Technical note:
NLT/Farmscoper Benchmarking

1. Introduction

This technical note has been produced to present the results of a comparison of nitrate leaching predicted by the Environment Agency's Nitrate Leaching Tool (NLT) and by Farmscoper 3 (ADAS, 2015). For this purpose a series of crop and livestock scenarios were set up which simulate a range of the main parameters. The results of the three different NLT approaches (Arable, Grassland and Outdoor Pigs/Lowland Sheep) were compared with Farmscoper output and discussed in individual sections below.

Discrepancies between NLT and Farmscoper results are expected given the different assumptions and algorithms used by each tool. The exercise presented here aims to highlight the differences in the results, illustrate reasons for them and discuss the implications.

2. Nitrate Leaching Tool algorithms

The NLT distinguishes between three land use types and applies a separate algorithm for each of them to calculate residual N.

- Arable and Vegetable Crops: Simple balance approach, Residual N = Input N – Output N
- Grassland: N-Cycle model
- Outdoor Pigs and Lowland Sheep: Arable based algorithm using coefficients derived from Farmscoper

The residual N, once calculated with the above algorithms, can then be modified by:

- Allowance for any uncultivated headland in the field;
- Application of mitigation options;
- Minimum Residual N = 20kgN/ha (not applicable to N-Cycle).

The proportion of residual N lost by leaching is then calculated via a formula derived from the NEAP-N model (not applicable to N-Cycle)

The algorithms used by NLT are discussed in detail in the technical reference document and are not further discussed here.

3. Farmscoper algorithm (as derived by scenario runs)

The workings of Farmscoper are difficult to decipher as the calculations, parameters and assumptions are mostly hidden from the user and password protected. However, based on numerous test scenarios it was possible to detect certain patterns and derive coefficients used by Farmscoper to calculate leached N.

Farmscoper seems to assume a specific baseline leaching from the soil depending on crop type and rainfall band chosen. Further leaching from animals, fertiliser or manure seem to be based on fixed ratios, again depending on crop type and rainfall band, of N input to N leached. Table 3-1 shows an example of Farmscoper calculations (Winter Wheat scenario A1 – A8) splitting the components that ultimately amount to the leached N and showing the fraction of the initial N input.

Table 3-1: Simplified Farmscoper algorithm

Scenario	**Fertiliser (kg/ha)**	**Manure (kg/ha)**	**Baseline Leaching Soil (kg N/ha)**	**Leaching from Fertiliser (kg N/ha)**	% of Fertiliser input	**Leaching from Manure (kg/ha)**	% of Manure input	**Total Leached N (kg/ha)[1]**
A1	0		19.05	0				19.05
A2	50		19.05	3.63	7.25 %			22.68
A3	200		19.05	14.51	7.25 %			33.56
A4	400		19.05	29.02	7.25 %			48.07
A5		10,000	19.05			14.11	0.141 %	33.16
A6		50,000	19.05			70.55	0.141 %	89.60
A7		200,000	19.05			282.20	0.141 %	301.26
A8	100	100,000	19.05	7.25	7.25 %	141.10	0.141 %	167.41

1. equals sum of baseline leaching, fertiliser and manure leaching

4. Scenario Results

This section describes the scenarios simulated for each of the three NLT land use types (Arable, Grassland and Pigs/Sheep) and presents the results as graphs. A spreadsheet listing the results is included in Appendix A.

Each of the scenarios was set up using:

- A field area of 1ha;
- Soil Type "Free Draining" (Farmscoper), Loam-Moderate (NLT);
- NLT Soil parameters: Soil Depth = 100cm, Stored Water = 450mm.

These values represent typical soil parameters for the Northwest of England (NGR: SD). The drainage value for the specific rainfall band and crop type used by Farmscoper was used as input HER/Drainage in the NLT, thus ensuring that drainage volumes were equivalent in the two models for each scenario.

4.1 Arable and Vegetable Crops

Winter Wheat was chosen as main crop for this scenario as it is one of the most commonly grown arable crops in the UK. Further scenarios were run using Spring Barley and Sugar Beet as example crops.

Winter Wheat

The scenarios run for Winter Wheat are summarised in Table 4-1. The results are displayed in Figure 4-1 to Figure 4-3.

Table 4-1: Winter Wheat Scenarios

Scenario	Fertiliser (kg N)	Manure[1] (t)	Rainfall zone/HER
A1	0	0	900-1200 mm / 583mm
A2	50	0	900-1200 mm / 583mm
A3	200	0	900-1200 mm / 583mm
A4	400	0	900-1200 mm / 583mm
A5	0	10	900-1200 mm / 583mm
A6	0	50	900-1200 mm / 583mm
A7	0	200	900-1200 mm / 583mm
A8	100	100	900-1200 mm / 583mm
B1	0	0	<600 mm / 174mm
B2	50	0	<600 mm / 174mm
B3	200	0	<600 mm / 174mm
B4	400	0	<600 mm / 174mm
B5	0	10	<600 mm / 174mm
B6	0	50	<600 mm / 174mm
B7	0	200	<600 mm / 174mm
C1	0	0	>1500 mm / 1043mm
C2	50	0	>1500 mm / 1043mm
C3	200	0	>1500 mm / 1043mm
C4	400	0	>1500 mm / 1043mm
C5	0	10	>1500 mm / 1043mm
C6	0	50	>1500 mm / 1043mm
C7	0	200	>1500 mm / 1043mm

1 Manure Type: Farmscoper: Cattle Slurry (Dairy) NLT: Cattle Slurry (whole)-10% DM

Figure 4-1: Winter Wheat results (900 -1200 mm)

