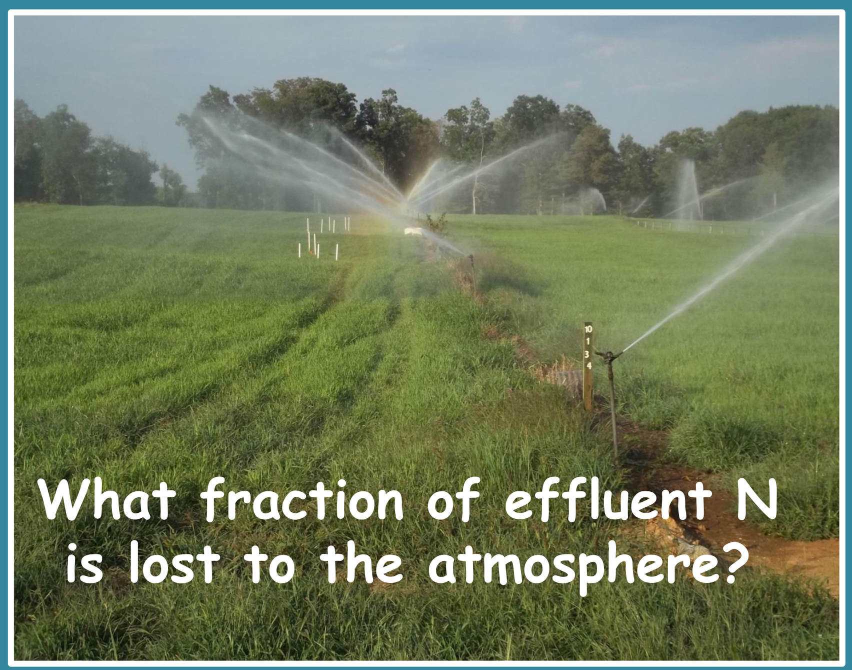

Estimating Denitrification From Tall Fescue Fields Irrigated With Municipal Wastewater

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Introduction

Nitrogen (N) is commonly the limiting parameter in design procedures for treated municipal wastewater effluent (MWE) irrigation with crop N uptake.

Design procedures estimate the expected atmospheric N losses (via denitrification (den.) and ammonia volatilization) and soil N storage while optimizing crop N uptake and most importantly avoiding nitrate leaching. **Fig.1** shows the N-related processes considered in design of MWE irrigation systems.

