LTRA 9 - Developing Sustainable Conservation Agricultural Production Systems for Smallholder Farmers in Southern Africa

University of Tennessee

LTRA 9 – Southern Africa

- Lesotho
  - Maize based systems
- Mozambique
  - Maize and cassava based systems
- Changes in soil quality under long-term CA
- Sequestration of C under CA
- Partners: National University of Lesotho, CIMMYT, Growing Nations, IIAM, Lesotho Ministry of Agriculture
- Ten graduate students:
  - Lesotho (2), Mozambique (3); Kenya (1); USA (4)
  - 1 PhD; 9 MS (3 completed)

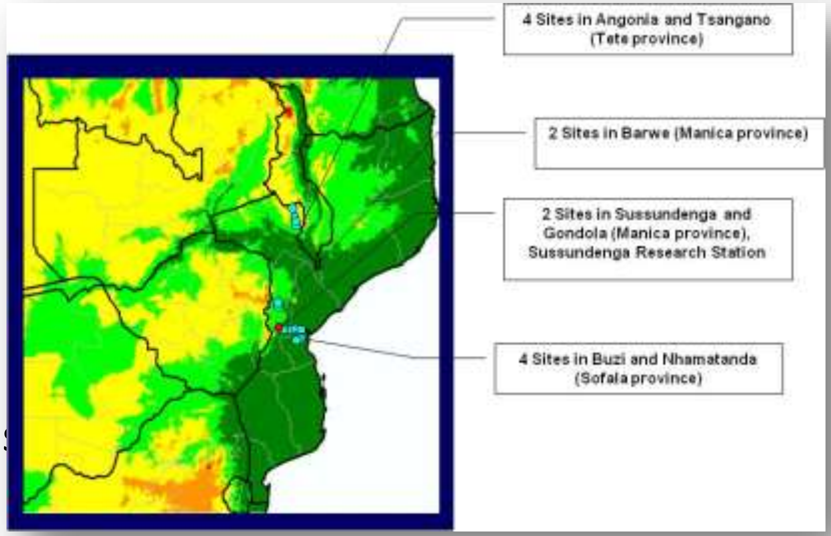
Agricultural Research

Adoption, Returns, Payments for Environmental Services (PES) and Conservation Agriculture Practices (CAPs).

By:
Timoteo Simone

Mozambique Highlights

Jab planter



Demonstration plots (CIMMYT/IIAM)

- Check, Basins, Jab planter
- Maize/cowpea rotations
- N = 638 farmers, 22 villages
- NPK/Urea (all plots)
- Herbicide on CA plots

Basins

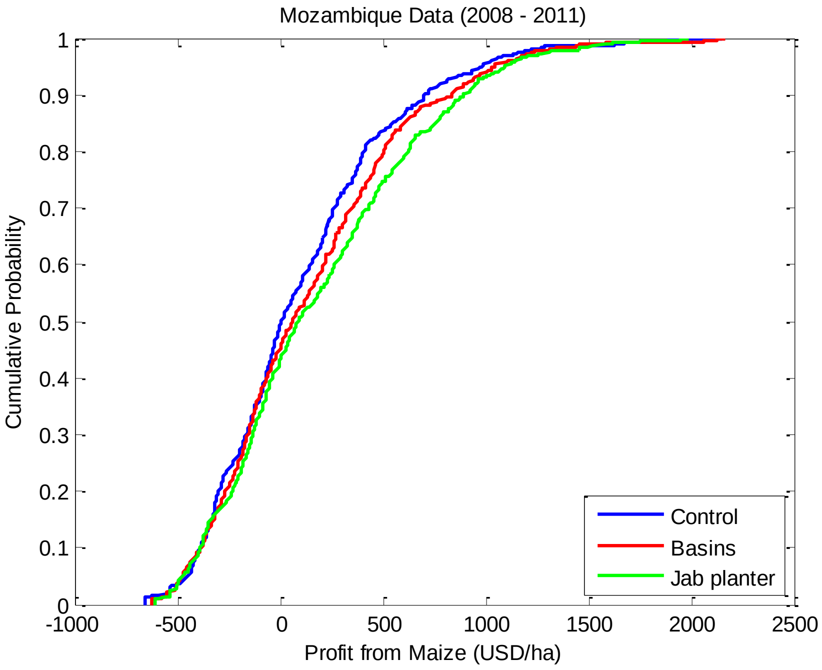
Household Survey (Manica, Tete)

- Sample 10% of 5,265 households (HH)
- Stratified sampling of villages
  - “Exposed”/CA (204 HH)
  - “Exposed”/Non-CA (3,001 HH)
  - Unexposed (2,244 HH)
  - Systematic sampling

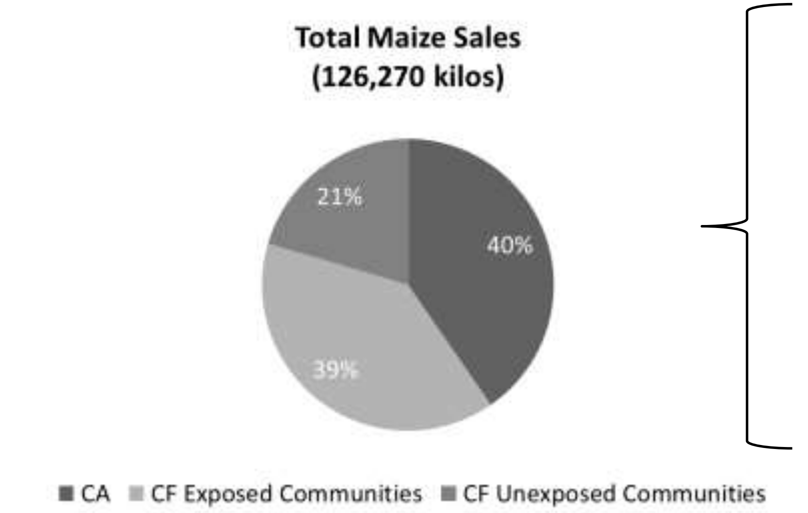
Net returns: conventional tillage treatments and CA planting technologies, Mozambique, 2008 – 2011 (N = 631 farms)

Net returns (USD ha^{-1})	Control	Basin	Jab planter
Mean	104	148	195
Std. Dev.	452	478	499
CV	435	323	257
----H_0: distributions not different*----			
Control		0.07 (0.0776)	0.12 (0.0002)

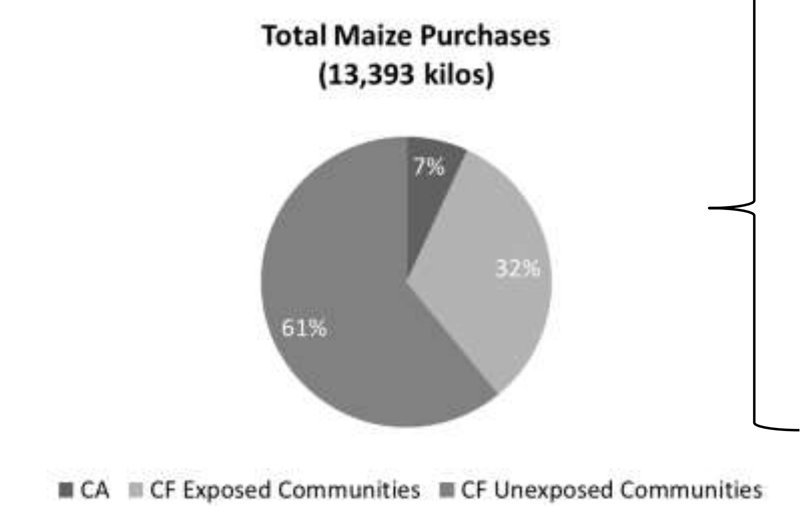
*Kolmogorov-Smirnoff test; D-statistic (p-value)