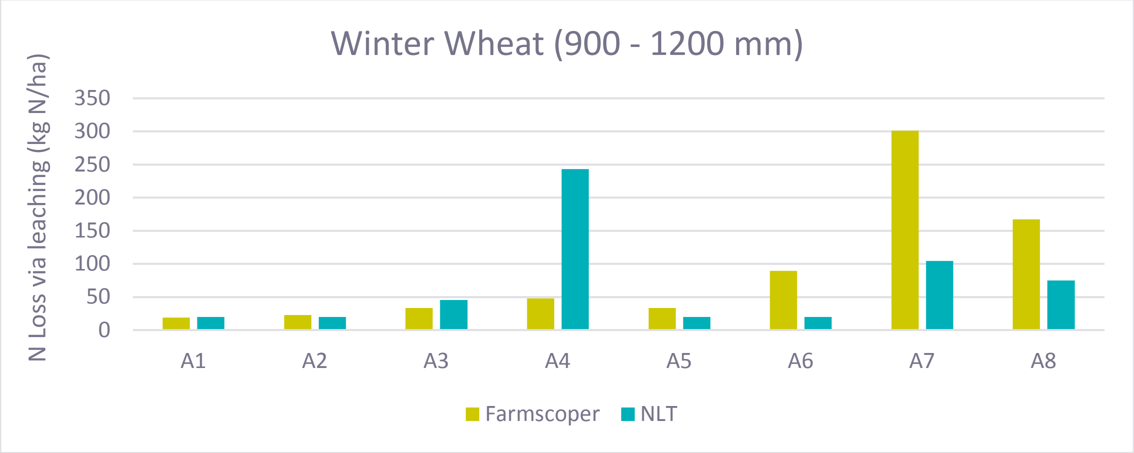


Figure 4-2: Winter Wheat results (<600 mm)

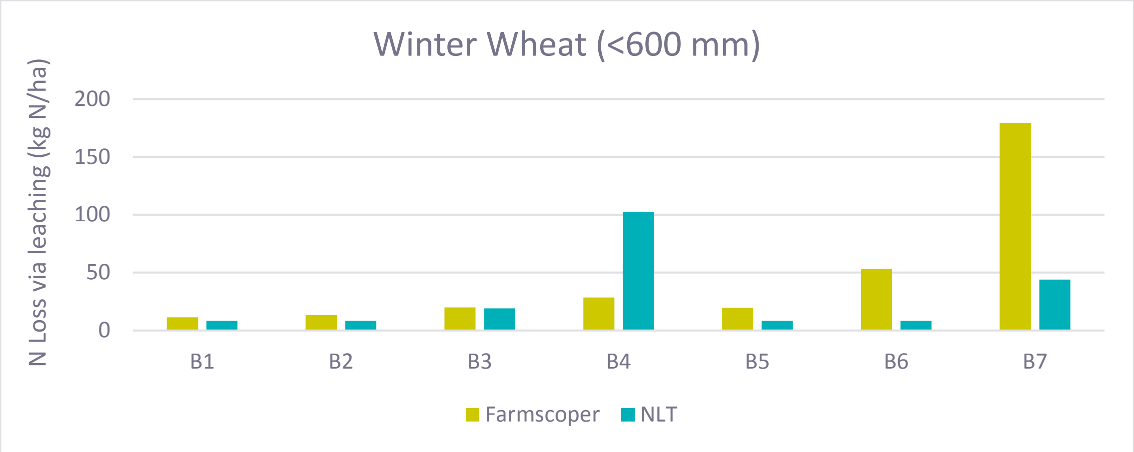
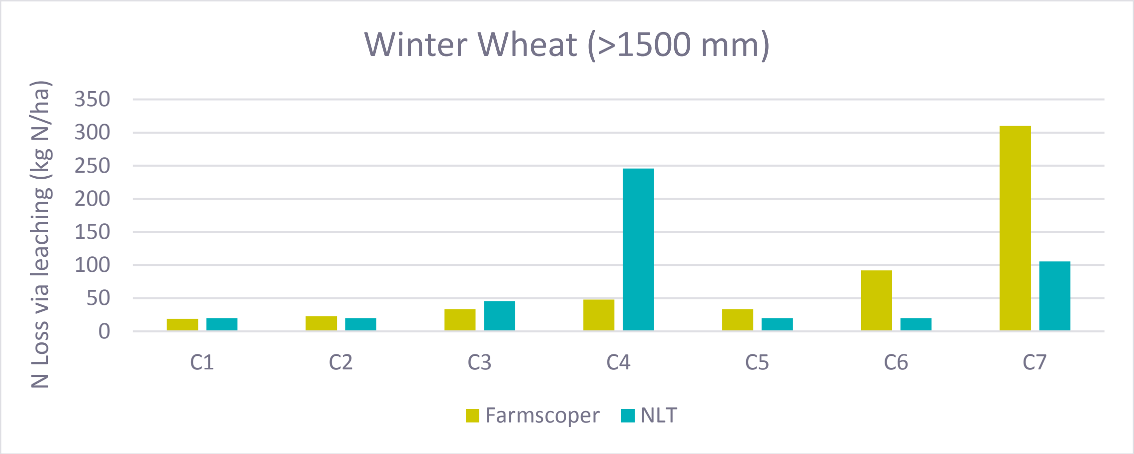


