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Feed Use in the NZ Dairy Industry

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Feed Use in the NZ Dairy Industry

A review of feed volumes consumed by New Zealand dairy cows since 1990-91, including future estimates to 2030-31

Prepared for the Ministry of Primary Industries

June 2016

DairyNZ Economics Group

Contents

Executive Summary

This report provides a summary of the trends in non-pasture feed use on New Zealand dairy farms from 199091 to 2014-15 as well as future projections of feed demand out to 2030-31, including the breakdown between pasture, crops grown, harvested supplementary feed and imported supplementary feed. The dairy industry has expanded considerably over the last 25 years with additional land areas used for dairy production; the industry has become more intensive with higher stocking rates and increased per cow milk production. Improved milk production has occurred from increased feed levels, particularly pasture (including hay and pasture silage), palm kernel extract (PKE), maize silage and in recent years fodder beet as well as improvements in feed conversion efficiency (FCE) partly through increased days in milk.

Given the absence of feed data, this project has utilised multiple approaches to estimate the volume of nonpasture feeds consumed by dairy cows, regardless of where the feed is grown. This includes the Feed Demand Approach which sourced data from *New Zealand Dairy Statistics* and derived feed requirements per cow given values for average liveweight and milksolids production per cow. The Farm Data Approach used DairyBase benchmark data to calculate adjusted total supplements eaten per cow. The National Statistical Approach, obtained individual feed data from many sources, some published and some from experienced people working in specialist feed and research organisations. The proportion of individual feeds grown, but consumed by dairy cows (as opposed to other livestock or other uses) was the most challenging component to estimate.

The total amount of feed eaten by New Zealand dairy cows has increased 161 per cent over the last 25 years, a growth rate of 3.8 per cent CAGR (compound annual growth rate). This increase has occurred primarily (80%) through more cows, from both new dairy land and increased stocking rates. On a per cow basis feed eaten has increased one tonne (0.8% CAGR) to 4.93 tonnes dry matter per cow in 2014-15. Imported supplements, including PKE increased 7.6 per cent CAGR, harvested supplement including maize silage and barley increased 6.7 per cent CAGR while grown crops including fodder beet, kale and swedes increased 4.9 per cent CAGR between 1990-91 and 2014-15 – refer to Figure 9.

	Cows Milked (million)	Feed Demand (million t DM)	Feed Demand (t DM/cow)	Pasture eaten (t DM/cow)	Crop eaten (t DM/cow)	Harvested supplement (t DM/cow)	Imported Supplement (t DM/cow)
1990-91	2.40	9.46	3.94	3.77	0.03	0.08	0.05
2000-01	3.49	15.71	4.51	4.21	0.04	0.15	0.11
2010-11	4.53	21.06	4.65	4.01	0.06	0.23	0.35
2014-15	5.02	24.73	4.93	4.04	0.18	0.31	0.39

Feed eaten per hectare increased 53 per cent (+1.7% CAGR) or 4.9 tonne from 1990-91 to 2014-15. This is a faster increase than on a per cow basis as it includes an increase in stocking rate. Pasture eaten accounted for just over half the increase in feed eaten per hectare, while imported supplements (+1.0 tonne), harvested supplement (+0.7 tonnes) and grown crops (+0.4 tonnes) all increased over the past 25 years.

	Feed Demand (t DM/ha)	Pasture eaten (t DM/ha)	Crop eaten (t DM/ha)	Harvested supplement (t DM/ha)	Imported Supplement (t DM/ha)
1990-91	9.24	8.86	0.08	0.20	0.11
2000-01	11.82	11.04	0.10	0.40	0.28
2010-11	12.85	11.08	0.16	0.63	0.98
2014-15	14.16	11.61	0.52	0.90	1.13

Non-pasture feeds consumed by dairy cows increased from 0.16 tonnes DM per cow in 1990-91 to 0.89 tonnes per cow in 2014-15. As a proportion of a cow's total diet non-pasture feeds increased from 4.2 per cent in 1990-91 to 18.0 per cent in 2030-31. Harvested crop increased steadily over the last 25 years, while imported supplements increased significantly during the 2000s and crop eaten increased significantly recently. The amount of pasture eaten per cow increased in the 1990s, but eased during the 2000s. Pasture eaten per hectare increased 1.7 per cent per year to 2006-07, but growth slowed to a rate of 0.7 per cent since.

	Feed Demand (t DM/ha)	Pasture eaten (t DM/ha)	Crop eaten (t DM/ha)	Harvested supplement (t DM/ha)	Imported Supplement (t DM/ha)
1990-91	100.0%	95.8%	0.9%	2.1%	1.2%
2000-01	100.0%	93.4%	0.8%	3.4%	2.4%

2010-11	100.0%	86.2%	1.3%	4.9%	7.6%
2014-15	100.0%	82.0%	3.7%	6.3%	8.0%

Predicting future feed consumed is extremely difficult, particularly given the low milk prices currently experienced, volatile seasonal weather conditions and environmental pressures to reduce nutrient losses and different options farmers may take to achieve targets. As a result, two forecast scenarios were developed to 2030-31; modest milksolids growth which increased milk production by 0.8 per cent per year; while the high growth scenario assumed milk production would increase at twice this rate of 1.7 per cent per year. In both moderate and high growth scenarios, effective hectares increase slowly at the same rate. There were two pathways to the modest growth scenario, either through holding stocking rates constant and a modest increase in milksolids per cow or by reducing stocking rates and increasing milksolids per cow more to achieve the same overall production. The high growth forecast scenario also assumed stocking rates would increase from 2.8 to 3.0 cows per hectare.

Annual per cow feed demand was derived based on estimated milksolids per cow and constant average cow liveweights. Two pathways were developed for the high growth scenario with either pasture and crop or imported supplementary feed being the drivers of the additional feed consumed, while for the modest growth scenario it was assumed the growth would be driven from increased pasture and crop eaten per cow.

A summary of the key feed use per hectare in 2030-31 is provided in the table below. The modest growth scenario with constant stocking rates feed eaten increases to 14.40 tonnes per hectare, with the increase occurring from more pasture and fodder beet consumed, while PKE imports and maize silage decline. The second modest growth scenario with reduced stocking rates shows feed eaten per hectare only reaches 14.08 tonnes dry matter per hectare with the difference being lower pasture consumed per hectare.

In the high growth supplements scenario, total feed eaten increases to 15.70 tonnes per hectare due to increased milksolids production. The majority of the additional feed consumed will be from increased PKE, maize silage and barley. In the high growth pasture and crop scenario, the increase in feed eaten will be driven by twice as much fodder beet, while the volumes of imported supplements were capped at current levels. Pasture eaten per hectare is one tonne higher than the modest growth constant stocking rate scenario.

The modest growth scenario with constant stocking rate is considered to be the most likely dairy industry pathway into the future, although if more growth occurs over the next decade the high growth pasture and crop scenario is considered the more likely of the two scenarios developed for this project.

2030-31	Modest Growth Constant SR	Modest Growth Low SR	High Growth- Supplements	High Growth - Pasture & Crop
Milksolids (billion kg)	2.1	2.1	2.3	2.3
Milksolids per cow	403	426	415	415
Milksolids per hectare	1,127	1,127	1,245	1,245
Stocking rate	2.80	2.65	3.00	3.00
Cows milked	5.15	4.88	5.52	5.52
Feed eaten (t DM/ha)	14.40	14.08	15.70	15.70
Pasture (t DM/ha)	12.13	11.81	12.24	12.82
Crop (t DM/ha)	0.97	0.97	0.99	0.96
Harvested supplements (t DM/ha)	0.61	0.61	0..95	0.82
Imported supplements (t DM/ha)	0.68	0.68	1.52	1.10

Introduction

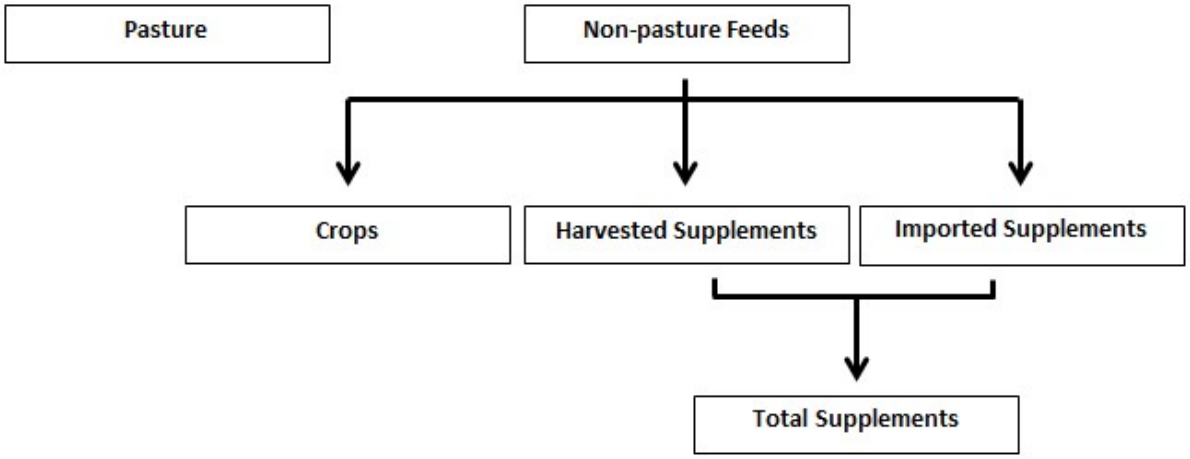
The purpose of this study is to quantify the volume of non-pasture feed consumed by New Zealand dairy cows since 1990-91, including future estimates to 2030-31. This information will be used by the Ministry of Primary Industries (MPI) to consider how non-pasture feed consumption may affect estimates of New Zealand's greenhouse gas inventory. The usage of non-pasture feed was low in the early 1990s, largely comprising maize grain and maize silage along with winter and summer crops such as barley, kale, swedes and turnips. The use of non-pasture feeds increased gradually in line with growing stocking rates until 2006-07. The following 2007-08 season, milk prices increased to record levels which also coincided with a severe drought. The response from dairy farmers was to purchase more supplementary feed (particularly palm kernel expeller, PKE), in order to continue milking to capture the advantages of the high milk prices. Volumes of non-pasture feeds, particularly

palm kernel expeller, have increased further since as many farmers have intensified in response to high milk prices, dry seasonal conditions and increased feeding infrastructure on farms. Conversely, many farmers are currently reviewing their farm systems and adjusting to the lower milk prices by reducing cow numbers, keeping more young stock and wintering cows on the milking platform as well as reducing expenditure on harvested and imported supplementary feeds. It is unclear at this stage if these adjustments will be sustained in the future or if it is a short term adjustment.

Objective

This report aims to quantify the usage of non-pasture feeds on New Zealand dairy farms between 1990-91 and 2014-15. For the purpose of this report, all non-pasture based feeds consumed by dairy cows (excluding young stock) include grown crops and harvested and purchased supplement. Excluded from these figures are pasture hay and silage or any forage herbs such as chicory and plantain as well as lucerne as these are included as pasture. Liquid feeds such as proliq are recorded in tonnes of dry matter and are included as 'other supplements' under the National Statistical Approach. Figure 1 below illustrates the distinction between crops, harvested supplements and imported supplements as non-pasture feeds.

Figure 1: Feed categories including pasture and non-pasture feeds



Following the development of future industry growth, this project then aims to forecast the use of non-pasture feed use in the New Zealand dairy industry for each season up to 2030-31. Also provided in this report is an overview of the main non-pasture feed types in terms of the method of feeding, metabolisable energy, crude protein and nitrogen content.

Background

Over the last 25 years the New Zealand dairy industry has experienced considerable expansion with the total number of cows more than doubling from 2.4 million in 1990-91 to 5.0 million in 2014-15[1]. The increase in cow numbers resulted from more dairy effective hectares, particularly from the expansion of dairying in the South Island, as well as an increase in stocking rates. Effective hectares are defined as the area available to dairy cows for grazing; this does not include houses, sheds, tracks, bush, waterways and steep areas which are not grazed but may include areas sown in crop. National milk production has increased 4.5 per cent per year from 0.6 billion kilograms to 1.9 billion kilograms of milksolids since 1990-91. This growth in milk production was due to more cows but in part also due to increases in milksolids production per cow, the result of genetic gain, improved farm management, improved pastures and increased use of supplementary feed[2].

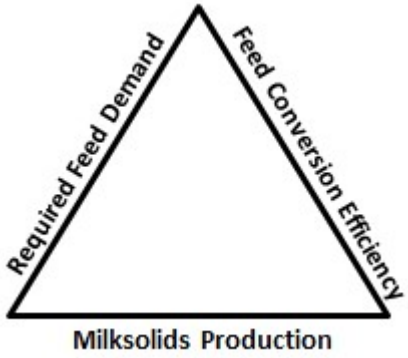
Despite the increased use of supplementary feed, pasture continues to be the dominant feed offered to New Zealand dairy cows. In 1990-91 the proportion of pasture eaten by a dairy cow was 96 per cent of the total diet. This decreased to 82 per cent over the last 25 years. A suitable temperate climate with regular rainfall and fertile

[1] New Zealand Dairy Statistics 2014-15
[2] New Zealand Dairy Statistics 2002-03

soils allows for extensive pasture growth and grazing all year round. This underpins New Zealand's internationally competitive position and has kept our cost of production lower than many other major dairy exporting countries.

In order to overcome short-term pasture deficits, maintain cow body condition and to improve milksolids production, supplements offered to New Zealand dairy cows have increased significantly over the past 25 years. There is a very strong relationship between the volume of feed consumed and milk production per cow. Feed conversion efficiency (FCE) measures how effectively dairy cows convert feed eaten (dry matter) into milksolids production. The relationship between FCE, feed demand and milksolids production is shown Figure 2. Two FCE measures are used in this report, one divides milksolids production (kg MS) by feed demand (t DM) to give the kilograms of milksolids produced per tonne of feed eaten. The other divides feed demand (kg DM) by milksolids production (kg MS) to give the kilograms of dry matter feed required to produce one kilogram of milksolids. Driven by genetic gains and increased lactation length, both measures of FCE have improved steadily since 1990-91.

Figure 2: Relationship between feed demand, FCE and milksolids production



$$\frac{\text{Milksolids Production (kg MS)}}{\text{Required Feed Demand (t DM)}} = \text{Feed Conversion Efficiency (kg MS/ t DM)}$$

$$\frac{\text{Required Feed Demand (kg DM)}}{\text{Milksolids Production (kg MS)}} = \text{Feed Conversion Efficiency (kg DM/ kg MS)}$$

This report investigates the trends in non-pasture feed use on New Zealand dairy farms since 1990-91. Unfortunately there is limited data to provide accurate volumes of all the different non-pasture feeds consumed by dairy cows. Therefore, multiple approaches along with some key assumptions were employed in order to improve the accuracy of the figures and to ensure the figures were sensible. Milksolids production per cow, liveweight, stocking rate and effective hectares from the *New Zealand Dairy Statistics* were used to provide a guide for national feed demand each season.

Methodology

This report employs multiple approaches to derive the estimated volume of non-pasture feeds

- Feed Demand Approach - total feed eaten can be derived from data obtained from *New Zealand Dairy Statistics* publications and an estimate of feed demand per cow.
- Farm Data Approach - utilises benchmarking reports that are based on empirical farm data from DairyBase, the industry's benchmarking database. DairyBase provides data to estimate national supplementary feed eaten on a per cow and per hectare basis.
- National Statistical Approach - gathers data from external sources in order to give an overall representation of non-pasture feed use from 1990-91 to 2014-15.

In reality, none of these methodologies on their own can provide the necessary data. Combining these three approaches ensures the results in this study are realistic and consistent with industry knowledge and understanding. Where necessary, adjustments were made so that the three approaches, provided valid results. This includes accounting for bias in DairyBase towards farms using higher than average imported supplementary

feeds as well as removing volumes of various feeds that are consumed by non-dairy animals and dairy young stock.

Feed Demand Approach

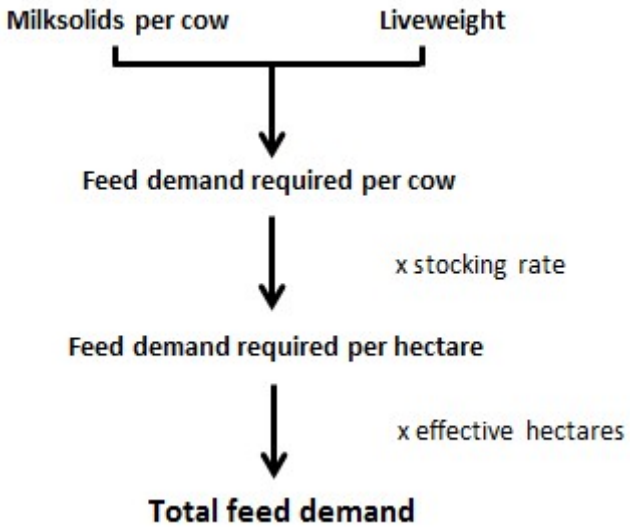
Feed requirements per cow were derived from the average liveweight and milksolids production per cow data sources from *New Zealand Dairy Statistics*. FCE could then be calculated, as shown in Figure 2.

A national average cow liveweight (kg) was calculated for each season where data was available (1996-97 to 2014-15) using *New Zealand Dairy Statistics* publications by weighting liveweight by age (3 year olds and up) and breed category. The average over this period was used for seasons prior to 1996-97 where liveweight data was not available as there was little change in trend for liveweight over this time. Although cows are being fed more and producing more milk, national breeds have shown a trend towards more crossbred cows and less of the heavier Holstein-Friesians. Therefore, little change in average liveweight has occurred (refer to Figure 5).

For each season, average per cow milksolids production and the calculated average liveweight were used to compute feed demand requirements per cow given a standardised metabolisable energy of 11.0 megajoules (MJ) per kilogram of dry matter (kg DM). This standardised value of 11 MJ/ kg DM provides a suitable estimate of metabolisable energy that is consumed by dairy cows on average[3]. Although pasture and other feed types differ in metabolisable energy, most fall within the range of 10 to 14 MJ/ kg DM, with those comprising a high proportion of a cow's diet, such as pasture, averaging 11 MJ/ kg DM.

Basal annual feed demand requirements per cow, as determined by cow liveweight and milksolids production, were based on the relationships identified by Nicol and Brookes (2007)[4]. These relationships, as restated in *DairyNZ Facts and Figures* (2010)[3], were then used to generate a smooth function through multiple regression, based on a second degree polynomial with cross terms, to provide unbiased interpolations[5]. This multiple regression relationship was then applied to each season using the corresponding liveweight and milksolids production per cow values sourced from *New Zealand Dairy Statistics* publications, to provide values for feed demand required per cow (t DM) for each season.

Figure 3: Feed demand calculation



Seasonal feed demand requirements per hectare could be obtained by multiplying the feed demand per cow by the average stocking rate for each season. Using total effective dairy hectares, the total required feed was

[3] DairyNZ Facts and Figures, 2010

[4] Nicol, A.M. and Brookes, I.M. 2007. The Metabolisable Energy Requirements of Grazing Livestock, in Pasture and Supplements for Grazing Animals, PV Rattray, IM Brooks & AM Nicol (Eds), Occasional Publication No. 14, New Zealand Society for Animal Production

[5] The relationship was estimated for actual feed demand (excluding an allowance for wastage). The estimated equation was Feed Demand = $0.2 + 0.0041*LW + 0.0076*MS - 5.8*10^{-7}*LW^2 - 1.1*10^{-6}*MS^2 + 1.5*10^{-6}LW*MS$

calculated from feed demand requirements per hectare. These three measures provided national volumes of feed eaten by dairy cows on a per cow, per hectare and total basis for the last 25 years.

As a sensibility check, the two feed conversion efficiency measures shown above were calculated for this 25 year period. Both measures showed improved efficiency of feed use in terms of milksolids production. There has been a decrease in the feed required to produce one kilogram of milksolids from approximately 16.2 kilograms of dry matter eaten per kilogram of milksolids produced in 1990-91 to around 13.1 kilograms in 2014-15. The other FCE measure showed that milksolids produced per tonne of feed eaten increased from about 62 kilograms milksolids per tonne of dry matter eaten to 76 kilograms milksolids- refer to Table 1.

Another measure of FCE is the calculation of milksolids production as a percentage of liveweight. This shows milksolids production per cow relative to cow liveweight and indicates the efficiency of a cow in terms of producing its own liveweight in milk. Over this 25 year period, milksolids as a percentage of liveweight has increased steadily from 52 to 82 per cent, illustrating an increase in efficiency of per cow production as liveweights have not changed significantly. This suggests that feed eaten per cow is now more effectively utilised for milksolids production, rather than for activity and maintenance. Table 1 below provides these three efficiency measures from 1990-91 to 2014-15. These three measures have a very strong correlation with each other, with the correlation between milksolids as a percentage of liveweight and FCE (kg MS/ t DM) as 99.6 per cent, FCE (kg MS/ t DM) and FCE (kg DM/ kg MS) as 99.5 per cent and FCE (kg DM/ kg MS) and milksolids as a percentage of liveweight as 98.3 per cent.