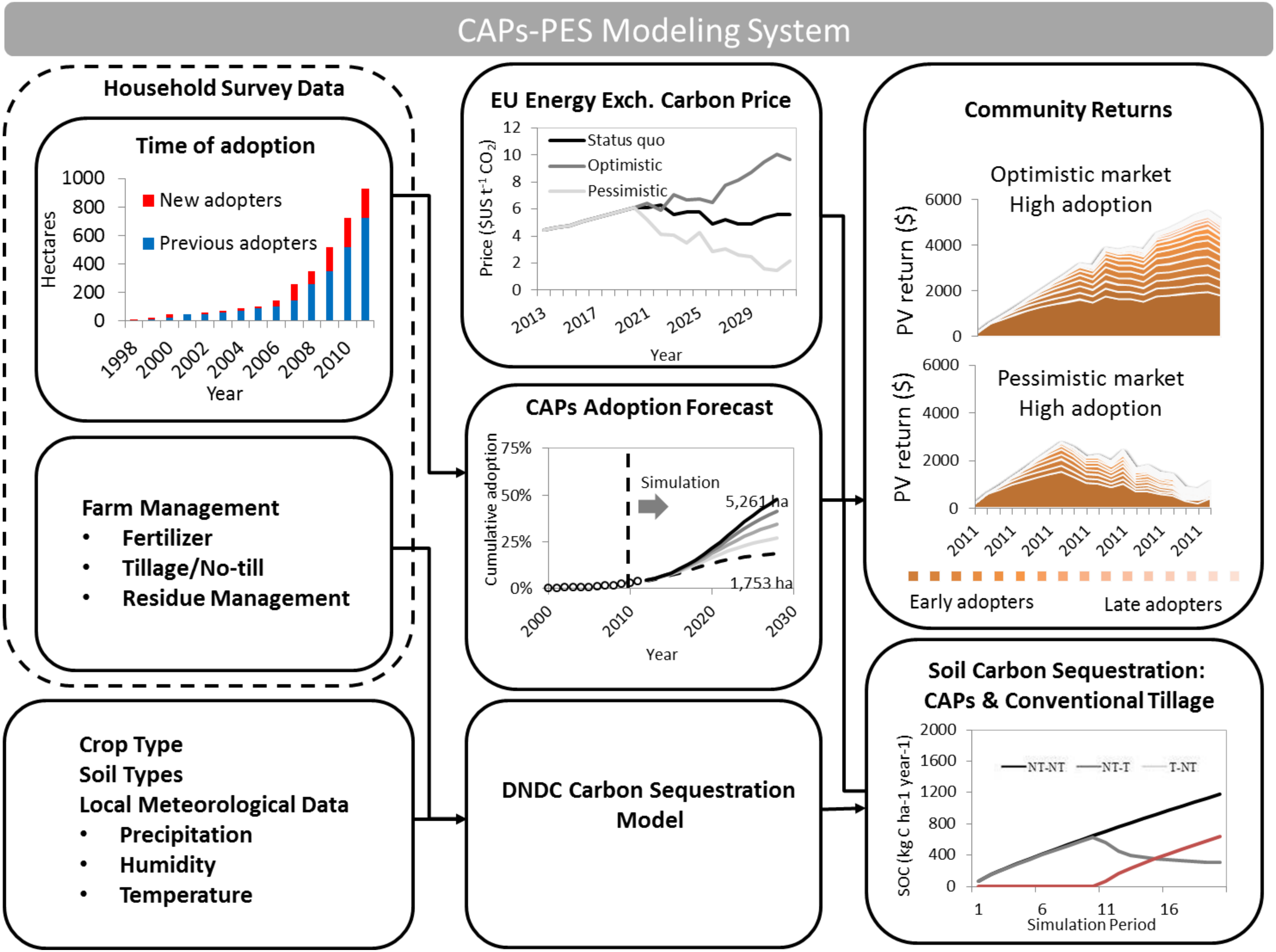
Maize sales and purchases



(1) Total farmers selling maize: 265.
(2) Total number of CA farmers selling maize: 88 (33% of farmers in the sales market).
(3) Total number of conventional farmers selling maize in exposed villages: 114 (43% of farmers in the market).
(4) Total number of conventional farmers selling maize in unexposed villages: 63 (24% of farmers in the market).



(1) Total farmers purchasing maize: 102.
(2) Total number of CA farmers buying maize: 9 (8% of farmers in the purchases market).
(3) Total number of conventional farmers buying maize in exposed villages: 47 (46% of farmers in the purchases market).
(4) Total number of conventional farmers buying maize in unexposed villages: 46 (45% of farmers in the purchases market).



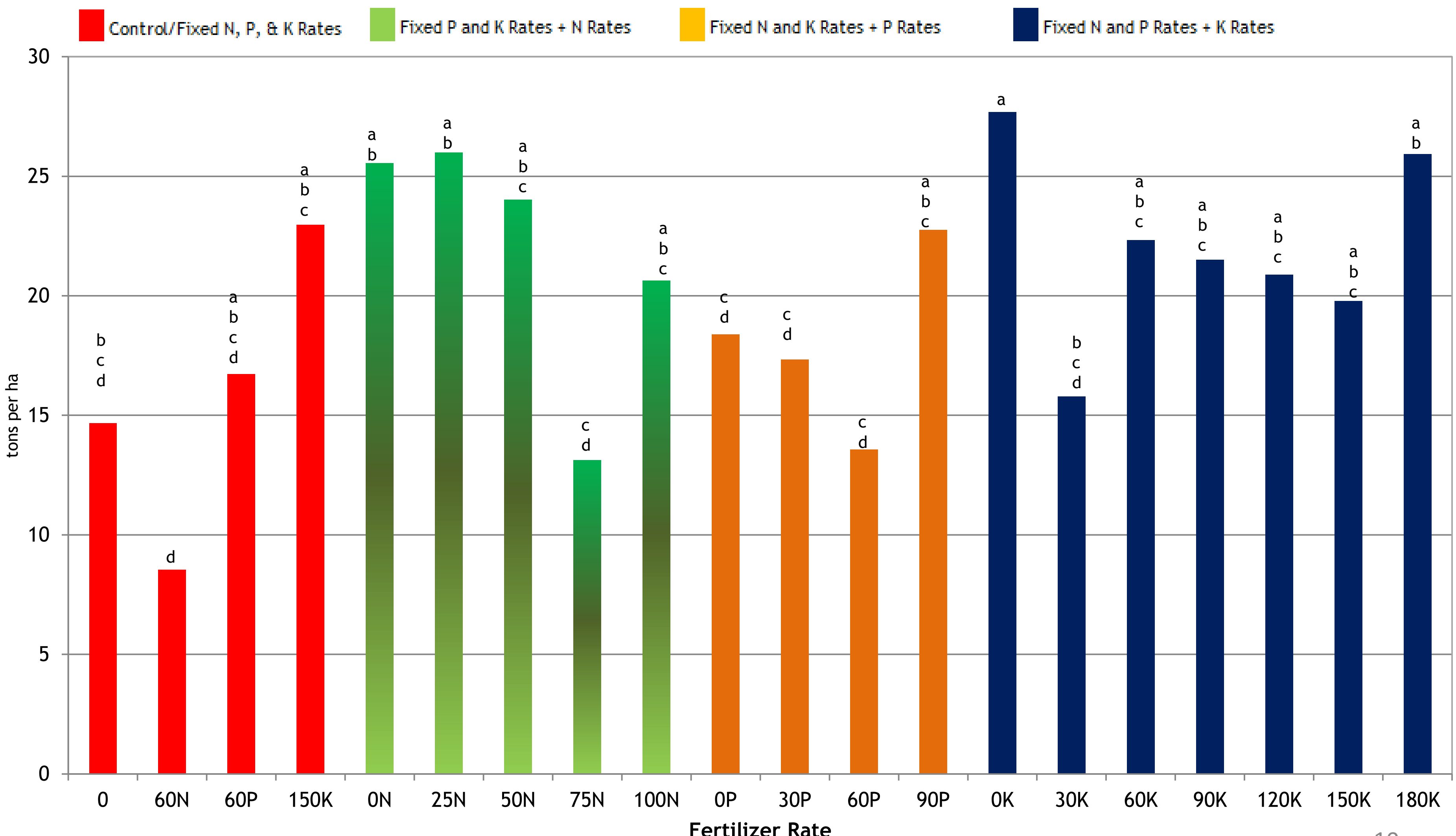
CAPs-PES Modeling System
Household Survey Data
Time of adoption
Hectares
1000
800
600
400
200
0
New adopters
Previous adopters
1998
2000
2002
2004
2006
2008
2010
Year
Farm Management
• Fertilizer
• Tillage/No-till
• Residue Management
Crop Type
Soil Types
Local Meteorological Data
• Precipitation
• Humidity
• Temperature
EU Energy Exch. Carbon Price
Price ($US t-1 CO2)
12
10
8
6
4
2
0
Status quo
Optimistic
Pessimistic
2013
2017
2021
2025
2029
Year
CAPs Adoption Forecast
Cumulative adoption
75%
50%
25%
0%
Simulation
5,261 ha
1,753 ha
2000
2010
2020
2030
Year
DNDC Carbon Sequestration Model
Community Returns
Optimistic market
High adoption
PV return ($)
6000
4000
2000
0
Pessimistic market
High adoption
PV return ($)
6000
4000
2000
0
2011
2011
2011
2011
2011
2011
2011
Early adopters
Late adopters
Soil Carbon Sequestration: CAPs & Conventional Tillage
SOC (kg C ha-1 year-1)
2000
1600
1200
800
400
0
NT-NT
NT-T
T-NT
1
6
11
16
Simulation Period

Cassava Tuber Yield and Quality as Influenced by NPK Fertilizer.