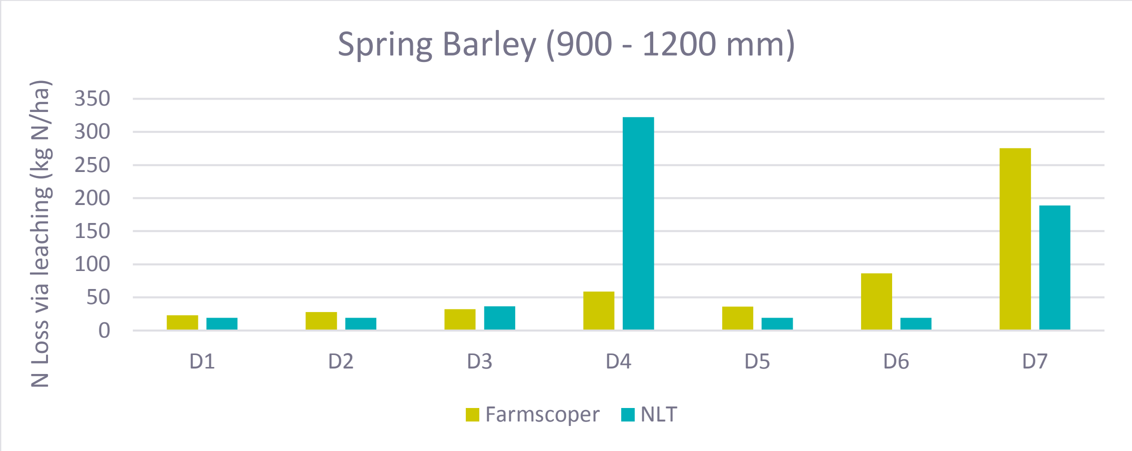
Figure 4-3: Winter Wheat results (> 1500 mm)



Spring Barley

Scenarios for Spring Barley were set up as the Winter Wheat scenarios A1 – A7 (see Table 4-1), apart from scenario A3 which was run with 100 kg Fertiliser N application reflecting a realistic value, close to the literature recommendation. The HER value used in NLT was 537 mm which is equal to the Farmscoper drainage value. The results are displayed in Figure 4-4.

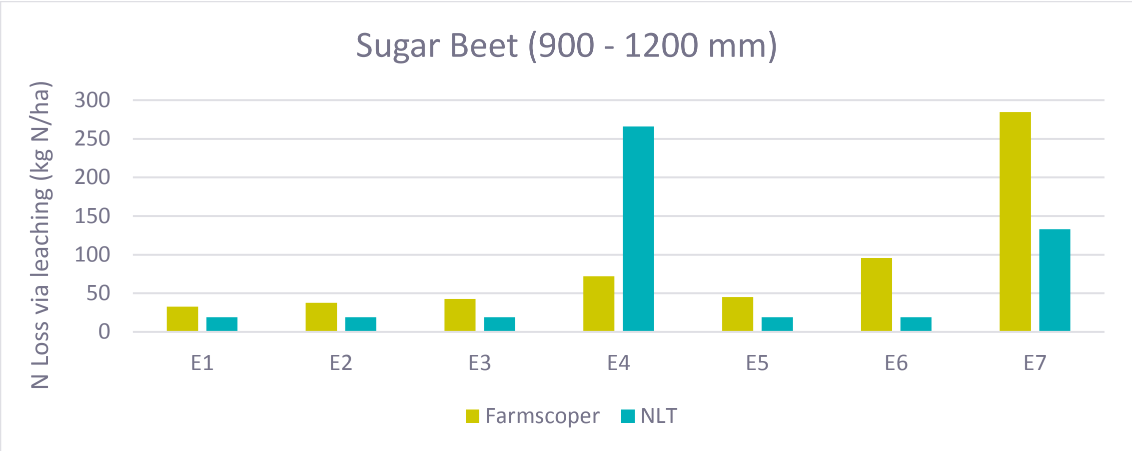
Figure 4-4: Spring Barley results (900 -1200 mm)



Sugar Beet

Scenarios for Sugar Beet were set up as the Winter Wheat scenarios A1 – A7 (see Table 4-1), apart from scenario A3 which was run with 100 kg Fertiliser N application reflecting a realistic value, close to the literature recommendation. The HER value used in NLT was 534 mm which is equal to the Farmscoper drainage value. The results are displayed in Figure 4-5.

Figure 4-5: Sugar Beet results (900 -1200 mm)



4.2 Grassland

Beef was chosen as Grassland scenario with field parameters summarised in Table 4-2. A stocking density of 4 animals per ha (high stocking density) was selected and a grazing period of “Grazed “ in NLT, which equals 7 months, to reflect the 54% grazing time assumed by Farmscoper as closely as possible. The NLT climate zone, which N-Cycle algorithm is based on, was selected to match the Farmscoper rainfall band. The results of the grassland scenarios are displayed in Figure 4-6 to Figure 4-8.

Table 4-2: Beef scenarios

Scenario	Fertiliser (kg N)	Rainfall zone/HER	NLT Climate Zone
F1	0	900-1200 mm / 566 mm	Climate Zone 2
F2	25	900-1200 mm / 566 mm	Climate Zone 2
F3	100	900-1200 mm / 566 mm	Climate Zone 2
F4	300	900-1200 mm / 566 mm	Climate Zone 2
G1	0	<600 mm / 104mm	Climate Zone 3
G2	25	<600 mm / 104mm	Climate Zone 3
G3	100	<600 mm / 104mm	Climate Zone 3
G4	300	<600 mm / 104mm	Climate Zone 3
H1	0	>1500 mm / 1139mm	Climate Zone 1
H2	25	>1500 mm / 1139mm	Climate Zone 1
H3	100	>1500 mm / 1139mm	Climate Zone 1
H4	300	>1500 mm / 1139mm	Climate Zone 1