Table 1: Feed Conversion Efficiency measures from 1990-91 to 2014-15[1, 4]

Season	MS % Liveweight	FCE (kg MS/ t DM)	FCE (kg DM/ kg MS)
1990-91	51.8%	61.8	16.2
1991-92	51.8%	61.8	16.2
1992-93	55.7%	64.1	15.6
1993-94	59.6%	66.4	15.1
1994-95	57.1%	65.0	15.4
1995-96	58.9%	66.0	15.2
1996-97	66.5%	69.9	14.3
1997-98	61.6%	67.5	14.8
1998-99	59.4%	66.2	15.1
1999-00	63.7%	68.5	14.6
2000-01	66.1%	69.8	14.3
2001-02	66.3%	69.8	14.3
2002-03	66.9%	70.2	14.3
2003-04	68.5%	70.9	14.1
2004-05	66.4%	69.9	14.3
2005-06	70.3%	71.7	13.9
2006-07	73.0%	72.9	13.7
2007-08	67.4%	70.4	14.2
2008-09	71.0%	72.0	13.9
2009-10	68.4%	70.9	14.1
2010-11	70.5%	71.8	13.9
2011-12	76.0%	74.4	13.4
2012-13	73.7%	73.3	13.6
2013-14	78.6%	75.4	13.3

2014-15	81.2%	76.4	13.1

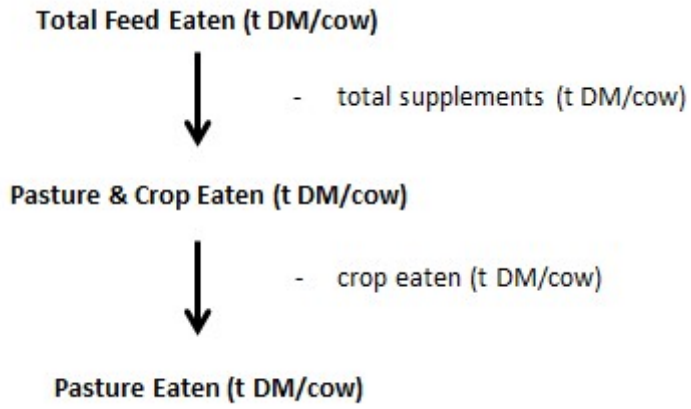
Source: New Zealand Dairy Statistics, DairyNZ Economics Group

Farm Data Approach

DairyBase contains physical and financial information for a selection of New Zealand dairy farms. DairyBase captures a sample of farms that have voluntarily entered data, typically these farms are larger, higher producing farms than depicted by the *New Zealand Dairy Statistics* but this report aims to remove any bias that may be present in this data set. DairyBase is a tool that enables users to benchmark farm performance by comparing their own farm to industry aggregates or targets. The Farm Data Approach used weighted average New Zealand data from DairyBase to estimate supplements eaten (per cow and per hectare).

DairyBase benchmark data from 2006-07 to 2014-15 was used to calculate an adjusted total supplements eaten per cow value, scaled to milksolids production per cow from the *New Zealand Dairy Statistics*. The purpose of this was to obtain a national estimate of supplements eaten (excluding crop), rather than use what was stated in the benchmarking reports given DairyBase contains a self-selected sample of farms and could be biased. Supplements (t DM/cow) were estimated for seasons prior to 2006-07. Feed demand per cow from the Feed Demand Approach was used in conjunction with supplements per cow to calculate pasture and crop eaten per cow. A sum of the crops grown and consumed by dairy cows from the National Statistical Approach discussed in the next section was used to split pasture and crop eaten volumes. This process is shown in Figure 4 and was also carried out on a per hectare basis.

Figure 4: Pasture eaten calculation



As a sensibility check, FCE calculated in the Feed Demand Approach was compared to the FCE values derived from each seasonal DairyBase benchmarking report, scaled to milksolids production using the *New Zealand Dairy Statistics*. This was to assess the suitability of combining the two approaches and to ensure they closely aligned.

National Statistical Approach

This approach involved the collection of national supplementary feed data from various sources to form a time series of the different non-pasture feed types consumed by dairy cows from 1990-91 to 2014-15. Data for each June ending season was recorded for consistency and for comparison with dairy industry milk production data. The aim of the National Statistical Approach was to utilise data available from external sources so that an overall representation of non-pasture feed use could be obtained for the dairy industry. Data was obtained for three key measures; area sown nationally (hectares), national harvest volume (tonnes) and imported (to New Zealand) quantities (tonnes). Depending on the type of supplementary feed and the data available, one, two or three of these measures were used to estimate its use in the dairy industry.

Where no national level data was available, professional or industry estimates for that feed type were sought. Seed sales data and sowing rate were supplied by feed industry professionals such as Pioneer, FAR and PGG Wrightsons, which were used to calculate area sown and was considered the best estimate available for some feed types.

Where data for area sown could be obtained for a supplementary feed, it was used to estimate national harvest volume by multiplying an expected yield for that feed type. However, if any harvest volume data for the time series of the particular feed was available, this was used.

The volume of each supplement type was calculated using a standardised dry matter percentage. It was then determined, based on feedback from knowledgeable feed industry opinions, what proportion of total harvest volume was destined for dairy cows. From this, the actual volume of the feed eaten (tonnes of dry matter) was calculated by multiplying by the average utilisation for that feed. Utilisation is defined as the proportion of the feed which is consumed by dairy cows (excluding young stock) after taking into account the losses associated with the method of feeding, storage and transport of the feed. Utilisation for a given feed can vary depending on the management practices observed on farm. Industry opinions and use of the *DairyNZ Facts and Figures* publication were consulted in order to determine utilisation for each feed type based the most common method of feeding, storage and transport.

Seeds sales (kg) x Sowing rate (kg/ha) = Area sown (ha)

Area sown (ha) x Yield = Volume (t)

Volume (t) x DM% x % to Dairy x Utilisation % = Total feed eaten (t DM)

A similar procedure was applied for imported supplementary feeds. Import quantities (tonnes) for certain feed types were extracted from *Statistics New Zealand.* Once import quantity data was collected for a supplementary feed, conversion to dry matter tonnes was applied, if applicable, using the dry matter percentage for that feed type. An assessment was made on what proportion of the total import quantity was destined for dairy cows. From this, the actual volume of the feed eaten (tonnes of dry matter) was calculated by multiplying by the average utilisation.

Import volume (t) x DM% x % to Dairy x Utilisation % = Total feed eaten (t DM)

The data collection process required the use of national databases, external reports, industry assessments, feed expert opinions and literature reviews. Together these sources provided a national estimate of the volumes of 17 supplementary feed types consumed by dairy cows. A sum of the crops grown and consumed by dairy cows (feeds grazed in situ or fed by cut and carry methods such as fodder beet, kale, rape, turnips, swedes and other brassicas) was used to split pasture and crop eaten volumes in the Farm Data Approach.

This approach was limited by the availability of data, and in many cases values were missing which required subjective techniques to fill these gaps. For instance, where yields could be assumed constant between seasons, area sown and yield for that feed type were used to calculate total volume. Also for feed types derived from other sources, such as brewer's grain, yields of by-product as a proportion of production were considered constant and total production was used as a proxy for determining total volume. In other cases the missing data values for particular seasons were estimated using linear interpolation and discussions with those in the industry.

Comparing Approaches

The final stage combined the three approaches outlined above, ensuring the results from each approach were consistent with one another. The National Statistical Approach and Feed Demand Approach were considered 'top-down' methods which utilised data available from several external sources such as national databases and publications, external reports, industry assessments, expert opinions and literature reviews. Given the National Statistical Approach was unable to capture all non-pasture feed use on New Zealand dairy farms due to the limited availability of data, this was treated as a rough depiction of the trends in non-pasture feed use over this 25 year period. The Farm Data Approach was considered as a 'bottom-up' method of analysis which utilised robust dairy industry data sources.

Given the considerable variation in supplementary feed types offered to dairy cows, not all supplementary feed types could be accurately recorded in the National Statistical Approach. Total supplements eaten from the Farm Data Approach was compared to the sum of all individual supplement types (harvested and imported supplements excluding crops) recorded in the National Statistical Approach. Total supplements eaten from the Farm Data Approach are derived from DairyBase benchmark data which was used to calculate adjusted total supplements eaten per cow values, scaled to milksolids production per cow from the *New Zealand Dairy Statistics*. In DairyBase, supplements are recorded separately while pasture and crop are grouped together thus the sum of the crops grown and consumed by dairy cows from the National Statistical Approach was used to split pasture and crop eaten volumes.

Each feed type was placed into one category only, either as crops, harvested supplements and imported supplements based on management practices. Crops grown and consumed by dairy cows (feeds grazed in situ or fed by cut and carry methods such as fodder beet, kale, rape, turnips, swedes and other brassicas) from the National Statistical Approach were used to split pasture and crop eaten in the Farm Data Approach, creating pasture eaten as a residual. In a similar method, supplements eaten from the Farm Data Approach were split into harvested supplements (feeds either grown and harvested on farm or harvested off farm and purchased such as maize grain, maize silage, barley, wheat, oats and cereal whole crop silage) and imported supplements (non-harvested purchased feeds such as PKE, brewer's grain, soyabean meal, cottonseed meal, tapioca and other supplements). The sum of harvested supplements and imported supplements from the National Statistical Approach equalled total supplements eaten derived from the Farm Data Approach as the 'other supplements' category was used to balance the two approaches and encompassed all other non-pasture feed types used on New Zealand dairy farms that could not be individually captured using the National Statistical Approach.

Feed Characteristics

In addition to the three approaches used to quantify non-pasture feed use on New Zealand dairy farms, data on the most common method of feeding, metabolisable energy, crude protein and nitrogen content for each feed type were gathered. Collecting information regarding the most common method of feeding was done through discussion with industry professionals. This was used as a basis for determining appropriate utilisation percentages for each feed type. Metabolisable energy and crude protein values were also sourced from the *DairyNZ Facts and Figures* publication for the majority of feed types, although rape, other brassicas and cottonseed meal were unpublished and were therefore omitted from Table 23. Metabolisable energy (ME MJ/kg DM) is a measure of feed quality. It estimates the amount of usable or metabolisable energy (ME) in a given dry weight of feed as megajoules of energy per kilogram of dry matter. The *DairyNZ Facts and Figures* estimates crude protein as a percentage of dry matter weight from the nitrogen content of the feed (g/kg DM). This is completed by following recognised industry practice and multiplying nitrogen content by 6.25. In order to obtain nitrogen content for each feed type in this study, crude protein values were used to back calculate nitrogen content (g/kg DM) by following recognised industry practice and dividing crude protein as a percentage of dry matter weight by 6.25.

Assumptions and Limitations

In the preparation of this report a number of assumptions were required regarding the robustness and treatment of the data. For the Feed Demand Approach, dairy industry statistics were used to derive national feed demand. Under this approach, two year olds entering the milking herd were excluded on the basis that this report was to focus on mature milking cows and to avoid estimating feed used for liveweight gain relative to milksolids production. The methodology used implies that the energy requirement of liveweight gain by two year olds during their first season wouldn't be captured. Inclusion of two year olds (weighting of 20% of the average herd) did not have a significant impact (a 10-15 kg decrease observed) on average liveweight across breeds in terms of altering feed demand requirements per cow.

It is implicitly assumed under this methodology that culling patterns and the average days in milk have remained constant over this 25 year period. It has been recognised that culling patterns and days in milk would have changed during this time but was considered negligible in terms of calculating national feed demand. It should be noted that because these differences could not be captured under this approach, efficiency gains reflected by improvements in the FCE measures are likely to be overestimated. This report focuses on lactating cows only as

recorded in the *New Zealand Dairy Statistics* and so replacement young stock reared to support the industry have been implicitly excluded.

For the Farm Data Approach using DairyBase, there are assumptions surrounding how representative the sample for each season is on a national level. DairyBase contains a self-selected sample which comprises only a small proportion of the national dairy herd. Given this, there is assumed to be some bias towards larger, higher producing farms in the sample. Therefore, it may be likely that supplementary feed use is overestimated due to the skew towards higher producing farms which may utilise more non-pasture feeds. To account for this, values were adjusted using data from the *New Zealand Dairy Statistics* as an index to reduce this bias. This approach used available DairyBase benchmarking reports from 2006-07 to 2014-15 to determine supplements (t DM/cow) and to compare FCE (kg MS/t DM) with that from the Feed Demand Approach. Seasons prior to 2006-07 were not available as DairyBase was not yet operating, so supplements were estimated using linear extrapolation with guidance from industry experts, however these should be considered as estimates only. Another limitation of the Farm Data Approach is the aggregation of pasture and crop values recorded in DairyBase. Therefore, crop data sourced from the National Statistical Approach was considered the best method to split pasture and crop eaten for this project. The volume of crops eaten will impact on the amount of pasture eaten, i.e. if the volume of crops are overestimated then the volume of pasture eaten will be underestimated, and vice versa.

For the National Statistical Approach, annual data was collected on a June year basis from a wide range of sources which can lead to consistency issues. The approach required the area of some particular feed types to be converted to total volumes through yield calculations and volumes of some particular feeds to be converted to dry matter tonnes using standard percentages. As estimated yields for each feed type were greatly unknown, industry expert opinion and literature reviews were consulted to approximate appropriate yields (t/ha). This is susceptible to error depending on the source and feed type but is expected to be reasonable at an aggregate level. Dry matter percentages for each feed type were gathered from the *DairyNZ Facts and Figures* publication and were considered as the best available information. However, as some sources did not specify whether the data was recorded in tonnes wet weight or tonnes dry matter, a judgement by the authors was required. In addition, the volume of feed, in dry matter tonnes, was apportioned to the estimated amount fed to dairy cows. This was an attempt to exclude the volume fed to livestock other than dairy. The proportion of the feed type consumed by dairy cows was determined by industry expert opinions which were considered as a guide. Wastage was also taken into consideration with utilisation of each feed determined by the most common method of feeding, storage and transport based on industry opinions and sourced from the *DairyNZ Facts and Figures* publication. However, as there is considerable variation in the methods of feeding particular supplement types across New Zealand dairy farms, the utilisation percentages used in this paper are considered as estimates. Considering this procedure, there are likely to be some inaccuracies in each of the assumptions, which combined could be significant. More time and effort was devoted to the larger nonpasture feed types such as PKE, maize silage and fodder beet.

This report aims to give a comprehensive overview of non-pasture feed consumed by dairy cows from 1990-91 to 2014-15 but given the lack of supplementary feed data, required estimating some values using linear extrapolated based on available data points and discussion with industry experts was required. Although this was considered the best solution and uses the best available data, estimates may not truly reflect the actual number.

Results

The results show that during this period there was an increasing trend in non-pasture feed use. In particular, the volumes of PKE use on New Zealand dairy farms have increased considerably over the last decade. Maize silage volumes have increased steadily while the emergence of fodder beet crops has seen a rapid rise in areas grown with less than 500 hectares in 2007-08 increasing to approximately 50,000 hectares grown in 2014-15. These three feeds are the most common accounting for 71.3 per cent of the estimated total supplementary feed consumed by New Zealand dairy cows in 2014-15. Figures 5, 6, 7 and 8 show the change in the volumes and proportion of the different non-pasture feed types from 1990-91 to 2014-15.

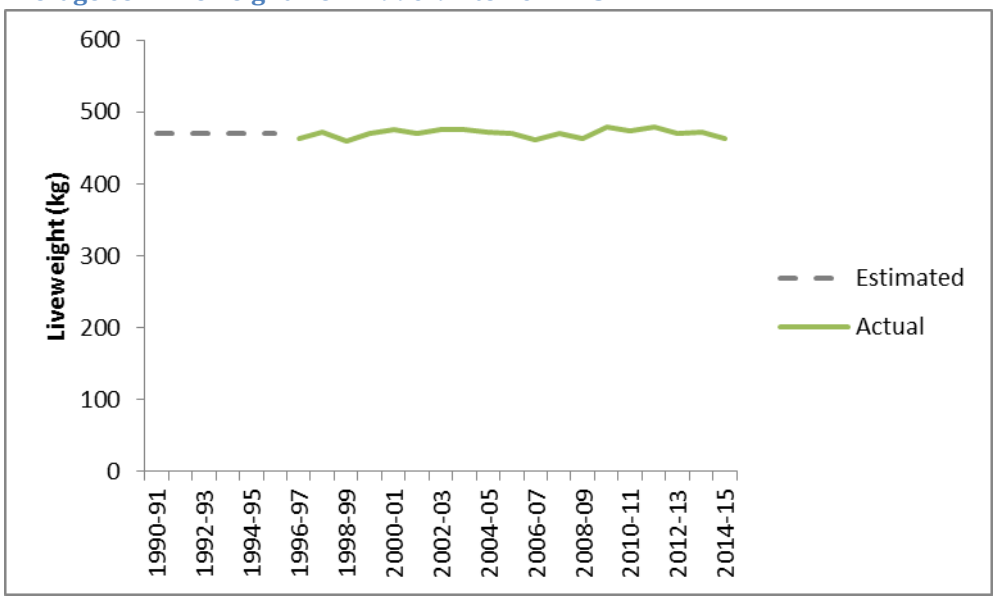
Feed Demand Approach

The Feed Demand Approach calculated seasonal feed demand requirements based on published industry values from the *New Zealand Dairy Statistics.* Feed requirements (t DM/year) increased as milksolids production per cow increased 55 per cent (4.7 kilograms milksolids per cow per year) over the 25 year period. The amount of feed (kg DM) required to produce each kilogram of milksolids has decreased over time, illustrating an increase in efficiency.

Weighted average liveweight values calculated from *New Zealand Dairy Statistics* for seasons 1996-97 to 201415 did not show a significant change in trend during this period despite cows being fed more. This reflects the change in national breeds towards lighter crossbred cows. In 2014-15 nearly half (46%) the cows in New Zealand were Holstein-Friesian / Jersey crossbred, with 35 per cent Holstein-Friesians and 10 per cent Jersey. This compares with 18 per cent Holstein-Friesian / Jersey crossbred, 57 per cent Holstein-Friesians and 16 per cent Jersey breeds in the mid-1990s. Milksolids production per cow as a per centage of liveweight shows an increasing trend reflecting constant liveweight but increasing milksolids production per cow over this period.

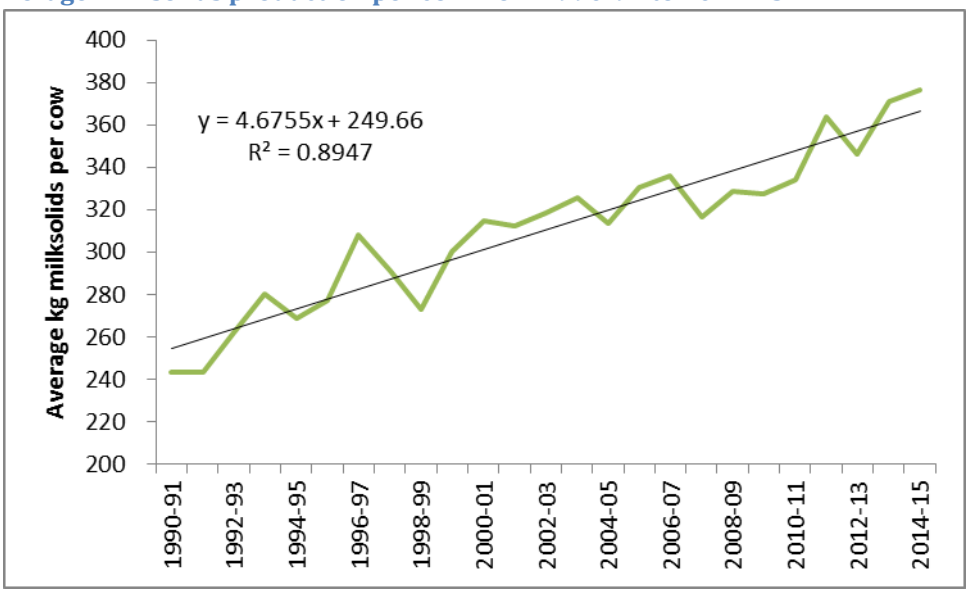
As liveweight did not change considerably from 1996-97 to 2014-15, the average over this period (470 kg) was used for seasons prior to 1996-97 as an estimate. This is shown in Figure 5 below. Adjusting liveweight values up or down by 10 kg prior to 1996-97 had little impact on the derived feed demand on a per cow, per hectare and total basis, so the estimate of 470 kg for these seasons was considered satisfactory. Figures 6 and 7 below show the close relationship between milksolids production per cow and required feed demand per cow given the relatively constant average liveweight values over this period.

