grown Q208. Q183 is resistant to Pachymetra. Pachymetra may have contributed to the losses in Q208 planted in blocks previously planted to Q208. It is advisable to practice rotating varieties to avoid any potential build-up of pathogens compared to continually planting one variety.

Effect of Pachymetra resistance of previous/current varieties

The same two methods of tracking blocks were used to compare the performance of the current crop in blocks that had previously grown varieties with different Pachymetra resistance. Only P-1R data was included as these crops are most likely to be affected by Pachymetra levels in soil from previous crop. There were insufficient blocks of susceptible varieties to include them in the analyses.

Three sets of analyses were undertaken. In the first set all varieties rated as resistant and intermediate to Pachymetra are included. In the second set of analyses specific varieties were examined.

Results for the first set are given in Figure 110. Blue coloured bars are Previously Resistant (R) while orange-coloured bars are Previously Intermediate (I). In Figure 110, for Method 1 the first blue bar is for Resistant x Resistant and there were 43 blocks that averaged $2,300/ha.

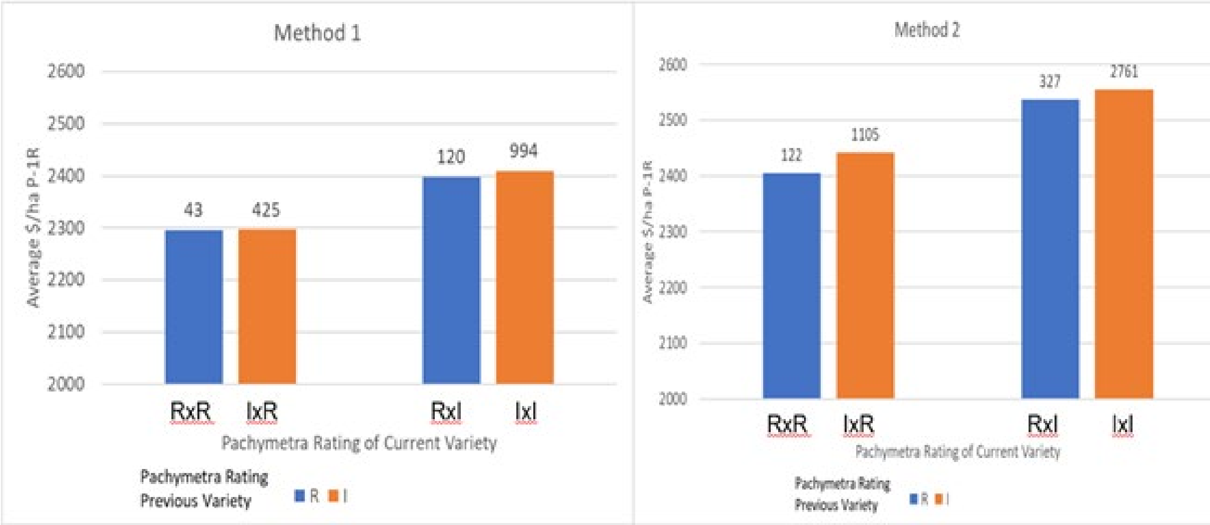


Figure 110: Effect of Pachymetra resistance of previous/current variety on $/ha using Method 1 and 2 for tracking blocks.

In the second set of analyses the individual ratings for varieties on a 1-9 scale were examined. A rating of 1-3 are Resistant, 4 is Intermediate-Resistant, 5 is Intermediate and 6 is Intermediate-Susceptible. In the first blue bar is for Resistant in previous crop cycle followed by a variety rated as a 1 in current crop cycle. The numbers above the bars indicate the number of blocks (Figure 111).

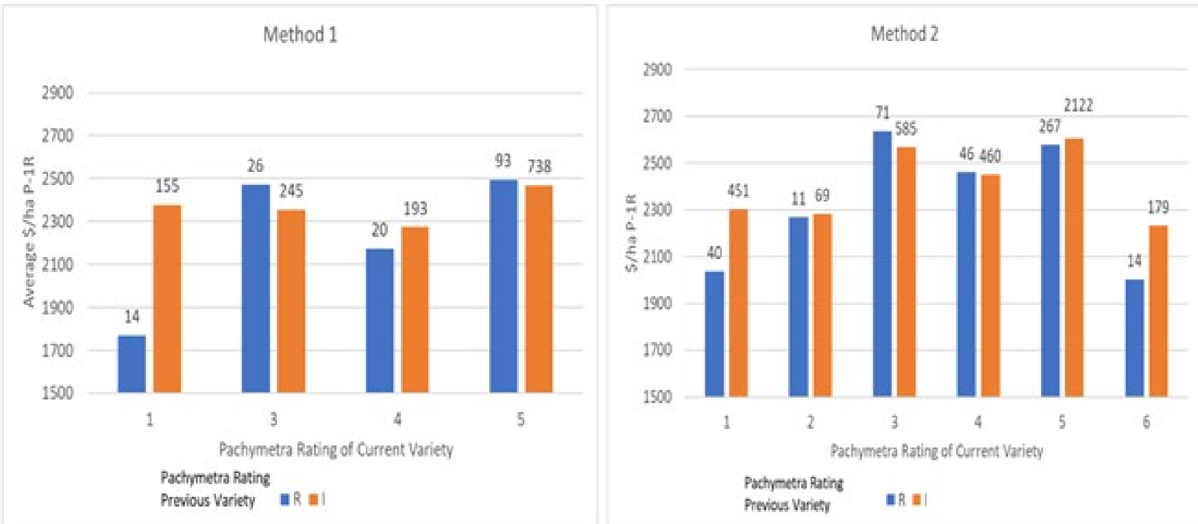


Figure 111: Effect of Pachymetra resistance of previous/current variety on $/ha using Method 1 and 2 for tracking blocks. Ratings in the current crop cycle have been rated 1,2,3,4,5,6.

In the third set of analyses different varieties were examined where Previously there was Resistant and Intermediate rated varieties. In the first blue bar is for Resistant in previous crop cycle followed by Q208 in current crop cycle. The numbers above the bars indicate the number of blocks (Figure 112).

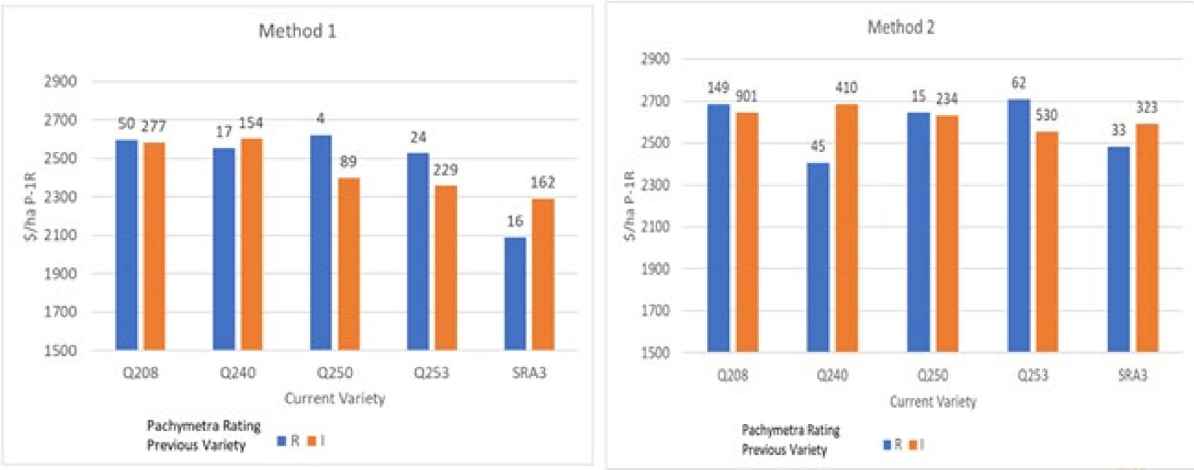


Figure 112: Effect of Pachymetra resistance of previous/current variety on $/ha using Method 1 and 2 for tracking blocks.

There is no consistent effect associated with Pachymetra resistance. Some varieties appeared to perform slightly better after a resistant variety compared with following an intermediate variety.

5.3 Extension strategies

Adoption of project outputs to aid in industry decision making and improve on-farm profitability

This project has used innovative tools to analyse and summarise mill data within a region to identify those farm production units performing below potential and the factors associated with this. An increased understanding of the factors affecting productivity will broaden the adoption of improved farming practices by working with local industry to enable more appropriate selection of varieties to match field conditions, addressing impediments to farm productivity and Nutrient Management Planning. An improved knowledge of how climatic conditions influence sub-regional productivity performance in Burdekin, Tully and Herbert will assist industry extension programs and on-farm management decisions.

The project has developed a data platform for an Industry Productivity Data Analysis and Reporting Tool (IP-DART) which:

- Created *productivity performance groupings* based on cane yield, CCS, sugar yield and dollars per hectare to identify opportunities for tailored extension practices in Tully, Burdekin and Herbert. The Burdekin, Tully and Herbert are large mill areas and contain 854, 361 and 834 farms respectively. Any data reduction technique to analyse vast amounts of productivity data to identify groups of farms with similar productivity over time will be assist local extension providers. Local extension productivity services can then develop extension programs, based on the factors identified, to show sugarcane growers the potential productivity benefits they could achieve by addressing these factors. An improved knowledge of how climatic conditions influence sub-regional productivity performance in Tully and Herbert will assist industry extension programs and on-farm management decisions.

- Extension providers have been able to use the productivity performance groupings to *identify opportunities for tailored extension practices* by customising variety and on-farm management recommendations for individual growers. In the Herbert the change in productivity ($/ha) between the period 2005-13 and 2014-19 was examined and the Bottom 30 and Top 30 farms were identified. As applied in 2014/054 these two contrasting groups were characterised and then the factors for which they were different was applied to the results to target group.

- Compiled *farm productivity reporting tool* for Tully and Herbert industries which allows growers to benchmark their farm performance relative to all others in their productivity district. A series of shed meetings were held in Tully in 2019 to launch the CAPAs and explain their content. After this the CAPAs and soil maps for 361 farms were uploaded to the TSL grower portal to enable easy access for all growers. In the Herbert, approximately 25% of growers attended shed meetings held in March 2021 and were given their CAPAs. For growers who could not attend the shed meetings but have requested CAPAs the content of the reports have been discussed with them in one-on-one meetings. More detailed CAPAs based on cane yield, CCS and sugar yield were produced for some growers. This allowed particular growers to be compared to all neighbouring farms. HCPSL are now working one-on-

one with individual growers to address productivity drivers like Approved Clean seed adoption, Pachymetra, micro-nutrient deficiencies (especially zinc), crop ripening through the use of Moddus™ to improve early CCS and the use of fallow cover crops. Growers who did not receive a CAPA report at shed meetings will now be engaged on a one-on-one basis through HCPSL industry led productivity improvement and benchmarking project and through general extension activities.

- Developed a *single consistent source of data* for all users in Tully and Herbert which was used for to streamline Nutrient Management and Variety Management Plans and available for use in industry reports.

In Tully there are three distinct areas where advisory groups have used project outputs:

1. Cluster analysis at farm level
   - Growers who participate in the Tully Variety Management Group (TVMG) receive mill performance data on new varieties and recommendations on what variety to plant. The cluster analysis undertaken in Tully became the benchmark of how to run the TVMG. Typically, TSL would approach growers to work closely with because they are a) interested, b) approachable, and c) their farms are indicative of a local subdistrict in terms of soil type, rainfall topography etc. However, with the cluster analysis TSL was able to change their approach because it clearly showed groups of growers with low to average productivity that would benefit from being members of the TVMG to and improve the whole of Tully industry. To quote Greg Shannon, Productivity Manager at TSL, the "Tully industry was able to develop a five-year 2016-20 strategic plan for the TVMG by using the clustering results to target individual growers. This included four large growers who joined in 2017-18 and are still involved". Greg estimates that by applying the results of the clustering this allowed him to identify growers some 2-3 years earlier than normal. This helped to add 300,000 tonnes of cane to the TVMG programme from 2018 which has bought the overall direct influence of the TVMG to 1.9M tonnes out of 2.45M tonnes estimated in 2021.

2. Soil mapping and Pachymetra survey mapping
   - The Pachymetra survey maps have been used to easily identify hot spots to growers. This saved the Tully industry 2-3 years in terms of being able to promote Pachymetra resistant varieties into the hot spot areas *e.g.* SRA 6 and Q253 into El Arish, Feluga and Lower Tully. The soils maps have also been widely used by advisors to develop nutrient management plans and in BMP. In terms of TSL farms which represent up 6% of the total Tully Cane Productivity Area (CPA), the soil maps have enabled TSL to save much time and money for soil sampling.

3. The individual CAPA reports
   - CAPA reports have been used to formulate variety plans and help growers decide what to propagate for commercial planting the following year. To date 30% of the Tully CPA has received a variety plan, with about 10% of these using the new individual CAPA reports. By the end of 2021 season it is expected that 50% of the Tully CPA will have a variety plan of which 25% will have been done using the new individual CAPA reports.

5.4 Ratoon Index

Ratooning index for varieties

Ratoonability is a feature of varieties that has been identified by growers as having great importance to profitability. Maintaining acceptable profitability for more ratoon crops can greatly improve a grower's overall returns because he can spread the high cost of planting over more years and have less periods of fallow when no income is produced.