Figure 4-6: Beef results (900 -1200 mm)

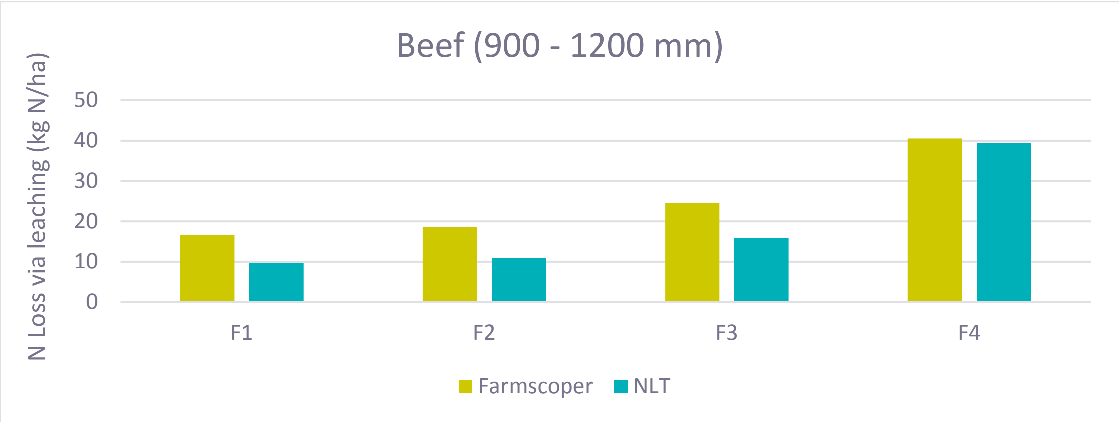


Figure 4-7: Beef results (<600 mm)

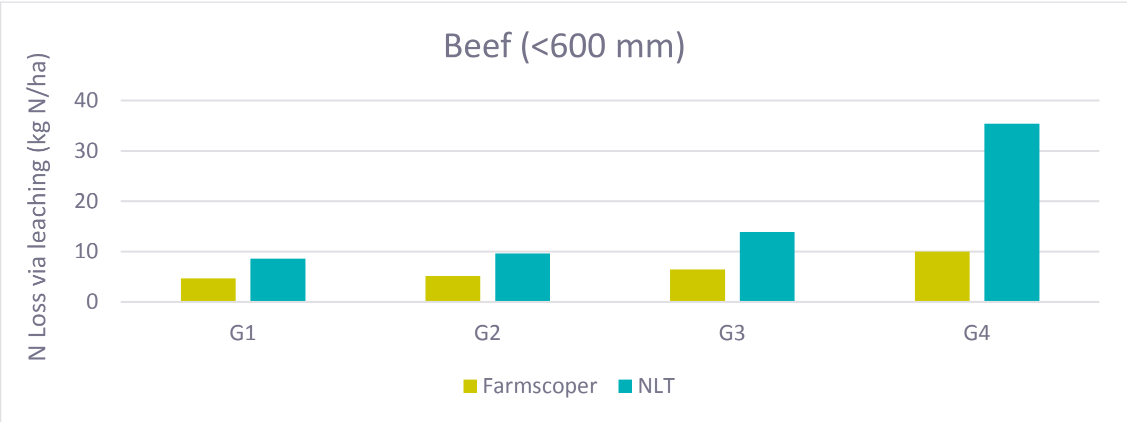
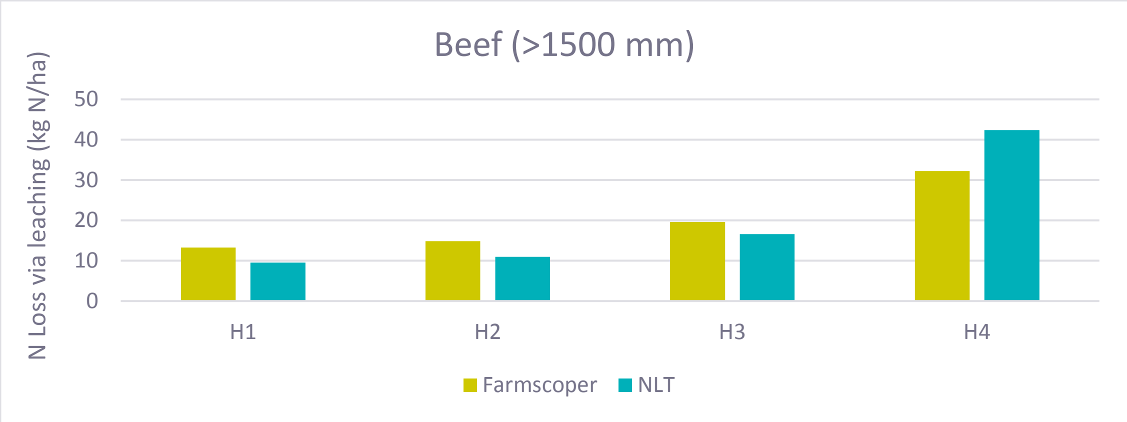


Figure 4-8: Beef results (>1500 mm)



4.3 Outdoor Pigs and Sheep

Scenarios for Outdoor Pigs and Lowland Sheep were set up as the Grassland Scenarios F1 – F4 (Rainfall band: 900-1200 mm) and G1 to G4 (Rainfall band: <600 mm). The results are displayed in Figure 4-9 to Figure 4-12.

