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AgResearch Ballantrae long-term phosphorus fertiliser and sheep grazing study: Monitoring in 2015-16

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AgResearch Ballantrae long-term phosphorus fertiliser and sheep grazing study: Monitoring in 2015-2016.

Report prepared for THE FERTILISER ASSOCIATION OF NEW ZEALAND INCORPORATED (“FANZ”)

May 2016

Alec Mackay, Des Costall, John Koolaard

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1. Executive Summary

It has been 10 years since soil fertility and 20 years since pasture production has been measured and reported for the AgResearch Ballantrae long-term phosphorus fertiliser and sheep grazing study. Funded by The Fertiliser Association of New Zealand, this report covers the measurement of pasture production and composition on the farmlet that has received no fertiliser since 1980 (LFNF), the farmlet that has received 125 kg single superphosphate (SSP)/ha/year (LFLF) and the farmlet that has received 375 kg SSP/ha/year (HFHF) for the 2015-16 year.

Annual pasture production was 6,917 kg DM/ha on the LFNF farmlet, increasing to 9,708 kg DM/ha on the LFLF farmlet. On the HFHF farmlet pasture production was 11,289 kg DM/ha, 61% and 16% higher than the LFNF and LFLF farmlets, respectively. Pastures on the LFNF farmlet were dominated by low fertility grasses (56%), other species (14%) and dead matter (23%), with legumes and high fertility grasses largely absent. Low fertility grasses were in fact a dominant component of the sward on all farmlets, reflecting the set stocking, sheep only grazing regime.

A feature of the LFNF farmlet, and to a lesser degree the LFLF farmlet was the percentage of the pasture not grazed by sheep during the year. On the LFNF farmlet the sheep are no longer grazing the steep banks (>26°) and significant areas of the moderate slope class. We have estimated that only about 65-70% of the farmlet is being actively grazed by animals. In sharp contrast animals graze all slopes and aspects year round on the HFHF farmlet.

A comparison of the pasture growth rates in 2015-16 with those measured back in the 1980's found pasture growth rates on the LFLF farmlet in 2015-16 were on par with those measured back in the 1980's, those on the LFNF farmlet had not declined since the 1980's and pasture production on the HFHF farmlet in 2015-16 (11,289 kgDM/ha) was lower than in the 1980's (13,025 kgDM/ha). The difference in pasture production on the HFHF farmlet in 2015-16 compared with the 1980's can be attributed to differences in pasture growth rates on the East aspect of the farmlet in 2015-16. It is important to note that the comparison is limited to a single production year (2015-16).

Changes in soil Olsen P values on the LFLF are consistent with theory, but on the HFHF farmlet Olsen P values would have been predicted to be higher than those measured.

Field sites with well documented, long-term diverse management histories, like the long-term phosphorus fertiliser and sheep grazing study at Ballantrae provide invaluable insights into the behaviour of our pastoral ecosystems beyond current boundaries. The longer these studies are run the more valuable they become.

2. Background

The long-term fertiliser and grazing study at AgResearch Ballantrae is the only resource now being actively managed and available for monitoring long-term trends in soil fertility and pasture production in hill country in New Zealand (Mackay and Lambert 2011). The only other resource of this nature in New Zealand is the long-term fertiliser trial under irrigation at Winchmore (Smith et al., 2012). Both these field sites provide invaluable data sets on the long-term influence of phosphorus (P) fertiliser on soil fertility and biology, pasture ecology and animal production that is of interest to both science and producers. Since 1980, 130+ research and conference publications have reported on studies utilising the long-term fertiliser and sheep grazing study at Ballantrae. A SCOPUS® database analysis revealed these have been cited >750 times. The field site is not only an invaluable asset for research and development, but also very powerful teaching and extension resource.

It has been 10 years since soil fertility and close to 20 years since pasture production have been measured on the long-term fertiliser and grazing study. This study re-introduced the measurement of pasture growth, with an annual report produced for the Fertiliser Association of New Zealand and findings reported to the industry through industry visits, workshops and conference presentations. A popular article will be prepared, along with an update of the hand outs provided to visitors to the long-term site each year.

