Assessing Crop Rotational Nitrogen Use Efficiency Using an N Balance Approach

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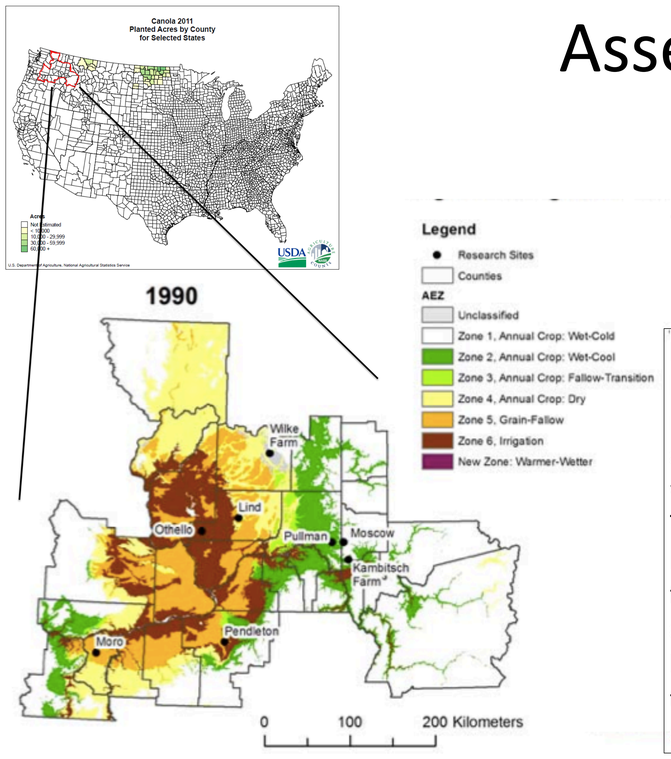
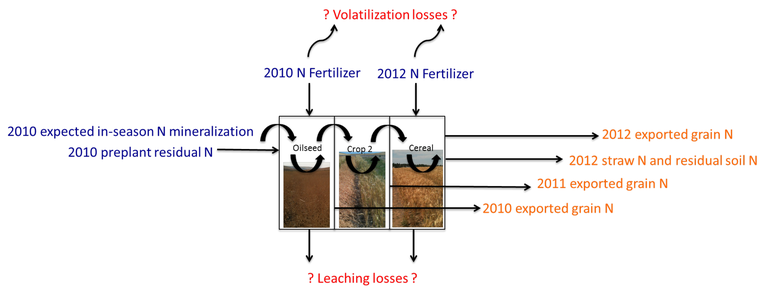
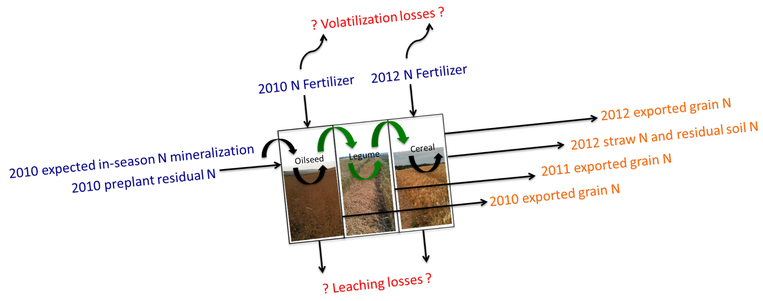