Figure 5: Average cow liveweight from 1990-91 to 2014-15[1]



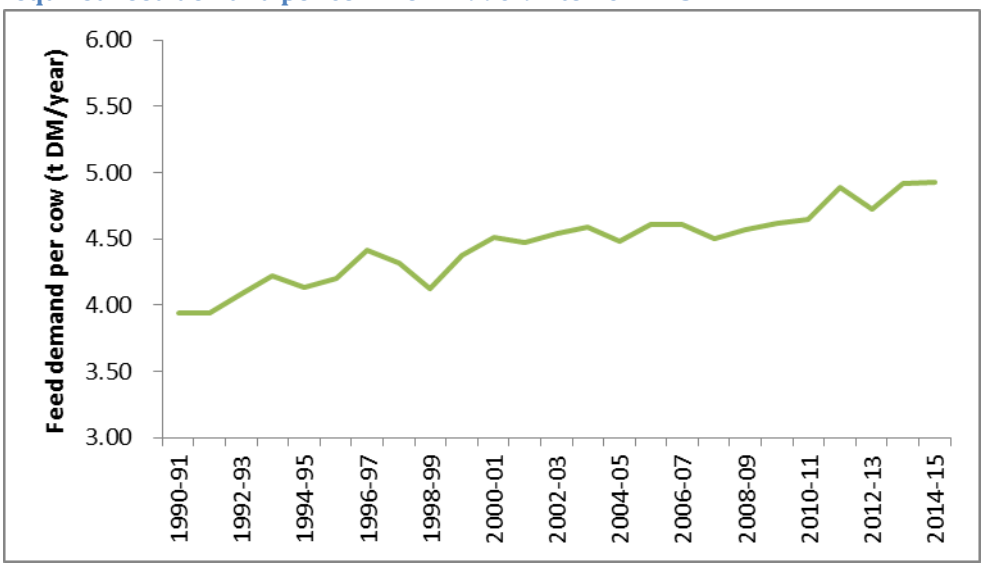
Source: New Zealand Dairy Statistics, DairyNZ Economics Group

Figure 6: Average milksolids production per cow from 1990-91 to 2014-15[1]



Source: New Zealand Dairy Statistics

Figure 7: Required feed demand per cow from 1990-91 to 2014-15[1, 4]



Source: New Zealand Dairy Statistics, DairyNZ Economics Group

Table 2 provides a summary of the findings from the Feed Demand Approach for seasons 1990-91 to 2014-15. It shows the growth in national feed demand from 9,460,125 t DM/year in 1990-91 to 24,725,673 in 2014-15 as milksolids production per cow, stocking rate and effective hectares have all increased significantly over this period with liveweight remaining constant. Figure 7 above shows the trend in feed demand requirements per cow from 1990-91. Over the last 25 years the volume of feed consumed has increased approximately 1.0 tonne per cow. On a per hectare basis, the increase was approximately 4.9 tonnes to 14.2 tonnes per hectare.

Table 2: Feed Demand Approach Summary[1, 4]

Season	Cow numbers	Effective area (hectares)	Stocking Rate (cows/ha)	Total Milksolids (kg)	MS/cow	MS/ha	Liveweight (kg)	Feed Demand (t DM/cow/year)	Feed Demand (t DM/ha/year)	Feed Demand (t DM/year)	FCE (kg DM/ kg MS)
1990-91	2,402,145	1,023,545	2.35	584,431,673	243	571	470	3.94	9.24	9,460,125	16.19
1991-92	2,438,641	1,024,639	2.38	593,577,747	243	579	470	3.94	9.37	9,605,924	16.18
1992-93	2,603,049	1,069,892	2.43	681,414,722	262	637	470	4.08	9.93	10,623,652	15.59
1993-94	2,736,452	1,122,509	2.44	767,054,643	280	683	470	4.22	10.30	11,558,521	15.07
1994-95	2,830,977	1,175,940	2.41	760,502,560	269	647	470	4.13	9.95	11,703,644	15.39
1995-96	2,935,759	1,208,352	2.43	813,642,050	277	673	470	4.20	10.20	12,329,100	15.15
1996-97	3,064,523	1,267,726	2.42	943,962,984	308	745	463	4.41	10.66	13,513,206	14.32
1997-98	3,222,591	1,276,551	2.52	937,612,608	291	734	472	4.31	10.89	13,899,579	14.82
1998-99	3,289,319	1,306,942	2.52	897,886,543	273	687	459	4.13	10.38	13,571,937	15.12
1999-00	3,269,362	1,292,566	2.53	980,814,360	300	759	471	4.38	11.07	14,311,014	14.59
2000-01	3,485,883	1,329,173	2.62	1,096,267,357	314	825	475	4.51	11.82	15,710,441	14.33
2001-02	3,692,703	1,404,930	2.63	1,152,471,714	312	820	471	4.47	11.75	16,506,362	14.32
2002-03	3,740,637	1,463,281	2.56	1,190,758,776	318	814	476	4.54	11.60	16,972,603	14.25
2003-04	3,851,302	1,421,147	2.71	1,253,689,956	326	882	475	4.59	12.44	17,672,301	14.10
2004-05	3,867,659	1,411,594	2.74	1,212,682,827	314	859	472	4.49	12.29	17,349,528	14.31
2005-06	3,832,145	1,398,966	2.74	1,267,438,112	331	906	471	4.61	12.63	17,669,962	13.94
2006-07	3,916,812	1,412,925	2.77	1,316,302,622	336	932	461	4.61	12.78	18,058,564	13.72
2007-08	4,012,867	1,436,549	2.79	1,269,777,203	316	884	469	4.50	12.56	18,047,140	14.21
2008-09	4,252,881	1,519,117	2.80	1,397,798,054	329	920	463	4.57	12.78	19,414,898	13.89
2009-10	4,396,675	1,563,495	2.81	1,438,499,535	327	920	478	4.61	12.98	20,288,128	14.10
2010-11	4,528,736	1,638,706	2.76	1,513,177,937	334	923	474	4.65	12.85	21,060,609	13.92

2011-12	4,634,226	1,638,546	2.83	1,684,884,542	364	1,028	478	4.89	13.83	22,657,858	13.45
2012-13	4,784,250	1,677,395	2.85	1,657,722,313	346	988	470	4.73	13.49	22,621,748	13.65
2013-14	4,922,806	1,716,464	2.87	1,824,971,520	371	1,063	472	4.92	14.10	24,197,763	13.26
2014-15	5,018,333	1,746,156	2.87	1,889,885,247	377	1,082	464	4.93	14.16	24,725,673	13.08

Source: New Zealand Dairy Statistics, DairyNZ Economics Group

Farm Data Approach

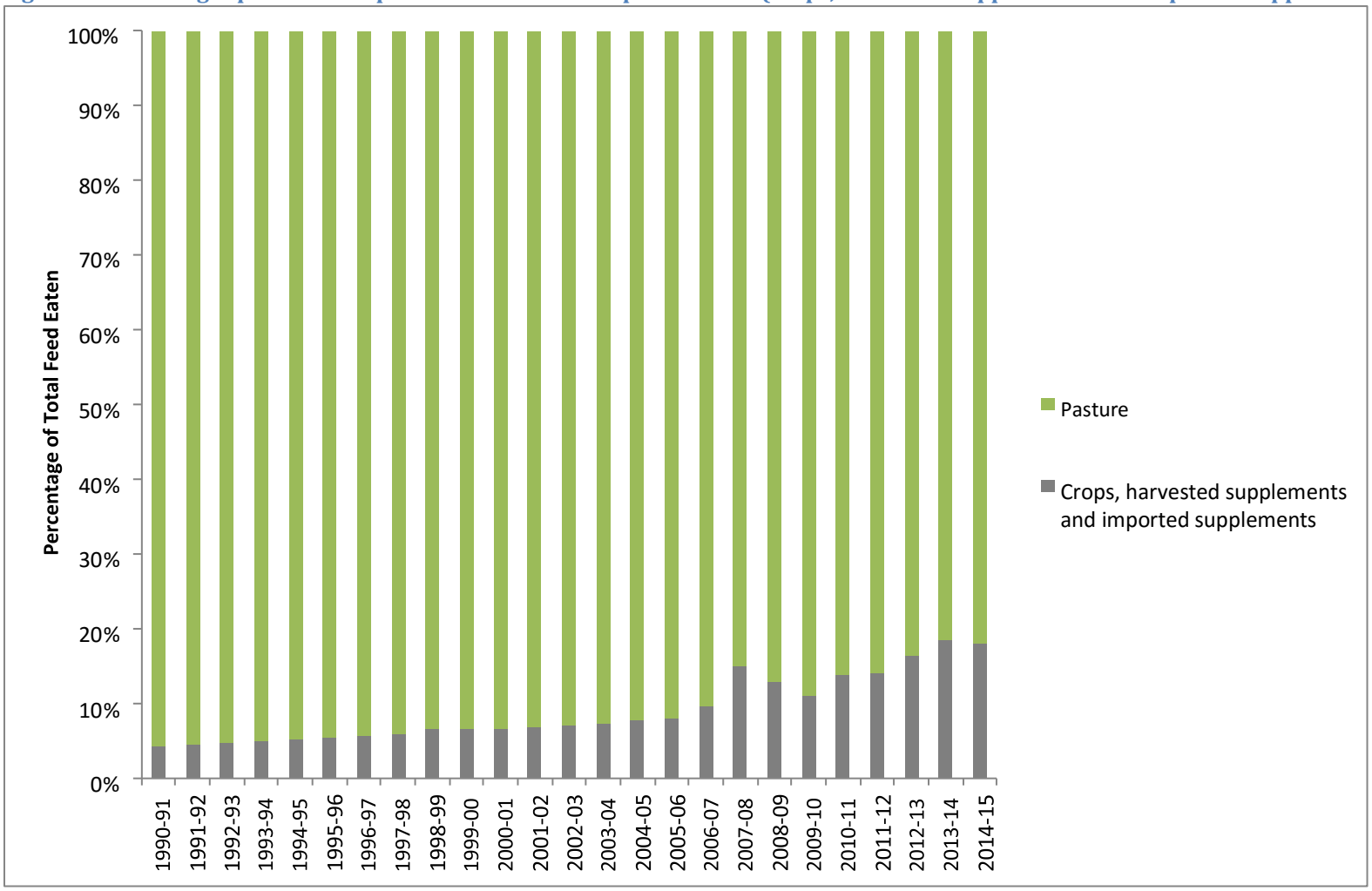
DairyBase benchmarking reports were used to compute adjusted supplements eaten per hectare values for the seasons 2006-07 to 2014-15 with milksolids production per hectare from the *New Zealand Dairy Statistics* used as an index to reduce production bias. For seasons prior to 2006-07, supplements (t DM/ha) were estimated using linear interpolation with guidance from industry professionals. Using feed demand (t DM/cow) from the Feed Demand Approach, adjusted supplements (t DM/cow) and an estimation of crop eaten (t DM/cow) using the National Statistical Approach, pasture eaten (t DM/cow) was created as a residual.

This methodology showed increasing supplement use as well as a steady increase in total feed eaten and pasture (calculated as a residual) eaten over time, in line with expectations. Supplements and crop eaten as a percentage of total feed increased significantly over this period from 4 per cent in 1990-91 to 18 per cent in 2014-15. Figure 8 shows the percentage split between pasture and total supplements including crops over this 25 year period. It is implicit under this approach that feed substitution between pasture and supplements including crops occurs, as supplements and crops increase, the remaining dry matter intake required for the level of milksolids production comes from pasture which is calculated as a residual.

FCE (kg MS/ t DM) was calculated by dividing milksolids production per hectare by feed demand per hectare from the Feed Demand Approach and compared to the FCE values derived from each seasonal DairyBase benchmarking report, scaled to milksolids production using the *New Zealand Dairy Statistics*. This was to assess the suitability of combining the two approaches and to ensure they closely aligned. In Tables 3 and 4 FCE from the two approaches are given and show a high level of similarity.

Table 3 provides a summary of the Farm Data Approach on a per cow basis for seasons 1990-91 to 2014-15. This summary was also derived on a per hectare basis and is shown in Table 4.

Figure 8: Percentage spilt between pasture eaten and non-pasture feed (crops, harvested supplements and imported supplements) eaten



Source: DairyNZ Economics Group

Table 3: Per cow summary using the Farm Data Approach [6]

Season	Total Feed Demand (t DM/cow)	Pasture (t DM/cow)	Crop (t DM/cow)	Harvested Supplements (t DM/cow)	Imported Supplements (t DM/cow)	Total Supplements & Crop (t DM/cow)	Supplements & Crop % of Feed Demand	FCE (kg MS/ t DM)	DairyBase FCE (kg MS/ t DM)
1990-91	3.94	3.77	0.03	0.08	0.05	0.16	4.2%	61.8	
1991-92	3.94	3.76	0.04	0.08	0.06	0.18	4.6%	61.8	
1992-93	4.08	3.89	0.04	0.08	0.08	0.19	4.7%	64.1	
1993-94	4.22	4.02	0.04	0.07	0.10	0.20	4.9%	66.4	
1994-95	4.13	3.92	0.04	0.08	0.10	0.22	5.3%	65.0	
1995-96	4.20	3.97	0.04	0.10	0.09	0.23	5.5%	66.0	
1996-97	4.41	4.16	0.04	0.09	0.12	0.25	5.6%	69.9	
1997-98	4.31	4.06	0.04	0.10	0.12	0.26	6.0%	67.5	
1998-99	4.13	3.85	0.04	0.12	0.12	0.27	6.6%	66.2	
1999-00	4.38	4.09	0.04	0.14	0.11	0.29	6.5%	68.5	
2000-01	4.51	4.21	0.04	0.15	0.11	0.30	6.6%	69.8	
2001-02	4.47	4.16	0.04	0.16	0.11	0.31	6.9%	69.8	
2002-03	4.54	4.21	0.04	0.18	0.11	0.32	7.1%	70.2	
2003-04	4.59	4.25	0.04	0.20	0.10	0.34	7.3%	70.9	
2004-05	4.49	4.14	0.04	0.21	0.10	0.35	7.8%	69.9	

[6] DairyBase Benchmarking Reports, 2007-08 to 2014-15

2005-06	4.61	4.25	0.04	0.23	0.10	0.37	7.9%	71.7	
2006-07	4.61	4.16	0.04	0.29	0.12	0.45	9.7%	72.9	71.4
2007-08	4.50	3.83	0.04	0.35	0.28	0.67	14.9%	70.4	69.3
2008-09	4.57	3.98	0.04	0.32	0.23	0.59	12.9%	72.0	72.4
2009-10	4.61	4.10	0.05	0.23	0.23	0.51	11.1%	70.9	70.8
2010-11	4.65	4.01	0.06	0.23	0.35	0.64	13.8%	71.8	73.4
2011-12	4.89	4.20	0.07	0.24	0.38	0.69	14.1%	74.4	75.5
2012-13	4.73	3.96	0.11	0.26	0.40	0.77	16.3%	73.3	71.9
2013-14	4.92	4.01	0.19	0.31	0.41	0.90	18.4%	75.4	76.5
2014-15	4.93	4.04	0.18	0.31	0.39	0.89	18.0%	76.4	75.9

Table 4: Per hectare summary using the Farm Data Approach[6]

Season	Total Feed Demand (t DM/ha)	Pasture (t DM/ha)	Crop (t DM/ha)	Harvested Supplements (t DM/ha)	Imported Supplements (t DM/ha)	Total Supplements & Crop (t DM/ha)	Supplements & Crop % of Feed Demand	FCE (kg MS/ t DM)	DairyBase FCE (kg MS/ t DM)
1990-91	9.24	8.86	0.08	0.20	0.11	0.39	4.2%	61.8	
1991-92	9.37	8.95	0.09	0.19	0.15	0.43	4.6%	61.8	
1992-93	9.93	9.46	0.09	0.19	0.19	0.47	4.7%	64.1	
1993-94	10.30	9.80	0.09	0.17	0.24	0.50	4.9%	66.4	
1994-95	9.95	9.43	0.09	0.19	0.25	0.53	5.3%	65.0	
1995-96	10.20	9.64	0.09	0.24	0.23	0.56	5.5%	66.0	
1996-97	10.66	10.07	0.09	0.22	0.28	0.59	5.6%	69.9	
1997-98	10.89	10.24	0.09	0.25	0.31	0.65	6.0%	67.5	

1998-99	10.38	9.70	0.09	0.29	0.30	0.68	6.6%	66.2	
1999-00	11.07	10.35	0.10	0.34	0.28	0.72	6.5%	68.5	
2000-01	11.82	11.04	0.10	0.40	0.28	0.78	6.6%	69.8	
2001-02	11.75	10.93	0.10	0.43	0.29	0.82	6.9%	69.8	
2002-03	11.60	10.77	0.10	0.46	0.27	0.83	7.1%	70.2	
2003-04	12.44	11.52	0.10	0.53	0.28	0.91	7.3%	70.9	
2004-05	12.29	11.33	0.11	0.59	0.27	0.96	7.8%	69.9	
2005-06	12.63	11.63	0.11	0.63	0.26	1.00	7.9%	71.7	
2006-07	12.78	11.54	0.11	0.81	0.32	1.24	9.7%	72.9	71.4
2007-08	12.56	10.69	0.12	0.98	0.78	1.88	14.9%	70.4	69.3
2008-09	12.78	11.13	0.12	0.88	0.64	1.65	12.9%	72.0	72.4
2009-10	12.98	11.54	0.14	0.65	0.65	1.44	11.1%	70.9	70.8
2010-11	12.85	11.08	0.16	0.63	0.98	1.77	13.8%	71.8	73.4
2011-12	13.83	11.88	0.21	0.67	1.07	1.95	14.1%	74.4	75.5
2012-13	13.49	11.29	0.31	0.73	1.15	2.19	16.3%	73.3	71.9
2013-14	14.10	11.50	0.53	0.89	1.17	2.59	18.4%	75.4	76.5
2014-15	14.16	11.61	0.52	0.90	1.13	2.55	18.0%	76.4	75.9

National Statistical Approach

This approach involved the collection of national supplementary feed data as a time series from 1990-91 to 2014-15. Data was obtained for three key measures; area sown nationally (hectares), national harvest volume (tonnes) and import quantity (tonnes). The data collection process required the use of national databases, external reports, industry assessments, expert opinions and literature reviews. Together these sources provided a national estimate of non-pasture feed use for the New Zealand dairy industry.

The most common types of non-pasture feeds are reviewed in this section, illustrating their use over the last 25 years. Of the 17 supplementary feed types included in this report, PKE, maize silage and fodder beet have emerged as the most prolific non-pasture feed types. For PKE, import volumes started to pick up in the mid2000s as it provided farmers with a cheap, easy to manage feed source to sustain lactation during the shoulders of the season or during dry periods as well as increasing milksolids production in seasons with higher milk price. Maize silage increased in use from the early to mid-2000s and has fluctuated around this level since. Maize silage is typically fed in autumn to improve body condition near the end of the season but also provides farmers with a cheap, easily stored feed that can be used throughout the season. In recent years, fodder beet has become a key supplement used by the dairy industry as a feed for cows both over winter and increasingly during lactation. Fodder beet use in New Zealand has increased significantly in the last five years as it is capable of high yields relative to other crops, which reduces cost per kilogram of dry matter.

Palm Kernel Extract (PKE)

In the early 1990s PKE was not a common supplementary feed for dairy cows. However, over the last 25 year period import volumes have increased significantly making PKE the most common feed supplement for dairy cows in 2014-15. Table 5 shows the use of PKE as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 5: Total PKE eaten by dairy cows from 1990-91 to 2014-15[7]

Season	Volume Imported (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	-	90%	95%	80%	-
1991-92	15	90%	95%	80%	10
1992-93	15	90%	95%	80%	10
1993-94	-	90%	95%	80%	-
1994-95	-	90%	95%	80%	-
1995-96	-	90%	95%	80%	-
1996-97	186	90%	95%	80%	127
1997-98	40	90%	95%	80%	28
1998-99	128	90%	95%	80%	87
1999-00	366	90%	95%	80%	250
2000-01	4,232	90%	95%	80%	2,895
2001-02	24,730	90%	95%	82%	17,338
2002-03	31,573	90%	95%	82%	22,136
2003-04	54,425	90%	95%	84%	39,088
2004-05	126,029	90%	95%	85%	91,592
2005-06	225,374	90%	95%	85%	163,791
2006-07	364,469	90%	95%	86%	267,994
2007-08	809,259	90%	95%	88%	608,887
2008-09	914,572	90%	95%	90%	703,763
2009-10	996,888	90%	95%	90%	767,105
2010-11	1,413,867	90%	95%	90%	1,087,970
2011-12	1,411,524	90%	95%	90%	1,086,167
2012-13	1,464,219	90%	94%	90%	1,114,857
2013-14	1,890,569	90%	93%	90%	1,424,166
2014-15	1,949,526	90%	92%	90%	1,452,787

Maize Grain

Maize grain used as a supplementary feed for dairy cows has been reasonably static over the last two and a half decades, fluctuating between 40,000 to 50,000 tonnes DM per season. Table 6 shows the use of maize grain as

[7] Statistics NZ Infoshare, Harmonised Trade- Imports. Oil-cake and other solid residues; whether or not ground or in the form of pellets, resulting from the extraction of cotton seed oils (1990-2015 Annual-June).

a supplementary feed from 1990-91 to 2014-15 after taking into account utilisation and the estimated proportion destined for the dairy industry.

Table 6: Total maize grain eaten by dairy cows from 1990-91 to 2014-15[8, 9, 10, 11]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t DM)	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	19,046	9.63	183,388	25%	95%	43,555
1991-92	17,966	9.12	163,842	25%	95%	38,912
1992-93	15,925	8.36	133,100	25%	95%	31,611
1993-94	14,700	9.71	142,800	25%	95%	33,915
1994-95	16,505	9.74	160,797	25%	95%	38,189
1995-96	18,559	11.30	209,700	25%	95%	49,804
1996-97	19,500	9.95	194,000	25%	95%	46,075
1997-98	17,500	10.06	176,000	25%	95%	41,800
1998-99	19,446	10.13	197,000	25%	95%	46,788
1999-00	17,700	10.23	181,000	25%	95%	42,988
2000-01	17,000	10.40	176,800	25%	95%	41,990
2001-02	14,178	10.50	148,847	25%	95%	35,351
2002-03	19,500	10.86	211,685	25%	95%	50,275
2003-04	20,300	11.54	234,248	25%	95%	55,634
2004-05	19,200	10.95	210,253	25%	95%	49,935
2005-06	19,700	10.95	215,649	25%	95%	51,217
2006-07	17,000	10.92	185,627	25%	95%	44,086
2007-08	18,300	11.23	205,557	25%	95%	48,820
2008-09	21,600	11.01	237,844	25%	95%	56,488
2009-10	17,500	10.79	188,812	25%	95%	44,843
2010-11	18,500	11.36	210,200	25%	95%	49,923
2011-12	19,400	10.89	211,200	25%	95%	50,160
2012-13	18,600	10.84	201,700	25%	95%	47,904
2013-14	21,600	10.98	237,200	25%	95%	56,335
2014-15	19,800	11.43	226,300	25%	95%	53,746

Maize Silage

Maize silage has seen considerable increases since the early 1990s, rising from around 4,000 hectares in 199091 to 70,000 hectares in 2014-15. A large proportion is used as feed for dairy cows, with just over 1,200,000 tonnes dry matter eaten in 2014-15. Table 7 shows the use of maize silage as a supplementary feed from 1990-91 to 2014-15 after taking into account utilisation and the estimated proportion destined for the dairy industry.