3. Methods

Location

AgResearch Ballantrae Hill Country Research Station located in the Southern Hawke's Bay, New Zealand (40,8180S 175,8500E) is typical of much of the North Island's hill country which covers 3.5 million ha (28% of the total farmland in New Zealand). It is located 125 m to 350 m above sea level with an average air temperature of 12.8°C and an annual rainfall of 1270 mm evenly distributed throughout the year. The soils are of sedimentary origin originally formed under forest which was cleared and sown to grassland about 100 years ago.

Self-contained experimental 5-10 ha farmlets, two receiving low (LF) and two receiving high (HF) fertiliser inputs were first established in 1975. Since 1980, one of the low fertiliser farmlets has continued to receive 125 kg superphosphate (SSP)/ha/year and is stocked at 10.6 su/ha; and one of the high fertiliser farmlets has received 375 kg SSP/ha/year and is stocked at 16.0 su/ha. Since 1980 fertiliser has been withheld from one of the low and one of the high fertiliser farmlets. The farmlets are continuously grazed by breeding ewes, with replacements introduced in the autumn.

Base Monitoring

The study monitors pasture growth and composition on the farmlet that has not received fertiliser since 1980 (LFNF), the farmlet receiving 125 kg single superphosphate (SSP)/ha/year (LFLF) and the farmlet receiving 375 kg SSP/ha/year (HFHF).

Pasture production was measured on six (three aspects x two replicates) moderate slopes (13-25°) on each of the three farmlets, using exclusion cages. The location of cages coincided with the same locations used previously to monitor pasture growth (1975-1987) on the farmlets. They are also the location from which soil samples have been taken to track soil fertility. Cages were placed on the sites at the end of January 2015 and cut every 4-8 weeks depending on the season through to March 2016. A total of 7 cuts were taken. Pasture composition was assessed in summer (15^{th} February 2016).

Soil fertility analysis was not measured this year, as a comprehensive soil sampling programme was completed in the late winter of 2014. Routine monitoring of soil fertility into the future would be limited to the moderate slope sites, with a comprehensive sampling of all three slopes classes less frequently.

Boxplots are used to summarise and present the pasture growth, annual pasture production and species composition data from each of the six cages sites from each farmlet. The boxplot is a convenient way of graphically depicting a set of numerical data by displaying its 25^{th}, 50^{th} and 75^{th} percentiles, sometimes termed quartiles. The 50^{th} percentile is the median. (NB: The X^{th} percentile is that number which is numerically larger than X percent of the data values). The bottom and top of the box are the 25^{th} and 75^{th} percentiles respectively, and the band inside the box is the median. The length of the box is termed the inter-quartile range or IQR. The "whiskers" are lines extending from the ends of the box to the minimum or maximum values, so long as those values are within 1.5 times the IQR of the lower/upper quartile. Data values that are further from the box than 1.5 times the IQR are designated as outliers, and these are plotted as individual points (asterisks) (Tukey 1977).

4. Results

4.1 Pasture production

Seasonal and annual pasture production for the 2015-16 year are presented in Figure 1 and 2, respectively. There was a considerable amount of variation in the amount of pasture grown both within and across the three farmlets in 2015-16 (Fig. 1). In addition to soil fertility, pasture growth at individual cage sites was influenced strongly by soil moisture levels, which was a factor of not just aspect, but also slope position as it influenced drainage and seepage (Section 9).

Pasture growth rates were higher on the HFHF than LFLF farmlet in summer (Fig 1). Growth rates on both the HFHF and LFLF were higher than the LFNF farmlet in the spring and summer periods. These are all periods of peak pasture growth. Differences in pasture growth between the farmlets were small during the winter months.