Figure 4-9: Outdoor Pigs results (900 -1200 mm)

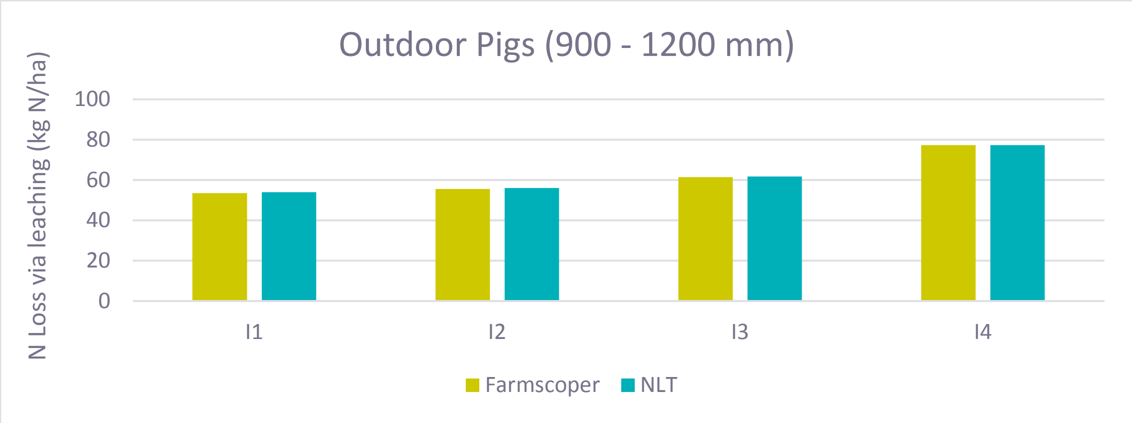


Figure 4-10: Outdoor Pigs results (<600 mm)

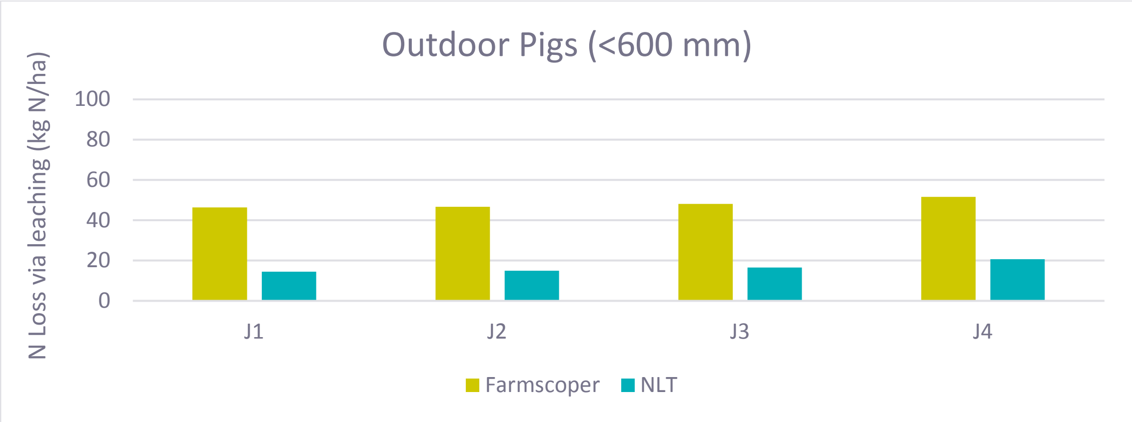


Figure 4-11: Lowland Sheep results (900 -1200 mm)

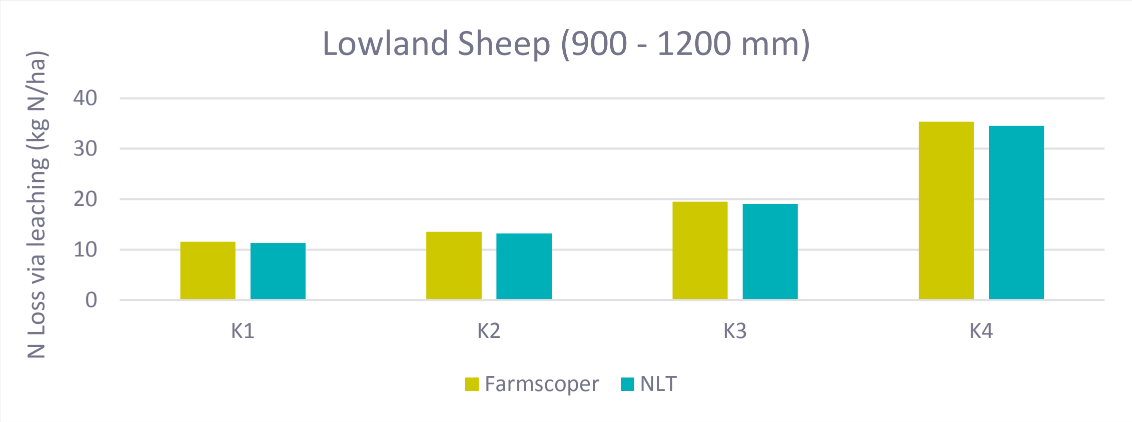
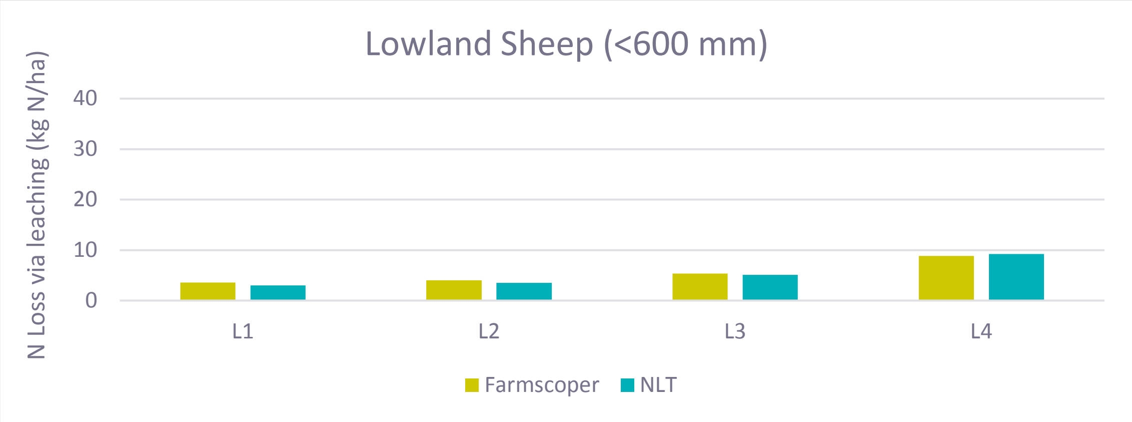


