EFFECT OF IRRIGATION PRACTICES ON SOIL NITROGEN CYCLING MICROBIAL POPULATIONS AND NITROUS OXIDE EMISSIONS IN A MERLOT VINEYARD IN THE OKANAGAN VALLEY OF BRITISH COLUMBIA

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Objectives of This Presentation

- AGGP1
  - Does irrigation source affect abundance of N-cycling soil microbial populations, N_2O emissions and soil physico-chemical properties in a Merlot vineyard in the Okanagan Valley?
  - Are N_2O emissions correlated with changes in abundance of nitrifying or denitrifying populations?
- AGGP2
  - Overview of regional scale project
  - Progress to date

Climate of the Okanagan Valley

- Characterized by hot dry summers and crisp, overcast winters with air temperatures below freezing for about ten weeks
  - Average summer temperatures high 20's
  - Most rain falls between April and June, little rain over the summer months
- Irrigation changes the plant productivity dramatically and allows a range of crops to be grown, predominantly apples, cherries and grapes
- In AGGP1 we studied how irrigation source (micro-sprinkler or drip) affected the abundance of the N-cycling soil microbial populations in a Merlot grape vineyard

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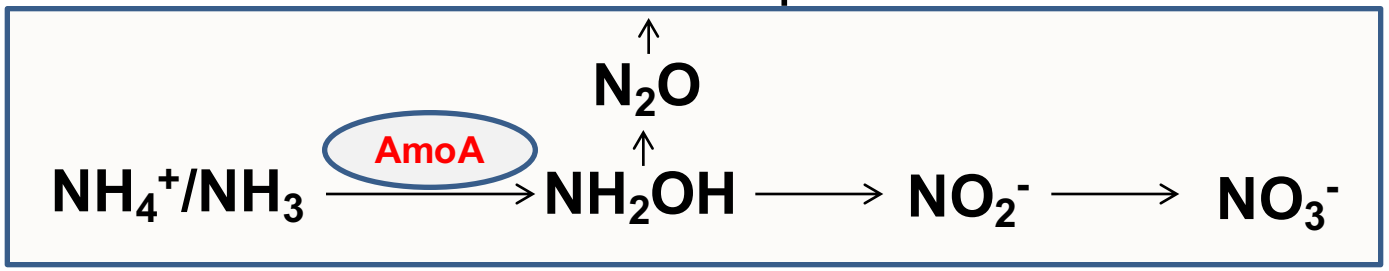
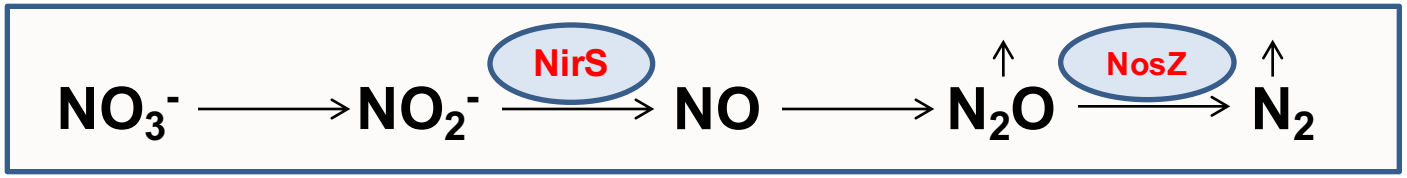
Major Soil Microbial Processes Contributing to Nitrous Oxide Emissions and Genes Measured

- Nitrification – aerobic autotrophic bacteria and archaea



  - *AmoA*: ammonium monooxygenase

- Denitrification – anaerobic heterotrophs



  - *NirS*: nitrite reductase
  - *NosZ*: nitrous oxide reductase

- We also measured *16SrRNA,* a measure of the total soil bacterial abundance

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Methodology

- Merlot/SO4 vineyard, established 2011
- Sandy loam soil
- pH 6.2 - 6.5
- Two irrigation treatments: drip or micro-sprinkler
  - Delivered 100% of water lost previous day to evapotranspiration
  - Randomized complete block, split plots
- Soils were sampled from 5-10 cm depth, 20 cm from irrigation source in 2013 and 2014
- Sampled in February (Thaw), in May after irrigation start (Irrig), in June after fertilization (Fert), and in September (Fall)
  - Standard soil analyses conducted by BC Ministry of Environment
- N_2O flux measured regularly during irrigation, fertigation and winter months
  - Using non-flow-through, non-steady-state chambers and Bruker 456 GC
    - Fentabil et al. 2016. Agric. Water Management 171: 49-62