[8] Brooker, W.J. (2009). Production, distribution and utilisation of maize.

[9] Agricultural Production Statistics (June 2015P). Table 8 Grain Crops 2003-2015. Statistics NZ

[10] Statistics NZ Infoshare, Agriculture. Area Sown and Total Yield (1990-2015 Annual-June).

[11] AIMI Maize Reports, 2012 to 2015

Table 7: Total maize silage eaten by dairy cows from 1990-91 to 2014-15[8, 11,12]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t DM)	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	4,000	19.01	76,040	98%	70%	52,163
1991-92	4,000	19.01	76,040	98%	70%	52,163
1992-93	4,000	19.01	76,040	98%	70%	52,163
1993-94	3,000	19.01	57,030	98%	70%	39,123
1994-95	6,000	19.01	114,060	98%	70%	78,245
1995-96	7,000	20.89	146,247	98%	70%	100,326
1996-97	7,000	19.28	134,950	98%	70%	92,576
1997-98	10,000	18.82	188,177	98%	70%	129,090
1998-99	14,000	20.21	282,898	98%	70%	194,068
1999-00	16,240	20.85	338,541	98%	70%	232,239
2000-01	20,787	19.59	407,138	98%	70%	279,297
2001-02	24,000	19.89	477,320	98%	70%	327,442
2002-03	30,000	19.27	577,978	98%	70%	396,493
2003-04	36,000	20.41	734,818	98%	70%	504,085
2004-05	40,500	19.73	799,105	98%	71%	556,017
2005-06	40,500	21.40	866,829	98%	72%	611,635
2006-07	60,000	19.99	1,199,188	98%	73%	857,899
2007-08	72,000	21.34	1,536,296	98%	74%	1,114,122
2008-09	60,000	23.74	1,424,260	98%	75%	1,046,831
2009-10	50,000	21.44	1,071,967	98%	76%	798,401
2010-11	44,778	23.28	1,042,546	98%	78%	796,922
2011-12	50,744	20.56	1,043,358	98%	80%	817,993
2012-13	52,153	22.85	1,191,697	98%	82%	957,648
2013-14	65,116	23.15	1,507,522	98%	84%	1,240,992
2014-15	68,130	22.60	1,539,721	97%	85%	1,269,500

Barley

The areas sown of barley has been reasonably constant over the last 25 years, but the proportion to dairy cows is thought to have increased which has seen barley use increase in line with cow numbers and growth of dairying in the South Island during this time. Table 8 shows the use of barley as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 8: Total barley eaten by dairy cows from 1990-91 to 2014-15[9, 10]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	83,740	4.56	382,043	87%	16%	90%	47,862

[12] Yield data obtained via Pioneer personal contact

1991-92	67,380	4.73	318,787	87%	17%	90%	42,434
1992-93	79,785	4.88	389,523	87%	18%	90%	54,899
1993-94	76,858	5.15	395,476	87%	19%	90%	58,835
1994-95	68,206	4.44	302,804	87%	20%	90%	47,419
1995-96	76,601	4.79	367,181	87%	21%	90%	60,376
1996-97	65,000	5.00	325,000	87%	22%	90%	55,985
1997-98	65,000	5.00	325,000	87%	23%	90%	58,529
1998-99	55,792	5.00	278,960	87%	24%	90%	52,422
1999-00	65,000	5.00	325,000	87%	25%	90%	63,619
2000-01	65,000	5.00	325,000	87%	26%	90%	66,164
2001-02	78,097	5.65	440,883	87%	27%	91%	94,243
2002-03	63,400	5.86	371,837	87%	28%	92%	83,333
2003-04	48,500	4.66	226,082	87%	29%	93%	53,048
2004-05	49,800	6.06	302,023	87%	30%	94%	74,098
2005-06	47,100	5.88	277,020	87%	31%	95%	70,977
2006-07	51,500	6.52	335,627	87%	32%	95%	88,767
2007-08	67,400	6.06	408,730	87%	33%	95%	111,479
2008-09	77,700	5.60	435,270	87%	34%	95%	122,315
2009-10	52,300	5.89	308,298	87%	35%	95%	89,183
2010-11	64,900	5.67	367,958	87%	36%	95%	109,482
2011-12	65,700	6.68	438,789	87%	37%	95%	134,184
2012-13	61,300	6.79	416,478	87%	38%	95%	130,803
2013-14	59,300	6.84	405,747	87%	39%	95%	130,786
2014-15	64,200	6.81	437,100	87%	40%	95%	144,505

Wheat

The volume of wheat eaten by dairy cows has increased over the last 25 years, but is only a small proportion of the total harvest of wheat grown in New Zealand with other uses including food manufacturing and other livestock feeds. Table 9 shows the use of wheat as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 9: Total wheat eaten by dairy cows from 1990-91 to 2014-15[9, 10]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	37,527	4.81	180,690	88%	10%	90%	14,311
1991-92	37,797	5.05	191,039	88%	10%	90%	15,130
1992-93	40,861	5.37	219,414	88%	10%	90%	17,378
1993-94	44,668	5.41	241,853	88%	10%	90%	19,155
1994-95	52,362	4.68	245,173	88%	10%	90%	19,418
1995-96	50,607	5.47	277,014	88%	10%	90%	21,940
1996-97	45,000	6.50	292,500	88%	10%	90%	23,166

1997-98	45,000	6.50	292,500	88%	10%	90%	23,166
1998-99	52,797	6.50	343,181	88%	10%	90%	27,180
1999-00	45,000	6.50	292,500	88%	10%	90%	23,166
2000-01	45,000	6.50	292,500	88%	10%	90%	23,166
2001-02	42,187	7.15	301,499	88%	10%	91%	24,144
2002-03	42,600	7.49	318,916	88%	10%	92%	25,819
2003-04	39,100	6.54	255,860	88%	10%	93%	20,940
2004-05	39,400	8.10	318,947	88%	10%	94%	26,383
2005-06	38,000	6.89	261,798	88%	10%	95%	21,886
2006-07	40,500	8.50	344,434	88%	10%	95%	28,795
2007-08	42,300	8.12	343,350	88%	10%	95%	28,704
2008-09	53,900	7.49	403,463	88%	10%	95%	33,730
2009-10	54,800	8.12	444,890	88%	11%	95%	40,912
2010-11	52,600	7.29	383,262	88%	12%	95%	38,449
2011-12	54,800	8.92	488,614	88%	13%	95%	53,103
2012-13	49,200	9.10	447,799	88%	14%	95%	52,410
2013-14	47,900	8.63	413,497	88%	15%	95%	51,853
2014-15	47,700	8.67	413,500	88%	16%	95%	55,310

Oats

The volume of oats eaten by dairy cows is small and has been reasonably constant over the last 25 years. Table 10 shows the use of oats as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry. **Table 10: Total oats eaten by dairy cows from 1990-91 to 2014-15[9, 10]**

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	14,790	3.87	57,187	89%	10%	85%	4,326
1991-92	14,033	4.11	57,625	89%	10%	85%	4,359
1992-93	14,179	4.01	56,793	89%	10%	85%	4,296
1993-94	12,947	4.46	57,718	89%	10%	85%	4,366
1994-95	10,063	3.85	38,735	89%	10%	85%	2,930
1995-96	10,094	4.08	41,217	89%	10%	85%	3,118
1996-97	10,000	4.00	40,000	89%	10%	85%	3,026
1997-98	10,000	4.00	40,000	89%	10%	85%	3,026
1998-99	9,929	4.00	39,716	89%	10%	85%	3,005
1999-00	8,750	4.00	35,000	89%	10%	85%	2,648
2000-01	8,750	4.00	35,000	89%	10%	85%	2,648
2001-02	7,353	4.76	34,986	89%	10%	85%	2,647
2002-03	5,900	5.07	29,934	89%	10%	85%	2,265
2003-04	7,500	4.11	30,844	89%	10%	85%	2,333
2004-05	7,900	3.63	28,714	89%	10%	85%	2,172

2005-06	6,300	4.52	28,478	89%	10%	85%	2,154
2006-07	5,800	4.75	27,531	89%	10%	85%	2,083
2007-08	5,200	4.90	25,463	89%	10%	85%	1,926
2008-09	7,400	4.55	33,703	89%	10%	85%	2,550
2009-10	8,900	5.35	47,608	89%	10%	85%	3,602
2010-11	6,100	4.67	28,466	89%	10%	85%	2,153
2011-12	3,900	4.65	18,118	89%	10%	85%	1,371
2012-13	5,400	5.23	28,225	89%	10%	85%	2,135
2013-14	6,700	5.19	34,741	89%	10%	85%	2,628
2014-15	6,400	5.25	33,569	89%	10%	85%	2,539

Cereal Whole Crop Silage

The number of hectares grown for cereal whole crop silage increased from early the 1990s to the early 2000s where the estimated peak was approximately 50,000 hectares. Since the mid-2000s, area sown for cereal whole crop silage has declined to levels less than in the early 1990s. Cereal whole crop silage eaten by dairy cows followed a similar trend with peak consumption occurring in 2006-07 with 120,000 t DM. Following this, levels declined, but not to levels below that of the early 1990s as a greater proportion of cereal whole crop silage was used as supplementary feed for dairy cows during this period. Table 11 shows the use of cereal whole crop silage as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 11: Total cereal whole crop silage eaten by dairy cows from 1990-91 to 2014-15[13]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	20,000	12.00	240,000	35%	60%	80%	40,320
1991-92	20,000	12.00	240,000	35%	60%	80%	40,320
1992-93	20,000	12.00	240,000	35%	60%	80%	40,320
1993-94	20,000	12.00	240,000	35%	60%	80%	40,320
1994-95	20,000	12.00	240,000	35%	60%	80%	40,320
1995-96	30,000	12.00	360,000	35%	60%	80%	60,480
1996-97	30,000	12.00	360,000	35%	60%	80%	60,480
1997-98	30,000	12.00	360,000	35%	60%	80%	60,480
1998-99	30,000	12.00	360,000	35%	60%	80%	60,480
1999-00	40,000	12.00	480,000	35%	60%	80%	80,640
2000-01	50,000	12.00	600,000	35%	70%	80%	117,600
2001-02	50,000	12.00	600,000	35%	70%	80%	117,600
2002-03	50,000	12.00	600,000	35%	70%	80%	117,600
2003-04	50,000	12.00	600,000	35%	70%	80%	117,600
2004-05	50,000	12.00	600,000	35%	70%	80%	117,600
2005-06	50,000	12.00	600,000	35%	70%	80%	117,600
2006-07	44,800	12.00	537,600	35%	80%	80%	120,422

[13] Plant & Food Research personal communication using Agricom data

2007-08	40,000	12.00	480,000	35%	80%	80%	107,520
2008-09	30,000	12.00	360,000	35%	80%	80%	80,640
2009-10	17,520	12.00	210,240	35%	80%	80%	47,094
2010-11	15,000	12.00	180,000	35%	80%	80%	40,320
2011-12	15,000	12.00	180,000	35%	80%	80%	40,320
2012-13	15,000	12.00	180,000	35%	80%	80%	40,320
2013-14	15,000	12.00	180,000	35%	80%	80%	40,320
2014-15	15,000	12.00	180,000	35%	80%	80%	40,320

Fodder Beet

The volume of fodder beet eaten by dairy cows has increased considerably in recent years, particularly due to increased use in the South Island. Table 12 shows the use of fodder beet as a supplementary feed from 199091 to 2014-15 after taking into account utilisation and the estimated proportion destined for the dairy industry.

Table 12: Total fodder beet eaten by dairy cows from 1990-91 to 2014-15[14, 15, 16, 17]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t DM)	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	50	18.00	900	10%	95%	86
1991-92	50	18.00	900	10%	95%	86
1992-93	50	18.00	900	10%	95%	86
1993-94	50	18.00	900	10%	95%	86
1994-95	50	18.00	900	10%	95%	86
1995-96	50	18.00	900	10%	95%	86
1996-97	50	18.00	900	10%	95%	86
1997-98	50	18.00	900	10%	95%	86
1998-99	50	18.00	900	10%	95%	86
1999-00	50	18.00	900	10%	95%	86
2000-01	50	18.00	900	10%	95%	86
2001-02	100	18.00	1,800	75%	95%	1,283
2002-03	100	18.00	1,800	75%	95%	1,283
2003-04	100	18.00	1,800	75%	95%	1,283
2004-05	100	18.00	1,800	75%	95%	1,283
2005-06	100	18.00	1,800	75%	95%	1,283
2006-07	100	18.00	1,800	75%	95%	1,283
2007-08	500	21.00	10,500	90%	95%	8,978
2008-09	1,000	21.00	21,000	90%	95%	17,955
2009-10	2,500	21.00	52,500	90%	95%	44,888
2010-11	5,000	21.00	105,000	90%	95%	89,775

[14] Gibbs, J., Saldias, B. & Trotter, C. (n.d.) Feeding Fodder beet in lactation and to replacement heifers.

[15] Matthew, C., Nelson, N.J., Ferguson, D. & Xie, Y. (2011). Fodder beet revisited.

[16] FAR personal contact, supplementary crops data

[17] Yield data obtained via personal contact at Lincoln University

2011-12	10,000	21.00	210,000	80%	95%	159,600
2012-13	20,000	21.00	420,000	80%	95%	319,200
2013-14	45,000	21.00	945,000	75%	95%	673,313
2014-15	50,000	21.00	1,050,000	70%	95%	698,250

Kale

The volume of kale eaten by dairy cows has increased steadily over the last 25 years. Table 13 shows the use of kale as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 13: Total kale eaten by dairy cows from 1990-91 to 2014-15[16]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	68,500	15.00	1,027,500	13%	40%	85%	45,416
1991-92	70,000	15.00	1,050,000	13%	41%	85%	46,990
1992-93	71,500	15.00	1,072,500	13%	41%	85%	48,590
1993-94	73,000	15.00	1,095,000	13%	42%	85%	50,214
1994-95	74,500	15.00	1,117,500	13%	42%	85%	51,863
1995-96	76,000	15.00	1,140,000	13%	43%	85%	53,537
1996-97	77,500	15.00	1,162,500	13%	43%	85%	55,236
1997-98	79,000	15.00	1,185,000	13%	44%	85%	56,960
1998-99	80,500	15.00	1,207,500	13%	44%	85%	58,709
1999-00	82,000	15.00	1,230,000	13%	45%	85%	60,482
2000-01	83,500	15.00	1,252,500	13%	45%	85%	62,281
2001-02	85,000	15.00	1,275,000	13%	46%	85%	64,104
2002-03	86,500	15.00	1,297,500	13%	46%	85%	65,952
2003-04	88,000	15.00	1,320,000	13%	47%	85%	67,825
2004-05	89,500	15.00	1,342,500	13%	47%	85%	69,278
2005-06	91,000	15.00	1,365,000	13%	47%	85%	70,740
2006-07	92,500	15.00	1,387,500	13%	47%	85%	72,213
2007-08	94,000	15.00	1,410,000	13%	47%	85%	73,696
2008-09	95,500	15.00	1,432,500	13%	48%	85%	75,188
2009-10	97,000	15.00	1,455,000	13%	48%	85%	76,691
2010-11	98,500	15.00	1,477,500	13%	48%	85%	78,203
2011-12	100,000	15.00	1,500,000	13%	48%	85%	79,726
2012-13	125,000	15.00	1,875,000	13%	48%	85%	100,072
2013-14	150,000	15.00	2,250,000	13%	49%	85%	120,583
2014-15	150,000	15.00	2,250,000	13%	49%	85%	121,080

Rape

The volume of rape eaten by dairy cows is small but has increased steadily over the last 25 years. Table 14 shows the use of rape as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry. **Table 14: Total Rape eaten by dairy cows from 1990-91 to 2014-15**[16]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	34,000	7.00	238,000	15%	10%	80%	2,856
1991-92	37,000	7.00	259,000	15%	10%	80%	3,108
1992-93	40,000	7.00	280,000	15%	10%	80%	3,360
1993-94	43,000	7.00	301,000	15%	10%	80%	3,612
1994-95	46,000	7.00	322,000	15%	10%	80%	3,864
1995-96	49,000	7.00	343,000	15%	10%	80%	4,116
1996-97	52,000	7.00	364,000	15%	10%	80%	4,368
1997-98	55,000	7.00	385,000	15%	10%	80%	4,620
1998-99	58,000	7.00	406,000	15%	10%	80%	4,872
1999-00	61,000	7.00	427,000	15%	10%	80%	5,124
2000-01	63,000	7.00	441,000	15%	10%	80%	5,292
2001-02	65,000	7.00	455,000	15%	10%	80%	5,460
2002-03	67,000	7.00	469,000	15%	10%	80%	5,628
2003-04	69,000	7.00	483,000	15%	10%	80%	5,796
2004-05	71,000	7.00	497,000	15%	10%	80%	5,964
2005-06	73,000	7.00	511,000	15%	10%	80%	6,132
2006-07	75,000	7.00	525,000	15%	10%	80%	6,300
2007-08	77,000	7.00	539,000	15%	10%	80%	6,468
2008-09	79,000	7.00	553,000	15%	10%	80%	6,636
2009-10	81,000	7.00	567,000	15%	10%	80%	6,804
2010-11	83,000	7.00	581,000	15%	10%	80%	6,972
2011-12	85,000	7.00	595,000	15%	10%	80%	7,140
2012-13	100,000	7.00	700,000	15%	10%	80%	8,400
2013-14	130,000	7.00	910,000	15%	10%	80%	10,920
2014-15	130,000	7.00	910,000	15%	10%	80%	10,920

Turnips

The volume of turnips eaten by dairy cows has been reasonably steady over the last 25 years. Table 15 shows the use of turnips as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry. **Table 15: Total turnips eaten by dairy cows from 1990-91 to 2014-15**[18]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)

[18] PGG Wrightson personal communication, seed data

1990-91	47,200	10.00	472,000	10%	40%	85%	16,048
1991-92	47,400	10.00	474,000	10%	40%	85%	16,116
1992-93	47,600	10.00	476,000	10%	40%	85%	16,184
1993-94	47,800	10.00	478,000	10%	40%	85%	16,252
1994-95	48,000	10.00	480,000	10%	40%	85%	16,320
1995-96	48,200	10.00	482,000	10%	40%	85%	16,388
1996-97	48,400	10.00	484,000	10%	40%	85%	16,456
1997-98	48,600	10.00	486,000	10%	40%	85%	16,524
1998-99	48,800	10.00	488,000	10%	40%	85%	16,592
1999-00	49,000	10.00	490,000	10%	40%	85%	16,660
2000-01	49,500	10.00	495,000	10%	40%	85%	16,830
2001-02	50,000	10.00	500,000	10%	40%	85%	17,000
2002-03	50,500	10.00	505,000	10%	40%	85%	17,170
2003-04	51,000	10.00	510,000	10%	40%	85%	17,340
2004-05	51,500	10.00	515,000	10%	40%	85%	17,510
2005-06	52,000	10.00	520,000	10%	40%	85%	17,680
2006-07	52,500	10.00	525,000	10%	40%	85%	17,850
2007-08	53,000	10.00	530,000	10%	40%	85%	18,020
2008-09	53,500	10.00	535,000	10%	40%	85%	18,190
2009-10	54,000	10.00	540,000	10%	40%	85%	18,360
2010-11	55,000	10.00	550,000	10%	40%	85%	18,700
2011-12	56,000	10.00	560,000	10%	40%	85%	19,040
2012-13	57,000	10.00	570,000	10%	40%	85%	19,380
2013-14	65,000	10.00	650,000	10%	40%	85%	22,100
2014-15	60,000	10.00	600,000	10%	40%	85%	20,400

Swedes

The volumes of swedes eaten by dairy cows has increased over the last 25 years as a larger proportion of national harvest volumes are thought to have gone to dairy, although volumes eaten declined in 2014-15 due to animal health issues. Table 16 shows the use of swedes as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 16: Total swedes eaten by dairy cows from 1990-91 to 2014-15[18]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	100,000	14.00	1,400,000	11%	13%	80%	15,400
1991-92	100,000	14.00	1,400,000	11%	15%	80%	17,864
1992-93	100,000	14.00	1,400,000	11%	17%	80%	20,328
1993-94	100,000	14.00	1,400,000	11%	19%	80%	22,792
1994-95	100,000	14.00	1,400,000	11%	21%	80%	25,256
1995-96	100,000	14.00	1,400,000	11%	23%	80%	27,720