Shaw (1989) proposed an index to measure ratoon performance. His measure looked at the cumulative yield loss (tonnes cane/ha) relative to a reference yield which he suggested could be plant crop yield or the average of plant and first ratoon yield. He used the index to compare ratooning in different estates and different years in Jamaica. He suggested that replanting should be done when the cumulative yield loss exceeds the replanting cost.

In project 2014/054 that preceded this project, several potential measures of ratoonability, based on the mill data were considered. The measures considered were:

1. Loss in ha from P crop through to 4^{th} or 5^{th} ratoon for a given planting year
2. Actual yield and the rate of loss in yield ($/ha) across crops
3. Slope of the regression line of crop class vs cane yield
4. Cumulative cane yield relative to the P crop for the ratoons.

5. A ratoon index based on hectares harvested (ha) was examined and was calculated as follows:

Ratoon index = (P ha x 0) + (1R ha x 1) + (2R ha x 2) + (3R ha x 3)+ (4R ha x 4) + (5R ha x 5) + …/total area harvested.

The benefit of measure 1 is that it is a measure of the actual decisions made by growers on how long to continue ratooning a variety. The problem with this measure is that it requires many years to obtain data for a variety (perhaps at least 10 years) and events such as disease incursions can mean that growers make decisions not on ratoonability but on removing a susceptible variety before the disease causes serious losses. Option 1 was used in this project as a reference to allow a comparison of alternative measures of ratoonability. The years selected for analysis in this project were not confounded by major disease outbreaks or exceptional weather events.

Measure 2 looked at the economic return to growers over a 10-year period. A model was developed that combined a varieties actual $/ha returns, the rate of decline in $/ha and how often a grower ploughed out and replanted the variety during a 10-year period given a set of thresholds for acceptable returns. This method requires a rather complex model and would be difficult to implement as an automated feature for comparing ratoonability of varieties. In this project, we attempted to develop a similar but simpler method that retained the key features of this measure but could be easily developed into an automated measure of ratoonability.

Measure 3 and 4 examine the slope of decline in yield or cumulative loss of cane yield relative to plant crop. These measures have a major problem in that they do not consider economic returns. A variety with a low $/ha return but returns decline at a slow rate would be rated higher than a variety that has a high return but declined at a faster rate. Over a crop cycle the high return variety may provide the greater economic return and could be the variety that is recommended. Even though the rate of decline in yield was not considered as an independent measure of ratoonability, it is an integral component of the simplified measured of profitability across a crop cycle.

The definition of “ratoonability” we have used in this project is:

“Number of years a crop remains profitable”

This definition focuses on profitability of the crop and the years between planting and plough-out. It could be used to compare varieties, districts or mill areas. The acceptable threshold for profitability may vary between areas and between growers depending on their returns and costs.

In this project, we selected the Herbert as a case study, and we used mill data for the years 2013 to 2019. Initially we examined ratoon performance across ratoons to understand how economic returns declined over crop classes and how growers managed ratoon crops and different varieties. We examined the combined data for the years 2013 to 2019 and we also followed individual blocks from plant to fifth ratoon (5R) for blocks planted in 2013 and 2014. When we refer to performance of a ratoon or variety, we are referring to the $/ha returns. For the Herbert mill area, the dollars per hectare were calculated using the following formula:

*Dollars/ha = ((((Sugar price * 0.009 * (CCS-4)) + Price Adj) *TCH)-(TCH*(Harvest costs + levies)))*

Where:

Sugar Price is $400/t, Price Adjustment is $0.635 and Harvest Costs and Levies were $8.50 and $0.518, respectively.

To simplify analyses only the major varieties and new varieties released during the period were included in the analyses.

Trends in Performance and Decline in Planted Area

Performance of different climate zones within the Herbert region and different varieties within the climate zones were examined. The climate zones in the Herbert have been defined in project 2017/009 (Figure 94).

The average $/ha for each crop class from plant to 5R for all blocks and all years and percent of plant crop hectares for blocks planted in 2013 and 2014 are shown in Figure 113. This figure shows that $/ha declines at a similar rate between plant and 1R and between 1R and 2R. The rate of decline slows between 2R and 3R and the rate of decline slows even further between 3R and 4R and there was minimal decline between 4R and 5R. The slowing in the rate or decline between 2R and 5R can be easily explained when the graph for percent of plant crop hectares for blocks planted in 2013 and 2014 is examined. The rate of decline in hectares is slow between plant and 2R and then increases with each crop after 2R. Approximately 70% of the area planted in 2013 and 2014 remained at 5R. It is assumed that growers plough-out poorer performing blocks and therefore the average $/ha in older ratoons stops falling as only the higher performing blocks are retained. Average performance of blocks retained to 5R was just below $1900/ha.

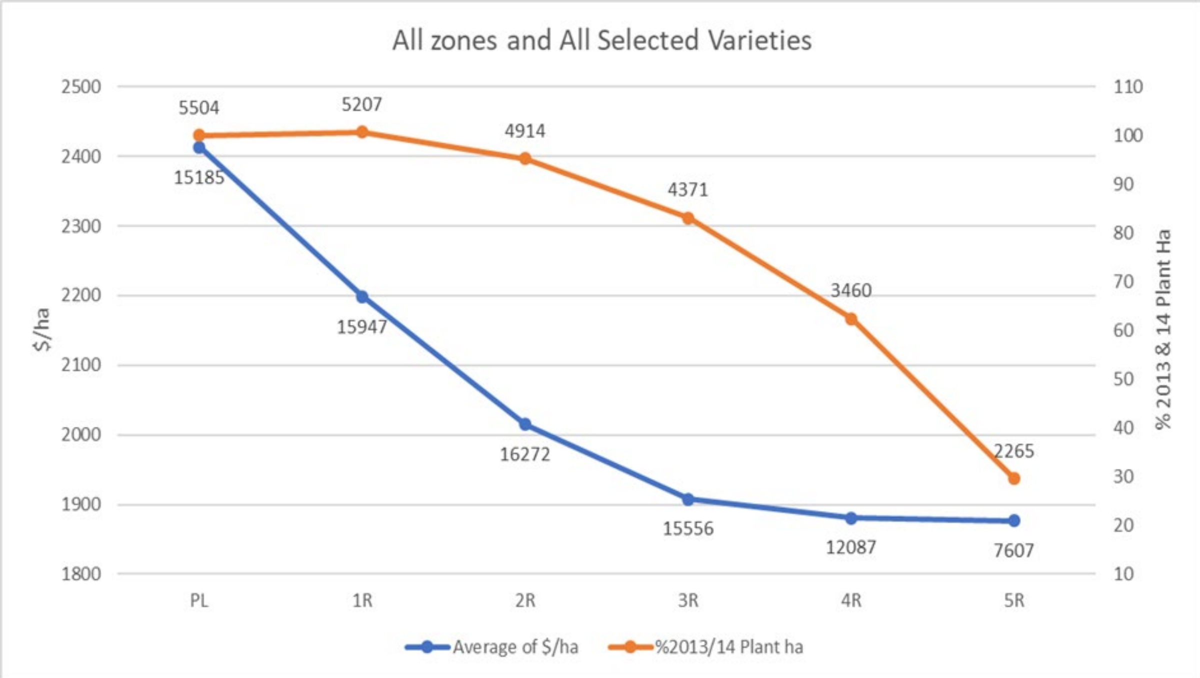


Figure 113: Average $/ha returns for all plant and ratoon crops in the Herbert 2013-2019 and the hectares of crops planted in 2013 and 2014 and in ratoon crops (1R to 5R) expressed as a percentage of the hectares of the plant crop. The number of blocks included in each average is shown beside the points on the graphs.

The performance of crop classes in the five climate zones is shown in Figure 114. The Wet Zone has the lowest $/ha returns of the five climate zones and Ingham Line and Stone River have the highest returns. Returns in Abergowrie and Central zones were similar and fell between the Wet Zone and the Ingham and Stone River zones. The pattern of decline in returns was similar for each zone except that Ingham Line had a sharper drop in returns between 4R and 5R.

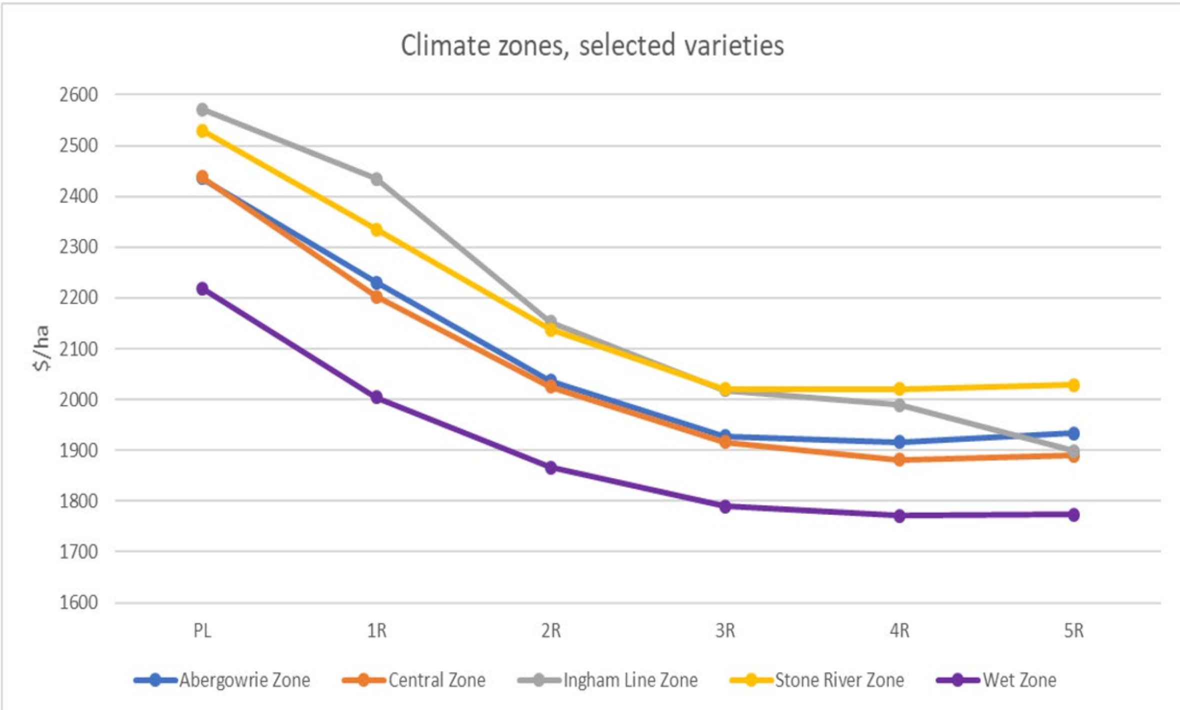
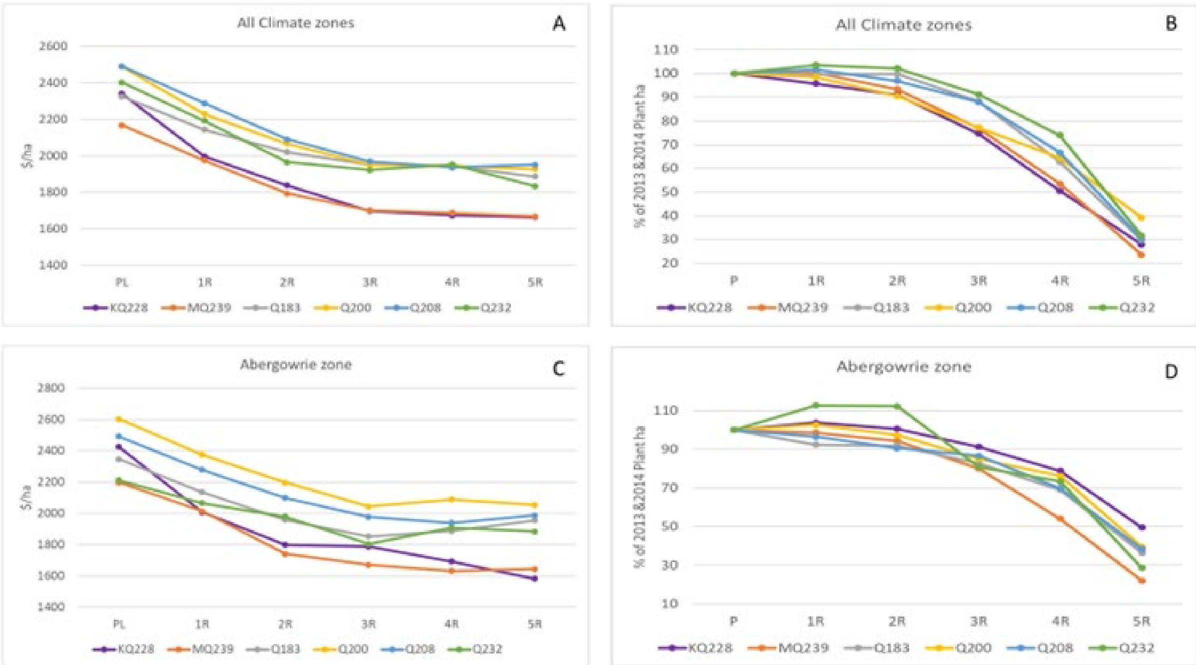
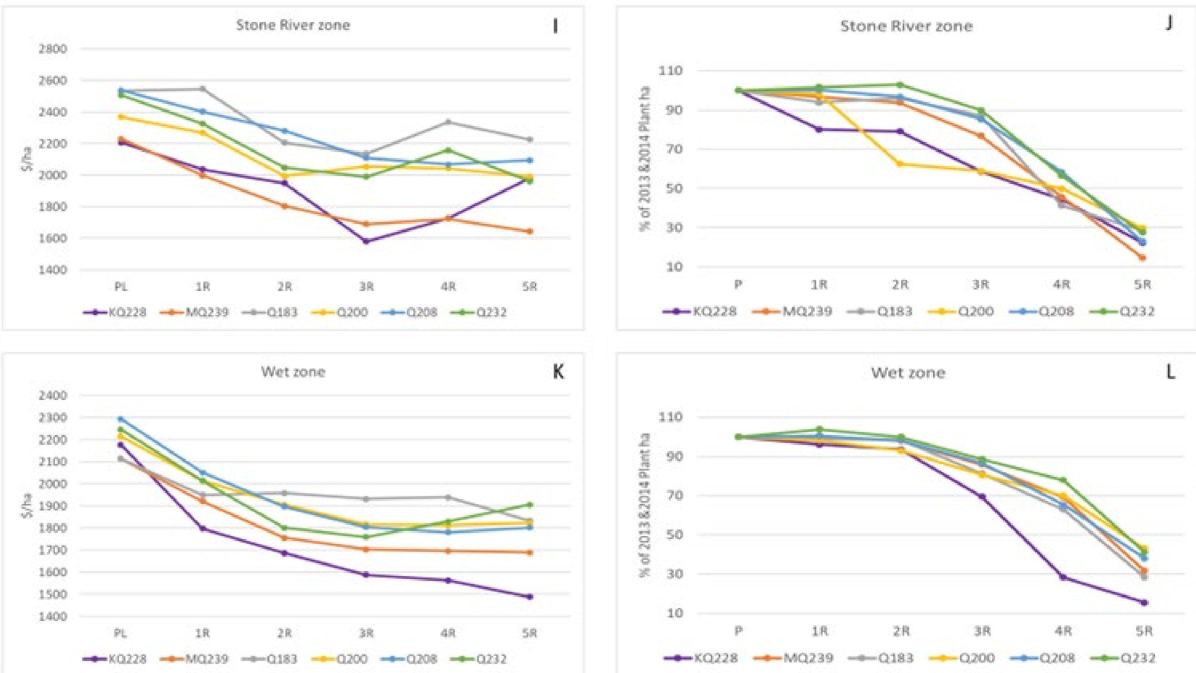