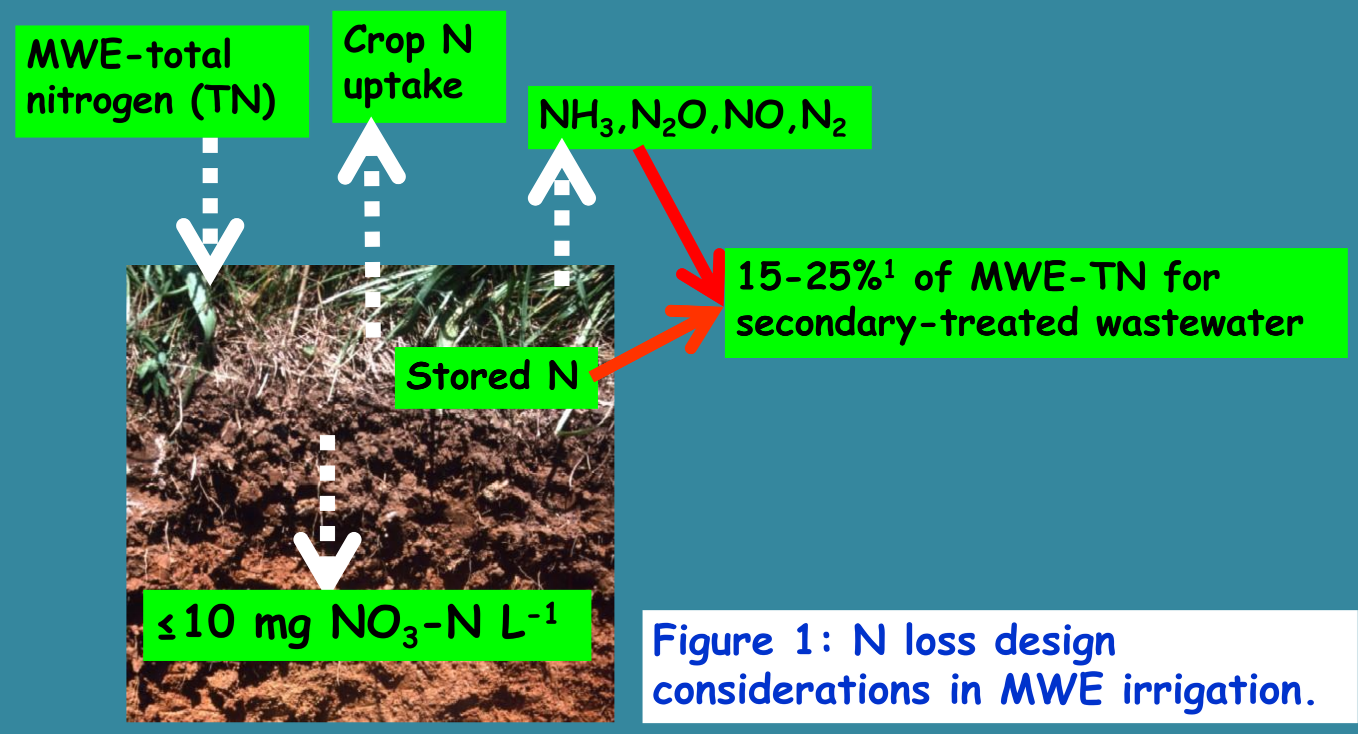


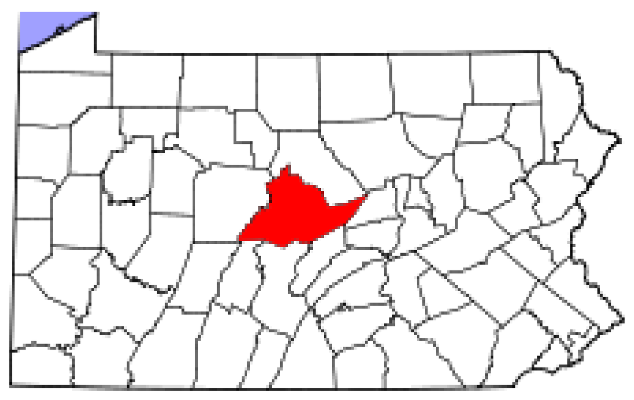
Figure 1: N loss design considerations in MWE irrigation.

For nitrate-dominated MWEs, denitrification is assumed to contribute proportionately more to the atmospheric N losses in Fig. 1. However, few studies have verified these N losses.

Research objective: To provide more precise estimates of the fraction of MWE-TN lost to the atmosphere through measurement and simulation of denitrification.

Site description

Location: Penn State University (PSU) Living Filter (LF), University Park, PA.
Latitude: 40º49' 44.025" N
Longtitude: 77º52'7.866" W
Crop: Tall Fescue (*Festuca arundinacea*)
Soil type: Hagerstown silt loam
MWE irrigation rate: ~50 mm wk^{-1}
Secondary treated MWE-TN: ~12 – 15 mg L^{-1} (~60-80% nitrate N)
Annual average MWE-nitrate N: ~10 mg L^{-1}
Bulk density (0 – 12 cm): 1.25 g cm^{-3}



Materials and Methods

- Denitrification was estimated in the laboratory using the acetylene inhibition soil core (50 mm dia. and 100 mm long) incubation method. Core head space was analyzed for N_2O by gas chromatography. Soil cores were collected before irrigation and 4-5 h after irrigation ceased.

- The DeNitrificationDeComposition (DNDC v.9.5) model was run in the site mode to simulate atmospheric N losses from the grass field. A fertigation file for the model inputs was created using Urea Ammonium Nitrate (UAN) fertilizer applications: 122 (2011) and 109 (2012) kg N ha^{-1}; MWE-nitrate N: 709 (2011) and 570 (2012) kg N ha^{-1}; and the MWE irrigation depth. Other site specific model inputs included soil properties, crop parameters and harvesting dates.

- Measured and simulated den. N losses were reported as a percentage of MWE-TN and MWE-nitrate N.

- Percent water saturation (0-6cm) was calculated based on volumetric water content and soil porosity.

References

[1]United States Environmental Protection Agency (USEPA). 2006. Chapter 8: Process design-slow rate systems. *In Land treatment of municipal wastewater effluents: Process design manual.* EPA/625/R-06/0162006. Office of research and development, Cincinnati, Ohio USA.

[2]Bremner, M.J. and K. Shaw. 1958. Denitrification in soil. II. Factors affecting denitrification. J. Agric. Science. 51: 40-52.