1996-97	100,000	14.00	1,400,000	11%	25%	80%	30,184
1997-98	100,000	14.00	1,400,000	11%	26%	80%	32,032
1998-99	100,000	14.00	1,400,000	11%	28%	80%	33,880
1999-00	100,000	14.00	1,400,000	11%	29%	80%	35,728
2000-01	100,000	14.00	1,400,000	11%	31%	80%	37,576
2001-02	100,000	14.00	1,400,000	11%	32%	80%	39,424
2002-03	100,000	14.00	1,400,000	11%	34%	80%	41,272
2003-04	100,000	14.00	1,400,000	11%	35%	80%	43,120
2004-05	100,000	14.00	1,400,000	11%	37%	80%	44,968
2005-06	100,000	14.00	1,400,000	11%	38%	80%	46,816
2006-07	100,000	14.00	1,400,000	11%	40%	80%	48,664
2007-08	101,000	14.00	1,414,000	11%	41%	80%	51,017
2008-09	103,000	14.00	1,442,000	11%	43%	80%	53,931
2009-10	105,000	14.00	1,470,000	11%	44%	80%	56,918
2010-11	107,000	14.00	1,498,000	11%	46%	80%	59,980
2011-12	109,000	14.00	1,526,000	11%	47%	80%	63,115
2012-13	111,000	14.00	1,554,000	11%	49%	80%	66,325
2013-14	125,000	14.00	1,750,000	11%	50%	80%	77,000
2014-15	93,000	14.00	1,302,000	11%	40%	80%	45,830

Other Brassicas

The volume of other brassicas eaten by dairy cows is small but has increased considerably over the last 25 years. Table 17 shows the use of other brassicas as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 17: Total other brassicas eaten by dairy cows from 1990-91 to 2014-15[18]

Season	Area Sown (hectares)	Yield (tonnes per hectare)	Total Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	26,000	12.00	312,000	15%	10%	80%	3,744
1991-92	30,000	12.00	360,000	15%	10%	80%	4,320
1992-93	34,000	12.00	408,000	15%	10%	80%	4,896
1993-94	38,000	12.00	456,000	15%	10%	80%	5,472
1994-95	42,000	12.00	504,000	15%	10%	80%	6,048
1995-96	46,000	12.00	552,000	15%	10%	80%	6,624
1996-97	50,000	12.00	600,000	15%	10%	80%	7,200
1997-98	54,000	12.00	648,000	15%	10%	80%	7,776
1998-99	58,000	12.00	696,000	15%	10%	80%	8,352
1999-00	62,000	12.00	744,000	15%	10%	80%	8,928
2000-01	66,000	12.00	792,000	15%	10%	80%	9,504
2001-02	68,000	12.00	816,000	15%	10%	80%	9,792
2002-03	70,000	12.00	840,000	15%	10%	80%	10,080

2003-04	72,000	12.00	864,000	15%	10%	80%	10,368
2004-05	74,000	12.00	888,000	15%	10%	80%	10,656
2005-06	76,000	12.00	912,000	15%	10%	80%	10,944
2006-07	78,000	12.00	936,000	15%	10%	80%	11,232
2007-08	80,000	12.00	960,000	15%	10%	80%	11,520
2008-09	82,000	12.00	984,000	15%	10%	80%	11,808
2009-10	84,000	12.00	1,008,000	15%	10%	80%	12,096
2010-11	86,000	12.00	1,032,000	15%	10%	80%	12,384
2011-12	88,000	12.00	1,056,000	15%	10%	80%	12,672
2012-13	90,000	12.00	1,080,000	15%	10%	80%	12,960
2013-14	92,000	12.00	1,104,000	15%	10%	80%	13,248
2014-15	90,000	12.00	1,080,000	15%	10%	80%	12,960

Brewer's Grain

The volume of brewer's grain eaten by dairy cows has been reasonably constant over the last 25 years, following beer production which has been steady. Table 18 shows the use of brewer's grain as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 18: Total brewer's grain eaten by dairy cows from 1990-91 to 2014-15[19]

Season	Volume (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	32,500	23%	75%	90%	5,046
1991-92	32,500	23%	75%	90%	5,046
1992-93	32,500	23%	75%	90%	5,046
1993-94	32,500	23%	75%	90%	5,046
1994-95	32,500	23%	75%	90%	5,046
1995-96	32,500	23%	75%	90%	5,046
1996-97	32,536	23%	75%	90%	5,051
1997-98	32,515	23%	75%	90%	5,048
1998-99	32,671	23%	75%	90%	5,072
1999-00	31,506	23%	75%	90%	4,891
2000-01	31,582	23%	75%	90%	4,903
2001-02	32,419	23%	75%	90%	5,033
2002-03	32,315	23%	75%	90%	5,017
2003-04	32,256	23%	75%	90%	5,008
2004-05	32,563	23%	75%	90%	5,055
2005-06	31,906	23%	75%	90%	4,953
2006-07	32,186	23%	75%	90%	4,997

[19] James and Son personal communication, volumes supplied data

2007-08	33,246	23%	75%	90%	5,162
2008-09	31,565	23%	75%	90%	4,900
2009-10	30,861	23%	75%	90%	4,791
2010-11	30,907	23%	75%	90%	4,798
2011-12	28,859	23%	75%	90%	4,480
2012-13	29,774	23%	75%	90%	4,622
2013-14	29,000	23%	75%	90%	4,502
2014-15	29,000	23%	75%	90%	4,502

Tapioca

The volume of tapioca eaten by dairy cows is small but has increased over the last 25 years with its use in blended feeds also comprising PKE. Table 19 shows the use of tapioca as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 19: Total tapioca eaten by dairy cows from 1990-91 to 2014-15[20]

Season	Volume Imported (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	130	88%	10%	95%	11
1991-92	90	88%	10%	95%	8
1992-93	126	88%	10%	95%	11
1993-94	232	88%	10%	95%	19
1994-95	384	88%	10%	95%	32
1995-96	194	88%	10%	95%	16
1996-97	178	88%	10%	95%	15
1997-98	208	88%	10%	95%	17
1998-99	222	88%	12%	95%	22
1999-00	356	88%	14%	95%	42
2000-01	489	88%	16%	95%	65
2001-02	620	88%	18%	95%	93
2002-03	418	88%	20%	95%	70
2003-04	617	88%	30%	95%	155
2004-05	1,220	88%	50%	95%	510
2005-06	2,406	88%	55%	95%	1,107
2006-07	2,510	88%	60%	95%	1,259
2007-08	10,797	88%	90%	95%	8,124
2008-09	3,236	88%	60%	95%	1,623

[20] Statistics NZ Infoshare, Harmonised Trade- Imports. Food preparations; tapioca and substitutes therefor, prepared from starch, in the form of flakes, grains, pearls, siftings or similar (1990-2015 Annual-June).

2009-10	4,675	88%	65%	95%	2,541
2010-11	6,425	88%	70%	95%	3,760
2011-12	3,950	88%	75%	95%	2,477
2012-13	3,720	88%	80%	95%	2,488
2013-14	6,813	88%	80%	95%	4,557
2014-15	3,449	88%	80%	95%	2,307

Soyabean Meal

The volume of soyabean meal eaten by dairy cows is small relative to other supplement types but showed a reasonable increase during the mid-2000s and remained at this level since. Table 20 shows the use of soyabean meal as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 20: Total soyabean meal eaten by dairy cows from 1990-91 to 2014-15[21]

Season	Volume Imported (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	1,722	90%	10%	95%	147
1991-92	4,259	90%	10%	95%	364
1992-93	12,930	90%	10%	95%	1,105
1993-94	9,002	90%	10%	95%	770
1994-95	22,164	90%	10%	95%	1,895
1995-96	164	90%	10%	95%	14
1996-97	5,329	90%	10%	95%	456
1997-98	53,077	90%	10%	95%	4,538
1998-99	32,664	90%	10%	95%	2,793
1999-00	57,107	90%	10%	95%	4,883
2000-01	42,567	90%	10%	95%	3,639
2001-02	59,340	90%	10%	95%	5,074
2002-03	63,277	90%	10%	95%	5,410
2003-04	75,349	90%	10%	95%	6,442
2004-05	69,066	90%	10%	95%	5,905
2005-06	106,709	90%	10%	95%	9,124
2006-07	40,360	90%	10%	95%	3,451
2007-08	134,782	90%	10%	95%	11,524
2008-09	146,994	90%	10%	95%	12,568
2009-10	91,740	90%	10%	95%	7,844
2010-11	124,904	90%	10%	95%	10,679

[21] Statistics NZ Infoshare, Harmonised Trade- Imports. Oil-cake and other solid residues; whether or not ground or in the form of pellets, resulting from the extraction of soya-bean oil (1990-2015 Annual-June).

2011-12	134,858	90%	10%	95%	11,530
2012-13	138,100	90%	10%	95%	11,808
2013-14	193,844	90%	10%	95%	16,574
2014-15	219,256	90%	10%	95%	18,746

Cottonseed

The volume of cottonseed eaten by dairy cows is also small, with quantities increasing to more significant levels from 2010-11. Table 21 shows the use of cottonseed as a supplementary feed from 1990-91 to 2014-15 after taking into account dry matter percentage, utilisation and the estimated proportion destined for the dairy industry.

Table 21: Total cottonseed eaten by dairy cows from 1990-91 to 2014-15[22]

Season	Volume Imported (t)	Dry Matter %	% used for Dairy	Utilisation %	Feed Eaten by Dairy Cows (t DM)
1990-91	1	80%	95%	90%	1
1991-92	-	80%	95%	90%	-
1992-93	-	80%	95%	90%	-
1993-94	20	80%	95%	90%	14
1994-95	-	80%	95%	90%	-
1995-96	1	80%	95%	90%	1
1996-97	5	80%	95%	90%	3
1997-98	97	80%	95%	90%	67
1998-99	629	80%	95%	90%	430
1999-00	1	80%	95%	90%	1
2000-01	2	80%	95%	90%	2
2001-02	1,136	80%	95%	90%	777
2002-03	193	80%	95%	90%	132
2003-04	42	80%	95%	90%	28
2004-05	18	80%	95%	90%	12
2005-06	0	80%	95%	90%	0
2006-07	-	80%	95%	90%	-
2007-08	-	80%	95%	90%	-
2008-09	33	80%	95%	90%	23
2009-10	17	80%	95%	90%	12
2010-11	14,145	80%	95%	90%	9,675
2011-12	13,321	80%	95%	90%	9,112
2012-13	28,557	80%	95%	90%	19,533

[22] Statistics NZ Infoshare, Harmonised Trade- Imports. Oil-cake and other solid residues; whether or not ground or in the form of pellets, resulting from the extraction of cotton seed oils (1990-2015 Annual-June).

2013-14	22,347	80%	95%	90%	15,285
2014-15	19,296	80%	95%	90%	13,199

Other Supplements

Given the considerable variation in supplementary feed types offered to dairy cows, not all non-pasture feed types could be accurately recorded in the National Statistical Approach. Total supplements eaten derived in the Farm Data Approach (harvested and imported as shown in Table 3) using DairyBase benchmarking reports was compared to the sum of all individual supplement types (excluding crops) recorded in the National Statistical Approach. Total supplements eaten from the Farm Data Approach exceeded the sum of all individual supplements types (excluding crops) recorded in the National Statistical Approach, with the difference attributable to those feed types not captured in the National Statistical Approach. The difference was termed 'other supplements'. Table 22 below compares total supplements (harvested and imported) eaten from the Farm Data Approach to the sum of all individual supplement types (excluding crops) recorded in the National Statistical Approach to give 'other supplements'. Supplementary feeds that have not been captured and comprise 'other supplements' include molasses, proliq, imported grains, fishmeal, horticultural by-products such as vegetables and fruit and any other feed type fed to dairy cows.

Table 22: Other supplements derived as a residual from 1990-91 to 2014-15

Season	Total Supplements Eaten t DM (Farm Data Approach)	Total Supplements (excluding Crops) t DM (National Statistical Approach)	Other Supplements t DM
1990-91	312,279	207,742	104,537
1991-92	348,726	198,747	149,979
1992-93	406,076	206,840	199,236
1993-94	462,460	201,562	260,898
1994-95	515,238	233,494	281,744
1995-96	572,473	301,119	271,354
1996-97	637,421	286,960	350,461
1997-98	712,193	325,789	386,404
1998-99	769,701	392,346	377,354
1999-00	807,532	455,366	352,167
2000-01	906,330	542,369	363,961
2001-02	1,008,108	629,741	378,367
2002-03	1,069,822	708,550	361,272
2003-04	1,151,539	804,361	347,178
2004-05	1,206,710	929,281	277,429
2005-06	1,245,447	1,054,443	191,004
2006-07	1,416,411	1,419,753	172,915
2007-08	2,325,789	2,046,267	480,165
2008-09	2,105,419	2,065,431	252,632
2009-10	2,032,544	1,806,327	226,216

2010-11	2,638,317	2,154,132	484,184
2011-12	2,851,070	2,210,897	640,173
2012-13	3,153,503	2,384,528	768,974
2013-14	3,535,916	2,987,998	547,918
2014-15	3,544,697	3,057,462	487,235

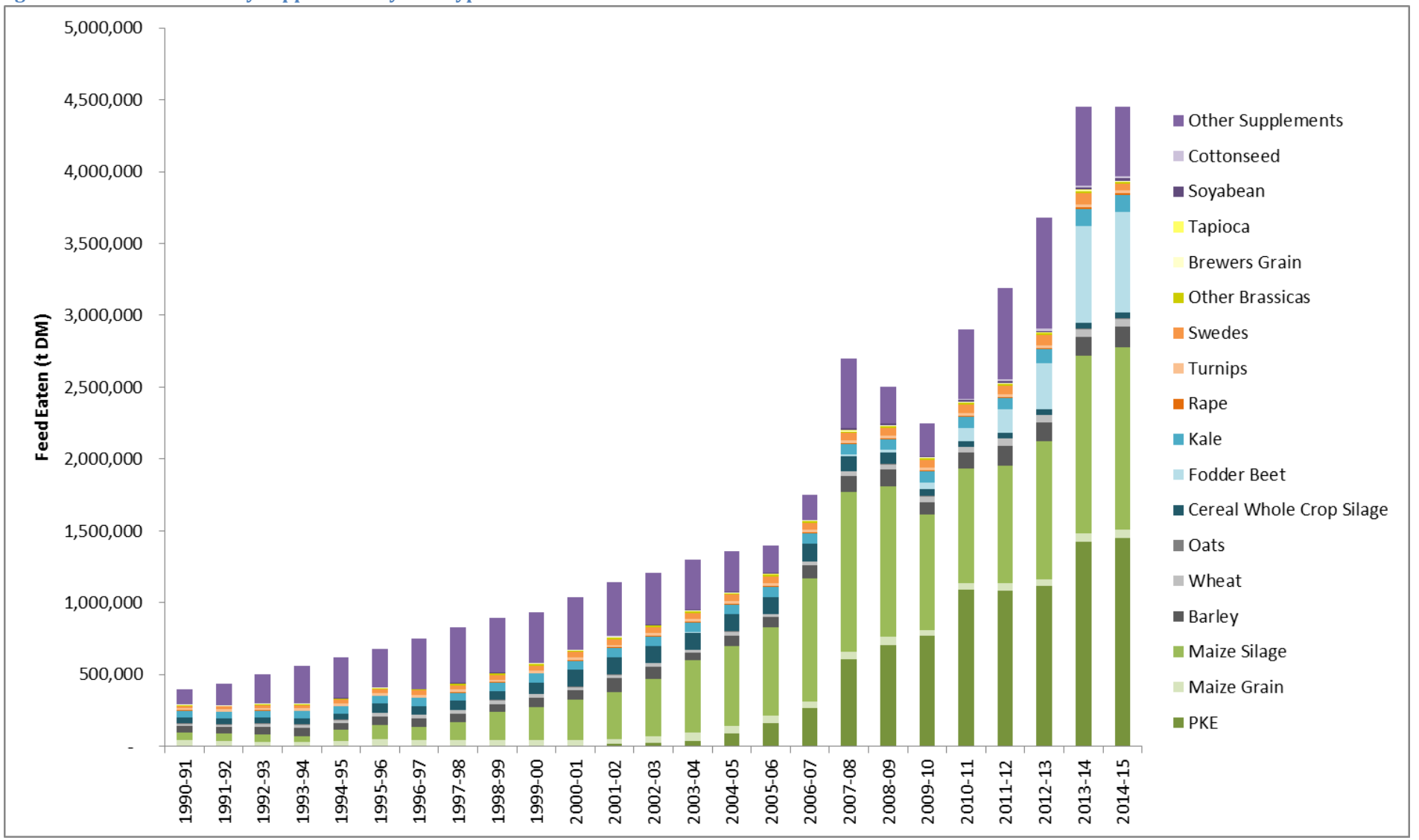
Source: DairyNZ Economics Group

Total Supplements from National Statistical Approach

Total feed eaten by supplementary feed type over the last 25 years is shown in Figure 9. It illustrates the increase in non-pasture feeding to dairy cows as well as showing the trends for each feed type over this period.

Figures 10, 11 and 12 show the division of supplementary feed eaten by type for seasons 1990-91, 2002-03 and 2014-15 respectively. The growth of PKE and maize silage as a proportion of total supplementary feed eaten is evident with maize silage comprising 42 per cent in 2002-03 and PKE comprising 36 per cent in 2014-15.

Figure 9: Total feed eaten by supplementary feed type from 1990-91 to 2014-15



Source: DairyNZ Economics Group

Figure 10: Total feed eaten by supplementary feed type in 1990-91

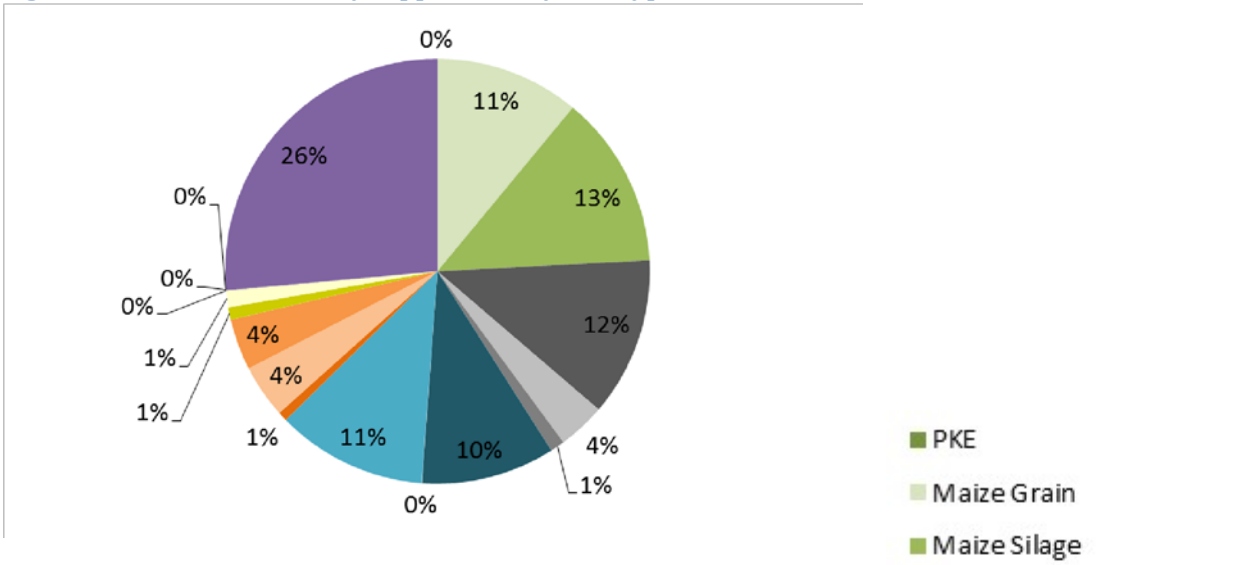


Figure 11: Total feed eaten by supplementary feed type in 2002-03

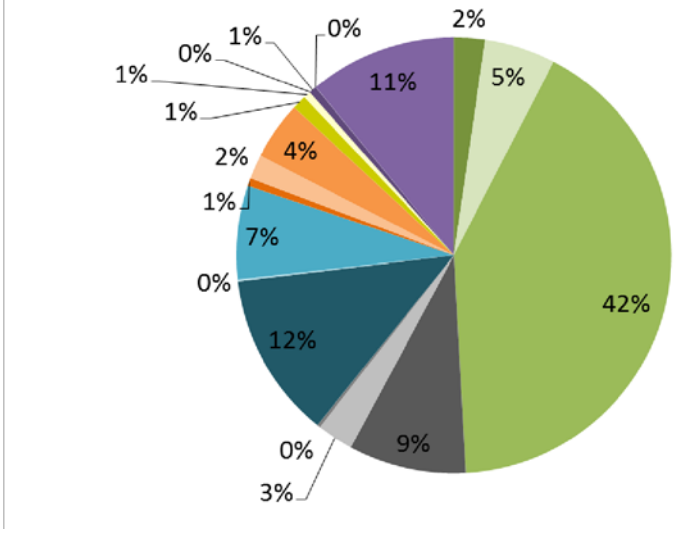
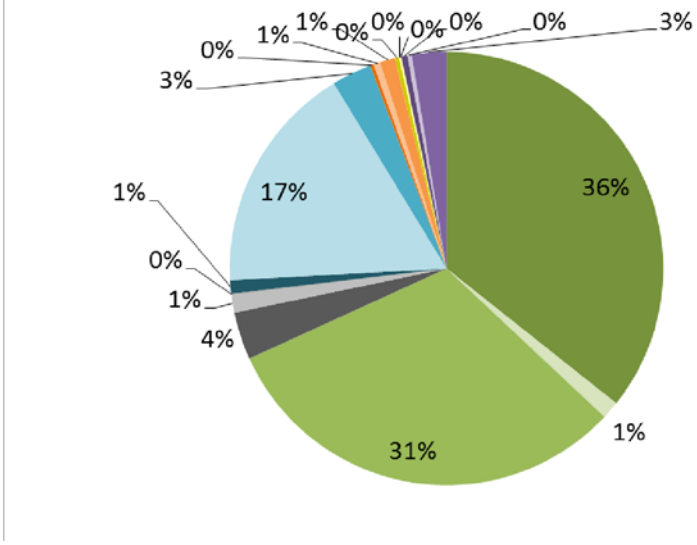


Figure 12: Total feed eaten by supplementary feed type in 2014-15



Source: DairyNZ Economics Group

Characteristics of Non-pasture Feeds

New Zealand dairy farms show considerable variation in the types of supplementary feeds used and this is reflected in different characteristics for each. The method of feeding has a significant impact on the utilisation percentage for a particular feed type. Collecting information regarding the most common method of feeding was done through discussion with industry professionals. This was used as a basis for determining appropriate utilisation percentages for each feed type. For feed types fed in shed, barns or in bins (concentrates such as PKE, maize grain, barley, wheat, oats, brewer's grain, tapioca, soyabean meal and cottonseed meal), the wastage was assumed to be low and were allocated high utilisation percentages. For the remaining feed types grazed in situ or harvested and fed in paddock (silages and crops such as maize silage, cereal whole crop silage, fodder beet, kale, rape, turnips, swedes and other brassicas), lower utilisation percentages were applied due to a higher level of wastage associated with feeding. For specific utilisation percentages for each feed, refer to Tables 5 to 21. Metabolisable energy and crude protein values were also sourced from the *DairyNZ Facts and Figures* publication for the majority of feed types, although rape, other brassicas and cottonseed meal were unpublished and were therefore omitted from Table 23. For each feed type, crude protein values were used to back calculate nitrogen content (g/kg DM) by following recognised industry practice and dividing crude protein as a percentage of dry matter weight by 6.25.