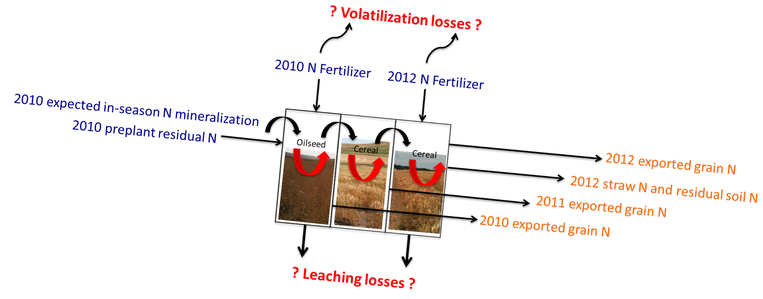
In annual cropping systems, nitrogen use efficiency (NUE) is typically estimated on a single crop basis. However, this approach ignores the dynamic nature of nitrogen cycling within multi-year crop rotations featuring a diverse set of crops. Our objective is to develop a component analysis of NUE of an entire crop rotation. As the first step, we will construct N budgets and calculate N balances, which are useful to demonstrate fertilizer carry-over and N recycling as important aspects of NUE. This approach will also provide insight into the propensity of cropping systems to retain and recycle N within a rotation. The rotational NUE analysis will factor in crop yields, grain and residue N, fertilizer N, N mineralization estimates, and changes in soil residual inorganic N. The analysis will be applied to two-and three-year rotation studies in the low, intermediate, and high rainfall zones of Eastern WA. There is evidence that fertilizer carry over contributes to overall rotational NUE. By tracking changes in soil N supply between crops, the rotational NUE will help us evaluate and adopt alternative cropping systems with the propensity to retain and recycle N within a rotation.



Inputs = Outputs



Inputs < Outputs



Inputs > Outputs

High rainfall zone

- **Palouse Conservation Field Station** is located in **Pullman, WA**, and averaged 20.8 inches of precipitation between 2010 and 2012.
- Temperatures reached lows of -8°F in November 2010 with highs of 98°F in August 2012.
- The soil is a Palouse Silt Loam (Fine-silty, mixed, superactive, mesic Pachic Ultic Haploxerolls).
- Winter wheat is the common cash crop, commonly grown in 2 to 4 year rotations with spring cereals and legumes. In this study, we designed a non-traditional 3-year rotation: oilseed-legume-winter cereal under direct seeding and zero-tillage.

Pullman (High rainfall): Sequence #1

2010 canola-2011 pea-2012 winter wheat					Overall	2010-2012	2011 Out-In	2012 Out-In
N Fertilizer Inputs	Total N Inputs	Grain N Outputs	N Balance	Export-Nf Input	Outputs-Inputs	N benefit of pea	pea	winter wheat
kg N/ha			GrainN/Nf	Grain N-Nf		kg/ha	kg/ha	
112	290 (± 14)	264 (± 12)	**2.36**	**152 (± 13)**	**60 (± 7)**	**9**	**6 (± 17)**	**6 (± 2)**
157							**54 (± 13)**	**9 (± 7)**
201	379 (±18)	297 (± 14)	**1.48**	**93 (± 38)**	**4 (± 22)**	**47**	**42 (± 35)**	**26 (± 13)**
290	468 (±26)	285 (± 13)	**1.01**	**-9 (± 24)**	**-90 (± 45)**	**50**	**21 (± 20)**	**19 (± 19)**

Pullman (High rainfall): Sequence #2

2010 canola-2011 wheat (unfertilized)-2012 winter wheat						2011 Out-In	2012 Out-In
N Fertilizer Inputs	Total N Inputs	Grain N Outputs	N Balance	Export-Nf Input	Outputs-Inputs	wheat	winter wheat
kg N/ha			GrainN/Nf	Grain N-Nf		kg/ha	
112	259(± 12)	341 (± 17)	**2.34**	**150 (± 25)**	**51 (± 9)**	**-13 (± 0)**	**0 (± 24)**
157						**-22 (± 36)**	**-14 (± 8)**
201	255 (± 10)	336 (± 14)	**1.24**	**49 (± 8)**	**-43 (± 16)**	**-15 (± 11)**	**0 (± 5)**
290	254 (± 9)	328 (± 12)	**0.85**	**-35 (± 9)**	**-140 (± 29)**	**-19 (± 13)**	**-17 (± 9)**

Intermediate rainfall zone

- **Wilke Farm** is located in **Davenport, WA**, west of Spokane. The farm averaged 14.3 inches of precipitation in 2010 and 2011.
- From 2010 to 2011, December temperatures ranged from -18.61 and -0.08°F with August reaching 92.7°F.
- The soil is a Broadax silt loam (Fine-silty, mixed, superactive, mesic Calcic Argixeroll).
- Winter wheat is typically grown in a 3 year rotation, with a spring cereal and summer fallow. We implemented the 3-year oilseed-legume-winter cereal sequence under no-tillage.