By:

Ivan Cuvaca

Cassava Tuber Yield Significant differences but site variability and planting materials may have affected results



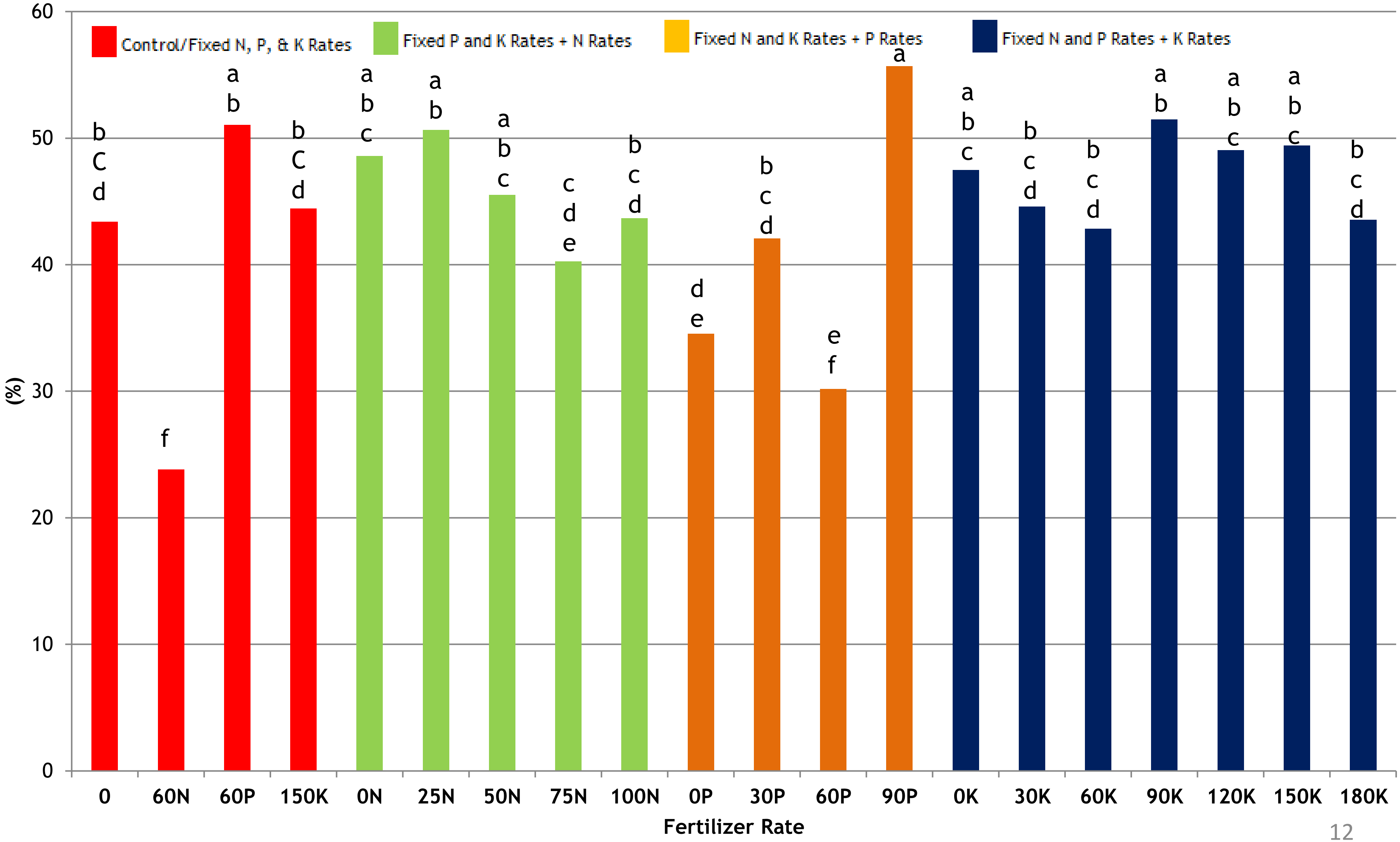
Treatments sharing superscripts are not statistically different (p>0.05)

Cassava Tuber Yield

Courtesy of Neal Eash (03/15/14)

Cassava Tuber Starch Content

- K rate does not influence starch but N decreases starch content
- Highest starch with 60 kg N / 90 kg P_2O_5 / 150 kg K_2O per ha



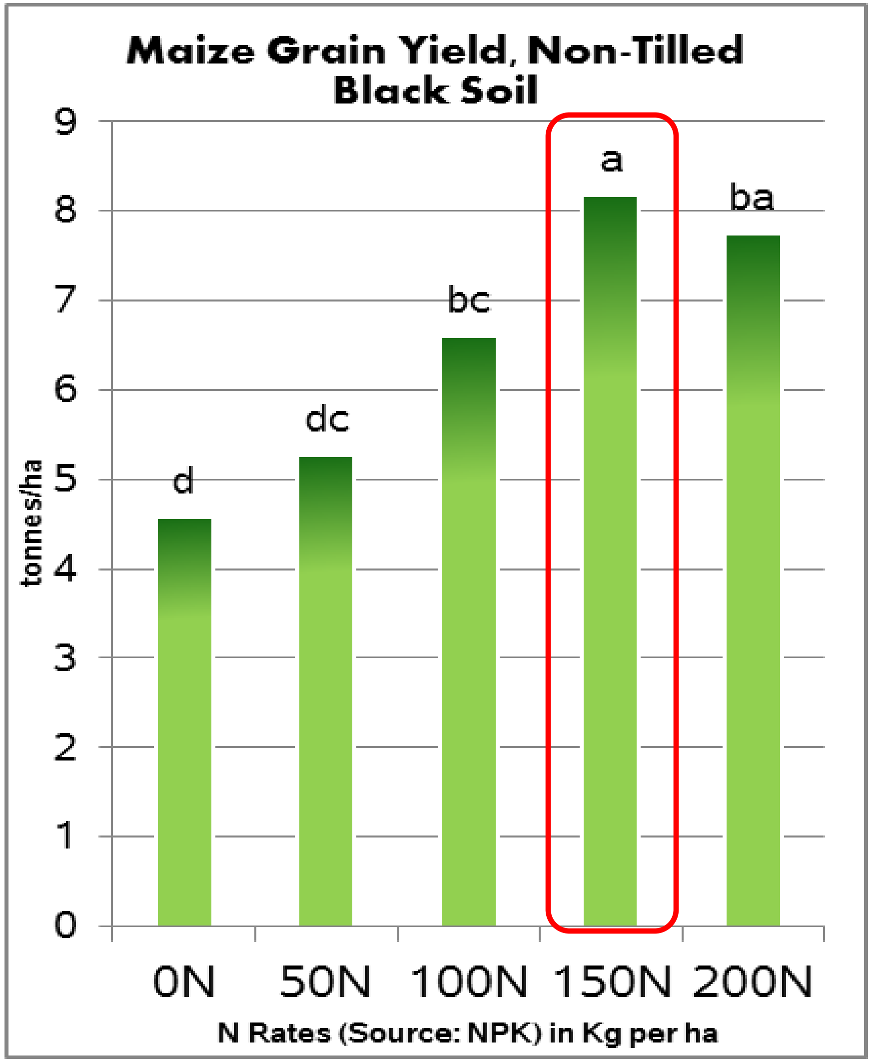
Treatments sharing superscripts are not statistically different (p>0.05)