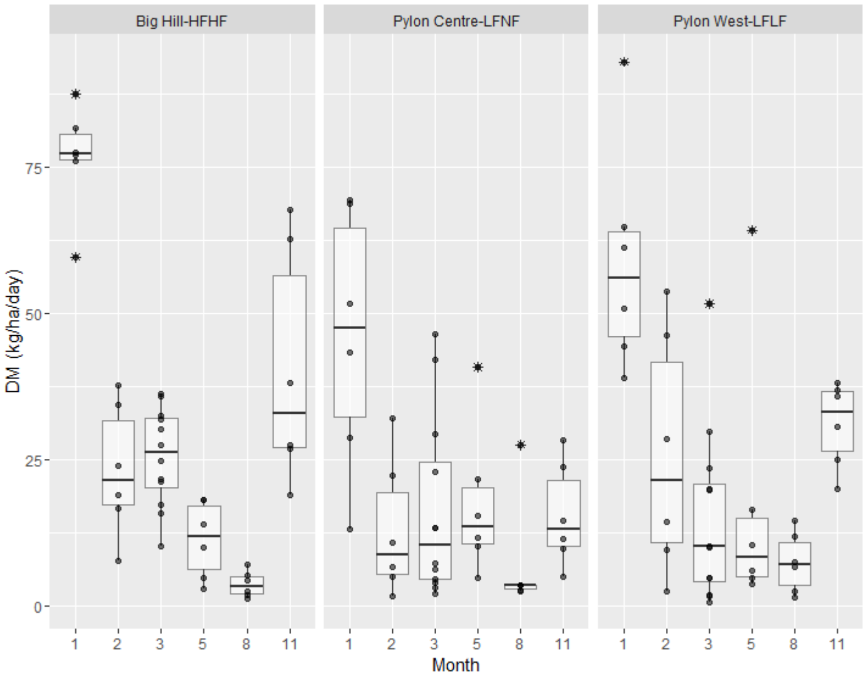

Figure 1. Pasture growth rates on moderate slopes on the Pylon Centre-LFNF, Pylon-West-LFLF and Big Hill-HFHF farmlet in 2015-16.

Annual pasture production increased from 6,917 kg DM/ha on the LFNF farmlet to 9,708 kg DM/ha on the LFLF farmlet an increase of 39% (Fig.2). On the HFHF farmlet pasture production was 11,289 kg DM/ha, 61 and 16% higher than the LFNF and LFLF farmlets, respectively.

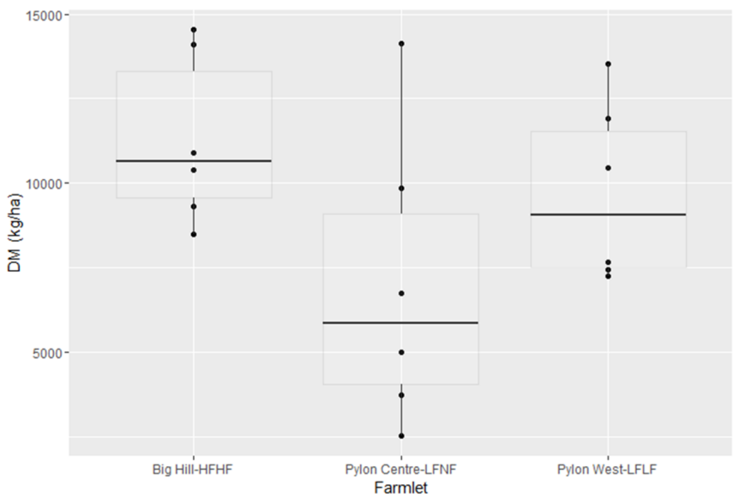

Figure 2. Annual pasture production on the moderate slope on the LFNF, LFLF and HFHF farmlet in 2015-16.

The variation and standard deviations are much higher for LFNF than HFHF. The F test for the ratio of variances had a P value of 0.25, which is not significant. There was only weak evidence of a difference between farmlet means.

4.2 Species composition

Under the set stocking sheep grazing system in place across the farmlets, low fertility grasses continue to dominate pasture composition even at high soil fertility. Pasture on the LFNF farmlet was dominated by low fertility grasses (56%), other species (14%) and dead matter (23%). Legumes and high fertility grasses were largely absent (Fig. 3). Features of the pastures on the HFHF farmlet were the higher white clover (8%) and lower dead matter (12%) contents.