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Methodology

- Total soil DNA was extracted using MoBio Power Soil kits
- Gene abundance determined using quantitative real-time PCR on a BioRad CFX cycler with Sybr Green
  - Linearized plasmids as standards
  - Standard primer pairs and cycling conditions
    - *amoA*1F-*amoA*2R
    - *nirS*Cd3aF-nirS*R3cd*
    - *nosZ*1F-*nosZ*1R
    - BACT1369F-PROK1492R *(16SrRNA)*
    - Efficiencies ranged from 91-102%
  - Data averaged over 2 years

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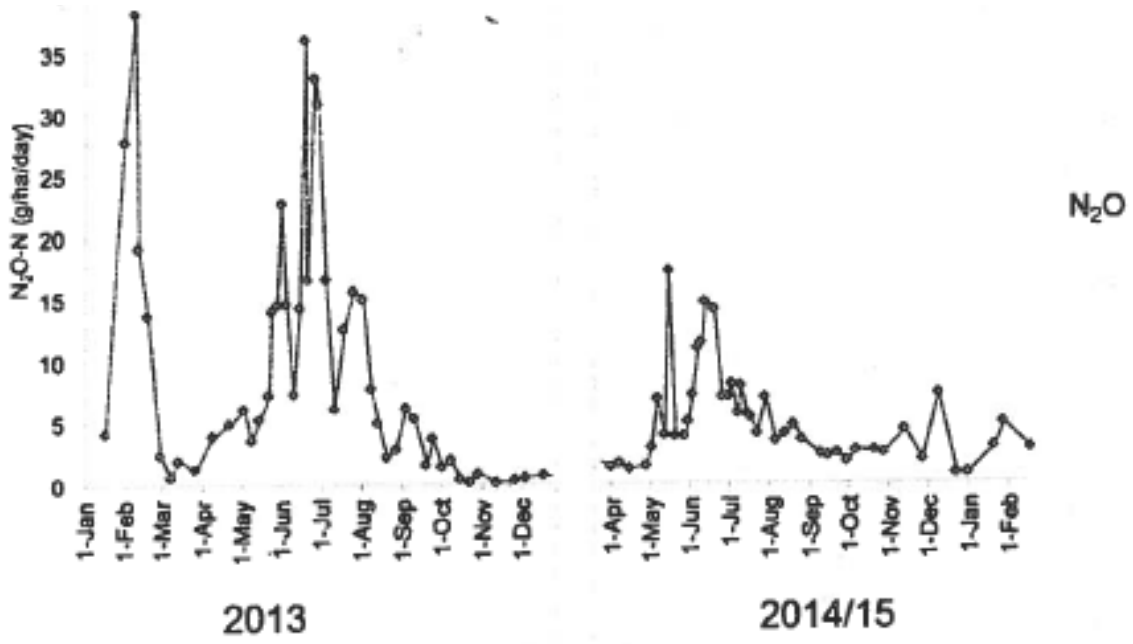
N_2O Emissions 2013-2015



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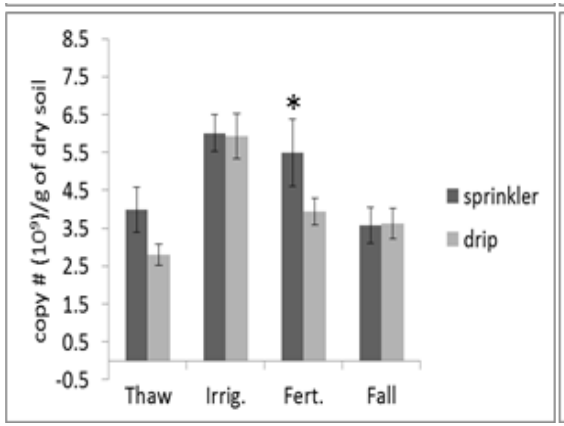
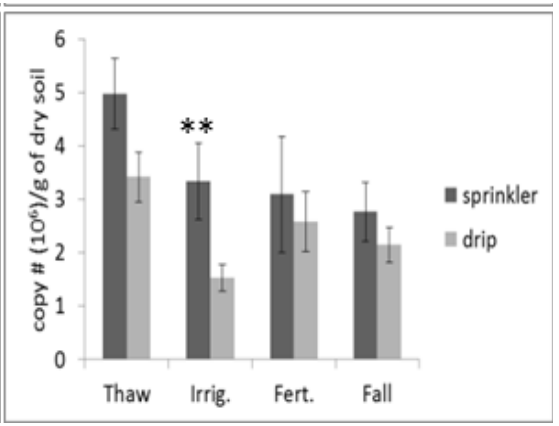
Effect of Irrigation Type on Gene Abundances