Table 23 below provides a summary of the characteristics for each non-pasture feed type, including metabolisable energy, crude protein and nitrogen content.

Table 23: Summary of the characteristics of each non-pasture feed type[4]

Supplement Type	Metabolisable Energy (ME MJ /kg DM)	Crude Protein (% of DM)	Nitrogen Content (g/kg DM)
PKE	11.0-11.5	14.00	2.24
Maize Grain	13.50	8.00	1.28
Maize Silage	10.8-11.0	8.00	1.28
Barley Grain	12.50	11.0-12.0	1.84
Wheat Grain	13.0-13.5	13.00	2.08
Oats	11.50	13.00	2.08
Cereal Whole Crop Silage	9.0-10.5	8.0-9.0	1.36
Fodder Beet	12.0-12.5	9.0-14.0	1.84
Kale	11.0-13.5	12.0-18.0	2.40
Turnips	12.00	12.0-18.0	2.40
Swedes	11.0-12.5	12.0-20.0	2.56
Brewers Grain	10.50	20.0-25.0	3.60
Tapioca	12.50	3.00	0.48
Soyabean Meal	12.50	47.0-53.0	8.00

Source: DairyNZ Facts and Figures, 2010

Forecast Methodology

This section describes the methodology used to forecast the scale and level of milksolids production of the New Zealand dairy industry from 2015-16 to 2030-31. There are two growth forecast scenarios; modest growth and

high growth, with the high growth scenario driven from two different feed pathways, increased supplementary feed and increased pasture and crop eaten. All scenarios assume the number of milking platform effective hectares increase slowly, but at the same rate i.e. all forecast scenarios have the same hectares assumed for each season. A base scenario for modest milk production growth is driven by increased pasture and grown crops consumed by dairy cows with two possibilities for stocking rates, one holding at current levels and a second reducing in light of environmental regulations and the possibility of more young stock and cows being wintered on the milking platform. Figure 13 below describes the four forecast scenarios.

Figure 13: Forecast scenarios summary

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Milksolids Growth	Modest (+0.8% CAGR)	Modest (+0.8% CAGR)	High (+1.7% CAGR)	High (+1.7% CAGR)
Stocking Rate (cows/ha)	Hold (2.8)	↓ (2.65)	↑ (3.0)	↑ (3.0)
Milksolids per cow	↑ (+1.9 kg MS/cow/year)	↑ (+3.7 kg MS/cow/year)	↑ (+2.8 kg MS/cow/year)	↑ (+2.8 kg MS/cow/year)
Total Feed Eaten per hectare	↑ (+0.5 t DM/ha)	↑ (+0.2 t DM/ha)	↑ (+1.8 t DM/ha)	↑ (+1.8 t DM/ha)
Pasture Eaten (t DM)	↑	↑	↑	↑
Crops Eaten (t DM)	↑	↑	↑	↑
Harvested Supplements Eaten (t DM)	↓	↓	↑	↓
Imported Supplements Eaten (t DM)	↓	↓	↑	↓

The national forecasts are a product of regional models, where herd numbers, effective hectares, stocking rates and milksolids per cow are all estimated. The model is founded on a series of three-way validations for two variables (detail below). The base data is 2014-15, but manual estimates are applied for 2015-16 and 2016-17. Regressions are then applied for the period 2017-18 to 2020-21 and then each five year period thereafter.

Effective dairy hectares were the first to be estimated using regional annual rates of change (either an increase or decrease) for each five year period. In determining the effective dairy hectares, consideration was given to actual land availability, pressures from alternative land use (both agricultural and non-agricultural), existing environmental pressures, and historical changes in dairy land use as well as the assumptions applied (refer to Forecast Assumptions section). However, in doing this no attempt was made to balance the area used for agricultural or total land use.

Stocking rate was then estimated, again using regional rates of change, to reflect the expected level of intensification (or de-intensification). Consideration has been given to changes in infrastructure that support intensified systems (both within and outside the farm gate), existing environmental pressures, changes in managerial ability that allow better balancing of feed demand and supply and the assumptions applied.

The resulting change in cow numbers (i.e. stocking rate x effective hectares) was then validated on the basis that such an increase (if applicable) was realistically achievable, and consistent with historical seasons.

Having established the cows and hectares, the next stage was to apply a productive potential to these resources. In order to derive total milksolids production, kilograms milksolids per cow was deemed to be the most appropriate variable to estimate. This removed the impact of off-farm grazing, and other intensification not associated with the effective milking platform, which could potentially be introduced using kilograms milksolids per hectare.

Although variable across the regions, a linear kilograms milksolids per cow increase has been applied through the long range projection. This reflects constant technological gains (including animal and plant genetic improvement) and constant increases in managerial ability expected over time. While technological

developments are likely to cause step-wise improvements to production, the purpose of this projection is to provide gradual long-term predictions.

The 'typical' climate and natural environment have an obvious impact on the ability to generate production. Farmer attitudes to risk also influence future production gains. For example, through choice of production system, pasture management, dealing with climatic events e.g. dry spells, labour management and levels of borrowing.

Forecast Assumptions

All forecasts require a series of assumptions to be set for the variables that can potentially impact the outcomes. For a projection of a long-term nature, such as contained in this paper, there are many assumptions required and therefore the results are more a projection of change rather than absolute numbers. As the future is uncertain we have provided four different scenarios to demonstrate a range of possible outcomes, but there are many more that could be considered.

The following have been identified as factors that could critically influence future cow numbers, effective dairy hectares and milk production:

- Commodity prices: while prices are at very low levels, we assume the medium and long term outlooks are positive and that milk prices over the next 15 years will average only slightly below those of the last 10-15 years. Whole Milk Powder (WMP) prices are projected to sustain a long-term average within a range of US$2,500 and US$2,800 per tonne WMP. We have not attempted to forecast volatility or year to year fluctuations in commodity prices.
- Commodity prices for competing land uses (sheep, beef and deer, horticulture and arable) are currently quite strong. Given the predictions for dairy, it is assumed the gap has closed, but dairy will continue to be the leader in farm profitability in the medium to long term.
- Milk Prices: it is assumed that the average dairy industry payout sustains a long-term average (within a range of $5 and $7) of around $5.80 per kilogram milksolids. This is $0.5/kg MS lower than the average of the last decade. However, volatility is not estimated.
- Trade conditions: it is assumed that 'free' markets prevail in their current state (i.e. contains some degree of EU and US protectionism). Removal of EU quotas has led to increased production, and oversupply on world markets, but this is expected to only exist in the short term. However, we do not see the Russian market being opened for the importation of Western dairy products.
- Population growth: it is assumed that population growth continues at current projections (a positive, but diminishing rate of growth), so too does the demand for dairy and protein-based foods.
- Bio-security: it is assumed that New Zealand remains free of any major plant or animal bio-security breach that could significantly impact milk supply. This includes no further incursions of Velvetleaf.
- PKE: it is assumed PKE will continue to be available for New Zealand to import. Different scenarios are run where the volumes of imported PKE decrease, hold at current levels and increase over the next 15 years.
- Government regulation: it is assumed that the New Zealand government (central) remain status quo. In particular, it assumes no Emissions Trading Scheme (or similar equivalent for Greenhouse gases) legislation is implemented for agriculture.
- Environmental regulation: regional councils around the country are taking different approaches to implementing catchment limits and regulations to protect and improve freshwater quality. We have

taken this into consideration when thinking about future growth and mitigations farms may need to take in different regions over the next 15 years.

- Water: it is assumed that current water availability (for stock and shed) remains status quo. For irrigation, assumptions were made for likely future irrigation schemes, particularly for Canterbury, Otago and Hawke's Bay. These form much of the additional hectares available for conversion to dairy, with most of the irrigation schemes having their own environmental requirements.
- Climate: it is assumed that each season is subject to 'typical' climatic conditions and is exclusive of any significant climate change. Further, it assumes no force majeure events, e.g. natural disaster.
- Cows: it is assumed that current genetic direction is maintained. Cow numbers in the projections refer to only 2 year old animals or older. Young stock are excluded, but an assumption of around 20 per cent replacement rates could be fairly assumed and held constant for the forecast horizon.
- Cow liveweights: liveweights are assumed to hold constant at 470 kilograms per cow for all scenarios, these weights reflect the average liveweight for a New Zealand dairy cow weighted by age and breed category over the last 25 years.
- Intensification: it is assumed that farm systems are close to or have reached their maximum intensity. It is believed that the current low milk prices and environmental regulations in the next 10 to 15 years will see more focus on home-grown feed, including the use of fertiliser, with similar or even less use of supplementary feeds. However, this does not necessarily mean less milk production. A second option assuming further intensification with higher stocking rates, and higher per cow milk production was also developed in order to test the likely range. Stocking rates in the various forecast scenarios range between 2.65 and 3.00 cows per hectare by 2030-31.

Forecast Feed Demand

Having developed predictions for the possible future size of the industry and milksolids production, feed demand is calculated based on expected average liveweight per cow and average milksolids production per cow. For both the modest and high growth forecast scenarios, liveweights are held constant on the basis that there will be more Friesian-Jersey crossbred cows with less Holstein-Friesian cows and a higher level of milksolids production per cow, but will be offset by an increase in feed consumed.

Feed demand per cow is derived in the same way it was estimated for the historical data. That is, a regression equation[5] was developed based on liveweights and milksolids per cow to determine the feed demand requirements per cow to achieve the forecast level of production. The base feed demand requirement is sourced from the *DairyNZ Facts and Figures* publication. Feed conversion efficiency is calculated and used as a further check that the feed demand is sensible.

Multiple assumptions under different scenarios are then made as to the likely split of feed use between the different types (pasture, grown crops, harvested supplement and imported supplement) to predict future trends and estimate the proportions of feeds consumed by dairy cows to 2030-31. This process takes into consideration the possible future availability of supplement types due to environmental issues as well as assumptions around milk price, feed costs, land use change in New Zealand and future dairy farm systems. The overall approach to these forecasts was developed and discussed by a number of farm systems and feed experts at DairyNZ and the likely future directions of various crops and supplementary feeds was discussed with feed experts (usually commercial sales people or technical researchers).

Given the uncertainties the future hold, the majority of forecasts at the individual feed level are applied in a linear fashion. This means the actual movement and quantities of individual feeds between years is a lot less

reliable than the actual projection of change and the levels in 2030-31. The impacts of milk prices, feed prices, seasonal weather variations, future regional environmental policy and/or any biosecurity/animal health issues from planting and feeding different feeds, along with changes in farm systems and management will have the largest impact on the mix of feeds consumed by dairy cows. It is important to note that while pasture is and will continue to be the largest feed consumed by New Zealand dairy cows, they eat quite a mix of feeds and this varies considerably regionally, seasonally and individually based on system type, availability of feeds, farmer preferences and nutritional requirements.

Forecast Results

The results and assumptions for each of the two milksolids growth forecast scenarios are discussed below. Additional hectares in dairy are assumed, but these are kept at the same level for all the forecasts scenarios. The modest growth scenario assumes total milksolids production grows at a rate of 0.8 per cent CAGR to 203031. The higher growth scenario assumes total milk production grows twice (+1.7% CAGR) as fast as the modest growth scenario. Differences in stocking rates and milksolids per cow drive the forecast scenarios.

Modest Growth Forecast Scenario 1

The key assumption for this modest growth scenario is that stocking rates will remain largely unchanged over the next 15 years at around 2.8 cows per hectare. This determines that cow numbers will only increase slightly from current levels to 5.15 million by 2030-31. On this basis, milksolids per cow increases at a rate of 1.9 kilograms per year. This growth rate is slightly less than half the milksolids per cow growth rate experienced between 2000-01 and 2014-15.

Feed demand based on this modest growth forecast scenario, would increase slowly from 4.97 tonnes per cow in 2015-16 to 5.15 tonnes per cow in 2030-31. This is based on the assumption that livestock weights remain constant at 470 kilograms per cow throughout the period. When stocking rates are considered, the growth in feed eaten per hectare increases 0.5 tonne per hectare to 14.4 tonne dry matter per hectare by 2030-31. The lift in future production is primarily from increased feed, although FCE improves slightly from 13.1 kg DM/ kg MS to 12.8. Once again this is expected to be at a much slower rate of FCE improvement over the next 15 years compared with the last 15 years, based on the large change in feed systems including the development and use of feeding infrastructures such as feed pads, in-shed feeding and barns and an improvement in days in milk.

Table 24 provides a summary of the modest growth forecast scenario 1 including expected cow numbers, effective hectares, milksolids production and derived total feed demand.

Table 24: Modest Growth Forecast Scenario 1 Summary Statistics

Season	Cow numbers	Effective area (hectares)	Stocking Rate (cows/ha)	Total Milksolids (kg)	MS/cow	MS/ha	Liveweight (kg)	Feed Demand (t DM/cow/year)	Feed Demand (t DM/ha/year)	Feed Demand (t DM/year)	FCE (kg DM/ kg MS)	FCE (kg MS/ t DM)	MS % of Liveweight
2015-16	4,909,181	1,752,306	2.80	1,858,967,300	379	1,061	470	4.97	13.92	24,388,594	13.12	76.22	80.6%
2016-17	4,892,372	1,751,056	2.79	1,843,001,227	377	1,053	470	4.95	13.84	24,233,519	13.15	76.05	80.2%
2017-18	4,917,615	1,757,006	2.80	1,862,832,425	379	1,060	470	4.97	13.91	24,435,497	13.12	76.23	80.6%
2018-19	4,942,793	1,762,956	2.80	1,882,739,122	381	1,068	470	4.98	13.98	24,637,851	13.09	76.42	81.0%
2019-20	4,967,908	1,768,906	2.81	1,902,720,934	383	1,076	470	5.00	14.04	24,840,577	13.06	76.60	81.5%
2020-21	4,992,958	1,774,856	2.81	1,922,777,477	385	1,083	470	5.02	14.11	25,043,672	13.02	76.78	81.9%
2021-22	5,023,712	1,784,406	2.82	1,945,185,234	387	1,090	470	5.03	14.17	25,276,474	12.99	76.96	82.4%
2022-23	5,057,979	1,795,206	2.82	1,968,984,708	389	1,097	470	5.05	14.22	25,527,136	12.96	77.13	82.8%
2023-24	5,092,247	1,806,006	2.82	1,992,918,431	391	1,103	470	5.06	14.27	25,778,749	12.94	77.31	83.3%
2024-25	5,126,516	1,816,806	2.82	2,016,986,411	393	1,110	470	5.08	14.33	26,031,310	12.91	77.48	83.7%
2025-26	5,160,787	1,827,606	2.82	2,041,188,654	396	1,117	470	5.09	14.38	26,284,820	12.88	77.66	84.2%
2026-27	5,161,790	1,831,506	2.82	2,049,492,312	397	1,119	470	5.10	14.39	26,348,536	12.86	77.78	84.5%
2027-28	5,159,117	1,834,156	2.81	2,056,431,348	399	1,121	470	5.12	14.39	26,394,161	12.83	77.91	84.8%
2028-29	5,156,342	1,836,806	2.81	2,063,320,902	400	1,123	470	5.13	14.39	26,439,171	12.81	78.04	85.1%
2029-30	5,153,465	1,839,456	2.80	2,070,160,515	402	1,125	470	5.14	14.40	26,483,562	12.79	78.17	85.5%
2030-31	5,150,486	1,842,106	2.80	2,076,949,729	403	1,127	470	5.15	14.40	26,527,330	12.77	78.29	85.8%

The most likely outcome of the increased feed supply in the modest growth forecast scenario 1 will be through pasture and crops. Fodder beet use is estimated to double from 815,000 tonnes DM to 1.6 million tonnes DM by 2022-23, based on the rapid rise in its popularity, due to reasonably high yields, low cost per kilogram of dry matter and lower nitrogen leaching advantages. The increased use of fodder beet started in the South Island but is spreading rapidly in the North Island. The growth in fodder beet will displace some other crops, such as maize grown for silage (-18%) and turnips (-19%) in the North Island, with the use of brassica crops declining (-18%) and swedes in the South Island down 28 per cent.

Under this scenario imported PKE volumes are expected to decline 35 per cent from the current levels. This is due to increasing pressure from milk companies to ensure milk composition (fat and protein mix) is not adversely affected and to reduce environmental and biosecurity risks.

Pasture including pasture silage is the residual feed in the calculation. A decrease in harvested crop (maize silage) and imported supplement (PKE) is partially offset by an increase in crop volumes (fodder beet). This means pasture consumed by cows will increase from 4.07 tonnes to 4.34 tonnes, equivalent to an increase of 0.7 tonne per hectare to 12.13 tonnes by 2030-31. Under this scenario the percentage of pasture consumed by dairy cows increases from 82 to 84 per cent. However, if fodder beet only increases at half the rate projected in this scenario, per hectare pasture consumed would increase to 12.35 tonnes (86% of total feed consumed).