Wilke (Intermediate rainfall): Sequence #1

2010 canola-2011 pea					Overall	2010-2011	2011 Out-In	2012 Out-In
Fertilizer N	Total N Inputs	Grain N Outputs	N Balance	Export-Nf Input	Outputs-Inputs	N benefit of pea	pea	winter wheat
kg N/ha			GrainN/Nf	Grain N-Nf		kg/ha	kg/ha	
0	303 (± 43)	79 (± 6)	**NA**	**74 (± 12)**	**-107 (± 40)**	**44**	**-60 (± 81)**	N/A
45							**-18 (± 12)**	N/A
134							**-25 (± 46)**	N/A
178	481 (± 64)	69 (± 5)	**0.37**	**-111 (± 13)**	**-296 (± 76)**	**36**	**-18 (± 13)**	N/A

Wilke (Intermediate Rainfall): Sequence #2

2010 canola-2011 wheat (unfertilized)					Overall		2011 Out-In	2012 Out-In
Fertilizer N	Total N Inputs	Grain N Outputs	N Balance	Export-Nf Input	Outputs-Inputs		wheat	winter wheat
kg N/ha			GrainN/Nf	Grain N-Nf			kg/ha	
0	303 (± 43)	97 (± 7)	**NA**	**92 (± 2)**	**-151 (± 40)**		**-64 (± 83)**	N/A
45							**-54 (± 15)**	N/A
134							**-59 (± 32)**	N/A
178	481 (± 64)	74 (± 5)	**0.40**	**-107 (± 14)**	**-332 (± 74)**		**-30 (± 23)**	N/A

Low rainfall zone

- **Hennings Farm** is located in **Ralston, WA**, east of Lind. The farm averaged 12.5 inches of rainfall from 1996 to 2000.
- Mean lows are typically in January at 21°F, with mean highs of 87.5°F in August.
- The soil is a Ritzville silt loam (coarse silty, mixed, mesic, Caldic Haploxeroll).
- Wheat is typically grown in a 2 year rotation with fallow, with some continuous no-till cereal

Ralston-Lind (Low Rainfall Zone): 4 Sequences

Crop Sequence	N Fertilizer Inputs	Grain N Outputs	N Balance	Total N Balance	Export-Nf Input	Overall
	kg N/ha		(Grain N/Nf)	M + Final Root Zone N)/	Grain N-Nf	Total Outputs-Inputs
WW-F	207	175	**0.86**	**0.85**	**-30**	**-6**
SW-Chem Fallow	207	169	**0.75**	**0.88**	**-46**	**-33**
continuous NT HRS	326	248	**0.77**	**0.86**	**-77**	**-28**
continuous NT HRS-SB	324	230	**0.71**	**0.80**	**-94**	**-42**

WW-F = winter wheat-fallow
SW-Chem Fallow = spring wheat-chemical fallow
Continuous NT HRS = continuous no-till hard red spring wheat
Continuous NT HRS-SB continuous no-till hard red spring wheat-spring barley

Summary

- Increasing N inputs resulted in overall more negative N balances (inputs exceeded outputs), N fertilizer use efficiency (grain N/applied fertilizer N), and N budgets.
- The **canola-pea-winter wheat** cropping system in the high rainfall zone **had positive N balances** (outputs exceeded inputs) for the pea and winter wheat crop rotations.
  - Supplemental N fixed biologically by peas
  - Elevated mineralization in the subsequent rotation, reflecting the greater levels of fertilizer during the 2010 canola rotation
- In comparison, the **canola-spring wheat (unfertilized)-winter wheat cropping sequence in Pullman and both sequences in the intermediate zone**, showed an overall **negative N balance**.
  - N can be immobilized in residue, microbial, or soil organic nitrogen pools
  - Mineral N is also at risk for losses due to leaching or gaseous emissions.
  - High levels of residual N reduced N recovery
- A legume in the cropping sequence led to a N benefit (more positive balance), despite exporting seed N.
- **All cropping sequences** exhibited high N recoveries due to low precipitation and deep soils resulting in high N carry-over between growing seasons and low N losses.
  - Highest N recovery with deep rooted winter wheat under lower inputs
  - Lower N recovery with hard red spring wheat due to shallower roots and greater N fertilizer required by high protein wheat