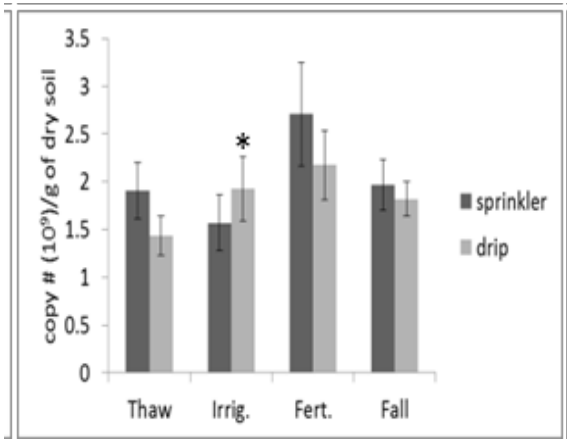
16SrRNA



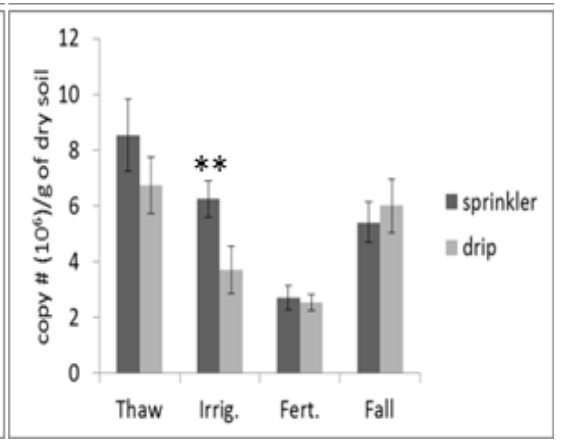
amoA



nirS



nosZ



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Effect of Irrigation Source on Soil Physicochemical Properties

- Soil NH_4^+-N content was higher under micro-sprinkler (3.34 mg/kg) than in drip-irrigated plots (1.68 mg/kg) at the onset of irrigation only.
- There were no significant effects of irrigation source at any of the sample times on:
  - % total N
  - NO_3^--N
  - % total C
  - % organic matter
  - Water-filled pore space (WFPS)*
  - pH

Drip
May 2013

Micro-sprinkler
May 2013

*ratio of volumetric soil water content to total soil porosity

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Correlations between Gene Abundances, N_2O Emissions and Environmental Variables

Gene Abundance		Temp	WFPS*	NO_3-N	NH_4-N	pH	N_2O
16SrRNA	P-value	< 0.001	ns	0.018	<0.001	0.007	ns
	R	0.40		0.19	0.29	-0.20	
amoA	P-value	< 0.001	0.001	0.004	ns	0.04	ns
	R	-0.33	-0.24	-0.23		0.15	
nirS	P-value	0.001	<0.001	ns	ns	0.005	< 0.001
	R	0.25	0.27			0.2	-0.32
nosZ	P-value	< 0.001	ns	<0.001	ns	ns	< 0.001
	R	-0.50		-0.35			-0.40

ns=not significant

- Nitrifier abundance was negatively correlated with WFPS
- *nirS* abundance was positively correlated with WFPS
- N_2O emissions were negatively correlated with denitrification gene abundances

*Water Filled Pore Space

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Conclusions

- Nitrification was likely the major N_2O-generating process during the growing season
  - Coarse textured soil and irrigation method which supplied only the water lost to evapotranspiration led to low WFPS during the irrigation period (Irrg, Fert, Fall)
  - WFPS averaged 63% across all treatments – aerobic conditions
  - Negative correlation between N_2O emission and *nirS* abundance
- At Irrig (May) sampling irrigation method significantly affected gene abundance
  - With Drip irrigation *amoA* and *nosZ* were lower and *nirS* higher than for micro-sprinkler
  - Water released by drip is under higher pressure which may cause greater displacement of soil nutrients – NH_4^+-N decreased significantly under drip
- Less N_2O was emitted under micro-sprinkler than under drip during the growing season (Fentabil et al 2016)
  - Likely related to lower *nirS* and higher *nosZ* abundance under micro-sprinkler leading to complete denitrification to N_2