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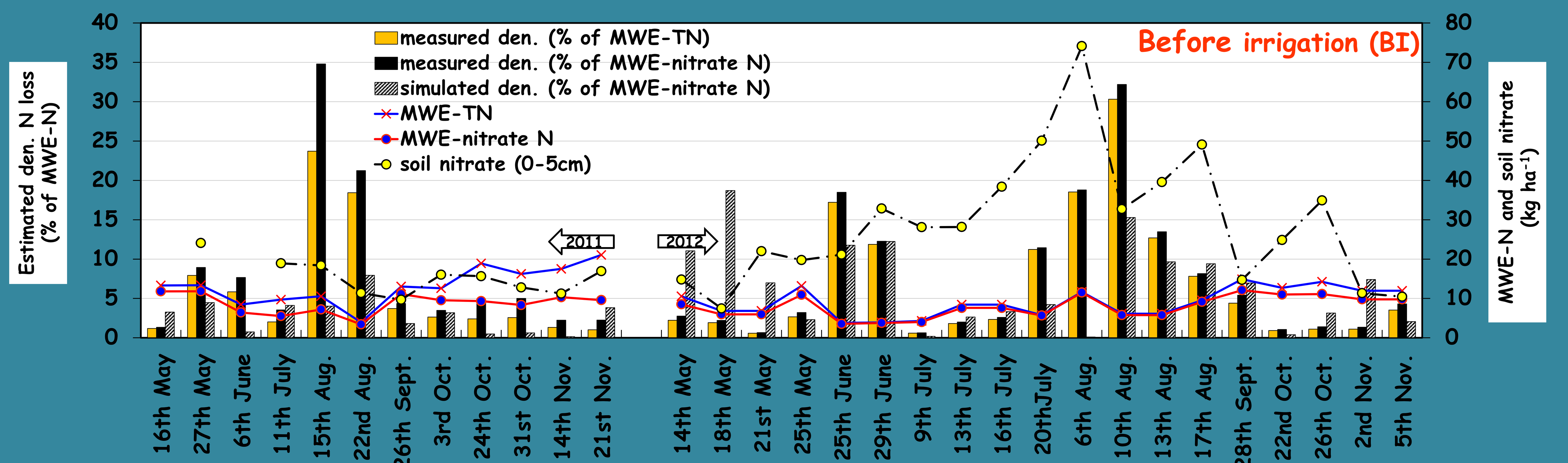
Results and Discussion