Figure 4-12: Lowland Sheep results (<600 mm)



5. Discussion

5.1 Arable and Vegetable Crops

Winter Wheat

The Winter Wheat scenarios show comparable results for NLT and Farmscoper for fields with small N input (scenarios 1, 2 and 5). For these scenarios the NLT reverts to the minimum residual N value (20 kg N/ha) as N inputs to the field do not exceed the offtake by more than 20 kg. This value is then input to the NEAP-N algorithm to calculate how much nitrate will actually leach as a function of soil properties and drainage. Farmscoper on the other hand, uses a baseline leaching value from soil which is between 11 – 20 kg N/ha depending on the rainfall band and then adds fixed fractions of the N input to the field (fertiliser/manure), which are again dependent on the selected rainfall band, as additional N loss via leaching. These two different approaches ultimately deliver similar results for small to moderate N input scenarios.

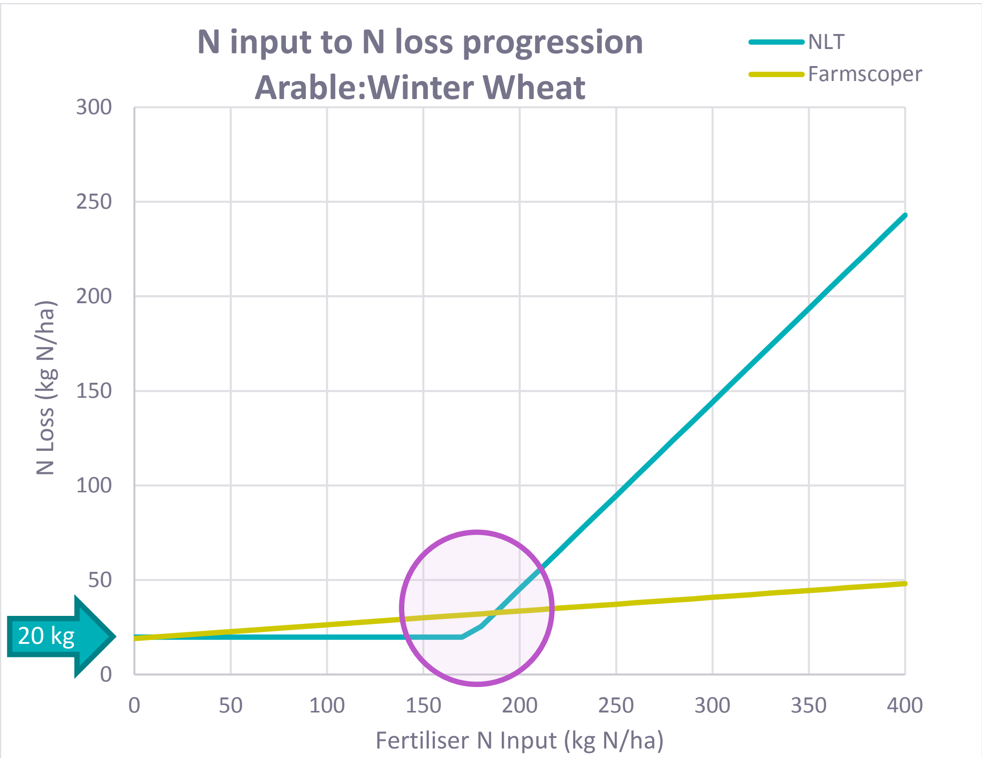
When very large amounts of Fertiliser N are applied (exceeding crop yield) to fields, the results of the two approaches increasingly diverge from each other. The NLT will flag excessive N application as N at risk of leaching resulting in very high potential N loss values (e.g. scenario 4). However, Farmscopers N leaching value still consists of the baseline leaching from soil plus the fixed fraction of Fertiliser N input, which results in a much more gradual rise of leached N with increasing Fertiliser N.

Scenario A3 is probably the most realistic Winter Wheat scenario with Fertiliser N close to the recommended literature value. NLT and Farmscoper show similar results for this scenario.