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AGGP2

- Understanding the impact of irrigation on soil C and N storage, and associated greenhouse gas emissions at a regional scale
  - Melanie Jones, Louise Nelson, Nathan Pelletier (UBCO)
    - 2 research associates (Andy Midwood and Tanja Voegel), 4 grad students, 2 research assistants, undergraduate students
  - Collaborators
    - Denise Neilsen, Tom Forge, Scott Smith, Kirsten Hannam (AAFC)
    - Anna Warwick-Sears (Ok. Basin Water Board)
    - Rob Birtles (Interior Health)
    - David Poon (BC Ministry of Agriculture)
    - Pete Millard (Landcare NZ)

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Objective and Major Activities

- Develop recommendations for the conditions under which irrigation can be used to increase soil C storage without stimulating loss of N through N_2O efflux
  - Conduct meta-analysis of existing research on changes in C and N pools in response to irrigation
  - Use the diverse cropping systems and soil types in the Okanagan Valley to conduct an extensive survey of irrigated and non-irrigated sites that vary in their long-term management regimes
    - Collect data on stored soil C and N pools
    - Measure CO_2 and N_2O emissions on a subset of these sites representing a range of soil types, cropping systems and management practices

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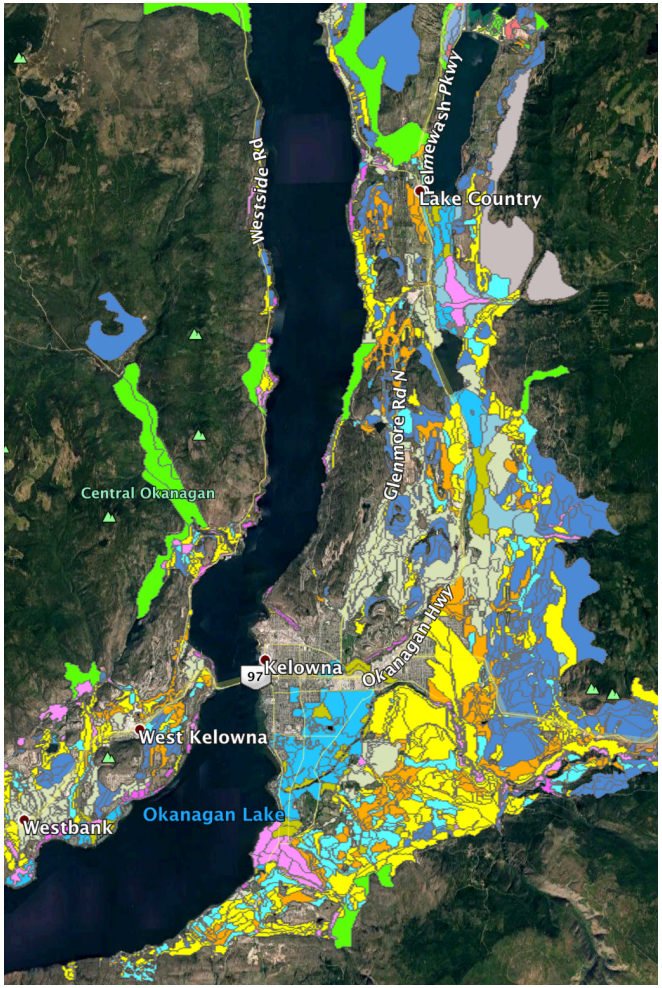
Major Activities (continued)

- Use molecular tools to identify the major N_2O-generating pathways and soil-related drivers of N_2O emissions
  - Develop novel droplet digital PCR methods to assess nitrification and denitrification gene abundances
  - Apply to field and laboratory microcosm studies
- Conduct lab studies to quantify contribution of bicarbonates in irrigation water to CO_2 efflux
- Conduct environmental life cycle assessment of organic amendments and delivery of irrigation water