Tables 25 and 26 shows the split of total feed per cow and per hectare for the modest growth scenario 1 between pasture, crop and supplements (harvested and imported). It shows the increase in pasture and crops eaten per cow increasing over this period with supplements (harvested and imported) decreasing on a per cow basis. Table 27 shows the forecasted changes in individual supplementary feed types for this scenario. **Table 25: Modest Growth Forecast Scenario 1 Feed Categories- per cow**

Season	Total Feed (t/cow)	Pasture (t DM/cow)	Crop (t DM/cow)	Harvested Supplements (t DM/cow)	Imported Supplements (t DM/cow)
2015-16	4.97	4.07	0.21	0.28	0.41
2016-17	4.95	4.09	0.21	0.27	0.38
2017-18	4.97	4.06	0.26	0.28	0.37
2018-19	4.98	4.07	0.28	0.28	0.36
2019-20	5.00	4.09	0.30	0.26	0.34
2020-21	5.02	4.12	0.32	0.25	0.32
2021-22	5.03	4.14	0.34	0.24	0.31
2022-23	5.05	4.16	0.36	0.23	0.30
2023-24	5.06	4.19	0.36	0.23	0.30
2024-25	5.08	4.22	0.35	0.22	0.29
2025-26	5.09	4.24	0.35	0.22	0.28
2026-27	5.10	4.26	0.35	0.22	0.27
2027-28	5.12	4.28	0.35	0.22	0.26
2028-29	5.13	4.30	0.35	0.22	0.26
2029-30	5.14	4.32	0.35	0.22	0.25
2030-31	5.15	4.34	0.35	0.22	0.24

Table 26: Modest Growth Forecast Scenario 1 Feed Categories- per hectare

Season	Total Feed Eaten (t/ha)	Pasture (t DM/ha)	Crop (t DM/ha)	Harvested Supplements (t DM/ha)	Imported Supplements (t DM/ha)
2015-16	13.92	11.39	0.59	0.78	1.16
2016-17	13.84	11.42	0.59	0.75	1.07
2017-18	13.91	11.37	0.71	0.78	1.04
2018-19	13.98	11.41	0.78	0.77	1.01
2019-20	14.04	11.50	0.84	0.74	0.96
2020-21	14.11	11.59	0.90	0.71	0.91
2021-22	14.17	11.65	0.96	0.67	0.88
2022-23	14.22	11.71	1.01	0.64	0.86
2023-24	14.27	11.80	1.00	0.64	0.83
2024-25	14.33	11.89	0.99	0.63	0.81
2025-26	14.38	11.98	0.99	0.62	0.79
2026-27	14.39	12.02	0.98	0.62	0.77
2027-28	14.39	12.05	0.98	0.62	0.75
2028-29	14.39	12.08	0.98	0.62	0.72
2029-30	14.40	12.10	0.97	0.61	0.70
2030-31	14.40	12.13	0.97	0.61	0.68

Table 27: Modest Growth Forecast Scenario 1 Supplementary Feed Breakdown (t DM)

Season	PKE	Maize Grain	Maize Silage	Barley	Wheat	Oats	Cereal whole crop silage	Fodder Beet	Kale	Rape	Turnips	Swedes	Other Brassicas	Brewers Grain	Tapioca	Soyabean	Cottonseed	Other Supplements	Total Supplements & Crop (t DM)	Total Supplements & Crop (t DM/cow)
2015-16	1,500,000	50,000	1,100,000	130,000	50,000	2,000	40,000	815,100	120,000	11,000	20,000	50,000	13,000	4,500	2,000	15,000	10,000	500,000	4,432,600	0.90
2016-17	1,400,000	50,000	1,050,000	128,000	49,000	2,000	40,000	815,100	120,000	11,000	19,750	50,000	12,900	4,500	2,000	15,000	10,000	450,000	4,229,250	0.86
2017-18	1,400,000	50,000	1,100,000	126,000	48,000	2,000	40,000	1,045,000	118,500	11,000	19,500	49,000	12,800	4,500	2,000	15,000	10,000	400,000	4,453,300	0.91
2018-19	1,400,000	50,000	1,100,000	124,000	47,000	2,000	40,000	1,175,625	117,000	11,000	19,250	48,000	12,700	4,500	2,000	15,000	10,000	350,000	4,528,075	0.92
2019-20	1,365,000	50,000	1,050,000	122,000	46,000	2,000	40,000	1,285,625	115,500	11,000	19,000	47,000	12,600	4,500	2,000	15,000	10,000	300,000	4,497,225	0.91
2020-21	1,330,000	50,000	1,000,000	120,000	45,000	2,000	40,000	1,395,625	114,000	11,000	18,750	46,000	12,500	4,500	2,000	15,000	10,000	250,000	4,466,375	0.89
2021-22	1,295,000	50,000	950,000	118,000	44,000	2,000	40,000	1,505,625	112,500	11,000	18,500	45,000	12,400	4,500	2,000	15,000	10,000	250,000	4,485,525	0.89
2022-23	1,260,000	50,000	900,000	116,000	43,000	2,000	40,000	1,615,625	111,000	11,000	18,250	44,000	12,300	4,500	2,000	15,000	10,000	250,000	4,504,675	0.89
2023-24	1,225,000	50,000	900,000	114,000	42,000	2,000	40,000	1,615,625	109,500	11,000	18,000	43,000	12,200	4,500	2,000	15,000	10,000	250,000	4,463,825	0.88
2024-25	1,190,000	50,000	900,000	112,000	41,000	2,000	40,000	1,615,625	108,000	11,000	17,750	42,000	12,100	4,500	2,000	15,000	10,000	250,000	4,422,975	0.86
2025-26	1,155,000	50,000	900,000	110,000	40,000	2,000	40,000	1,615,625	106,500	11,000	17,500	41,000	12,000	4,500	2,000	15,000	10,000	250,000	4,382,125	0.85
2026-27	1,120,000	50,000	900,000	108,000	39,000	2,000	40,000	1,615,625	105,000	11,000	17,250	40,000	11,900	4,500	2,000	15,000	10,000	250,000	4,341,275	0.84
2027-28	1,085,000	50,000	900,000	106,000	38,000	2,000	40,000	1,615,625	103,500	11,000	17,000	39,000	11,800	4,500	2,000	15,000	10,000	250,000	4,300,425	0.83
2028-29	1,050,000	50,000	900,000	104,000	37,000	2,000	40,000	1,615,625	102,000	11,000	16,750	38,000	11,700	4,500	2,000	15,000	10,000	250,000	4,259,575	0.83
2029-30	1,015,000	50,000	900,000	102,000	36,000	2,000	40,000	1,615,625	100,500	11,000	16,500	37,000	11,600	4,500	2,000	15,000	10,000	250,000	4,218,725	0.82
2030-31	980,000	50,000	900,000	100,000	35,000	2,000	40,000	1,615,625	99,000	11,000	16,250	36,000	11,500	4,500	2,000	15,000	10,000	250,000	4,177,875	0.81

Modest Growth Forecast Scenario 2

Total milk production growth in this scenario is exactly the same as the first modest growth scenario. The key assumption for the second modest growth scenario is that stocking rates will decrease to 2.65 cows per hectare by 2030-31. This determines that cow numbers will remain around current levels of 4.9 million cows. On this basis, milksolids per cow increases at a rate of 3.7 kilograms per year. This growth rate is nearly twice the milksolids per cow growth rate expected in the previous modest growth scenario.

Feed demand based on this scenario, would increase from 4.97 tonnes per cow in 2015-16 to 5.32 tonnes per cow in 2030-31, faster than the previous modest growth scenario. This is based on the assumption that livestock weights remain constant at 470 kilograms per cow throughout the period. However, when stocking rates are considered, the growth in feed eaten per hectare increase only 0.2 tonne per hectare to 14.1 tonne dry matter per hectare by 2030-31. The lift in future production is driven as much by increased FCE, which improves from 13.1 kg DM/ kg MS to 12.5, as it is by more feed eaten.

Table 28 provides a summary of the modest growth forecast scenario 2 including expected cow numbers, effective hectares, milksolids production and derived total feed demand.

Table 28: Modest Growth Forecast Scenario 2 Summary Statistics

Season	Cow numbers	Effective area (hectares)	Stocking Rate (cows/ha)	Total Milksolids (kg)	MS/cow	MS/ha	Liveweight (kg)	Feed Demand (t DM/cow/year)	Feed Demand (t DM/ha/year)	Feed Demand (t DM/year)	FCE (kg DM/ kg MS)	FCE (kg MS/ t DM)	MS % of Liveweight
2015-16	4,909,181	1,752,306	2.80	1,858,967,300	379	1,061	470	4.97	13.92	24,388,594	13.12	76.22	80.6%
2016-17	4,892,372	1,751,056	2.79	1,843,001,227	377	1,053	470	4.95	13.84	24,233,519	13.15	76.05	80.2%
2017-18	4,917,615	1,757,006	2.80	1,862,832,425	379	1,060	470	4.97	13.91	24,435,497	13.12	76.23	80.6%
2018-19	4,917,615	1,762,956	2.79	1,882,739,122	383	1,068	470	5.00	13.94	24,583,747	13.06	76.58	81.5%
2019-20	4,915,615	1,768,906	2.78	1,902,720,934	387	1,076	470	5.03	13.98	24,728,064	13.00	76.95	82.4%
2020-21	4,913,615	1,774,856	2.77	1,922,777,477	391	1,083	470	5.06	14.01	24,872,737	12.94	77.30	83.3%
2021-22	4,910,615	1,784,406	2.75	1,945,185,234	396	1,090	470	5.10	14.03	25,032,475	12.87	77.71	84.3%
2022-23	4,907,615	1,795,206	2.73	1,968,984,708	401	1,097	470	5.14	14.04	25,202,256	12.80	78.13	85.4%
2023-24	4,904,615	1,806,006	2.72	1,992,918,431	406	1,103	470	5.17	14.05	25,372,737	12.73	78.55	86.5%
2024-25	4,901,615	1,816,806	2.70	2,016,986,411	411	1,110	470	5.21	14.06	25,543,914	12.66	78.96	87.6%
2025-26	4,897,615	1,827,606	2.68	2,041,188,654	417	1,117	470	5.25	14.07	25,713,602	12.60	79.38	88.7%
2026-27	4,893,615	1,831,506	2.67	2,049,492,312	419	1,119	470	5.27	14.07	25,766,015	12.57	79.54	89.1%
2027-28	4,889,615	1,834,156	2.67	2,056,431,348	421	1,121	470	5.28	14.07	25,808,342	12.55	79.68	89.5%
2028-29	4,885,615	1,836,806	2.66	2,063,320,902	422	1,123	470	5.29	14.07	25,850,271	12.53	79.82	89.9%
2029-30	4,880,615	1,839,456	2.65	2,070,160,515	424	1,125	470	5.30	14.07	25,889,611	12.51	79.96	90.2%
2030-31	4,875,615	1,842,106	2.65	2,076,949,729	426	1,127	470	5.32	14.08	25,928,543	12.48	80.10	90.6%

The most likely outcome of the increased feed supply in the modest growth forecast scenario 2 will be through pasture and crops. As with the modest growth forecast scenario 1, fodder beet is estimated to increase rapidly from 815,000 tonnes DM to 1.6 million tonnes DM by 2022-23, and will displace some other crops, such as maize grown for silage (-18%) turnips (-19%), brassica crops (-18%) and swedes (-28%).

Under this scenario imported PKE volumes are expected to decline 35 per cent from the current levels. Pasture including pasture silage is the residual feed in the calculation. A decrease in harvested crop (maize silage) and imported supplement (PKE) is partially offset by an increase in crop volumes (fodder beet). This means pasture consumed by cows will need to increase from 4.07 tonnes to 4.46 tonnes, equivalent to an increase of 0.4 tonne per hectare to 11.81 tonnes by 2030-31 in order to achieve the level of production forecast.

Tables 29 and 30 shows the split of total feed per cow and per hectare for the modest growth scenario 2 between pasture, crop and supplements (harvested and imported). It shows the increase in pasture and crops eaten per cow increasing over this period with supplements (harvested and imported) decreasing on a per cow basis. Table 31 shows the forecasted changes in individual supplementary feed types for this scenario.

Table 29: Modest Growth Forecast Scenario 2 Feed Categories- per cow

Season	Total Feed (t/cow)	Pasture (t DM/cow)	Crop (t DM/cow)	Harvested Supplements (t DM/cow)	Imported Supplements (t DM/cow)
2015-16	4.97	4.07	0.21	0.28	0.41
2016-17	4.95	4.09	0.21	0.27	0.38
2017-18	4.97	4.06	0.26	0.28	0.37
2018-19	5.00	4.08	0.28	0.28	0.36
2019-20	5.03	4.12	0.30	0.27	0.35
2020-21	5.06	4.15	0.33	0.26	0.33
2021-22	5.10	4.18	0.35	0.25	0.32
2022-23	5.14	4.22	0.37	0.23	0.31
2023-24	5.17	4.26	0.37	0.23	0.31
2024-25	5.21	4.31	0.37	0.23	0.30
2025-26	5.25	4.36	0.37	0.23	0.29
2026-27	5.27	4.38	0.37	0.23	0.29
2027-28	5.28	4.40	0.37	0.23	0.28
2028-29	5.29	4.42	0.37	0.23	0.27
2029-30	5.30	4.44	0.37	0.23	0.27
2030-31	5.32	4.46	0.37	0.23	0.26

Table 30: Modest Growth Forecast Scenario 2 Feed Categories- per hectare

Season	Total Feed Eaten (t/ha)	Pasture (t DM/ha)	Crop (t DM/ha)	Harvested Supplements (t DM/ha)	Imported Supplements (t DM/ha)
2015-16	13.92	11.39	0.59	0.78	1.16
2016-17	13.84	11.42	0.59	0.75	1.07
2017-18	13.91	11.37	0.71	0.78	1.04
2018-19	13.94	11.38	0.78	0.77	1.01
2019-20	13.98	11.44	0.84	0.74	0.96
2020-21	14.01	11.50	0.90	0.71	0.91
2021-22	14.03	11.51	0.96	0.67	0.88
2022-23	14.04	11.53	1.01	0.64	0.86
2023-24	14.05	11.58	1.00	0.64	0.83
2024-25	14.06	11.63	0.99	0.63	0.81
2025-26	14.07	11.67	0.99	0.62	0.79
2026-27	14.07	11.70	0.98	0.62	0.77
2027-28	14.07	11.73	0.98	0.62	0.75
2028-29	14.07	11.75	0.98	0.62	0.72
2029-30	14.07	11.78	0.97	0.61	0.70
2030-31	14.08	11.81	0.97	0.61	0.68

Table 31: Modest Growth Forecast Scenario 2 Supplementary Feed Breakdown (t DM)

Season	PKE	Maize Grain	Maize Silage	Barley	Wheat	Oats	Cereal whole crop silage	Fodder Beet	Kale	Rape	Turnips	Swedes	Other Brassicas	Brewers Grain	Tapioca	Soyabean	Cottonseed	Other Supplements	Total Supplements & Crop (t DM)	Total Supplements & Crop (t DM/cow)
2015-16	1,500,000	50,000	1,100,000	130,000	50,000	2,000	40,000	815,100	120,000	11,000	20,000	50,000	13,000	4,500	2,000	15,000	10,000	500,000	4,432,600	0.90
2016-17	1,400,000	50,000	1,050,000	128,000	49,000	2,000	40,000	815,100	120,000	11,000	19,750	50,000	12,900	4,500	2,000	15,000	10,000	450,000	4,229,250	0.86
2017-18	1,400,000	50,000	1,100,000	126,000	48,000	2,000	40,000	1,045,000	118,500	11,000	19,500	49,000	12,800	4,500	2,000	15,000	10,000	400,000	4,453,300	0.91
2018-19	1,400,000	50,000	1,100,000	124,000	47,000	2,000	40,000	1,175,625	117,000	11,000	19,250	48,000	12,700	4,500	2,000	15,000	10,000	350,000	4,528,075	0.92
2019-20	1,365,000	50,000	1,050,000	122,000	46,000	2,000	40,000	1,285,625	115,500	11,000	19,000	47,000	12,600	4,500	2,000	15,000	10,000	300,000	4,497,225	0.91
2020-21	1,330,000	50,000	1,000,000	120,000	45,000	2,000	40,000	1,395,625	114,000	11,000	18,750	46,000	12,500	4,500	2,000	15,000	10,000	250,000	4,466,375	0.91
2021-22	1,295,000	50,000	950,000	118,000	44,000	2,000	40,000	1,505,625	112,500	11,000	18,500	45,000	12,400	4,500	2,000	15,000	10,000	250,000	4,485,525	0.91
2022-23	1,260,000	50,000	900,000	116,000	43,000	2,000	40,000	1,615,625	111,000	11,000	18,250	44,000	12,300	4,500	2,000	15,000	10,000	250,000	4,504,675	0.92
2023-24	1,225,000	50,000	900,000	114,000	42,000	2,000	40,000	1,615,625	109,500	11,000	18,000	43,000	12,200	4,500	2,000	15,000	10,000	250,000	4,463,825	0.91
2024-25	1,190,000	50,000	900,000	112,000	41,000	2,000	40,000	1,615,625	108,000	11,000	17,750	42,000	12,100	4,500	2,000	15,000	10,000	250,000	4,422,975	0.90
2025-26	1,155,000	50,000	900,000	110,000	40,000	2,000	40,000	1,615,625	106,500	11,000	17,500	41,000	12,000	4,500	2,000	15,000	10,000	250,000	4,382,125	0.89
2026-27	1,120,000	50,000	900,000	108,000	39,000	2,000	40,000	1,615,625	105,000	11,000	17,250	40,000	11,900	4,500	2,000	15,000	10,000	250,000	4,341,275	0.89
2027-28	1,085,000	50,000	900,000	106,000	38,000	2,000	40,000	1,615,625	103,500	11,000	17,000	39,000	11,800	4,500	2,000	15,000	10,000	250,000	4,300,425	0.88
2028-29	1,050,000	50,000	900,000	104,000	37,000	2,000	40,000	1,615,625	102,000	11,000	16,750	38,000	11,700	4,500	2,000	15,000	10,000	250,000	4,259,575	0.87
2029-30	1,015,000	50,000	900,000	102,000	36,000	2,000	40,000	1,615,625	100,500	11,000	16,500	37,000	11,600	4,500	2,000	15,000	10,000	250,000	4,218,725	0.86
2030-31	980,000	50,000	900,000	100,000	35,000	2,000	40,000	1,615,625	99,000	11,000	16,250	36,000	11,500	4,500	2,000	15,000	10,000	250,000	4,177,875	0.86

High Growth Forecast Scenario

Feed demand based on the high growth forecast scenario, would increase slowly from 4.97 tonnes per cow in 2015-16 to 5.24 tonnes per cow in 2030-31. This is based on the assumption that livestock weights remain similar to current levels throughout the period and that milk production per cow lifts modestly from around 379 kg MS to 415 kg MS in 2030-31. The lift in production is from both increased feed and FCE. FCE improves from 13.1 kg DM/ kg MS to 12.6.

Average stocking rates under this forecast scenario increase from around 2.8 cows per hectare to 3.0 cows per hectare. The results of the higher stocking rates increase cow numbers to 5.50 million in 2030-31. This compares to 5.15 million cows in the first modest growth scenario. Total milk production under the high growth scenario grows twice as fast as the modest scenario at 1.7 per cent compound annual growth rate (CAGR) compared with 0.8 per cent CAGR. Table 30 provides a summary of the high growth forecast scenario including expected cow numbers, effective hectares, milksolids production and derived total feed demand.

Table 32: High Growth Forecast Summary Statistics

Season	Cow numbers	Effective area (hectares)	Stocking Rate (cows/ha)	Total Milksolids (kg)	MS/cow	MS/ha	Liveweight (kg)	Feed Demand (t DM/cow/year)	Feed Demand (t DM/ha/year)	Feed Demand (t DM/year)	FCE (kg DM/ kg MS)	FCE (kg MS/ t DM)	MS % of Liveweight
2015-16	4,909,181	1,752,306	2.80	1,858,967,300	379	1,061	470	4.97	13.92	24,388,594	13.12	76.22	80.6%
2016-17	4,892,372	1,751,056	2.79	1,843,001,227	377	1,053	470	4.95	13.84	24,233,519	13.15	76.05	80.2%
2017-18	4,934,297	1,757,006	2.81	1,869,151,859	379	1,064	470	4.97	13.95	24,518,392	13.12	76.23	80.6%
2018-19	4,976,394	1,762,956	2.82	1,900,757,311	382	1,078	470	4.99	14.09	24,844,199	13.07	76.51	81.3%
2019-20	5,018,661	1,768,906	2.84	1,932,684,573	385	1,093	470	5.02	14.23	25,172,659	13.02	76.78	81.9%
2020-21	5,061,100	1,774,856	2.85	1,964,935,197	388	1,107	470	5.04	14.37	25,503,779	12.98	77.04	82.6%
2021-22	5,114,028	1,784,406	2.87	2,001,616,051	391	1,122	470	5.06	14.51	25,890,299	12.93	77.31	83.3%
2022-23	5,170,831	1,795,206	2.88	2,039,998,079	395	1,136	470	5.09	14.65	26,297,693	12.89	77.57	83.9%
2023-24	5,227,946	1,806,006	2.89	2,078,844,874	398	1,151	470	5.11	14.79	26,709,090	12.85	77.83	84.6%
2024-25	5,285,371	1,816,806	2.91	2,118,159,174	401	1,166	470	5.13	14.93	27,124,508	12.81	78.09	85.3%
2025-26	5,343,107	1,827,606	2.92	2,157,943,720	404	1,181	470	5.16	15.07	27,543,962	12.76	78.35	85.9%
2026-27	5,380,883	1,831,506	2.94	2,185,563,658	406	1,193	470	5.17	15.20	27,830,087	12.73	78.53	86.4%
2027-28	5,415,080	1,834,156	2.95	2,212,049,750	408	1,206	470	5.19	15.32	28,100,001	12.70	78.72	86.9%
2028-29	5,449,354	1,836,806	2.97	2,238,725,696	411	1,219	470	5.21	15.45	28,371,416	12.67	78.91	87.4%
2029-30	5,483,704	1,839,456	2.98	2,265,592,040	413	1,232	470	5.22	15.37	28,644,334	12.64	79.09	87.9%
2030-31	5,518,131	1,842,106	3.00	2,292,649,328	415	1,245	470	5.24	15.70	28,918,759	12.61	79.28	88.4%

The increased feed supply under the high growth forecast scenario could be through a combination of any of the feed types, but most likely driven by more PKE, fodder beet and/or more pasture consumed. We have examined two different options under the high growth forecast scenario – more supplementary feed and more pasture and crop.

High Growth Driven by Supplements

The consumption of PKE volumes by dairy cows is estimated to increase 33 per cent from the current levels to 2.0 million tonnes. In addition, the use of soyabean, cottonseed and tapioca feeds double to 2030-31. However, these imported feeds are of small volumes. Other imported feeds are also estimated to increase 50 per cent in this scenario. The increase in supplementary feed is not sufficient to meet the feed demands required under this scenario so the volume of pasture and crops will also need to increase. As with the modest growth scenario we have assumed there will be a rapid rise in the use of fodder beet, doubling the consumption to 1.6 million tonnes by 2022-23. Both maize silage and maize grain have been increased 25 per cent while barley increases 50 per cent from current levels.

Under this scenario pasture and pasture silage consumption increases 0.85 tonne (+7%) per hectare by 203031. The percentage of pasture consumed by dairy cows decreases from 82 to 78 per cent. Tables 33 and 34 shows the split between pasture, crop and supplements (harvested and imported) of total feed per cow and per hectare for the high growth scenario driven by supplements (scenario 3). It shows the increase in pasture, crops, supplements (harvested and imported) on a per cow basis. Table 35 shows the forecasted changes in individual supplementary feed types for this scenario.