Maize Yield Response to Fertilizer in Lesotho and Aspects of Soil Quality:

By

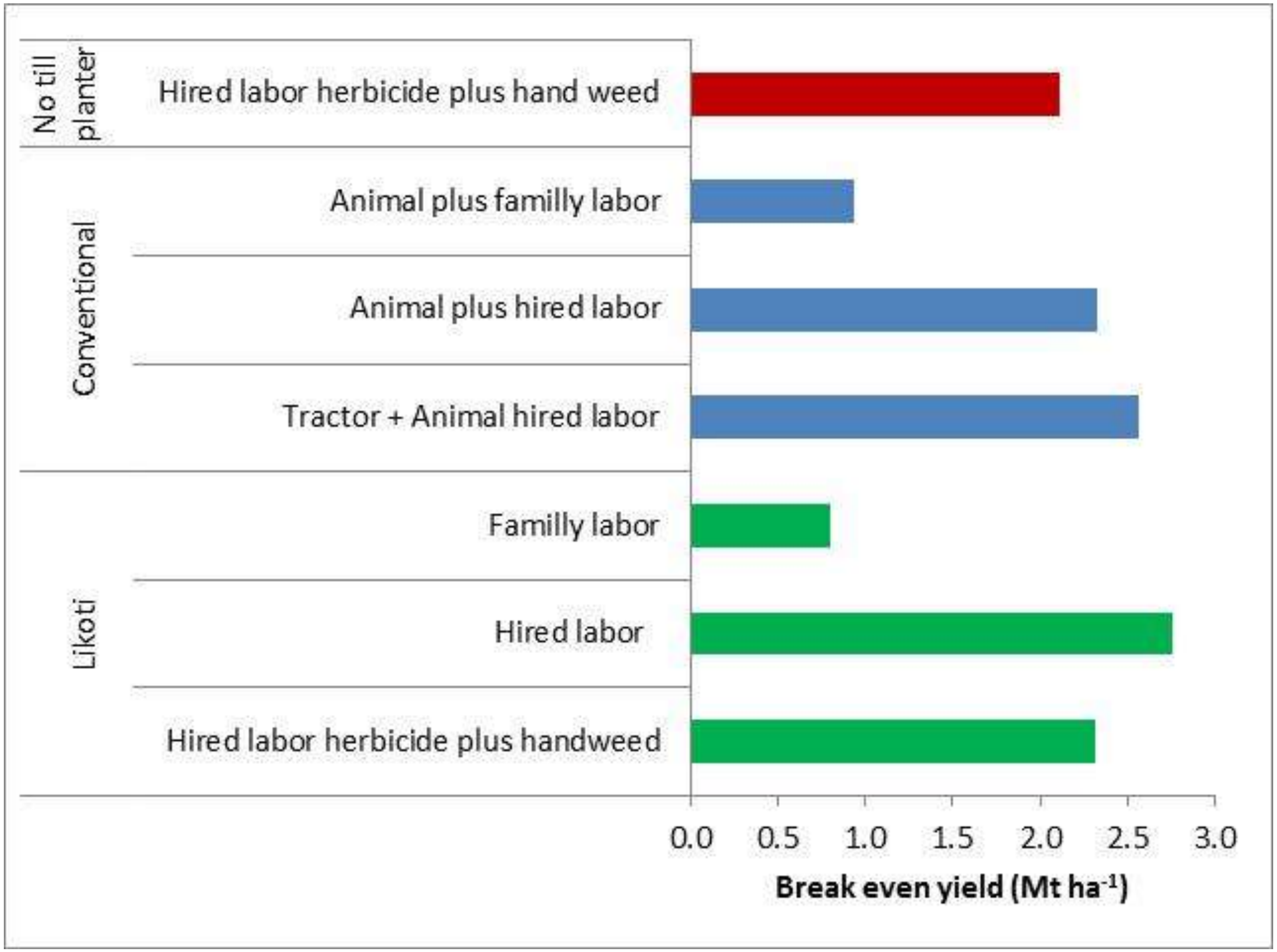
Molefi Mpheshea

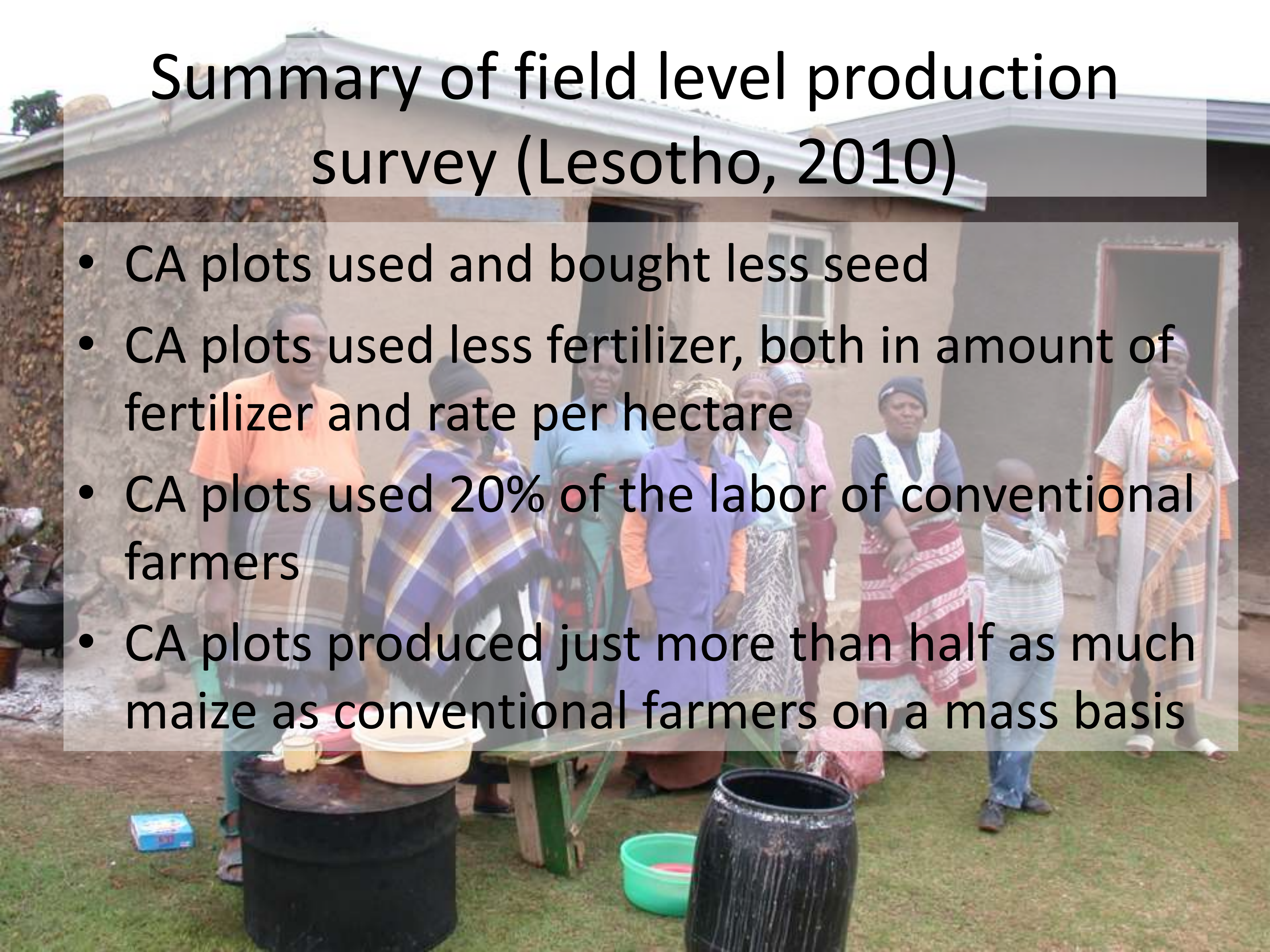
Maize yield response to N fertilizer (Maphutseng, Lesotho 2013)