Okanagan Valley – A Living Laboratory



- Irrigation is widely used throughout the Okanagan Valley
- Different crops, types of irrigation and different soils
- Excellent location to study the impact of irrigation on soil carbon and nitrogen levels and emissions

Carbon and Nitrogen

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Carbon and Nitrogen

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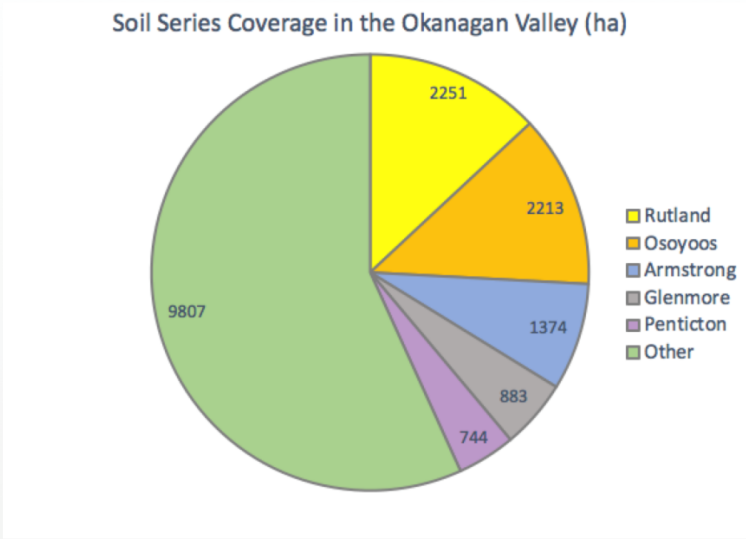
Soil Sampling Plan

- Sampling five different soil series/groups: Glenmore, Osoyoos, Penticton, Rutland and Armstrong
- Contrasting textural and organic C contents
- Represent about 50% of the total area across the valley
- Three depths, alleys and rows for apples, cherries and grapes

Soil Groups and Coverage (ha)

Rutland Group:		**Penticton Group:**	
Rutland	1696	Penticton	222
Gammil	397	Olhausen	178
Debeck	97	Munson	177
Peachland	54	Maynard	123
Ellison	4.9	Chapman	42
Osoyoos Group:			
Osoyoos	1415		
Parkill	479		
Trewitt	339		
Oyama	263		
Kaleden	42		
Cooperation	7		
Trepanier	3		
Dub Lake	2.5		
Armstrong Group:			
Armstrong	514		
Kelowna	410		
Harrland	172		
Bluespring	142		
Giants Head	70		
Hayman	64		
Glenmore Group:			
Westbank	429		
Glenmore	367		
Summerland	43		
Boucherie	42		



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Crops and Irrigation Types

- Apples irrigated by drip and micro-spray
- Cherries irrigated by micro-spray
- Grapes irrigated by drip
- Forage irrigated by various systems: traveling gun, hand-line and wheel-line

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Summary of Sites

Irrigation	Crop	Sites Required	Soil Types	Soil Samples 3 x depths (row and alley, or spatial)	Totals
none	none	5	5	3	75
Gun, wheel-line, hand-line	pasture forage	5	5	3	75
drip	apple	5	5	6	150
drip	grape	5	5	6	150
Micro-spray	apple	5	5	6	150
Micro-spray	cherry	5	5	6	150
Totals					750

Theoretical maximum number of sites: 150

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Progress to Date

- Literature review meta-analysis in progress
- Field soil sampling underway
  - Experimental design, soils, crops and irrigation methods finalized
  - Sites selected, field protocols finalized and tested
  - Grower questionnaire developed and delivered
  - 94 soils sampled to date
  - Database of growers and sites developed
- Personnel recruited
- Soil N-cycling studies in progress
  - Novel molecular methods for detection of nitrifying and denitrifying microbial populations optimized and manuscript ready to submit
  - Soil microcosm studies to determine soil physico-chemical properties influencing N-cycling initiated
- Life cycle assessment of net greenhouse gas emissions associated with alternative uses of wood chips and mulch underway

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Acknowledgements

- Agriculture and Agri-Food Canada, Agricultural Greenhouse Gases Program
- AAFC Summerland Research and Development Centre
- BC Ministry of Agriculture
- BC Wine Grape Council
- BC Tree Fruits
- Andy Midwood and Kirsten Hannam
- Numerous growers, vineyard managers and orchardists who allowed us to come onto their properties and take soil samples

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