It is noticeable that Farmscoper predicts greater nitrate leaching than the NLT for all scenarios with manure applications. This is due to the assumed N content of manures, and this is further discussed in Section 5.4.Figure 5-1 compares the progression of leached N with increasing N fertiliser input in both tools for the Winter Wheat scenario with field parameters set to match the A scenarios (900-1200mm). The NLT graph starts with a flat line representing the minimum residual N value (20 kg N/ha) subsequently breaking off to a steep ascent after the N input exceeds the offtake by more than 20 kg N/ha at around the recommended fertiliser mark (recommended for Winter Wheat: 188 kg N/ha). Farmscoper on the other hand shows a consistent increase in N loss throughout the increasing N application as described above. This illustration is effective in showing the following:

- The two methods show similar predictions for low N input fields, and for fields with more realistic N input (are marked purple on Figure 5-1);
- Farmscoper and NLT results for High N input fields quickly diverge from each other, with NLT showing a rapid increase, which underlines the main objective of NLT: to highlight high risk fields;
- This illustrates the cause for the large step change between scenarios 3 and 4 (200 to 400 kg N/ha).

Figure 5-1: N Input to N loss progression for arable land use



Spring Barley and Sugar Beet

The results for Spring Barley and Sugar Beet show a similar pattern as seen in Winter Wheat as the same underlying algorithms apply.

Scenarios with a small N input (scenarios 1, 2 and 5) show notably higher leached N predictions in Farmscoper compared to NLT as the baseline leaching value assumed by Farmscoper for Spring

Barley (23.3 kg N/ha) and especially for Sugar Beet (32.7 kg N/ha) are higher than the minimum leached N assumed by NLT (20 kg N/ha).

Scenario 4 shows the effects of a very high Fertiliser N application rate of 400 kg/ha, which is well in excess of recommended values for Spring Barley and Sugar Beet.

The results for scenarios with manure application show the same characteristics as described for Winter Wheat (see Section 5.4).

5.2 Grassland

NLT and Farmscoper calculations of leaching from grazed fields were compared using Beef as an example. The values calculated for the moderate rainfall band (900 - 1200mm) are fairly similar for the NLT and Farmscoper, especially for scenarios which use more ‘realistic’ fertiliser values (e.g. scenario F4). However if excessive amounts of fertiliser are applied, NLT predictions of nitrate leaching exceed those of Farmscoper. This is due to the fixed fertiliser ratio used by Farmscoper described above.

Farmscoper results for the dry rainfall band (<600 mm) suggest notably less leaching compared to the NLT calculations. This is mainly due to the fact that the climate zones used by N-Cycle in NLT are difficult to compare to the rainfall bands used in Farmscoper as they represent very different areas of the UK. The driest climate zone (zone 3) implies a much smaller reduction in N leaching compared to the dry rainfall zone in Farmscoper. NLT uses one of three climate zones to pick coefficients for the N-Cycle model, which will determine the proportion of leached N for a given field. This is much less sensitive than the NEAP-N calculation used for the other crop types (Arable/Pigs and Sheep) which takes HER, pore volume and profile depth for each field into account.

The results for the wet rainfall band (>1500 mm) are similar to the results for the moderate band discussed above. The NLT calculates slightly higher leached N values due to the higher drainage, whereas Farmscoper produces slightly lower values compared to the moderate rainfall scenarios. This relates to the fact that Farmscoper assumes that farms in the wettest areas will be less intensive and denitrification may be more likely.

Figure 5-2 compares the progression of leached N with increasing N fertiliser input in both tools for the Grassland scenario with field parameters set to match the F scenarios (900-1200mm). The NLT graph represents the curve of the underlying N-CYCLE model used for grassland calculations, whereas Farmscoper shows a consistent increase in N loss representing the sum of fixed ratios of leaching from soil, animals and fertiliser. This illustration is effective in showing the following:

- Overall results from the two approaches are comparable
- The best results are achieved in the ‘realistic’ range (area marked purple)
- Farmscoper and NLT results for High N input fields (>350 kg N/ha) quickly diverge

Figure 5-2: N Input to N loss progression for grassland: beef

5.3 Outdoor Pigs and Lowland Sheep

The scenarios for Outdoor Pigs and Lowland Sheep show very similar results in Farmscoper and the NLT. This is expected as the algorithm used in the NLT is based on coefficients derived from Farmscoper. The only exception is the Outdoor Pigs scenario J (dry rainfall band, <600 mm) which shows significantly lower leaching values in NLT compared to Farmscoper. Farmscoper assumes very similar leaching values from Outdoor Pigs throughout all of the rainfall bands, which is unusual as normally leaching decreases significantly in drier scenarios. This leads to consistently high leaching predictions from Farmscoper and much smaller values in the NLT for the very low HER value of the dry scenario.

5.4 Leaching from Manure

Scenarios with manure application (e.g. scenarios A5 to A8) show notably different results for NLT and Farmscoper. The main reason for this appears to be differences in the assumed N content of manures. The NLT calculates nitrogen at risk in manure using DEFRA manure N content coefficients (DEFRA, 2010) for readily available nitrogen (kg N/t). The values for manure N content used in Farmscoper can be viewed under the “manure details” section and are the DEFRA values for total rather than readily available nitrogen (DEFRA, 2010). Table 5-1 shows some examples of manure N content used in Farmscoper and NLT.