- Variable N
- P_2O_5 60 kg/ha; K_2O 30 kg/ha
- Recommend:
  150 kg N per ha
  60 kg P_2O_5 per ha
  30 kg K2O per ha
- No yield response to P or K (P and K recommendations based on crop removal rates)

Break even yields and technologies





Summary of field level production survey (Lesotho, 2010)

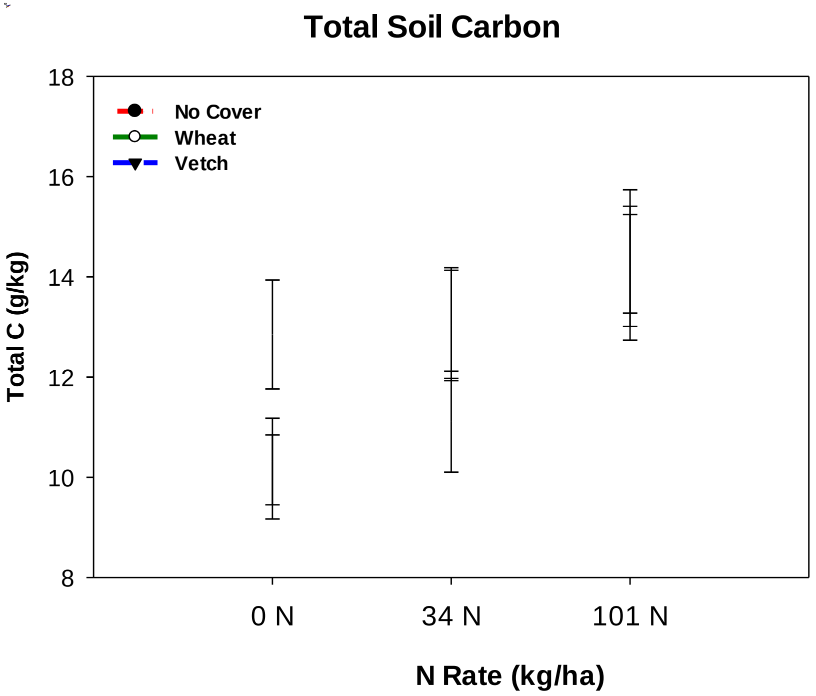
- CA plots used and bought less seed
- CA plots used less fertilizer, both in amount of fertilizer and rate per hectare
- CA plots used 20% of the labor of conventional farmers
- CA plots produced just more than half as much maize as conventional farmers on a mass basis

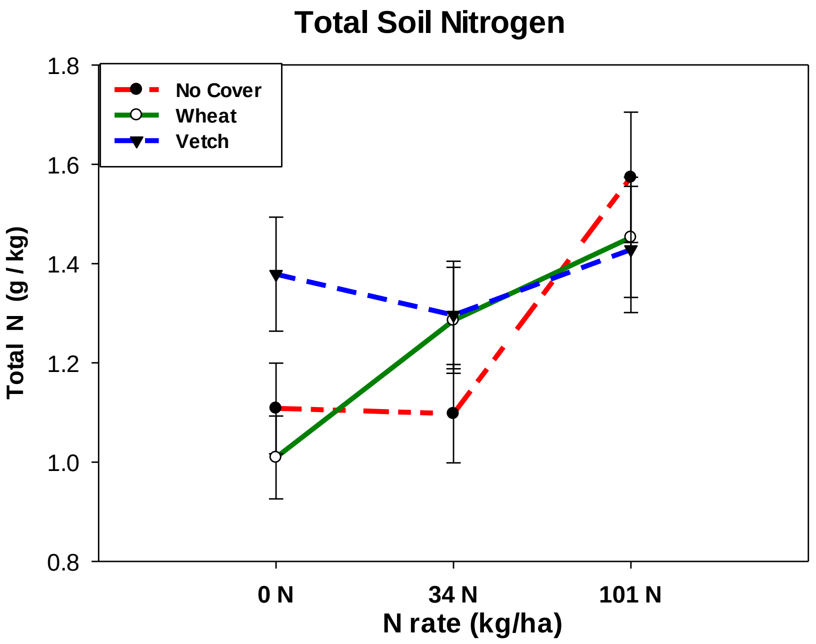
Lesotho Highlights

- Emphasis on basic agronomy: early planting, higher plant populations (3x typical), weed control with cover crops and fertilizer
- No yield difference between no-till and till
- Potential yield of 8 ton to 15 ton/ha from 150kg N/ha, 60 kg P_2O_5/ha and 30 kg K_2O/ha
- 8 to 30 fold increase in maize yield compared to national average yield (0.5 ton/ha)
- Baseline line surveys: Lesotho (2010; n=427)
- 4,500 farmers trained: workshops, field days

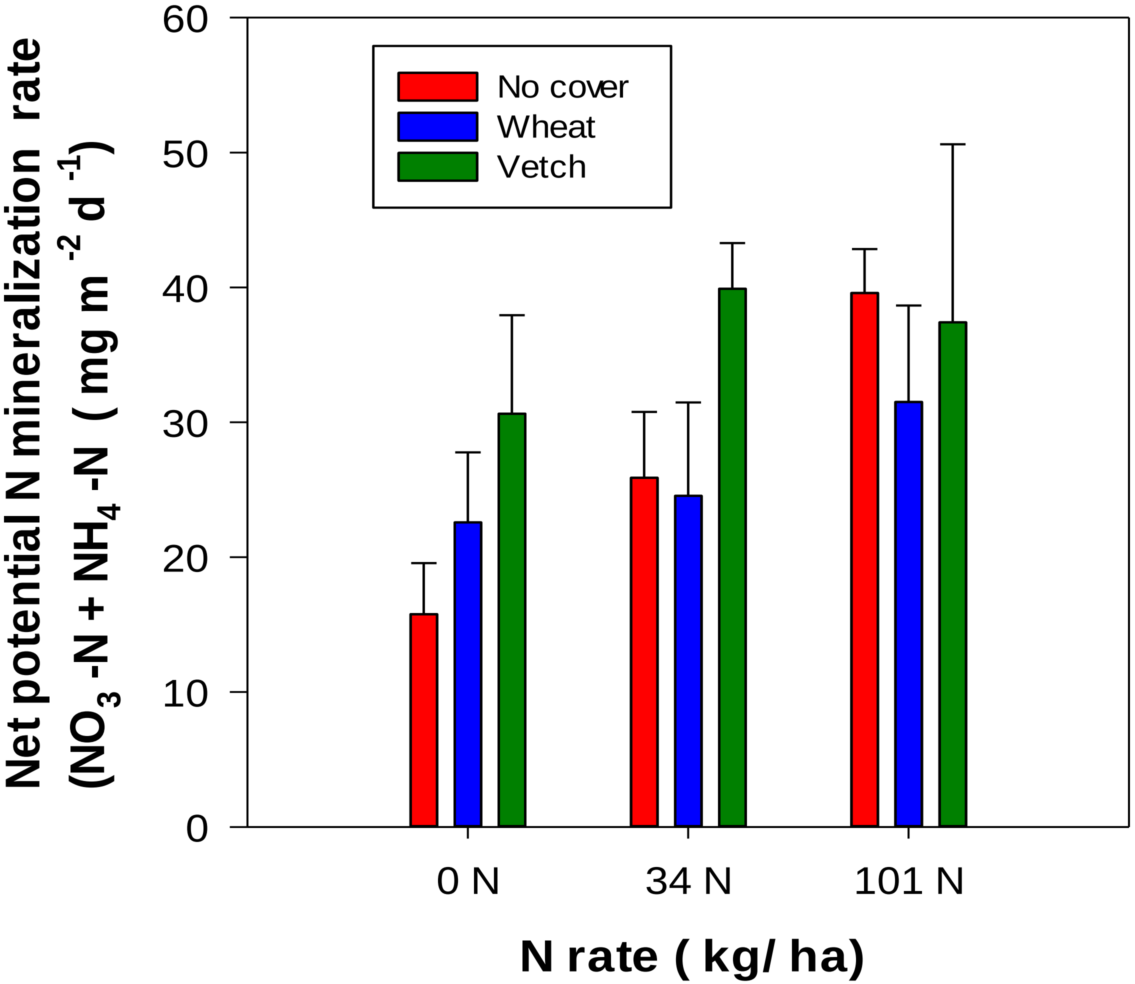
Impact of long term (>30 years) CA on Soil Quality

Total soil Nitrogen





Mineralization rate



Leguminous cover crops contribute highest amount of C and N stored in soil regardless of N fertilizer rate applied to soil.