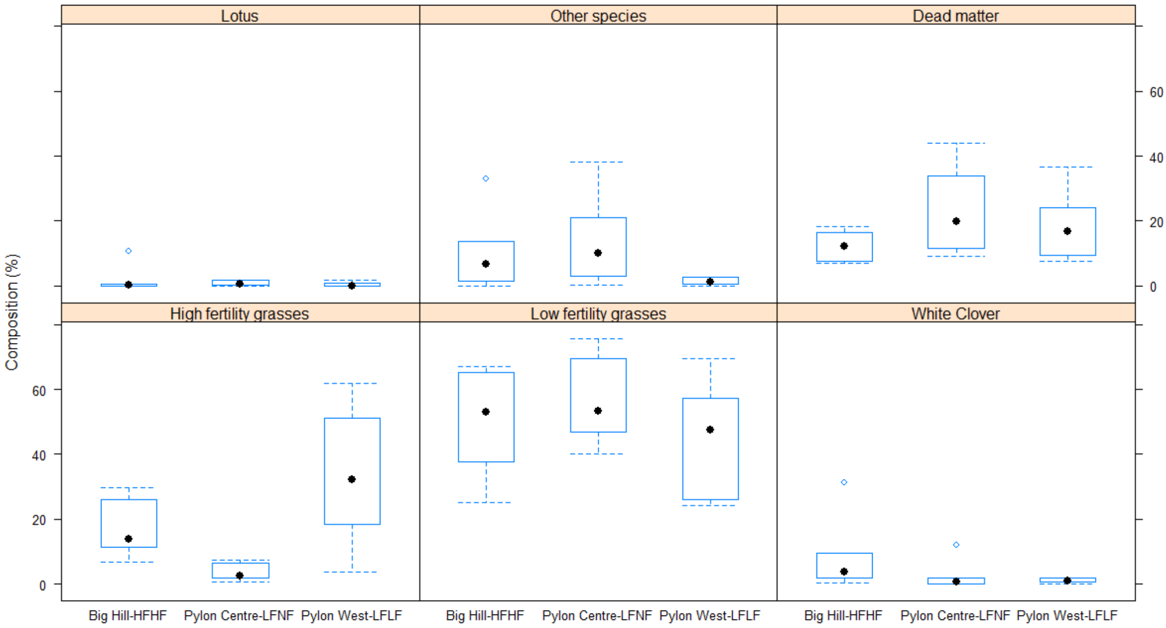

Figure 3. Plant species composition on the LFNF, LFLF and HFHF farmlets in summer 2016.

4.3 Soil analysis

A summary of the findings from the 2014 soil sampling of the long-term study is included in the report for completeness. More detail is available in Mackay and Costall (2016) presented at the recent NZGA Hill Country symposium in Rotorua.

In brief, the Olsen P levels in soil on the farmlet that has had no fertiliser since 1980 has dropped to 4 µg/ml (Fig. 4), ranging now from 2 to 7 µg/ml across the 18 sites in the farmlet.

The farmlet that has received 125 kg/ha/year of superphosphate since 1980 (LFLF) averages 13 µg/ml (range 3-26 µg/ml) and the farmlet that has received 375 kg/ha/year of superphosphate since 1980 (HFHF) averages 49 µg/ml (range 10-106 µg/ml).

In the LFLF farmlet the annual application of 125 kg superphosphate/ha/year has resulted in little change in Olsen P values since 1975, indicating the P fertiliser input is just balancing the P losses to soil, in product and by animal transfer within the paddock. This is matched by the fact there has been no or little change in the nominal long-term average sheep stocking rate on the farmlet since 1980 (Mackay & Lambert 2011). Until annual inputs are increased above maintenance no improvements in production are likely to occur.