Figure 114: Average $/ha returns for 2013-2019 for each crop class in the five climate zones in the Herbert.

The performance of the six major varieties across crop classes for the years 2013-2019 for all climate zones and percent of plant crop hectares for blocks planted in 2013 and 2014 are shown in Figure 115A and Figure 115B. KQ228 and MQ239 were the poorest performing varieties across all ratoons and they had the most rapid decline in area from plant to 5R. KQ228 and MQ239 performed poorly in all climate zones. This confirms that growers are ploughing out the least profitable blocks earlier. Q183, Q200, Q208 and Q232 had similar performance but Q200 and Q208 were slightly ahead of the other two varieties in most crop classes. Interestingly, Q200 had a more rapid decline in area in 2R and 3R but then stabilised. Q200 was the best performing variety across all ratoons in the Abergowrie and Central zones (Figure 115C and Figure 115E). In the Central zone, Q208 performed only slightly below Q200. Q183 and Q208 were the best performing varieties across ratoons in the Ingham Line and Stone River zones (Figure 115G and Figure 115I.). In the Wet zone, Q183, Q200 and Q208 were the best performing varieties (Figure 115K). In general, the poorer performing varieties had a more rapid drop in percent area in ratoon crops (Figure 115B, Figure 115D, Figure 115F, Figure 115H, Figure 115J and Figure 115L).





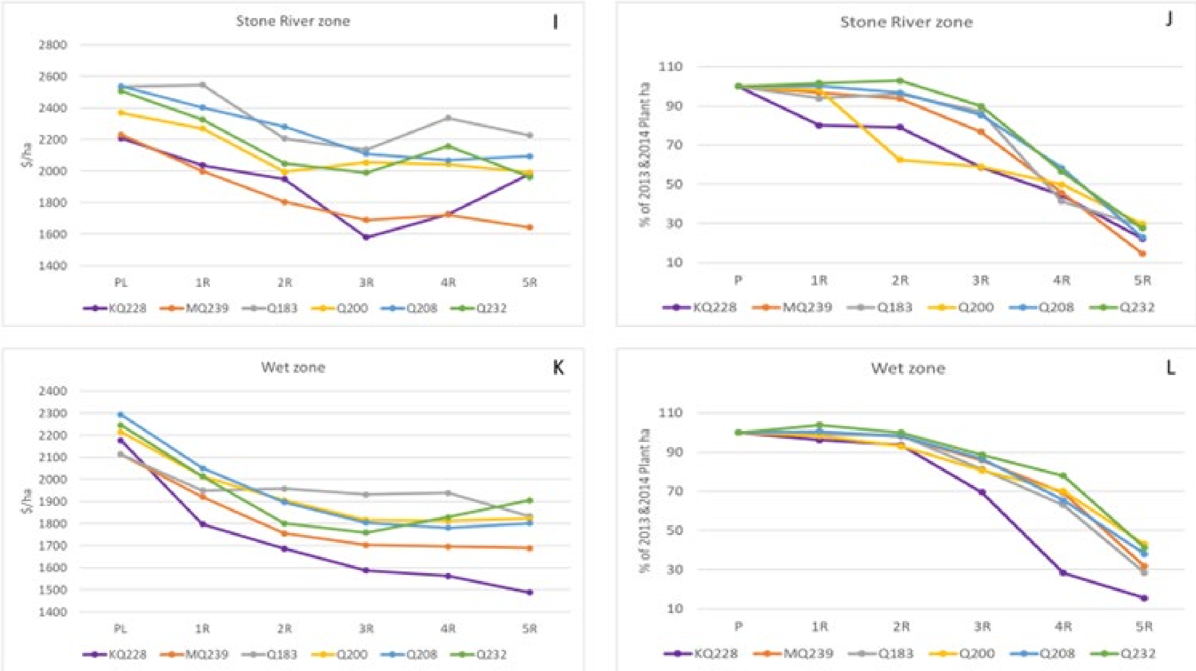


Figure 115: Average $/ha returns for the five major varieties in each crop class (A,C,E,G,I&K) for all climate zones and in the five individual climate zones. Also shown is the hectares of crops planted in 2013 and 2014 and in ratoon crops (1R to 5R) for the five individual climate zones.

An analysis was conducted of groups of blocks planted in 2013 and 2014 that were ploughed out after 2R, 3R, 4R or were still present at 5R to better understand when and why growers plough out blocks. The average $/ha was standardised to remove year effects by expressing the $/ha as a percentage of mill average for each year. The $/ha as a percent of mill average of blocks that were ploughed out before 3R (PO<3R), present at 3R but ploughed out before 4R (PO<4R), present at 4R but ploughed out before 5R (PO<5R) and crops that were still present at 5R (Pres5R) is presented in Figure 116. The regression lines and equations for decline in percent $/ha between 1R and 3R are shown for each group of blocks. For blocks ploughed out before 3R, the regression for decline in $/ha is for 1R to 2R. The analysis clearly shows that the longevity of blocks is related to the overall performance of the blocks, higher performing crops lead to longer ratoons. Growers the worst performing blocks before 3R. In most cases, the rate of decline in $/ha was greater for the blocks that were ploughed out earlier. The reason for the plateau in average $/ha in 4R and 5R crops is clearly explained by this graph which shows that the average is only made up of the higher performing blocks that are retained until 4R or 5R.

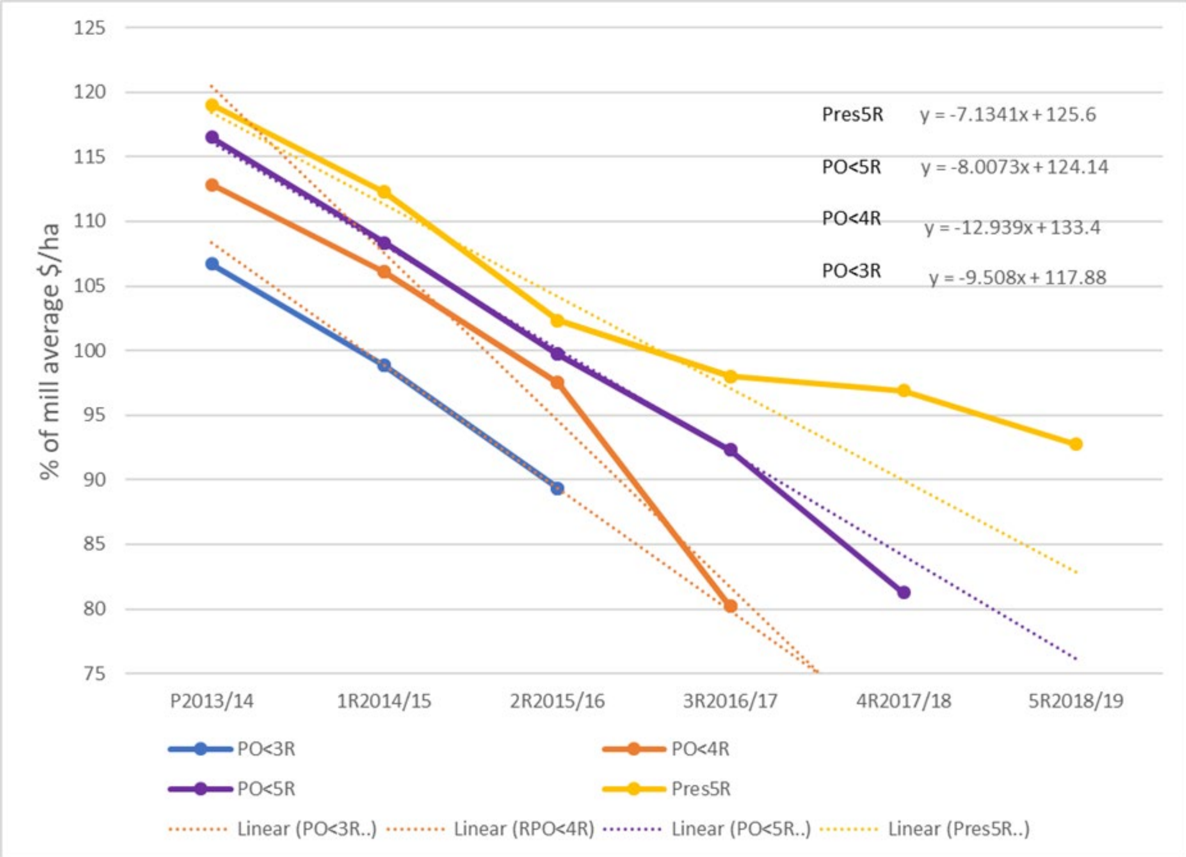


Figure 116: The average $/ha expressed as a percentage of mill average of blocks that were ploughed out before 3R (PO<3R), present at 3R but ploughed out before 4R (PO<4R), present at 4R but ploughed out before 5R (PO<5R) and crops that were still present at 5R (Pres5R). Analysis included blocks planted in 2013 and 2014 and subsequent 1R to 5R crops in 2014 to 2019. The regression lines and equations for decline in percent $/ha between 1R and 3R, and 1R to 2R for PO<3R, are shown for each group of blocks.

Indices of Ratoonability

Percent area ploughed out before 3R or present at 5R

Figure 117 compares the percentage of area plant crop blocks that were ploughed out before 3R (PO<3R), present at 3R but ploughed out before 4R (PO<4R), present at 4R but ploughed out before 5R (PO<5R) and crops that were still present at 5R (Pres5R) for each of the five major varieties. This graph clearly shows that a higher proportion of blocks of the poorer performing varieties (KQ228 and MQ239) are ploughed out before 4R and fewer blocks are still present at 5R. The percentage of area ploughed out before 3R or still present at 5R could be used as a simple measure of ratoonability of varieties.