Higher N rates = higher mineralization rate = loss of sequestered C and stored organic N.

Mineralization depends on the level of soil available N

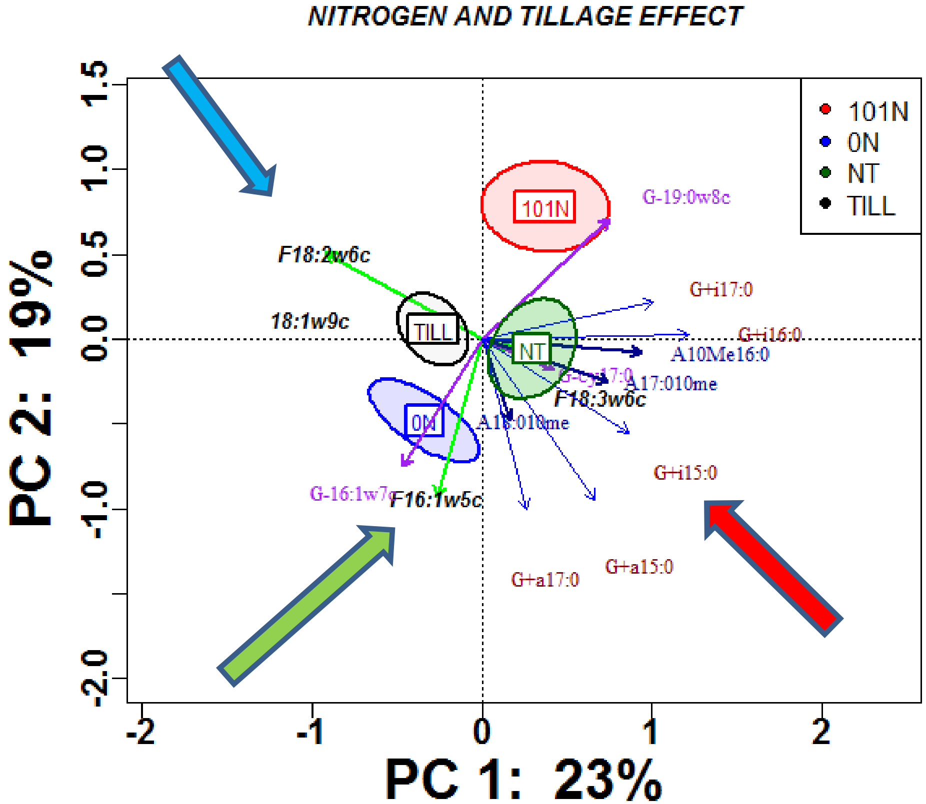
Do Microbial Populations Change Under Long Term CA?

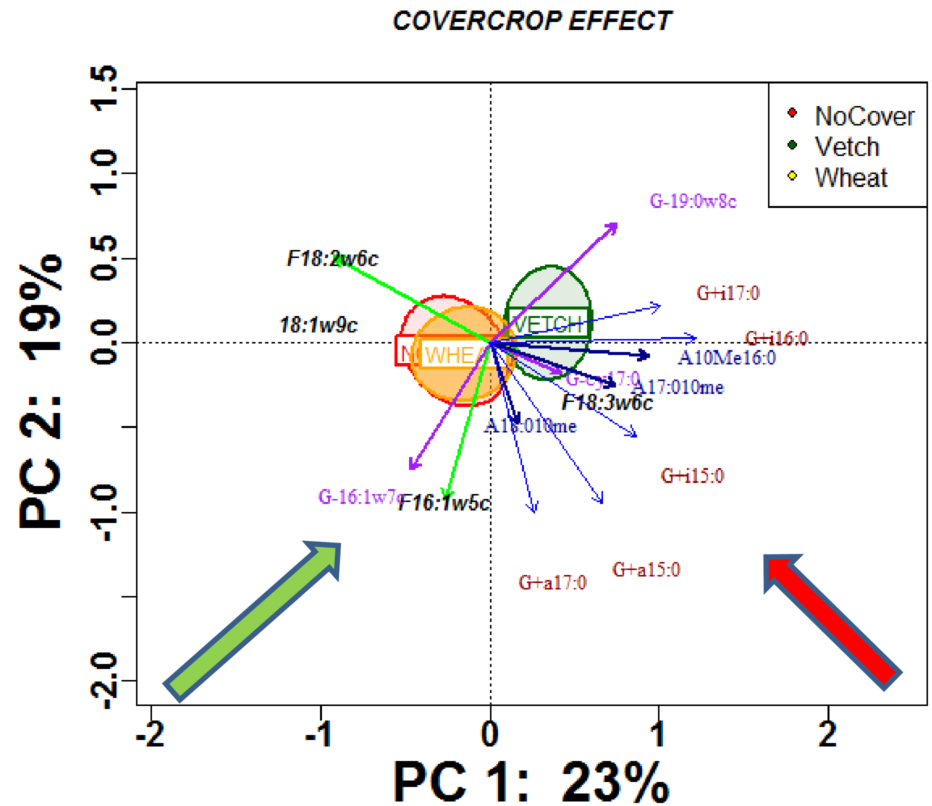
By:
Lilian Mbuthia

Compare microbial community structure, composition and activity under till and CA management systems

- Long term shifts
- Till vs NoTill
- Cover crop species
- Different rates of nitrogen