Table 5-1: Assumed Manure N content (kg N per tonne manure) NLT vs Farmscoper

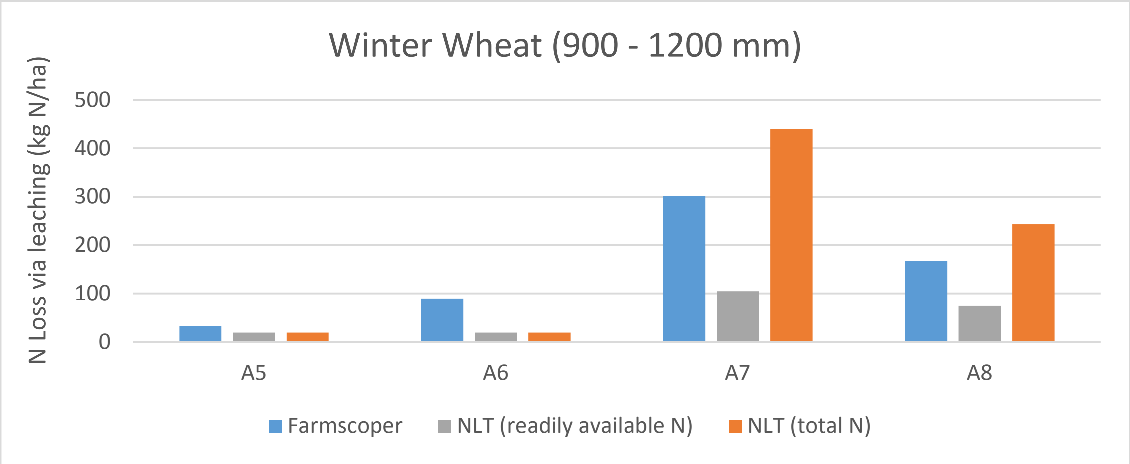
Manure Type	NLT Nitrogen Content (kg/t or kg/m^3) (DEFRA 2010)[1]	Farmscoper (ADAS, 2015) Nitrogen Content (kg/t or kg/m^3)
Cattle Slurry	1.3	3.0
Pig Slurry	2.8	4.0

Cattle FYM	1.2	6.0
Pig FYM	1.8	7.0

1 maximum N content from the range of available manure subtypes in NLT

Figure 5.1 shows predicted N leaching from Farmscoper and the NLT for arable scenarios A5 to A8, all of which include manure applications. Predictions are shown from the NLT assuming (a) manure N content equal to the readily available value, and; (b) manure N content equal to the total value. The scenarios are fully described in Section 4.1. For scenarios A5 and A6 the residual N remains equal to the default minimum value of 20 kg-N/ha. For scenarios A7 and A8, the increase in assumed manure N content results in a significant increase in predicted leaching to values which exceed those from Farmscoper. Overall, there is better agreement between the models when using manure total N content.

Figure 5-3 Predicted nitrate leaching from Farmscoper, from the NLT using readily available manure N content, and from the NLT using total manure N content.



6. Conclusion

As emphasised in the first part of this note, the two programs use a very different approach and assumptions to calculate residual N in the soil and some differences were therefore expected. Nevertheless, the comparison of Farmscoper to NLT nitrate leaching predictions show an overall reasonable match.

Although a number of Farmscoper assumptions remain hidden from the user, the fundamental algorithm to calculate the amount of nitrate leaching from a given N input appear to be coefficients which are applied depending on field parameters such as rainfall band and crop type. Factors such as a reduction or increase in crop yield in accordance with low or high N input are not accessible to the user.

NLT on the other hand has been run using a typical crop specific yield value (based on literature values) throughout all test scenarios. However, when N input values (fertiliser/manure) are unrealistically low the crop would not produce the yield that is assumed for the NLTs offtake calculation thus resulting in very low leaching predictions. This often results in NLT applying the minimum residual N of 20kg N/ha (which mostly reflects atmospheric N). If on the other hand the N input values are excessively high NLT will calculate a large residual N and will predict high N leaching. This underlines that NLTs simple N budget approach relies on reasonable user input. This budget approach albeit simple will quickly highlight high risk fields and generally fields with imbalanced field parameters. The comparison to Farmscoper has shown that the best results are achieved for fields with 'realistic' input parameters.

The user can adjust the yield values for each field in NLT, to allow for scenarios such as extreme N application, as application described above. The Farmscoper algorithm on the other hand seems to suggest an inbuilt mechanism which adjusts N offtake according to N input resulting in a much more gradual increase/decrease of leaching.

The discrepancies seen in this comparison are predominantly due to the differences in the fundamental workings of the two tools described above. Other factors that contribute to differences are:

- Leaching from manure due to different assumed N content of manures (see chapter 5.4),
  review of the values used in NLT might be necessary
- Climate Zones used by NCycle model don't compare precisely to Farmscoper rainfall bands
- Varying sets of field parameters and options in both tools (e.g. soil parameters/livestock options)

The exercise presented here has highlighted the different approach used by both tools to derive nitrate leaching. NLT uses a very transparent approach giving the user a range of options to setup specific field parameters. However, the NLT, more than Farmscoper, relies on reasonable input values to provide an accurate answer. Farmscoper is more restricted in terms of user input, however, catches potential lack of field parameter information by the user better than the NLT. The nitrate leaching predictions calculated by Farmscoper depict a controlled and gradual increase/decrease of leaching with increased/reduced N application. The NLT is very much configured to highlight high risk fields and will do so when N application to a field starts exceeding the N offtake. In doing so, it probably overestimates the leached N for extreme N application scenarios as all excess nitrate, depending on soil parameters (e.g. stored water), will be considered as leached by the NLT.

In general, predictions from the two tools are similar for a range of "reasonable" input values. The decision what tool to use to create 'better' answers to the question of nitrate leaching risk should be informed by the findings above and the qualitative rather than quantitative requirements of the predictions. The two tools will only give a rough estimate of 'real' quantitative risk with their very limited set of field parameters.

7. References

DEFRA, 2010. Fertiliser Manual (RB209), 8th Edition

ADAS, 2015. Farmscoper version 3, released October 2015

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Appendix A
NLT/Farmscoper Benchmarking Results

See accompanying spreadsheet “Appendix A - Results.xlsx”