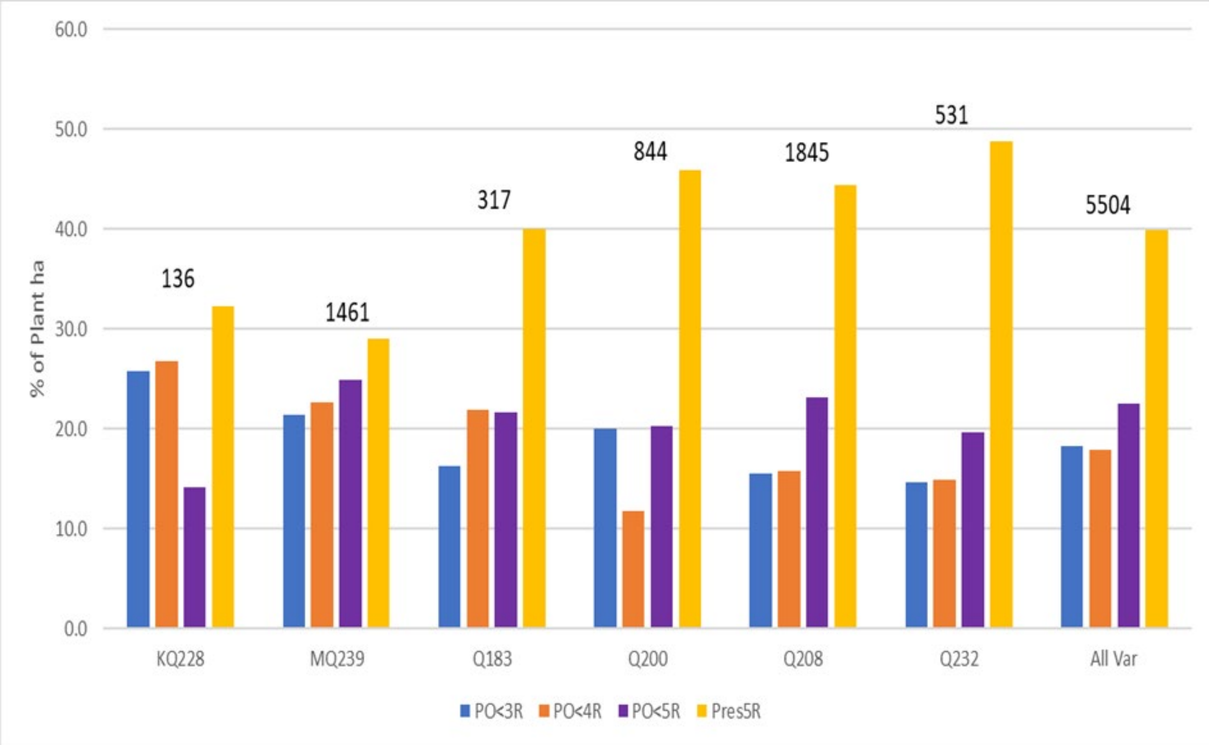


Figure 117: The area expressed as a percentage of the area of plant crop for blocks that were ploughed out before 3R (PO<3R), present at 3R but ploughed out before 4R (PO<4R), present at 4R but ploughed out before 5R (PO<5R) and crops that were still present at 5R (Pres5R). Analysis included blocks planted in 2013 and 2014 and subsequent ratoons in 2014 to 2019. The number of plant blocks of each variety is shown above the columns for that variety.

Years until planted area drops to 25% of initial area planted

We examined another measure of the rate of decline in area planted that estimated the number of years until the planted area dropped to 25% of the original area. Figure 116 shows that the area planted only drops slightly between plant and 2R and then drops at a fairly constant rate until 5R. We estimated the rate of decline of area as a percent of planted area between 2R and 5R by subtracting the percent area at 5R from the percent at 2R and dividing by the number of years and then we estimated the number of years from plant crop to 25% of original area by the following formula:

Years to 25% = ((%2R-25%)/(% Rate of decline 2R to 5R))+3

where 3 is number of years from P to 2R.

The estimated years to 25% area for the major varieties across all climate zones are shown in Figure 118. The differences between varieties were not great. MQ239 had the lowest number of years to 25% and Q200 the highest. Q200 had the highest % area at 5R of any variety across all climate zones in Figure 115B which agrees with the higher estimated years to 25% for this variety. Q200 showed an initial rapid drop in area between 1R and 3R in Figure 115B and then declined at a slower rate until 5R than other varieties. One interpretation of the observed pattern of decline in planted area of Q200 is that it was planted in some blocks to which it was not well suited and these were ploughed out early and it ratooned well in the remaining blocks where it was suited.

The estimated years to 25% for each climate zone are shown in Figure 119. The estimates vary greatly for varieties between climate zones. For example, KQ228 had the highest estimate in the Abergowrie Zone but the lowest in the Wet Zone. Q200 was estimated to have almost one-year more years to 25% area than the next highest variety in the Central zone and had the highest estimates for all other zones except Abergowrie.

Overall, we consider that these estimates of years to 25% area are confusing and do not fully explain the pattern of decline in area of varieties shown in Figure 115B-L and Figure 118. The percent area of blocks ploughed out before 3R or present at 5R in Figure 117 are possibly a much simpler and better measure of ratoonability.

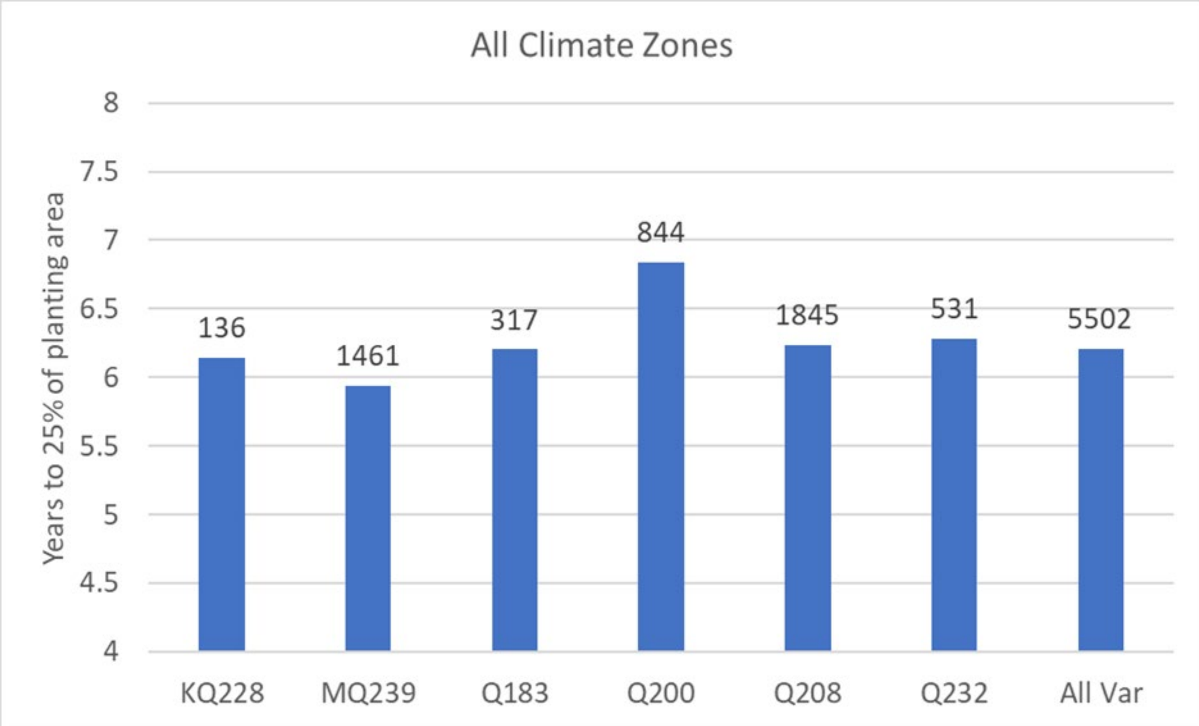


Figure 118: Estimated years until the area planted in 2013 and 2014 of each variety drops to 25% of the original planted area, all climate zones.

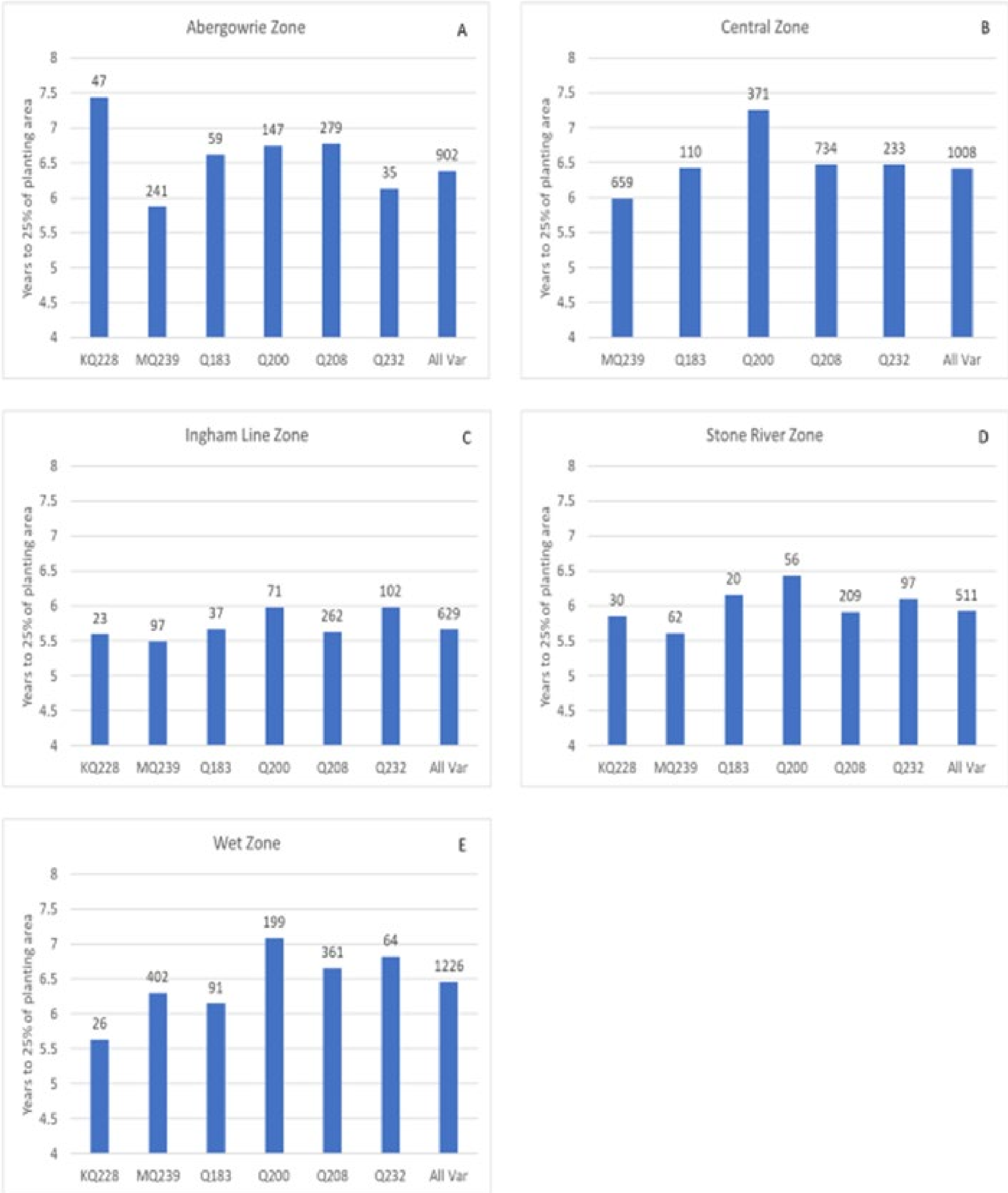


Figure 119: Estimated years until the area planted in 2013 and 2014 of each variety drops to 25% of the original planted area for the five climate zones.

Ratoonability Index – Years to threshold of Profitability

At the beginning of this section on ratoonability we defined ratoonability as the "number of years a crop remains profitable". An estimate of ratoonability therefore should include both the initial starting profitability of a crop and the rate of decline in profitability. We propose a ratoonability index based on these factors and a threshold when a grower would consider it is no longer profitable to continue ratooning a crop. Our ratoonability index was calculated using the following formula:

number of years = ((Av$/ha 1R – threshold of profitability)/($/ha 1R - $/ha 3R)/2))+2

The threshold for profitability was set at $1,600 in our examples. This is based on Figure 115 where the minimum plateau in in $/ha returns for the worst performing varieties in 4R and 5R was around $1,600 in most climate zones. This threshold will vary with a grower's management preference, an individual grower's cost structures and the sugar price. In periods of high sugar price, it has been shown that growers should be weighted more toward maximising tonnes sugar per hectare, whereas when the sugar price is low the objective should shift more toward minimising costs. Two years were added to allow for the year of plant and 1R crops since the estimate was based on the decline in $/ha after harvest of the 1R crop.

The ratoonability index we propose is relatively easy to calculate and the threshold for profitability could be easily programmed to be set by an individual grower or adviser. We started the calculations from 1R, not plant crop, because in some regions plant crop yields are inflated by crops that are planted in autumn and harvested at around 18 months of age. In theory, plant crop yield is not influenced by "ratooning", even though it is important in overall crop cycle performance.

The primary purpose of a ratoonability index would be to provide an estimate of the ratooning potential of varieties so that growers can make better decisions on which variety to choose to plant. Growers have a good idea of the ratoonability of varieties they have been growing for many years but would like advice for new varieties as early as possible after release of that variety. In the previous section, we looked at the percentage of crops of a variety that were present at 5R or an estimate on the number of years until a variety reached 25% of its initial planted area based on the decline in area from plant to 5R. Both these estimates of ratoonability require many years, probably at least 10 years after release of a variety, to obtain a reasonable estimate. The ratoonability index we have proposed requires a reasonable area of harvested crops of 3R for an estimate. For example, the first blocks of the variety Q240 in this study were harvested in 2013 and five years later in 2018 it had 654 ha of 3R harvested. We believe this would give a reasonable estimate of ratoonability. The estimates of ratoonability are dependent on the seasons the varieties experience during the period of available data. Ratoonability of a variety will vary in different seasons, with weather conditions, disease and pest outbreaks influencing how a variety will ratoon. The index is a method to compare varieties and the actual number of years is only a guide. When presenting the results of these analyses to growers it would be advisable to present a general ranking or rating for varieties not the actual figures.