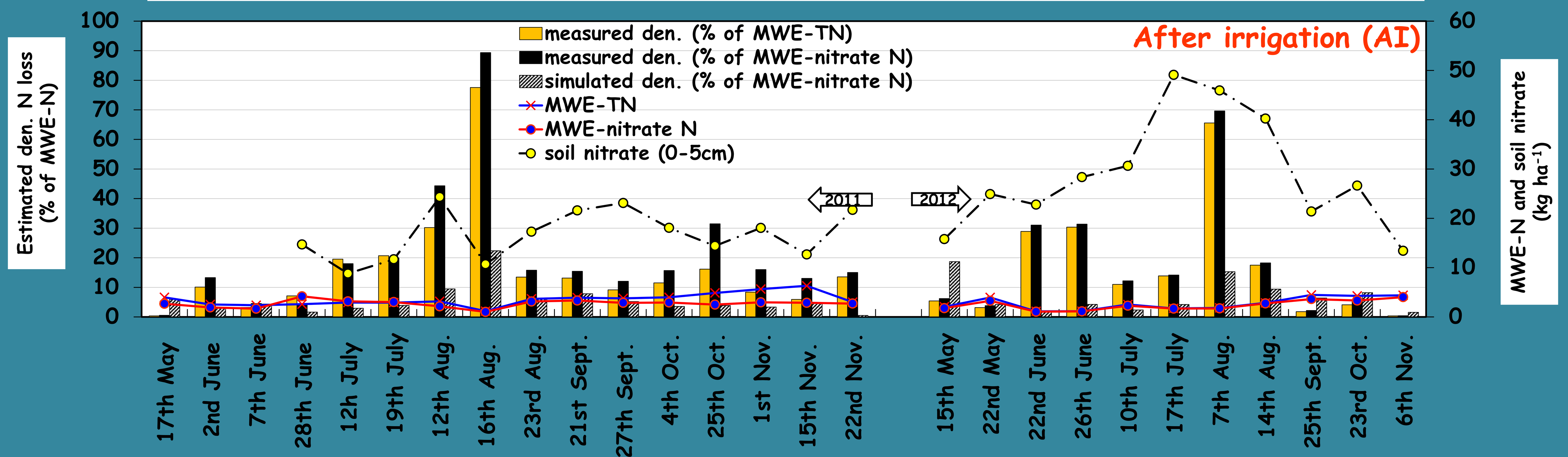


	16th May	27th May	6th June	11th July	15th Aug.	22nd Aug.	26th Sept.	3rd Oct.	24th Oct.	31st Oct.	14th Nov.	21st Nov.
Rainfall (mm)	0.00	12.15	0.25	0.25	5.84	0.25	26.42	0.00	0.45	0.00	0.76	47.50

	14th May	18th May	21st May	25th May	25th June	29th June	9th July	13th July	16th July	20thJuly	6th Aug.	10th Aug.	13th Aug.	17th Aug.	28th Sept.	22nd Oct.	26th Oct.	2nd Nov.	5th Nov.
Rainfall (mm)	48.26	0.00	19.30	0.00	0.76	0.00	0.03	0.21	0.03	18.66	0.00	2.29	9.91	0.51	0.21	0.76	0.00	0.76	0.00

Figure 2: Measured and simulated denitrification before irrigation.

- Average water saturation was 75% in 2011 and 71% in 2012, above the 60-70% threshold[2] needed for denitrification.
- 84% (n=31) of measured den. N losses were <15%, 13% were in the 15-25% range and 3% were >25% based on MWE-TN.
- Simulated den. N losses of MWE-nitrate N (%) were generally <15%.
- Soil nitrate peaked within 6-d (2011-see **Fig.3**) and 3-d (2012) after UAN application. Higher 2012 summer temperatures could have enhanced nitrification following fertilizer application.
- No correlation could be drawn between den. and rainfall induced water saturation, since sampling followed irrigations rather than rainfall.



	17th May	2nd June	7th June	28th June	12h July	19th July	12th Aug.	16th Aug.	23rd Aug.	21st Sept.	27th Sept.	4th Oct.	25th Oct.	1st Nov.	15th Nov.	22nd Nov.
Rainfall (mm)	7.62	0.25	0.35	4.62	0.00	0.00	0.51	2.79	2.54	0.00	8.89	0.00	0.25	0.00	0.00	0.00

	15th May	22nd May	22nd June	26th June	10th July	17th July	7th Aug.	14th Aug.	25th Sept.	23rd Oct.	6th Nov.
Rainfall (mm)	0.51	3.56	0.00	0.00	0.03	0.03	0.00	19.05	4.19	0.00	0.00

Figure 3: Measured and simulated denitrification after irrigation.

- Average water saturation was 90% in 2011 and 87% in 2012.
- 67% (n=31) of measured den. N losses were <15%, 15% were in the 15-25% range and 19% were >25% based on MWE-TN.
- Simulated den. N losses of MWE-nitrate N (%) were generally <15%.
- In 2011, the average soil nitrate concentration increased slightly from 15.8 kg ha^{-1} (28.0 ppm)-BI to 16.7 kg ha^{-1} (29.6 ppm)-AI and in 2012, soil nitrate was approx. the same 29.0 kg ha^{-1} (51.2 ppm)-BI and 51.4 ppm-AI.
- Water saturation was mostly due to irrigation rather than rainfall, since soil samples were collected 4-5 h after irrigation ceased and total irrigation water additions were much greater than rainfall.

Summary

- Measured den. N losses (% of MWE-TN) were generally:
  - (i) <15%, with the majority in May, June, Sept, Oct and Nov.
  - (ii) lower before irrigation than after irrigation.
  - (iii) highest in August. The den. N losses that were estimated within a week from UAN application in August were likely affected by fertilizer N.
- Measured den. N losses expressed as % of MWE-TN or as % of MWE-nitrate N were approx. equal, since 60-80% of MWE-TN was nitrate.
- Simulated denitrification was lower than measured.

Conclusions

- Lower values in the 15-25% range could be selected for the atmospheric N loss of MWE-TN (%) especially for nitrate dominated MWEs.
- Design procedures could be improved by using seasonal N loss values.

Considerations for future research

- Estimating the atmospheric N loss, and where possible soil N storage, for MWE-N application for a wider range of climates and crop production systems will further improve N loss design considerations for MWE irrigation.