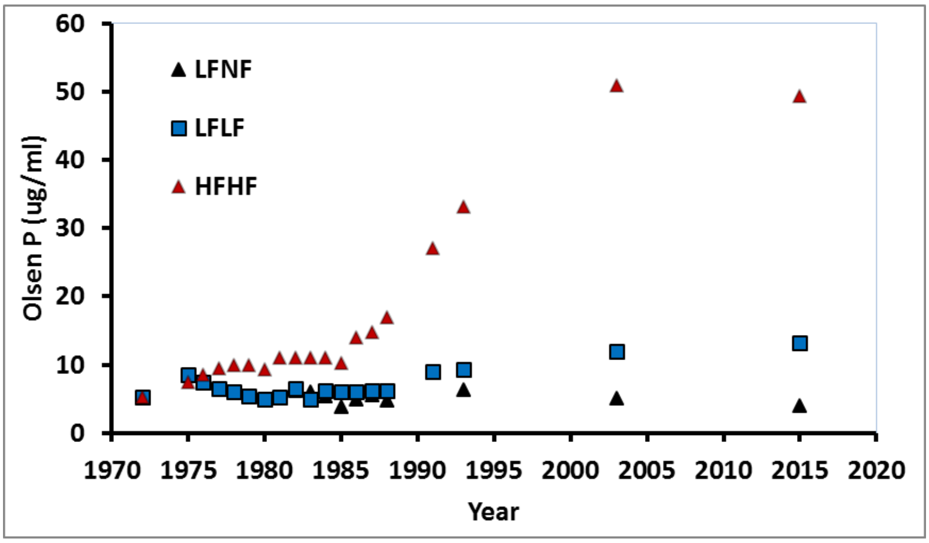

Figure 4 Changes in soil Olsen P levels (µg/ml) in the 0-75 mm soil depth in the farmlets that have had no fertiliser since 1980 (LFNF), received 125 kg/ha/year of superphosphate since 1980 (LFLF) or 375 kg/ha/year of superphosphate since 1980 (HFHF). From Mackay and Costall (2016).

On the HFHF farmlet Olsen P values averaged 49 µg/ml on the medium slope class. At this level the recommendation, if running a commercial operation, would be to reduce the superphosphate inputs by 100-125 kg/ha/year, to bring the Olsen P values below 30 and closer to 20. The Olsen P levels in the soil in the HFHF farmlet have not increased since the last sampling in 2003 (Fig. 4). Based on Morton & Roberts (2009) the amount of P above maintenance required (4-7 kg P/ha) to raise the Olsen P test by 1 unit for these soils should have translated into an increase of 10-20 units on the HFHF farmlet given stocking rate has not change over the last decade. Further as soil P fertility increases less soluble P is required to increase the Olsen P by 1 unit (Edmeades et al., 2006). The current findings suggest the reverse is occurring.

Soil pH levels in the topsoil (0-75 mm) across the three slopes and aspects for each of the LFNF, LFLF and HFHF farmlets averaged 5.5, 5.4 and 5.2, respectively. Average sulphate-S levels in the topsoil (0-75 mm) for the three slopes and aspects in the LFNF, LFLF and HFHF farmlets were 6, 9 and 11 µg/g, respectively. These reflected the fact that the LFLF and HFHF farmlets received annual S inputs in the superphosphate application.

4.4 Changes in pasture production since 1982-88

Each of the cage sites on the moderate slope on each of the three farmlets used for monitoring pasture growth in 2015-16 were the same sites used previously (1975-1988) to monitor pasture growth. Pasture growth rates from 1982-88 averaged 19, 26.6 to 35.7 kg DM/ha/day for the LFNF, LFLF and HFHF farmlets, respectively (Fig. 5). This represented an increase in pasture growth of 40% and 88% with the addition of 125 (LFLF) and 375 kg SPP/ ha/year (HFHF), respectively.

The monthly pattern of pasture growth measured on the LFNF and LFLF farmlet in 2015-16 aligned reasonably well with the pattern of pasture growth from these two farmlets back in 1982-88 (Fig. 5). Annual production on the two farmlets in 2015-16 also align with the average annual production reported for 1982-88 (Fig. 6). For both the LFNF and LFLF the average pasture production from 1982-88 was 6,916 and 9712 kg DM/ha, respectively and in 2015, 6,917 and 9,708 kg DM/ha, respectively.