The estimates of the ratoonability indices for the major varieties across all climate zones are shown in Figure 120. KQ228 and MQ239 clearly had the lowest ratoonability index across all climate zones. Q183 had the highest ratoonability index. Q208 had a slightly higher average $/ha return across plant to 5R than Q183 ($2,137/ha versus $2,073/ha respectively, (Figure 115A) but the rate of decline in $/ha between 1R and 3R for Q183 was lower than Q208 ($95/yr versus $160/yr respectively), which lead to the higher ratoonability estimate. The ratoonability estimates for Q200, Q208 and Q232 were similar.

We then looked at the ratoonability indices for varieties in each of the five climate zones (Figure 121 A-E). In Abergowrie zone, Q200 and Q208 had the highest ratoonability estimate and MQ239 the lowest. In the Central zone, Q232 had the highest ratoonability index followed by Q183 then Q200 and Q208. KQ228 and MQ239 had the lowest ratoonability indices in the Central zone, more than one year lower than the other varieties. Q183 had the highest ratoonability index in the Ingham Line zone, more than 4 years higher than the next best varieties, Q200 and Q208. KQ228 and Q232 were the next best varieties in Ingham Line and MQ239 had the lowest ratoonability index. In the Stone River zone, Q200 had the highest index followed by Q208 then Q183 and Q232. The ratoonability indices for MQ239 and KQ228 were 3 to 4 years lower than Q200. We did not include Q183 in the graph for the Wet zone because the ratoonability index was off the scale (>40 yr). In Figure 115K, the $/ha for Q183 in the Wet zone shows only a slight decline between 1R and 3R which led to the very high ratoonability index. The estimate was based on 231 blocks in 1R and 226 blocks in 3R which we would consider should give a reliable estimate. The ratoonability index for Q183 indicated that it is a good ratooner in this zone but the actual length of ratooning in unrealistic. Q200 was the next best variety in the Wet zone followed by Q208 and then Q232. KQ228 had the lowest ratoonability index in the Wet zone and MQ239 was the next lowest.

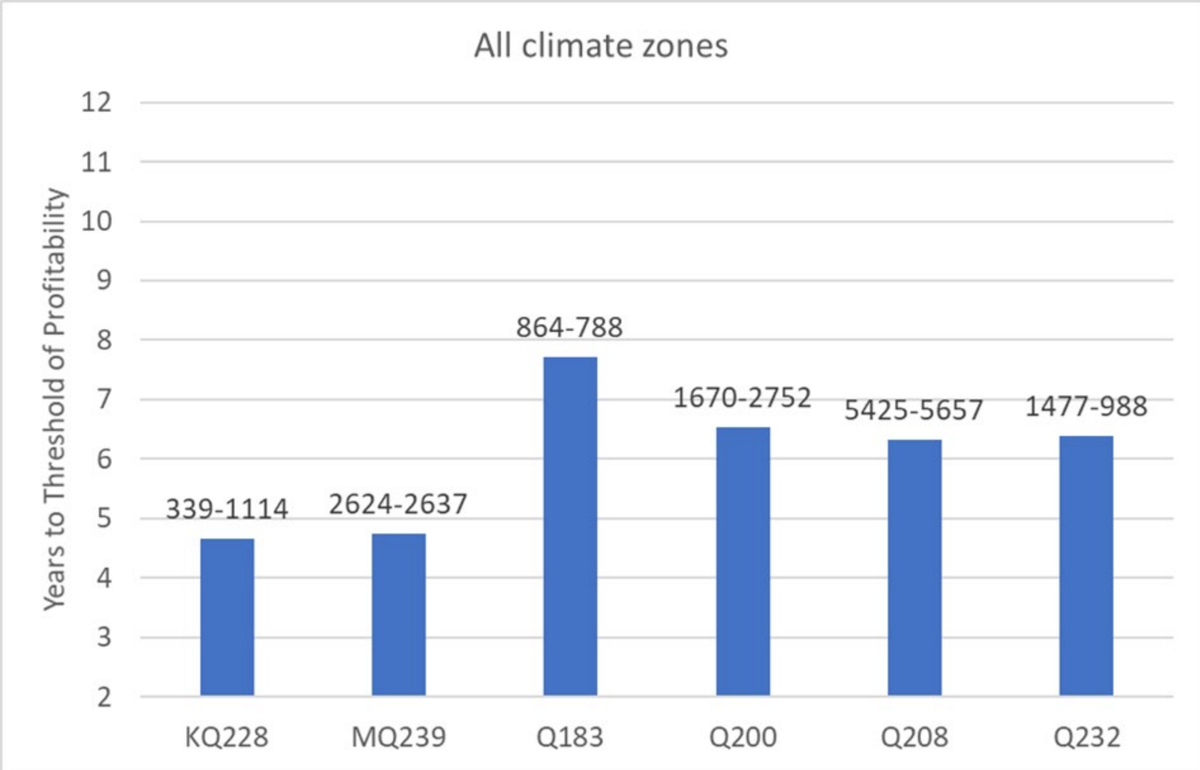


Figure 120: Ratoonability index (average number of years until a variety reaches the threshold of profitability) for six major varieties across all climate zones. The number of blocks in 1R and 3R on which the estimates were based are shown above the columns.

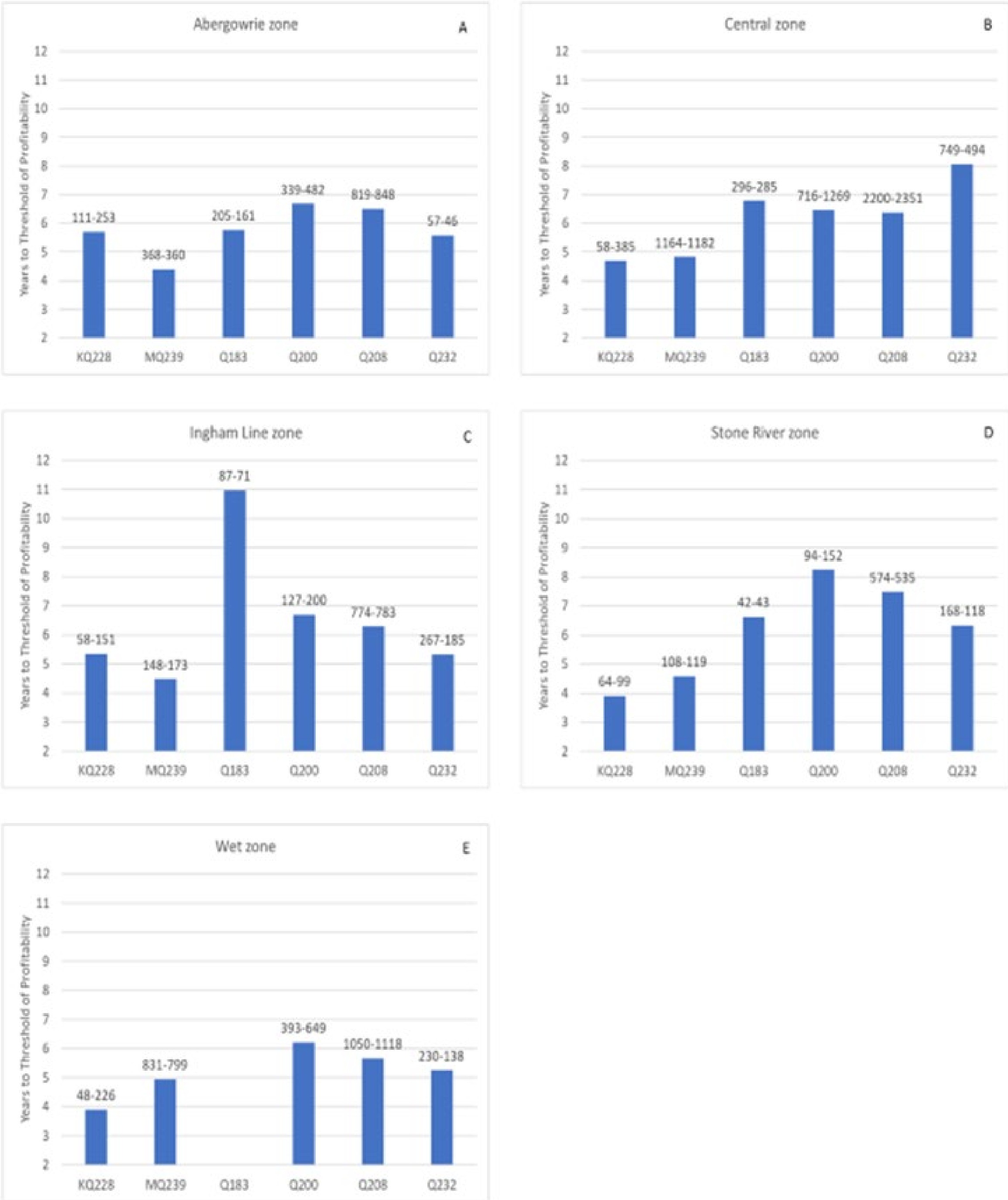


Figure 121: Ratoonability index (average number of years until a variety reaches the threshold of profitability) for the six major varieties in the five climate zones (A-E). The number of blocks in 1R and 3R on which the estimates were based are shown above the columns.

The ratoonability index could be used to review ratoonability of older varieties but its primary purpose would be to predict ratoonability in new varieties. We examined the ratoonability indices for the newer varieties, Q240, Q250 and Q253, relative to the older varieties Q183, Q200, Q208 and Q232 for the years 2018 and 2019 (Figure 122 and Figure 123 A-E). We restricted the analyses to these years because the newer varieties had only a few 3R blocks before 2018. The year 2018 gave above average yields which may explain the higher ratoonability indices for the older varieties relative to those calculated for the years 2013-2019 (Figure 121). Across all climate zones (Figure 122), Q183 had the highest ratoonability index (10.7) closely followed by the new variety Q253 (10.5), Q240 (8.3), Q208 (8.2) and Q250 (8.1) were the next best varieties. Q200 had an index of 7.2 and Q232 had an index of 6.8.

The ratoonability indices for varieties within each climate zone for 2018 and 2019 are shown in Figure 123 A-E. These indices are based on relatively low numbers of blocks in some cases and should be used with caution. Q240 had the highest ratoonability index in Abergowrie and the next highest ratoonability indices were for Q208, Q253, Q183, Q200 and the lowest was Q250. In the Central zone, the highest index was for Q253 followed by in order Q250, Q183, Q232, Q208, Q240 and Q200. Ingham Line, Stone River and the Wet zones had insufficient numbers of blocks to obtain a reasonable estimate for some varieties. The highest ratoonability index in the Ingham Line zone was for Q253 followed by Q183, Q208 and Q232. In the Stone River zone, the highest ratoonability index was obtained for Q240 followed by in order Q208, Q232 and Q253. Q208 had a very high ratoonability index in the Wet zone followed by in order Q240, Q200, Q232 and Q253. The large differences between climate zones means that care should be taken when comparing the ratoonability indices across all climate zones.

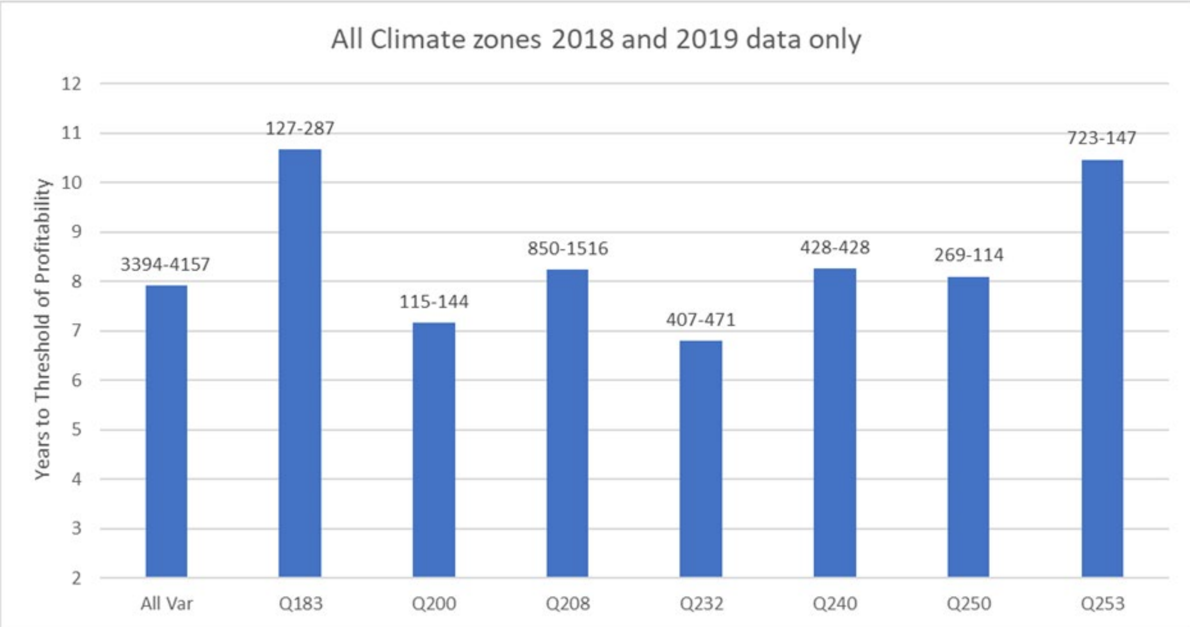


Figure 122: Ratoonability index (average number of years until a variety reaches the threshold of profitability) for four older varieties and three newer varieties across all climate zones in 2018 and 2019. The number of blocks in 1R and 3R on which the estimates were based are shown above the columns.