Table 33: High Growth Driven by Supplements Forecast Feed Categories- per cow

Season	Total Feed (t/cow)	Pasture (t DM/cow)	Crop (t DM/cow)	Harvested Supplements (t DM/cow)	Imported Supplements (t DM/cow)
2015-16	4.97	4.07	0.21	0.28	0.41
2016-17	4.95	4.03	0.21	0.29	0.43
2017-18	4.97	3.99	0.26	0.29	0.43
2018-19	4.99	3.98	0.28	0.29	0.44
2019-20	5.02	3.98	0.30	0.29	0.45
2020-21	5.04	3.97	0.32	0.30	0.45
2021-22	5.06	3.97	0.34	0.30	0.46
2022-23	5.09	3.97	0.35	0.30	0.46
2023-24	5.11	3.99	0.35	0.30	0.47
2024-25	5.13	4.01	0.35	0.30	0.47
2025-26	5.16	4.03	0.34	0.30	0.48
2026-27	5.17	4.04	0.34	0.31	0.48
2027-28	5.19	4.05	0.34	0.31	0.49
2028-29	5.21	4.06	0.34	0.31	0.50
2029-30	5.22	4.07	0.33	0.31	0.50
2030-31	5.24	4.08	0.33	0.32	0.51

Table 34: High Growth Driven by Supplements Forecast Feed Categories- per hectare

Season	Total Feed Eaten (t/ha)	Pasture (t DM/ha)	Crop (t DM/ha)	Harvested Supplements (t DM/ha)	Imported Supplements (t DM/ha)
2015-16	13.92	11.39	0.59	0.78	1.16
2016-17	13.84	11.26	0.59	0.80	1.19
2017-18	13.95	11.21	0.72	0.81	1.21
2018-19	14.09	11.24	0.79	0.82	1.24
2019-20	14.23	11.29	0.85	0.83	1.26
2020-21	14.37	11.33	0.91	0.84	1.29
2021-22	14.51	11.38	0.96	0.85	1.31
2022-23	14.65	11.44	1.02	0.86	1.33
2023-24	14.79	11.55	1.01	0.87	1.35
2024-25	14.93	11.67	1.01	0.88	1.37
2025-26	15.07	11.79	1.00	0.89	1.39
2026-27	15.20	11.88	1.00	0.90	1.42
2027-28	15.32	11.97	1.00	0.91	1.44
2028-29	15.45	12.06	1.00	0.92	1.47
2029-30	15.57	12.15	0.99	0.94	1.49
2030-31	15.70	12.24	0.99	0.95	1.52

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Table 35: High Growth Driven by Supplements Forecast Supplementary Feed Breakdown (t DM)

Season	PKE	Maize Grain	Maize Silage	Barley	Wheat	Oats	Cereal whole crop silage	Fodder Beet	Kale	Rape	Turnips	Swedes	Other Brassicas	Brewers Grain	Tapioca	Soyabean	Cottonseed	Other Supplements	Total Supplements & Crop (t DM)	Total Supplements & Crop (t DM/cow)
2015-16	1,500,000	50,000	1,100,000	130,000	50,000	2,000	40,000	815,100	120,000	11,000	20,000	50,000	13,000	4,500	2,000	15,000	10,000	500,000	4,432,600	0.90
2016-17	1,533,000	50,845	1,120,000	134,300	50,000	2,000	40,000	815,100	120,000	11,000	20,000	50,000	13,000	4,500	2,130	16,000	10,660	516,500	4,509,035	0.92
2017-18	1,566,000	51,690	1,140,000	138,600	50,000	2,000	40,000	1,045,000	120,000	11,000	20,000	50,000	13,000	4,500	2,260	17,000	11,320	533,000	4,815,370	0.98
2018-19	1,599,000	52,535	1,160,000	142,900	50,000	2,000	40,000	1,175,625	120,000	11,000	20,000	50,000	13,000	4,500	2,390	18,000	11,980	549,500	5,022,430	1.01
2019-20	1,632,000	53,380	1,180,000	147,200	50,000	2,000	40,000	1,285,625	120,000	11,000	20,000	50,000	13,000	4,500	2,520	19,000	12,640	566,000	5,208,865	1.04
2020-21	1,665,000	54,225	1,200,000	151,500	50,000	2,000	40,000	1,395,625	120,000	11,000	20,000	50,000	13,000	4,500	2,650	20,000	13,300	582,500	5,395,300	1.07
2021-22	1,698,000	55,070	1,220,000	155,800	50,000	2,000	40,000	1,505,625	120,000	11,000	20,000	50,000	13,000	4,500	2,780	21,000	13,960	599,000	5,581,735	1.09
2022-23	1,731,000	55,915	1,240,000	160,100	50,000	2,000	40,000	1,615,625	120,000	11,000	20,000	50,000	13,000	4,500	2,910	22,000	14,620	615,500	5,768,170	1.12
2023-24	1,764,000	56,760	1,260,000	164,400	50,000	2,000	40,000	1,615,625	120,000	11,000	20,000	50,000	13,000	4,500	3,040	23,000	15,280	632,000	5,844,605	1.12
2024-25	1,797,000	57,605	1,280,000	168,700	50,000	2,000	40,000	1,615,625	120,000	11,000	20,000	50,000	13,000	4,500	3,170	24,000	15,940	648,500	5,921,040	1.12
2025-26	1,830,000	58,450	1,300,000	173,000	50,000	2,000	40,000	1,615,625	120,000	11,000	20,000	50,000	13,000	4,500	3,300	25,000	16,600	665,000	5,997,475	1.12
2026-27	1,863,000	59,295	1,320,000	177,300	50,000	2,000	40,000	1,615,625	120,000	11,000	20,000	50,000	13,000	4,500	3,430	26,000	17,260	681,500	6,073,910	1.13
2027-28	1,896,000	60,140	1,340,000	181,600	50,000	2,000	40,000	1,615,625	120,000	11,000	20,000	50,000	13,000	4,500	3,560	27,000	17,920	698,000	6,150,345	1.14
2028-29	1,929,000	60,985	1,360,000	185,900	50,000	2,000	40,000	1,615,625	120,000	11,000	20,000	50,000	13,000	4,500	3,690	28,000	18,580	714,500	6,226,780	1.14
2029-30	1,962,000	61,830	1,380,000	190,200	50,000	2,000	40,000	1,615,625	120,000	11,000	20,000	50,000	13,000	4,500	3,820	29,000	19,240	731,000	6,303,215	1.15
2030-31	1,995,000	62,675	1,400,000	194,500	50,000	2,000	40,000	1,615,625	120,000	11,000	20,000	50,000	13,000	4,500	3,950	30,000	19,900	747,500	6,379,650	1.16

High Growth Driven by Pasture and Crops

The increased feed demand to 2030-31 under this scenario is met by increased volumes of pasture and crops eaten per cow. Another way to describe this scenario is that the volumes of imported supplements are capped at current levels. If all crops, harvested and imported supplementary feeds are restricted to current levels, pasture consumption will increase from 4.07 tonnes per cow to 4.28 tonnes per cow, equivalent to 11.39 tonnes per hectare increasing to 12.82 tonnes per hectare (+1.4 tonne/hectare). This is the maximum amount of pasture eaten possible under the two scenarios but would have pasture maintaining at 82 per cent of total feed consumed in 2030-31. However, under this scenario fodder beet doubles as in the previous scenarios. This will impact other grown crops by reducing their area harvested. All other grown crops were reduced by approximately 30 per cent from current volumes.

Tables 36 and 37 shows the split between pasture, crop and supplements (harvested and imported) of total feed per cow and per hectare for the high growth scenario driven by pasture and crops (scenario 4). It shows the increase in pasture and crops eaten per cow increasing over this period with supplements (harvested and imported) decreasing on a per cow basis. Table 38 shows the forecasted changes in individual supplementary feed types for this scenario.

Table 36: High Growth Driven by Pasture and Crops Forecast Feed Categories- per cow

Season	Total Feed (t/cow)	Pasture (t DM/cow)	Crop (t DM/cow)	Harvested Supplements (t DM/cow)	Imported Supplements (t DM/cow)
2015-16	4.97	4.07	0.21	0.28	0.41
2016-17	4.95	4.04	0.21	0.29	0.42
2017-18	4.97	4.01	0.25	0.30	0.41
2018-19	4.99	4.01	0.28	0.30	0.41
2019-20	5.02	4.01	0.30	0.31	0.40
2020-21	5.04	4.02	0.31	0.30	0.40
2021-22	5.06	4.04	0.33	0.30	0.40
2022-23	5.09	4.05	0.35	0.29	0.39
2023-24	5.11	4.09	0.34	0.29	0.39
2024-25	5.13	4.12	0.34	0.29	0.38
2025-26	5.16	4.16	0.33	0.28	0.38
2026-27	5.17	4.18	0.33	0.28	0.38
2027-28	5.19	4.21	0.33	0.28	0.38
2028-29	5.21	4.23	0.33	0.28	0.37
2029-30	5.22	4.25	0.32	0.28	0.37
2030-31	5.24	4.28	0.32	0.27	0.37

Table 37: High Growth Driven by Pasture and Crops Forecast Feed Categories- per hectare

Season	Total Feed Eaten (t/ha)	Pasture (t DM/ha)	Crop (t DM/ha)	Harvested Supplements (t DM/ha)	Imported Supplements (t DM/ha)
2015-16	13.92	11.39	0.59	0.78	1.16
2016-17	13.84	11.29	0.59	0.81	1.16
2017-18	13.95	11.26	0.71	0.83	1.16
2018-19	14.09	11.31	0.78	0.85	1.15
2019-20	14.23	11.37	0.84	0.87	1.15
2020-21	14.37	11.47	0.89	0.86	1.14
2021-22	14.51	11.57	0.95	0.86	1.14
2022-23	14.65	11.67	1.00	0.85	1.13
2023-24	14.79	11.83	0.99	0.84	1.12
2024-25	14.93	11.99	0.99	0.84	1.12
2025-26	15.07	12.15	0.98	0.83	1.11
2026-27	15.20	12.28	0.97	0.83	1.11
2027-28	15.32	12.42	0.97	0.83	1.11
2028-29	15.45	12.55	0.96	0.83	1.11
2029-30	15.57	12.68	0.96	0.83	1.10
2030-31	15.70	12.82	0.96	0.82	1.10

Table 38: High Growth Driven by Pasture and Crop Forecast Supplementary Feed Breakdown

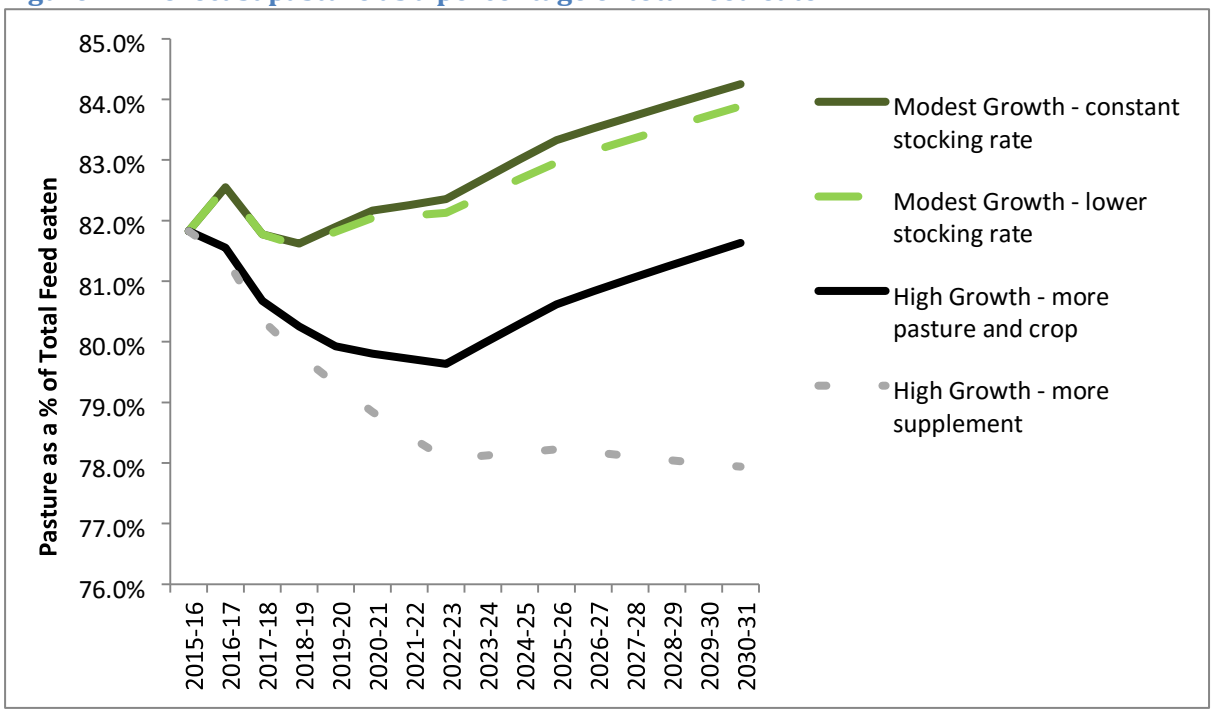
Season	PKE	Maize Grain	Maize Silage	Barley	Wheat	Oats	Cereal whole crop silage	Fodder Beet	Kale	Rape	Turnips	Swedes	Other Brassicas	Brewers Grain	Tapioca	Soyabean	Cottonseed	Other Supplements	Total Supplements & Crop (t DM)	Total Supplements & Crop (t DM/cow)
2015-16	1,500,000	50,000	1,100,000	130,000	50,000	2,000	40,000	815,100	120,000	11,000	20,000	50,000	13,000	4,500	2,000	15,000	10,000	500,000	4,432,600	0.90
2016-17	1,500,000	50,000	1,150,000	123,000	50,000	2,000	39,000	815,100	117,500	10,750	19,600	49,000	12,750	4,500	2,000	15,000	10,000	500,000	4,470,200	0.91
2017-18	1,500,000	50,000	1,200,000	116,000	50,000	2,000	38,000	1,045,000	115,000	10,500	19,200	48,000	12,500	4,500	2,000	15,000	10,000	500,000	4,737,700	0.96
2018-19	1,500,000	50,000	1,250,000	109,000	50,000	2,000	37,000	1,175,625	112,500	10,250	18,800	47,000	12,250	4,500	2,000	15,000	10,000	500,000	4,905,925	0.99
2019-20	1,500,000	50,000	1,300,000	102,000	50,000	2,000	36,000	1,285,625	110,000	10,000	18,400	46,000	12,000	4,500	2,000	15,000	10,000	500,000	5,053,525	1.01
2020-21	1,500,000	50,000	1,300,000	95,000	50,000	2,000	35,000	1,395,625	107,500	9,750	18,000	45,000	11,750	4,500	2,000	15,000	10,000	500,000	5,151,125	1.02
2021-22	1,500,000	50,000	1,300,000	90,000	50,000	2,000	34,000	1,505,625	105,000	9,500	17,600	44,000	11,500	4,500	2,000	15,000	10,000	500,000	5,250,725	1.03
2022-23	1,500,000	50,000	1,300,000	90,000	50,000	2,000	33,000	1,615,625	102,500	9,250	17,200	43,000	11,250	4,500	2,000	15,000	10,000	500,000	5,355,325	1.04
2023-24	1,500,000	50,000	1,300,000	90,000	50,000	2,000	32,000	1,615,625	100,000	9,000	16,800	42,000	11,000	4,500	2,000	15,000	10,000	500,000	5,349,925	1.02
2024-25	1,500,000	50,000	1,300,000	90,000	50,000	2,000	31,000	1,615,625	97,500	8,750	16,400	41,000	10,750	4,500	2,000	15,000	10,000	500,000	5,344,525	1.01
2025-26	1,500,000	50,000	1,300,000	90,000	50,000	2,000	30,000	1,615,625	95,000	8,500	16,000	40,000	10,500	4,500	2,000	15,000	10,000	500,000	5,339,125	1.00
2026-27	1,500,000	50,000	1,300,000	90,000	50,000	2,000	29,000	1,615,625	92,500	8,250	15,600	39,000	10,250	4,500	2,000	15,000	10,000	500,000	5,333,725	0.99
2027-28	1,500,000	50,000	1,300,000	90,000	50,000	2,000	28,000	1,615,625	90,000	8,000	15,200	38,000	10,000	4,500	2,000	15,000	10,000	500,000	5,328,325	0.98
2028-29	1,500,000	50,000	1,300,000	90,000	50,000	2,000	27,000	1,615,625	87,500	7,750	14,800	37,000	9,750	4,500	2,000	15,000	10,000	500,000	5,322,925	0.98
2029-30	1,500,000	50,000	1,300,000	90,000	50,000	2,000	26,000	1,615,625	85,000	7,500	14,400	36,000	9,500	4,500	2,000	15,000	10,000	500,000	5,317,525	0.97
2030-31	1,500,000	50,000	1,300,000	90,000	50,000	2,000	25,000	1,615,625	82,500	7,250	14,000	35,000	9,250	4,500	2,000	15,000	10,000	500,000	5,312,125	0.96

Forecast Summary

Forecasting the future size of the dairy industry and production is extremely difficult, let alone the different levels of feeds consumed by dairy cows. The projections provided in this paper are merely an indication of some possibilities, but there are many more alternatives. We have provided two different milksolids growth levels, with differing stocking rates and variations in the volumes of each of the feeds consumed. Figure 13 provides a summary of the four forecast scenarios.

Figure 14 below shows the percentage of pasture eaten for each of the scenarios. The high growth from more supplement scenario is a continuation of the trend observed over the last 25 years, while the modest growth scenario is the opposite with pasture increasing to around 84 per cent of total feed eaten. The high growth from more pasture and crop, has more reliance on the growth of crops in the first period to 2022-23 and then an increase in pasture eaten to 82 per cent in 2030-31, near the same proportion of pasture eaten in 2015-16.

Figure 14: Forecast pasture as a percentage of total feed eaten



Final Comments and Considerations

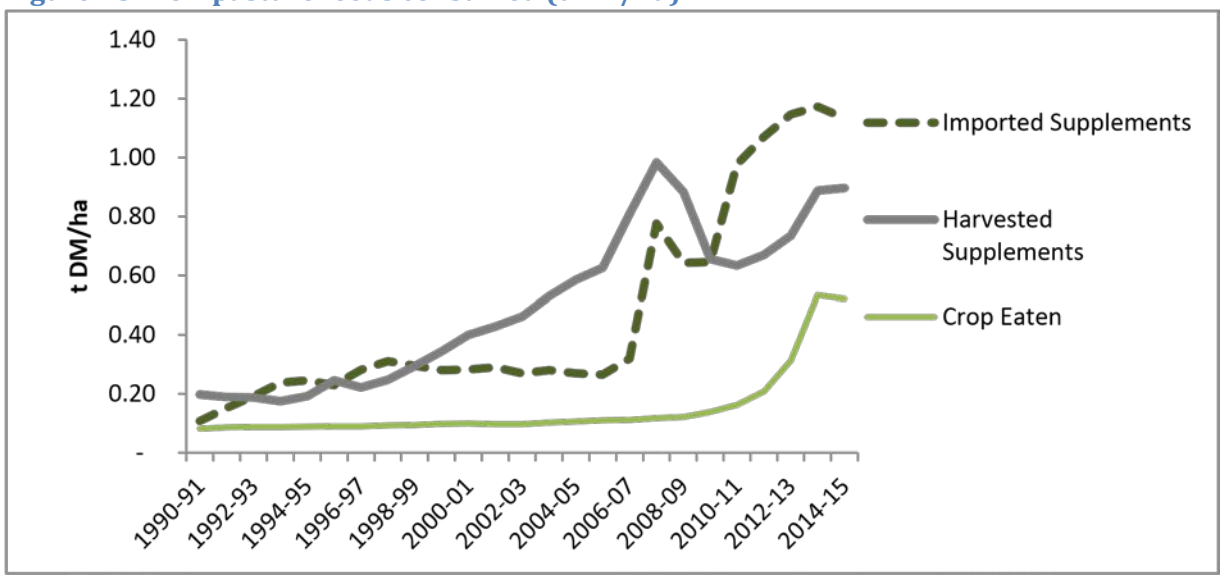
It is our opinion that the number of dairy cows milked, the level of milk production and corresponding total feed demand will impact Greenhouse gases. The split between the various feed types will also impact Greenhouse gas, but not to the same magnitude. This aside, the quantification of the various feed types will be very useful for the industry to monitor and respond to future changes.

It should be noted that this report has been written on a range of base assumptions given the lack of available data and disperse industry knowledge surrounding feed use in the New Zealand dairy industry. Considering this, best endeavours were undertaken to ensure that the approaches used in this analysis neither over- nor under estimate the true results. On a national level, the feed demand estimate is believed to be reasonable as well as consistent with various expert opinions from those working in the various feed industries.

More time was spent on ensuring the accuracy of the major feed types of PKE, maize silage and fodder beet. More work could be undertaken to improve the accuracy of some of the smaller feed types. On this basis, this report is a very good starting position in quantifying historical and future volumes of feed eaten by dairy cows. We will endeavour to improve the information and continue to update the data series annually.

A summary of the three non-pasture feed types is shown in Figure 15. While they have all grown on a per hectare basis from a low base, imported supplements have grown the most since 1990-91. However, it is unlikely this trend will continue in the future.

Figure 15: Non-pasture feeds consumed (t DM/ha)



As reflected by the four forecasting scenarios included in this report, there is considerable uncertainty around the future direction of the New Zealand dairy industry and the resulting composition of the average dairy cow's diet in terms of pasture, crops, harvested supplements and imported supplements. The scenarios provided are reliant on a variety of factors including environmental regulations and policy, market forces, trade conditions, population growth, climate, new technologies and the ability of New Zealand dairy farmers to expand or intensify systems. Given this uncertainty, the forecasting scenarios provided a guide to potential changes that could occur. However, there are many other scenarios that could also occur.