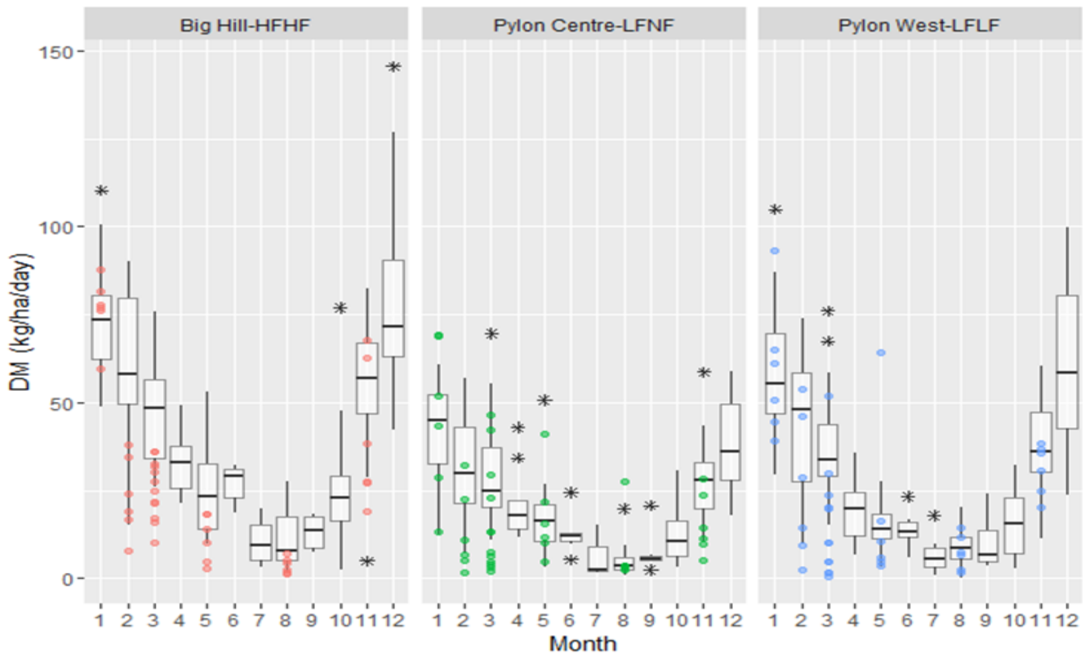

Figure 5. Pasture growth rates on moderate slopes on the LFNF, LFLF and HFHF farmlet from 1982-88. Pasture growth rates in 2015-16 are also included (Red, green and blue dots for the HFHF, LFNF and LFLF farmlets, respectively).

Pasture growth in the late summer, autumn and winter appears to be lower on the HFHF farmlet than for the same periods back in 1982-88 (Fig. 5). Annual production of 11,289 kg DM/ha on the HFHF farmlet in 2015-16, was lower than the average annual production (13,025 kg DM/ha) from the farmlet measured from 1982-88 (Fig. 6). Most of the difference in annual production can be tracked to the two East aspect sites where annual production in 2015-16 was only 65% of the average production recorded from 1982-88. There was no obvious physical damage to either the pastures or soils at these two cages sites, based on an examination of the photos taken in the summer of 2015 (appendix 9.3) or a close inspection this summer. On the other two farmlets pasture growth on the East aspect in 2015-16 was comparable (within 10%) of the growth rates measured during the 1982-88 period.