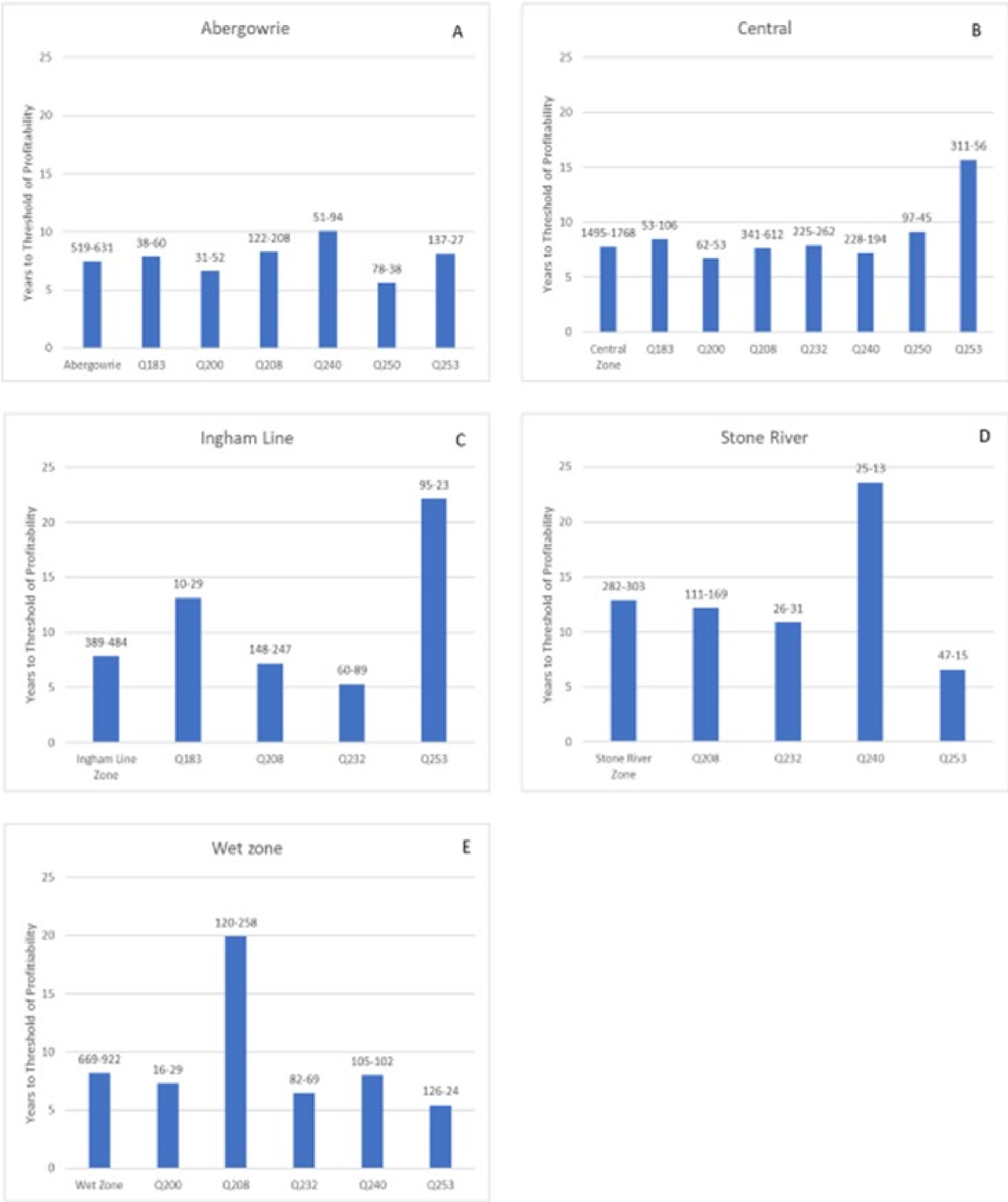


Figure 123: Ratoonability index (average number of years until a variety reaches the threshold of profitability) for a selection of older varieties and newer varieties across the five climate zones in 2018 and 2019. The number of blocks in 1R and 3R on which the estimates were based are shown above the columns.

There was no relationship between the estimated number of years until the area of crops planted in 2013 and 2014 drops to 25% of the original planting area and the ratoonability indices of the six major varieties calculated from 2013 to 2019 data (Figure 124). However, there was a significant relationship (R^2 = 0.58, Prob<0.1) between the percent of area ploughed out before 3R for crops planted in 2013 and 2014 and the ratoonability indices (Figure 125). The relationship between percent area retained until 5R and ratoonability indices approached significance. If the outlier Q183 were not included, the relationship between percent area retained until 5R and ratoonability indices would be highly significant.

Figure 124: Relationship between the estimated number of years until the area of crops planted in 2013 and 2014 drops to 25% of the original planting area and the ratoonability index (years to threshold of profitability) based on data from 2013-2019.

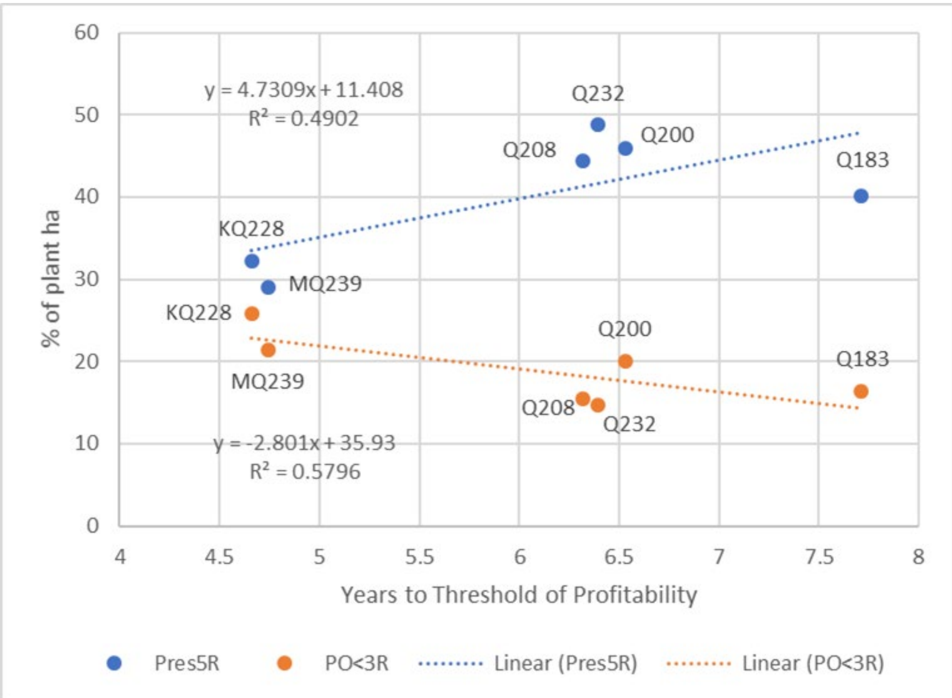


Figure 125: Relationship between the percent of planting area ploughed out before 3R (PO<3R) and percent of area present at 5R for crops planted in 2013 and 2014 and the ratoonability index (years to threshold of profitability) based on data from 2013-2019.

Conclusions

In this study, we examined several measures of ratoonability. The proposed ratoonability index combines the economic return of first ratoon crops and the rate of decline of economic returns between first and third ratoon to estimate the number of years until the crop reaches a defined economic threshold for profitability. In our study, we calculated the ratoonability indices for the major varieties grown between 2013 and 2019 in the Herbert. KQ228 and MQ239 had the lowest ratoonability indices across all climate zones in the Herbert and in nearly all of the individual climate zones. This is in good agreement with the graphs of $/ha returns across ratoons and the rate of plough out of these varieties. Q200, Q208 and Q232 had higher ratoonability indices across all climate zones, and in individual climate zones, than KQ228 and MQ239. This also agrees well with the graphs of $/ha returns for these varieties and the rate of plough out of these varieties. Q183 gave the highest ratoonability index across all climate zones and in the Ingham Line and Wet zones. The economic return for Q183 decreased at a slower rate than other varieties between first ratoon and third ratoon across all climate zones. Using our formula for ratoonability this led to this variety obtaining the highest value. However, the rate of plough out of Q183 was similar to or even faster than varieties such as Q200, Q208 and Q232. Our conclusion is that the ratoonability index is a reasonable measure of ratoonability and can identify poor ratooning varieties.

We examined the ratoonability indices of three newer varieties in comparison to four older varieties using data from 2018 and 2019. Q253 gave the highest ratoonability index of all varieties in the Central and Ingham Line zones. Q240 had the highest ratoonability index in the Abergowrie and Stone River zones and was the second highest in the Wet zone. The ratooning performance of these new varieties looks promising.

The percentage of area ploughed out before 3R was significantly related to the ratoonability indices for the major varieties. This is a simple measure of ratoonability and could be an adjunct to the ratoonability index. If growers are taking the hard decision to plough out crops before 3R, the performance of the variety in these blocks must be very poor and is a strong indicator that the variety has a serious overall performance problem.

5.5 Development a decision support tool to predict varietal composition

Variety performance 1990-2019

The dominant varieties in the Queensland cane supply across all mills from 1990-2000 and 2000-2019 based on % tonnes are plotted in Figure 126 and Figure 127. From 1990-2000, Q124 was the dominant variety in Queensland and peaked at 46% of the crop in 1999. In the Central, Herbert and Southern regions Q124 peaked at 88%, 59% and 46% respectively in 2000. An epidemic of Orange Rust hit in 2000 causing yield losses of at least 40% in Q124 and the area planted to Q124 rapidly decreased. By 2006 Q124 was less than 1% of the Queensland crop (Figure 127). Planting material of varieties other than Q124 was in short supply especially in the Central region and growers were desperate for any variety that was resistant to Orange Rust.

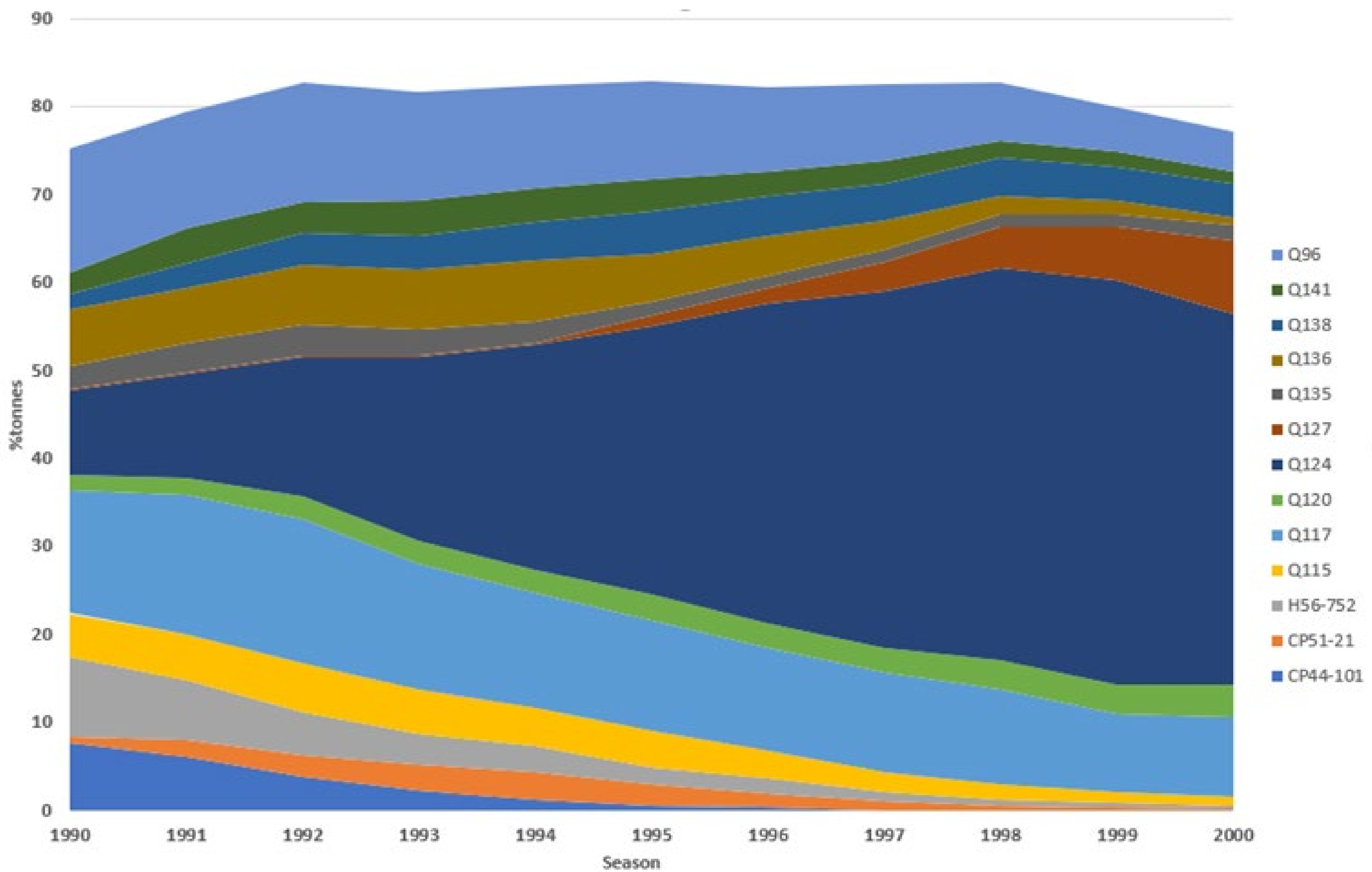


Figure 126: Percentage cane based on tonnes by variety from 1990-2000.

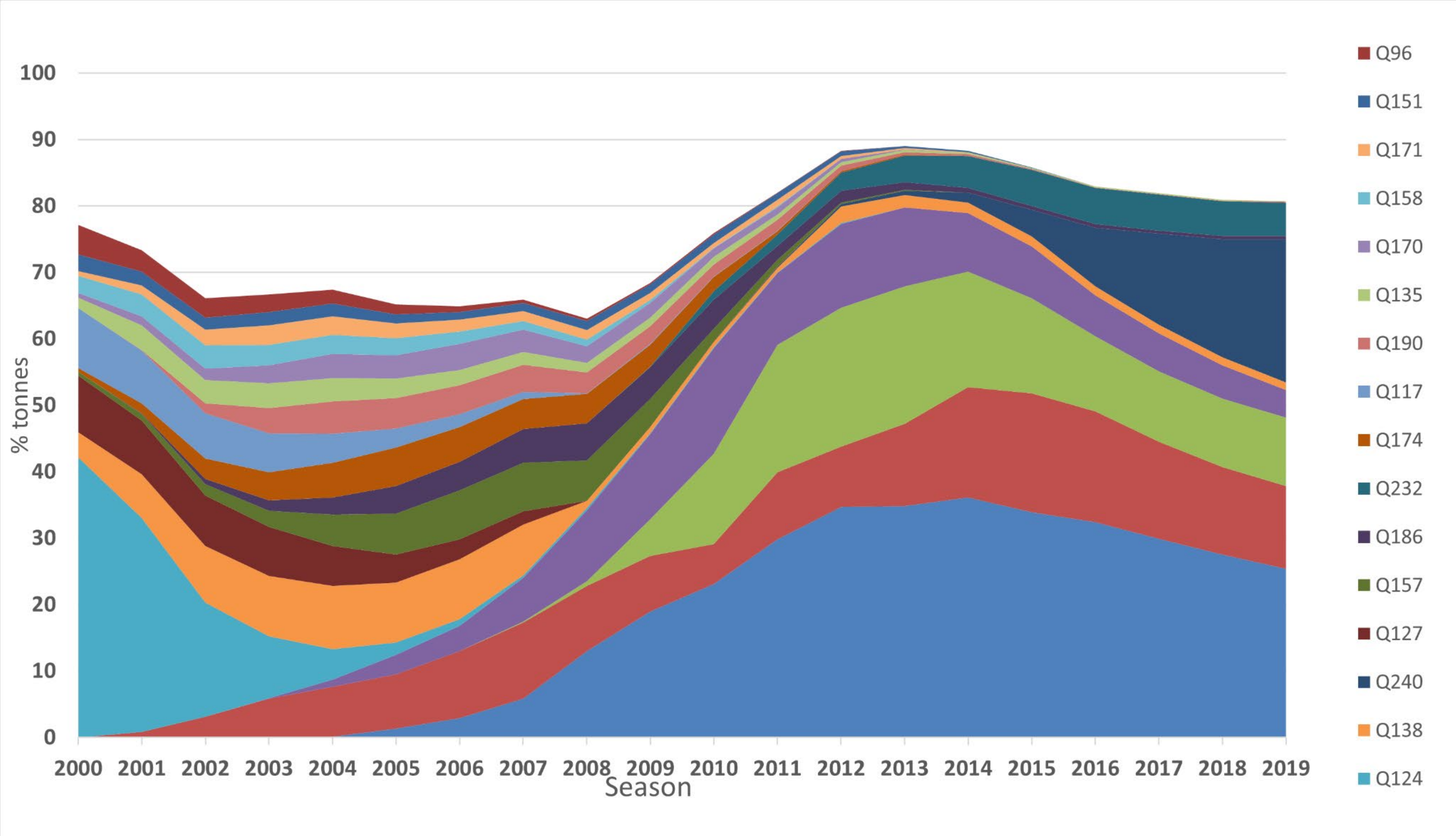


Figure 127: Percentage cane based on tonnes by variety from 2000-2019.

During the period after Q124 was phased out of production from 2003-2009 there were many varieties in small percentages that dominated the cane supply. Sugarcane smut was reported for the first time in Australia in the Ord River area of Western Australia in 1998. It caused serious losses in susceptible varieties such as Q117 and NCo310. Growers on the east coast were put on alert for a possible incursion. Some efforts were made to prepare for a possible incursion on the east coast but the orange rust epidemic interrupted preparations in many areas. BSES/SRA were screening varieties for smut resistance in Indonesia and Western Australia and had identified a number of high yielding smut resistant varieties. In June 2006, smut was detected in the Bundaberg/Isis region and soon after was found in Mackay and the Herbert. The disease spread to all regions over the next few years. In 2006, 8 of the top 10 varieties were susceptible to smut and 65% of the crop was produced by susceptible varieties. The major smut susceptible varieties in 2006 were Q138 (9%), Q157 (7.4%), Q174 (5.2%), Q190 (4.4), Q186 (4.3%), Q170 (3.9%), Q205 (3.3%) and Q188 (3.3%). The Herbert region had 80% of the crop planted to susceptible varieties. Growers were faced with another period of rapid change in varieties just 6 years after the disruption caused by orange rust. Fortunately, smut does not spread as quickly as orange rust and and growers generally had time to change varieties before major losses were experienced. SRA identified Q183, Q200, Q208, KQ228 and Q232 as smut resistant varieties with good productivity and these varieties replaced the smut susceptible varieties from 2008 to 2012.

Unfortunately, a number of pachymetra root rot resistant varieties were susceptible to smut. Varieties with only intermediate resistance to pachymetra root rot such as Q208, Q200, KQ228 and Q240 made up 70% of the crop from 2012 to 2019. It has been shown that these intermediate varieties can suffer losses of 10-20% in areas conducive to pachymetra root rot.

More recently Q240 has overtaken Q208 as the most widely grown variety in the Burdekin and Southern Queensland and second most widely grown variety in the Central region in 2019 and was the second most widely grown variety behind Q208 in Queenland (22% and 25% respectively). Q253 and SRA3 were varieties that increased their area significantly in 2019, especially in the Northern and Herbert regions.

Methodology – step 1

The aim is to develop a decision support tool to predict varietal composition and long-term sugar and cane quality parameters to allow mills to plan and implement factory changes that might be required for processing the crop expected in the future.

The hypothesis we wish to test if that the Final Assessment Trial (FAT) data contains hidden but useful information that can be used to predict which clones go on to become successful and widely-grown commercial varieties.

Using the FAT data across the regions, from 1991 to 2018, machine learning techniques have been applied to find traits and factors that can be used in a model to predict which of the clones in the trials go on to become successful commercial varieties that are widely grown and contribute the most to tonnes of sugarcane harvested in Queensland. Data from NSW was excluded as it contains both one and two year crops.

For the purpose of machine learning classification tools, each entry has been labelled 'commercially-successful' or 'not-as-widely-grown', based on tonnes harvested in Queensland of each variety listed, over that same time period. The data for the tonnes harvested were collated from SRA annual Varietal Composition and Distribution reports from 1991-2019. The varieties that appeared in the top 10 by tonnes harvested for each year were recorded and those varieties appearing in at least one annual top ten listing were given the 'commercially-successful' label in the dataset.

The Ensemble Classifier Prediction Model has been trained and saved, and it can be applied to the yearly FAT data to give early notice of potential new varieties coming through the breeding pipeline. It was hoped that this model could serve as a decision support tool to help when making decisions as to which clones to take forward in the trials.

The machine learning technique that has been used is an Ensemble Classification method that combines multiple classification algorithms into a single output. In addition, a Random Forest classification approach, solely to identify the specific traits and factors that influence commercial success has been used.

This machine learning approach was implemented in Python3 using the Sci-kit Learn functions in Jupyter notebook. Initial data cleaning and formatting was done in R and is contained in Appendix 4 (attached).

Appendix 4.html

The analysis was undertaken in three distinct parts:

1. Part 1 was conducted on the full FAT dataset from 1991-2018, including all the variables.
2. Part 2 was conducted on the full FAT dataset from 1991-2018, with all the variables excluding Orange Rust. The importance of the Orange Rust variable as highlighted here was thought to possibly be a hangover influence from very successful past varieties like Q124 that were present in the dataset. To investigate this, the analysis was run after removing the Orange Rust variable. This was done as Orange Rust is not currently a problem in the industry because contemporary varieties are resistance, although it was in the past. This was done to examine what characteristics emerged as important to success after it was removed from consideration.
3. Part 3 was conducted on the most recent FAT data, from 2006-2018, including all of the variables. This was done to see if the more recent data was still influenced by the Orange Rust ratings, or if another disease had risen to importance instead, and to determine if the full FAT dataset models remained appropriate for future predictions.

Details on the methodology, files and models associated with this work can be found in Appendix 5 (attached).

Appendix 5.html

Results

Machine learning techniques were successfully employed on the FAT dataset (1991-2018) to predict the commercial success of emerging clones. In this analysis, commercial success was defined as a variety achieving a Queensland top ten high yield (in tonnes), at least once within the time period 1991-2018. Three analyses were undertaken: 1) the full FAT dataset 1991-2018, 2) the same full FAT dataset excluding the Orange Rust variable and 3) a subset of the full dataset containing only the most recent FAT data 2006-2018.

Two distinct models were developed for each scenario: an Ensemble Classifier model for prediction with 100% accuracy on the test dataset, and a RandomForest Classifier model to investigate feature importance, also with 100% accuracy. Both of these models have been saved to file, ready for further use on FAT data obtained in the years to come. Code for future work has been included in this report.

Part 1 results show that some of the disease resistance ratings play an enormous role in the classification of commercial success likelihoods of the new varieties emerging from the sugarcane plant breeding pipeline.

As discussed earlier an epidemic of orange rust hit Queensland in 2000 and had a major effect on the dominant variety at the time Q124 (Figure 127). Of the variables in the full FAT dataset tested, the Orange Rust disease rating was the most important, contributing to 14.9% of the decision when classifying the data. Following this were the Red Rot and Pachymetra disease ratings, which contributed 13.7% and 11.6% towards the classification decision respectively. Next was the average ShortFibre (9.8%) and Fibre. FromFQ values (6.5%), the identity of the Male parent used in the crossing to produce the clone (6.0%), the Ratoon Stunting Disease rating (5.2%) and average Shear Strength (5.1%).

Of surprisingly little importance to commercial success outcomes were the Region (0.37%), Year (0.11%), and Mill details (0.01-0.03%) in the analysis of the data presented here. This analysis hints that the Regions are not as unique as they have been historically treated. Given the variation in size of the sugarcane farming industry in the different Regions, with the Burdekin region comprising more than a quarter of the entire Queensland's sugarcane crop, it was reassuring to see that this Burdekin bias was not reflected in the classification results. By looking across a 27 year time span and taking a whole-of-Queensland approach, this removed the noise in the data and may have had the effect of diluting Year and Region contributions. This analytical approach highlighted the option to elevate 'all-rounder' varieties in the selection process.

In this analysis, the clones that went on to become commercially successful were not limited to success in a single region, and were instead widely grown in several Regions across the state. In addition to selecting clones specialised to particular environments, the results here suggest for plant breeders to select clones that perform well in multiple Regions, where these 'all-rounder' clones would have a greater impact on yield across the industry. The Interstation Exchange Program provides local FAT data in the same year as release in another region was developed specifically to address this opportunity.

Of particular interest were the correlations with the 'Success.Tf' column, where the highest correlation was with 'Fiji.Leaf.Gall.Tf' at 0.35. Next highest was with 'Fibre.FromFQ' at 0.26 and 'Orange.Rust.Tf' and 'Leaf.Scald.Tf', both correlated with 'Success.Tf' at 0.21. So in addition to the importance of the 'Orange.Rust.Tf' variable in the prediction model, this feature had an overall correlation with 'Success.Tf' of 0.21.

Variables that had a negative correlation with 'Success.Tf' were also important. The results here show that 'Red.Rot.Tf' (at -0.37), 'Pachymetra.Tf' (-0.35), 'Common.Rust.Tf' (-0.27) and 'Ratoon.Stunting.Disease.Tf' (also -0.27) ratings were all significant factors that negatively impact on varietal commercial success. Further work is needed to find the specific ratings that impact on these correlations with success.

In Part 2 without Orange Rust, the variables 'Red Rot' (19.3%), 'Pachymetra' (14%), and the fibre quality characteristics 'AVGShortFibre' (8.5%) and 'AVGShearStrength' (8.2%) emerged as the most important features in the dataset for classifying samples and predicting commercial success. These features were also found to be important when Orange Rust was initially included in the analysis, so removing the Orange Rust variable did not overly affect the prediction model's other feature importance rankings or accuracy.

Similarly, without the 'Orange.Rust.Tf' variable, the largest feature correlations with 'Success.Tf' continued to include 'Red.Rot.Tf' (-0.39), 'Fiji.Leaf.Gall.Tf' (0.37), 'Pachymetra.Tf' (-0.32), 'Ratoon.Stunting.Disease.Tf' (-0.26) and 'Common.Rust.Tf' (-0.25).

In Part 3 analyses only the most recent FAT data (2006-2018) was considered. Although the threat of orange rust has been mitigated by effective resistance breeding, it still retained a high importance in the classification rankings, coming in fourth place (9%) behind Red Rot (14.5%), Pachymetra (13.8%) and Ratoon Stunting Disease (10.1%).