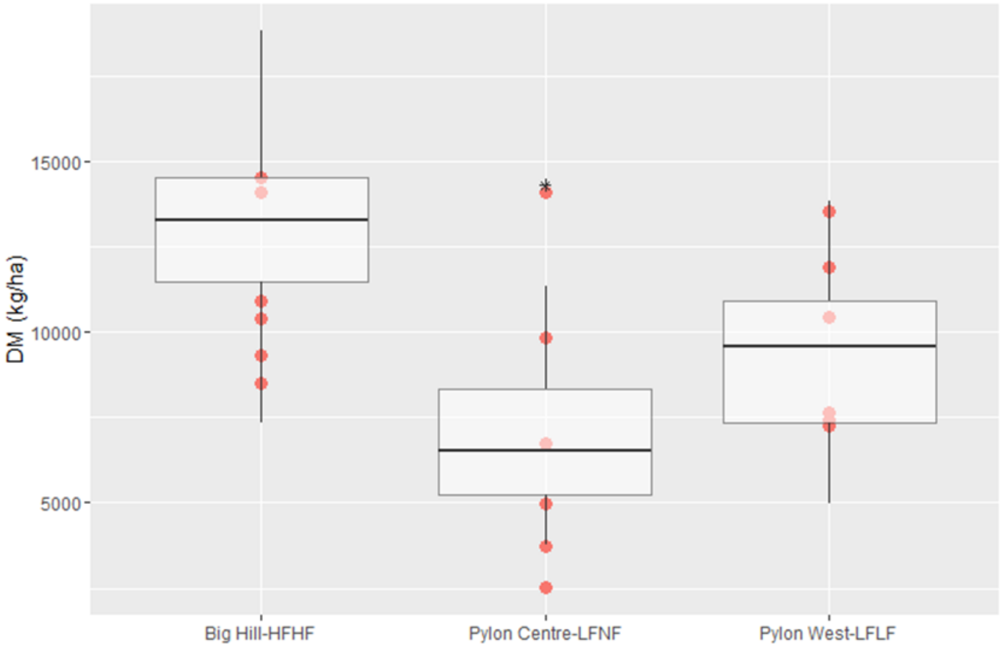

Figure 6. Annual pasture production on the moderate slope on the LFNF, LFLF and HFHF farmlet in 1982-88. Annual pasture production from each of the six cages sites for each of the three farmlets in 2015-16 are also included (Red dots).

5. Discussion

Average pasture growth rates in 2015-16 were 19, 27 and 31 kg DM/ha/day on the LFNF, LFLF and HFHF farmlets, respectively. These growth rates translate into annual pasture yields of 6,917, 9,708 and 11,289 kg DM/ha, respectively. The input of 125 and 375 kg SSP/ha/year has increased annual pasture production by 40% and 63%, respectively.

The differences in sheep stocking rates are greater than indicated by pasture growth with the input of 125 and 375 kg SSP/ha/year resulting in increases of 50 and 120%, respectively (Mackay and Costall 2016). The large apparent difference in the value of a fertiliser input when based on animal production rather than just pasture growth, reflects the fact a fertiliser input impacts beyond just yield to include pasture composition and nutritive value, which flows through and impacts on pasture utilisation, animal health and performance. This difference in animal performance occurred in spite of a dominance of low fertility grass species on all farmlets.

A feature of the LFNF farmlet and to a lesser degree the LFLF farmlets was the percentage of the pasture that is not grazed by sheep during the year (Appendix 9.1). On the LFNF farmlet the sheep are no longer grazing the steep banks (>26°) and significant areas on the moderate slope class. We have estimated that only about 65-70% of the farmlet is being actively grazed by animals. This means pasture utilisation across the LFNF farmlet is probably <50%. On the LFLF farmlet not all the steep banks are grazed (Appendix 9.2). This amounts to potentially 10-20% of the farmlet. In sharp contrast on the HFHF all slope classes on all aspects are being grazed year round by the animals (Appendix 9.3). The pronounced differences in grazing behaviour and levels of pasture utilisation between the LFNF and HFHF farmlet is a very visible feature of the long-term study.

One consequence of the limited defoliation of pasture by grazing animals on the steep banks on the LFNF are the higher rates of Manuka regrowth on this farmlet (Douglas et al., 2015).

The comparison of the pasture growth rates in 2015-16 with those measured back in 1982-87 from the same sites on each of the three farmlets produced a number of interesting results.

First pasture growth on the LFLF farmlet was on par with that measured back in the 1980’s (Figs 5 and 6). This aligns with the fact the application of 125 kg SSP/ha/year is close to a maintenance P application for the sheep stocking rate carried on this farmlet. This is supported by the Olsen P values which have also changed little over the last 35 years (Fig. 4).

If the decline in pasture growth on the moderate slope on the LFNF had continued to decline at the 1.5% p.a., recorded from 1981-87 as part of the fertiliser withholding study (Lambert et al.,1990), then annual production on the LFNF would be <5000 kg DM/ha. Surprisingly pasture growth on the LFNF farmlet has not declined but rather held at levels measured in the 1980’s. The biggest change observed on the LFNF farmlet has been the decline in the effective area grazed by sheep.