The prediction accuracy of using only the most recent FAT data (2006-2018) was exactly the same as using the full 1991-2018 FAT dataset (both 100% accurate), so there would be no problem in using only the Ensemble Classification models trained on the most recent data to predict on the commercial success of future emerging FAT clones.

Methodology – step 2

Further analysis was carried out by the project team as indicated below to see if we can improve the model and outcome of analysis undertaken in the previous sections.

The re-analysis was necessary because the 100% accuracy obtained from the developed model from the previous analysis was of concern as it shows that the algorithm is perfectly fitting the data, but the fear is that this may fall apart when exposed to new data for prediction. Also, the use of accuracy as performance metrics in the previous analysis may not be the most appropriate assessment method for classification problem.

Therefore, some additional tasks as indicated below were performed using similar machine learning approach on the dataset to see if we can achieve improvement on the results:

- Used full FAT dataset from 1991-2019 including Orange rust data, there is an additional one-year data.
- Use only varieties that occurred at least twice as top ten during 1991 to 2019 as against using varieties that occurred once as top 10 in previous analysis. We therefore excluded the four varieties Q171, Q188, Q209 and Q252 that occurred only once as top ten from the data, keeping only varieties that occurred at least twice as top ten in the data for the analysis.
- Explored the use of Receiver Operating Characteristic curve (ROC) / Area Under the Curve and Precision-Recall curves to assess the performance of the developed model instead of the use of accuracy from confusion matrix.:

Receiver Operating Characteristic curve (ROC) / Area Under the Curve (AUC): Receiver Operating Characteristic curve (ROC) / Area Under the Curve (AUC)/ROC is the commonly used tool when predicting the probability of a binary outcome to assess model performance. It is a plot of the false positive rate (x-axis) versus the true positive rate (y-axis) for several different candidate threshold values between 0 and 1. Put another way, it plots the false alarm rate versus the hit rate. ROC curves should be used when there are roughly equal numbers of observations for each class.

Precision-Recall: Because our response variable is highly imbalanced and ROC is best suited for roughly balanced binary outcome, in addition to ROC we also explored the use of precision-recall method which is robust against moderate to large class imbalance response variable to access the model performance. These are estimated as follows:

Precision (Positive Predictive Power) = True Positives / (True Positives + False Positives)
Recall (Sensitivity) = True Positives / (True Positives + False Negatives)

The analysis data consisted of FAT data across all Qld regions from 1991- 2019 and varietal composition data from 1991- 2019 to identify commercially successful Varieties. Outcome variable was a binary trait of either a variety was commercially successful (1) or not commercially successful (0). A variety was classified as commercially successful if it achieved a Queensland top ten high yield (in tonnes), at least twice within the period of 1991-2019, if not it was deemed not to be commercially successful.

The analysis was implemented in Python3 using the Sci-kit Learn functions. The data was split into two with 70% data used for model training and the remaining 30% of data for model testing. Five classification algorithms (Logistic Regression, Random Forest (RF), Gaussian Naive Bayes, Support Vector Machine (SVM) and Kneighbours (KNN)) were applied to the data to solve the problem. In addition, an Ensemble classifier that combined all the above classifiers was used for the prediction algorithm.

Results - Important features

The results showed that disease resistance ratings were the most important traits. The top 6 traits in order of importance are: Red Rot (15.8%), Orange Rust (13.6%), Pachymetra (10.2%), Male (8.8%), TCH (6.7%) and Assumed Fibre (6.4%). The result of model accuracy assessment by AUC/ROC and Precision-Recall were similar to that from confusion matrix in the previous analysis.

General comments and conclusion

On completion of the analysis with the above additional considerations, both approaches gave similar results regardless of the analysis method/approach. There were no major differences between the two results.

The 100% accuracy from the confusion matrix is a concern as the model may fail to generalize to future datasets. Hence, the results should be interpreted with caution. The outcome variable in the dataset was highly imbalanced - the commercially successful were about 92% versus 8% for not commercially successful. Further work should be focused on a bigger more balanced data size with a less skewed outcome variable which may give us more confidence in the accuracy of the predicted model. Analysis using data from a specific region may also result in more realistic results as varieties are released on a regional basis. These factors coupled with the use of climatic factors and removal of highly correlated variables could be explored. This may result in revealing additional agronomic variables such as sugar yield being correlated with commercial success.

There is growing interest in applying artificial intelligence and machine learning approaches to large complex datasets. The analysis conducted in this study demonstrates that models can be developed with high prediction accuracy statistics that still produce uninformative or incorrect predictions. This finding highlights the dependence of these approaches on the underlying datasets and the sensitivity to confounding effects, unbalanced distributions and autocorrelated characteristics. The study highlights that successful use of these approaches requires a strong functional understanding of underlying datasets, ground truthed reference points, and formal prediction validation to minimise the acceptance risk for spurious predictions.

6. RECOMMENDATIONS FOR FURTHER RD&A

The following items have been identified from completing this project as potential future research, development, and adoption activities.

Future investment should be directed towards developing a data management platform which will automate the data transfer, statistical analysis and reporting of industry data to support extension services and on-farm decision making in all mill areas. This data platform will link productivity and spatial data provided by mills with varietal data, climate information, SRA disease screening results, authoritative open-source geospatial data and, in future, farming practice data from growers. The data platform will provide a single consistent data source for all users.

Enhancements should include an interactive GIS based data platform that will enable the analysis of sugarcane industry data and the generation of ‘custom-made’ reports to assist extension services and on-farm decision making in all sugarcane regions. This tool will allow extension providers to streamline nutrient and variety management plans, assist growers to meet regulatory requirements and assist extension providers in designing strategic adoption packages for growers.

There is a need to explore opportunities for the major data custodians to:

- Better integrate multiple datasets from the one mill area,
- Understand the differences in data sets between mill areas and consider this in the design phase of the tool. Datasets from multiple mill regions will allow greater insights into the data.
- Adopt a uniform naming convention and provide data in a common standardised format,
- Ensure all data are spatially referenced to better allow traceability overtime,

- Develop governance policies which clearly documents quality control procedures for error checking and correction, and
- Share data across multiple platforms.
- Design a tool which considers security of digital information.

In the current project productivity analyses were limited to Tully, Burdekin and Herbert. In the new data management platform the analyses could be expanded to include the 3 NSW mills, Isis, Mackay, Plane Creek, Proserpine, South Johnstone, Mulgrave and Tableland mills.

7. PUBLICATIONS

An example CAPA for F9240 in Tully is attached.

F9240_2020.pdf

An example CAPA for Farm 0136A in Herbert is attached.

CAPA 0136A Herbert.pdf

Agnew, J, Ogden-Brown,J, Moore, K and Stringer, J (2017) Profiling growers to understand them and the factors impacting their production, Proceedings of the Australian Society of Sugar Cane Technologists, volume 39, 280-287.

Shannon, GJ, Magarey, RC, MacaGillycuddy, Stringer, JK and Lewis, M (2019) Pachymetra root rot surveys of the Tully district: update 2018, Proceedings of the Australian Society of Sugar Cane Technologists, volume 41, 262-267.

Stringer, JK, Skocaj, DM, Rigby, A, Olayemi, M, Everingham, YL and Sexton, J (2019) Productivity performance of climatological sub-regions within the Tully Mill area, Proceedings of the Australian Society of Sugar Cane Technologists, volume 41, 156–163.

Stringer, J, Croft, B, Asamoah, I, Di Bella, L, Sefton, M, Nielson, R, Larsen, P, Del Lai, R and Davies, I (2017) Innovative methods to analyse and summarise mill data to identify some of the key factors impacting on farm productivity in the Herbert, Proceedings of the Australian Society of Sugar Cane Technologists, volume 39, 49-55.

Milling Matters Summer 2019 https://sugarresearch.com.au/wp-content/uploads/2020/01/MillingMatters-Edition-11-2019_Web.pdf

Page 3.

Cane Connection Summer 2019 https://sugarresearch.com.au/wp-content/uploads/2019/11/CaneConnection-Summer-2019_F_Web.pdf

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8. ACKNOWLEDGEMENTS

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9. REFERENCES

BSES 1984 Laboratory Manual for Australian Sugar Mills Vol 1: Principles and practices, BSES, Brisbane.

Butler, DB (2019) Asreml: Fits the Linear Mixed Model, R package version 4.1.0.110, url = www.vsni.co.uk.

Cox, MC, Stringer, JK, Cervillen, RJ (2005) Productivity increases from new varieties in the Queensland sugar industry, Proceedings of the Australian Society of Sugarcane Technologists 27: 124-132.

Di Bella LP, Stringer JK, Wood AW, Royle AR, Holzberger GP (2008) What impact does time of harvest have on sugarcane crops in the Herbert River district? Proceedings of the Australian Society for Sugar Cane Technologists 30, 337.

Ellis, RN, Basford, KE, Cooper, M, Leslie, JK, & Bythe, DE 2001, 'A methodology for analysis of sugarcane productivity trends I – Analysis across districts', Aust. J.Agric. Res, vol 52, pp. 1001-1009.

Garside, AL 2013, Review of productivity trends in the Herbert sugarcane growing region. Herbert Cane Productivity Services Limited Publication 1/2013, pp. 7-8.

Henderson, CR, Kempthorne, O, Searle, SR, von Krosigk, CM (1959), 'The Estimation of Environmental and Genetic Trends from Records Subject to Culling', Biometrics, Vol 15, pp. 192–218.

Laws, RA, Wegner, MK, Basford, KE, Lawn, RJ (2004) The evaluation of the temporal stability of sugarcane farm performance based on yield and commercial cane sugar, Australian Journal of Agricultural Research 55: 335-344.

Lynch, T, Gregor, S, Midmore, D (2000) Intelligent support systems in agriculture: how can we do better? Australian Journal of Experimental Agriculture 40: 609-620.

Magarey RC, Sarich CE, Turner JD, Bull JI (2003) Influence of pachymetra root rot resistance on yield losses in central Queensland. Proceedings of the Australian Society of Sugar Cane Technologists 25: 8 pp.

McDonald L and Wood A (2001). Pre-harvest season productivity of sugarcane in different regions of Queensland, Proceedings of Australian Society of Sugarcane Technologists, 23:90-96.

Millard D, Croft B, Cox M, Payne D (2009) Development of a web-based decision-support tool and information resource for sugarcane varieties in the Australian sugar industry. Proceedings of the Australian Society of Sugar Cane Technologists 31, 316–325.

Norris S, Patane P, Norris C (2017) Has the industry benefited by reducing billet length? Proceedings of the Australian Society for Sugar Cane Technologists 39, 28.

Patane P (2020) Adoption of practices to mitigate harvest losses: Final report 2016/065. Sugar Research Australia, Indooroopilly.

Plunkett, G, Fletcher, R, Croft, BJ, Piperidis, G, Cox, MC (2014) Adoption of the web-based sugarcane variety decision support program, QCANESelect, Proceedings of the Australian Society of Sugar Cane Technologists 31, 316–325.

Ramburan, S, Paraskevopoulos, A, Saville, G, Jones, M (2010) Development of variety selection decision support system, SASTA 83: 80-91.

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Sexton J, Everingham Y, Skocaj D, Biggs J, Thorburn P, Schroeder B (2017) Identification of climatological sub-regions within the Tully mill area. Proceedings of the Australian Society for Sugar Cane Technologists 39, 6.

Shannon, GJ, Magarey, RC, MacaGillycuddy, Stringer, JK and Lewis, M (2019) Pachymetra root rot surveys of the Tully district: update 2018, Proceedings of the Australian Society of Sugar Cane Technologists, volume 41, 262-267.
Shaw, MEA (1989) An index to measure sugar cane performance, Sugar y Azucar 84: 19-26.

Stringer, J, Croft, B, Di Bella, L, Sefton, M, Nielson, R, Larsen, P, De Lai, R and Davies, I (2016) Optimising productivity and variety recommendations through analysis of mill data, Proceedings of the Australian Society of Sugarcane Technologists 38: 180-192.

Stringer, J, Croft, B, Asamoah, I, Di Bella, L, Sefton, M, Nielson, R, Larsen, P, De Lai, R and Davies, I (2017) Innovative methods to analyse and summarise mill data to identify some of the key factors impacting on farm productivity in the Herbert, Proceedings of the Australian Society of Sugarcane Technologists 39: 49-55.

Sugar Research Australia (2021) Variety Adoption Report. Sugar Research Australia, Indooroopilly.

Tabachnick, BG, Fidell, LS (2013) Using Multivariate Statistics , 6th ed. Boston: Pearson.

Toledo Piza, CMJ, de Macedo, EC, Miranda, MC & Bueno, OFA 2014, ‘Contrasting group analysis of Brazilian students with dyslexia and good readers using the computerized reading and writing assessment battery’, Frontiers in Psychology, vol 5, pp. 837.

Vitale, MM, Domanti, SA (1997) An investigation into the optimal length of sugar cane billets, Proceedings of the Australian Society of Sugarcane Technologists 19: 170-178.

Ward, JH Jr (1963) ‘Hierarchical grouping to optimize an objective function’, Journal of the American Statistical Association, vol 58, pp. 236–244.

Wilson, GL, Leslie, JK (1997) Productivity Trends in Sugarcane in the Wet Tropics, Proceedings of the Australian Society of Sugarcane Technologists (CD-ROM).