Pasture production on the HFHF farmlet in 2015-16 (11,289 kg DM/ha) was lower than in the 1980’s (13,025 kg DM/ha). The lower pasture growth rates measured over the last 12 months are consistent with the lower sheep stocking rates carried on this farmlet in recent years. The fact that the pasture growth rates on the LFLF farmlet in 2015-16 aligns with the pasture growth rates back in the 1980’s suggest that the differences in growth rates on the HFHF between the two periods is not simply due to climatic differences. It is important to note that the apparent difference in pasture growth between the two time periods on the HFHF farmlet is limited to a single production year in 2015-16. Most of the difference in pasture production between 2015-16 and the 1980's on the HFHF farmlet can be attributed to the lower pasture growth rates on the East aspect. At the present time we have not explanation for this finding. In comparison, on the other two farmlets there were no differences in pasture growth rates on the East aspect between the two time periods. It would be interesting to continue the monitoring of these sites for a further two years and to assess also what changes have occurred to the biology of these soils in recent years.

6. Summary

The long-term phosphorus fertiliser and sheep grazing study serve to highlight the long-term value of a phosphorus fertiliser investment to our legume based pasture systems. The input of 125 and 375 kg SSP/ha/year increased annual pasture growth rates by 40% and 63%, respectively, and sheep stocking rates by 50 and 120%, respectively.
A comparison of the pasture growth rates across the three farmlets in 2015-16 with pasture growth measured from the same sites on each of the three farmlets back in 1982-88 produced some predictable and some surprising results, highlighting the value of this well documented, long-term phosphorus fertiliser and sheep grazing study. It provides invaluable insights into the behaviour of our pastoral ecosystems beyond current boundaries.

7. Acknowledgments

We would like to acknowledge John Napier (farm manager) for his input and assistance with the day to day running of the trial, all the science, technical and farm staff and service staff that have being involved at the AgResearch Hill Country Research Station, Ballantrae since its establishment and the fertiliser industry for their support.

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9. **Appendix:** AgResearch Ballantrae Long-term phosphorus and sheep study moderate slope monitoring sites

9.1 LFNF Pylon Centre Farmlet – Medium slopes (13-25°).

LFNF Site 19 North West 275-30 deg.

LFNF Site 24 North West 275-30 deg.

Note: Large variation is apparent in physical conditions at the two replicate sites. Site 19 is well grazed whereas site 21 is poorly grazed, with a large amount of ungrazed understorey litter. Soil moisture conditions are also very different with 21 wetter than 19

LFNF Site 21 East 35-150 deg.

LFNF Site 29 East 35-150 deg.

Note: Site 21 is very well grazed; production from this site is as high as the HFHF farmlet through a combination of landscape position, nutrient return and soil moisture through a seepage zone. Site 29 is not so well grazed and has a large understorey of litter

LFNF Site 18 South West 275-30 deg. LFNF Site 30 South West 275-30 deg.

Note: Both these sites are poorly grazed, with a large litter build up.

9.2 LFLF Pylon West Farmlet – Medium slopes (13-25°).

LFLF Site 4 North West 275-30 deg. LFLF Site 5 North West 275-30 deg.

Note: Variation is apparent in the physical conditions at the two replicate sites. Site 4 is well grazed whereas site 5 is very poorly grazed. Soil moisture conditions also differ

LFLF Site 11 East 35-150 deg. LFLF Site 13 East 35-150 deg.

Note. Grazing management needs to be improved

LFLF Site 12 South West 275-30 deg. LFLF Site 33 South West 275-30 deg.

Note. Both sites are in areas that are poorly grazed and there is a substantial build-up of dead matter

9.3 HFHF Big Hill Farmlet – Medium slopes (13-25°).

HFHF Site 64 North West 275-30 deg. LFLF Site 71 North West 275-30 deg.

Note. Both sites well grazed, there would appear to be a variation in soil moisture conditions within each site

HFHF Site 59 East 35-150 deg. HFHF Site 62 East 35-150 deg.

Note. Reasonable grazing management. Both these sites produced less than in the 1980's.

HFHF Site 12 South West 275-30 deg. HFHF Site 33 South West 275-30 deg.

Note. Reasonably well grazed at both sites.