} Interactions





NoTill and Vetch Cover

Bacteria abundance (Gram + ; Actinomycetes) under NoTill

TILL > NoTill

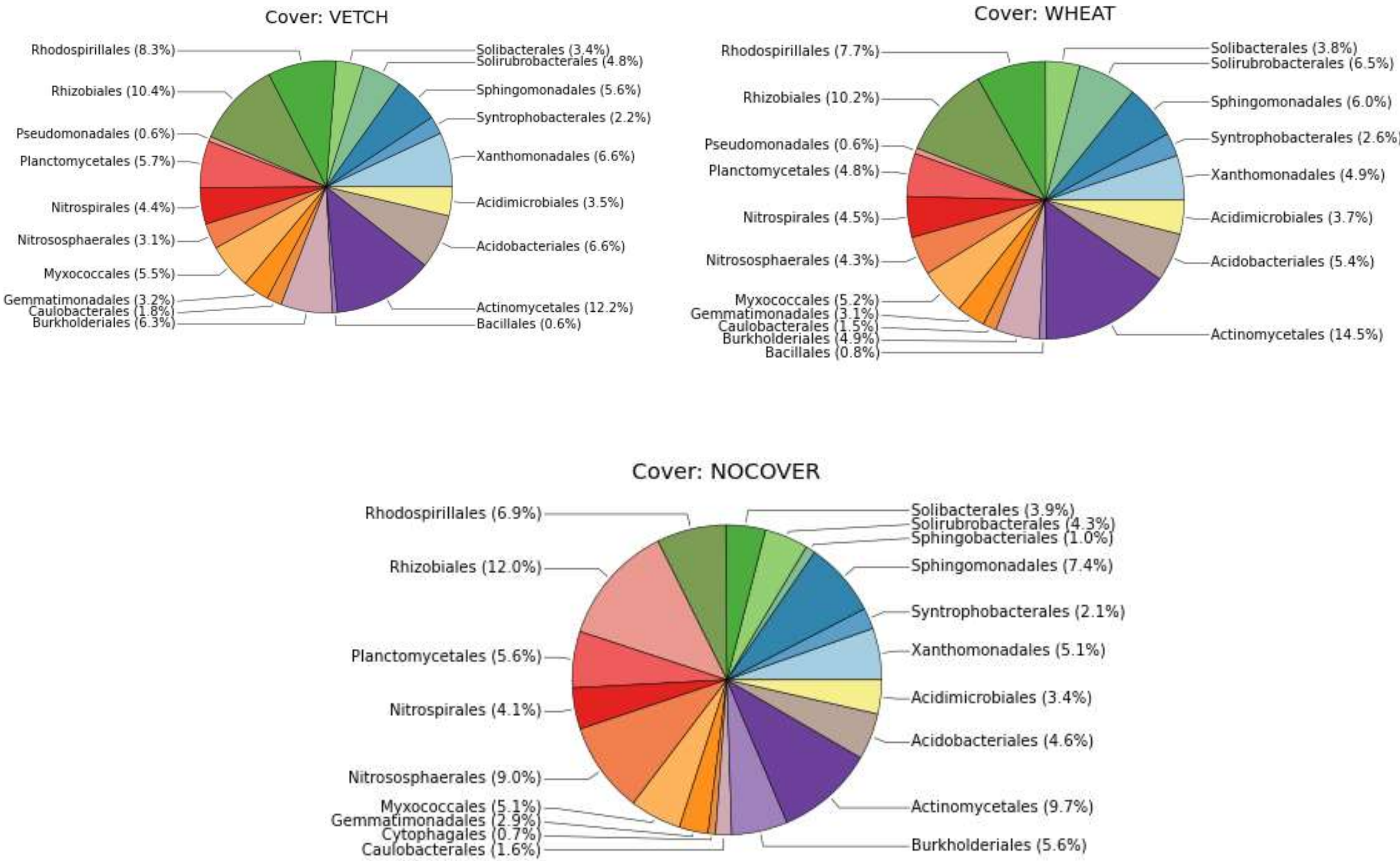
Saprophytic fungi

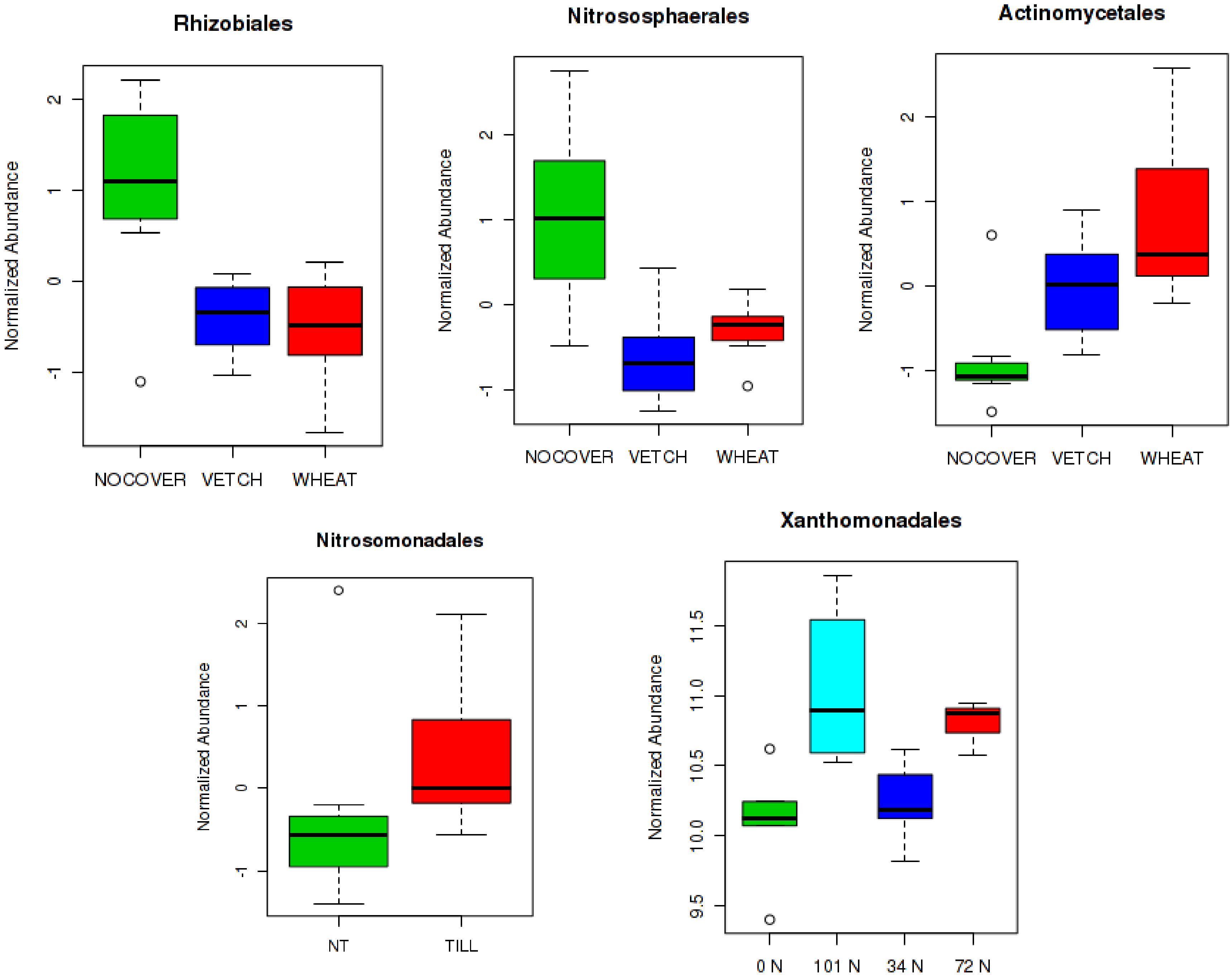
Fungi: bacteria ratio

Nitrogen Effect:

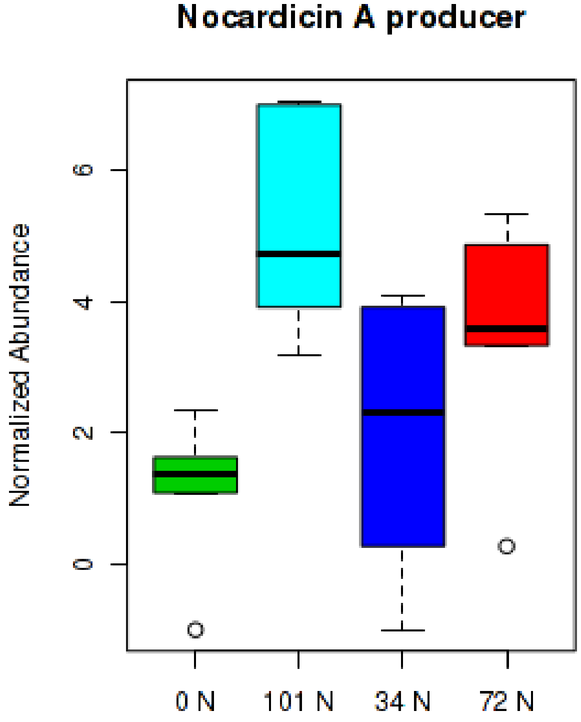
Gram - bacteria

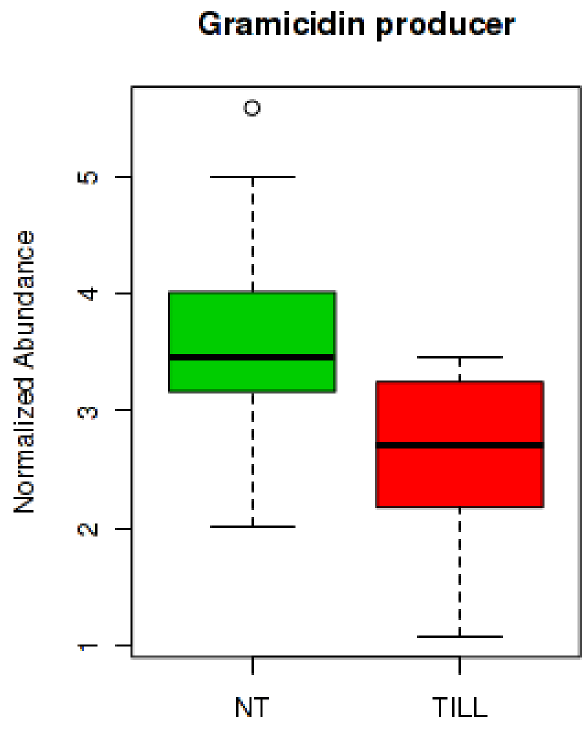
Mycorrhiza fungi

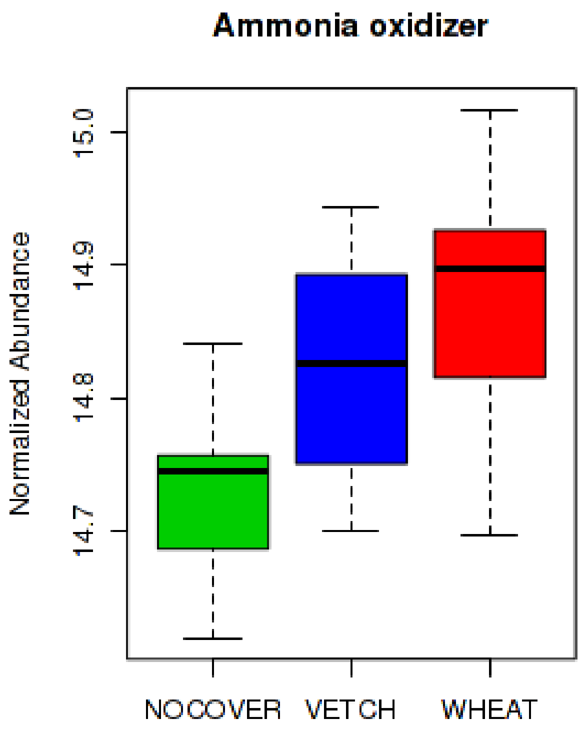

Cover: VETCH
Rhodospirillales (8.3%)
Rhizobiales (10.4%)
Pseudomonadales (0.6%)
Planctomycetales (5.7%)
Nitrospirales (4.4%)
Nitrososphaerales (3.1%)
Myxococcales (5.5%)
Gemmatimonadales (3.2%)
Caulobacterales (1.8%)
Burkholderiales (6.3%)
Solibacterales (3.4%)
Solirubrobacterales (4.8%)
Sphingomonadales (5.6%)
Syntrophobacterales (2.2%)
Xanthomonadales (6.6%)
Acidimicrobiales (3.5%)
Acidobacteriales (6.6%)
Actinomycetales (12.2%)
Bacillales (0.6%)
Cover: WHEAT
Rhodospirillales (7.7%)
Rhizobiales (10.2%)
Pseudomonadales (0.6%)
Planctomycetales (4.8%)
Nitrospirales (4.5%)
Nitrososphaerales (4.3%)
Myxococcales (5.2%)
Gemmatimonadales (3.1%)
Caulobacterales (1.5%)
Burkholderiales (4.9%)
Bacillales (0.8%)
Solibacterales (3.8%)
Solirubrobacterales (6.5%)
Sphingomonadales (6.0%)
Syntrophobacterales (2.6%)
Xanthomonadales (4.9%)
Acidimicrobiales (3.7%)
Acidobacteriales (5.4%)
Actinomycetales (14.5%)
Cover: NOCOVER
Rhodospirillales (6.9%)
Rhizobiales (12.0%)
Planctomycetales (5.6%)
Nitrospirales (4.1%)
Nitrososphaerales (9.0%)
Myxococcales (5.1%)
Gemmatimonadales (2.9%)
Cytophagales (0.7%)
Caulobacterales (1.6%)
Solibacterales (3.9%)
Solirubrobacterales (4.3%)
Sphingobacteriales (1.0%)
Sphingomonadales (7.4%)
Syntrophobacterales (2.1%)
Xanthomonadales (5.1%)
Acidimicrobiales (3.4%)
Acidobacteriales (4.6%)
Actinomycetales (9.7%)
Burkholderiales (5.6%)


Rhizobiales
Normalized Abundance
2
1
0
-1
NOCOVER
VETCH
WHEAT
Nitrososphaerales
Normalized Abundance
2
1
0
-1
NOCOVER
VETCH
WHEAT
Actinomycetales
Normalized Abundance
2
1
0
-1
NOCOVER
VETCH
WHEAT
Nitrosomonadales
Normalized Abundance
2
1
0
-1
NT
TILL
Xanthomonadales
Normalized Abundance
11.5
11.0
10.5
10.0
9.5
0 N
101 N
34 N
72 N

Examples Functional Differences







Implications

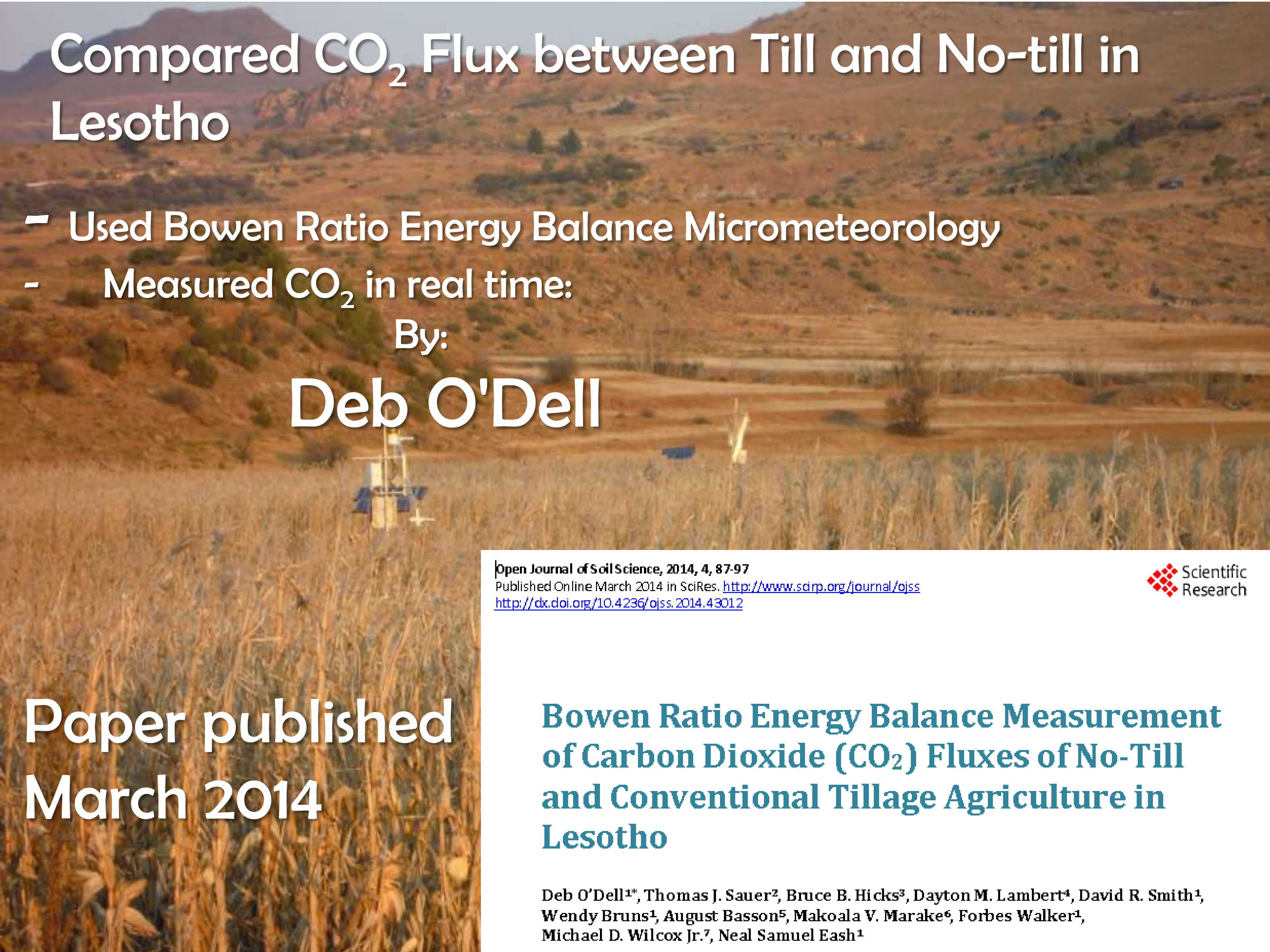
- CA practices shifts microbial community shifts
  - Less impact on highly abundant general functioning bacteria species e.g. Decomposers
  - Greater impact on lower abundant specific functional bacteria species e.g. Nitrogen fixers and plant growth promoter rhizobacteria (PGPR's)
  - Has implications on functioning and resilience of ecosystem and crop productivity
  - Genomics is a tool that can harness the potentials of microbial world-technology transfer to developing countries

Compared CO_2 Flux between Till and No-till in Lesotho

- Used Bowen Ratio Energy Balance Micrometeorology
- Measured CO_2 in real time:

By:

Deb O'Dell



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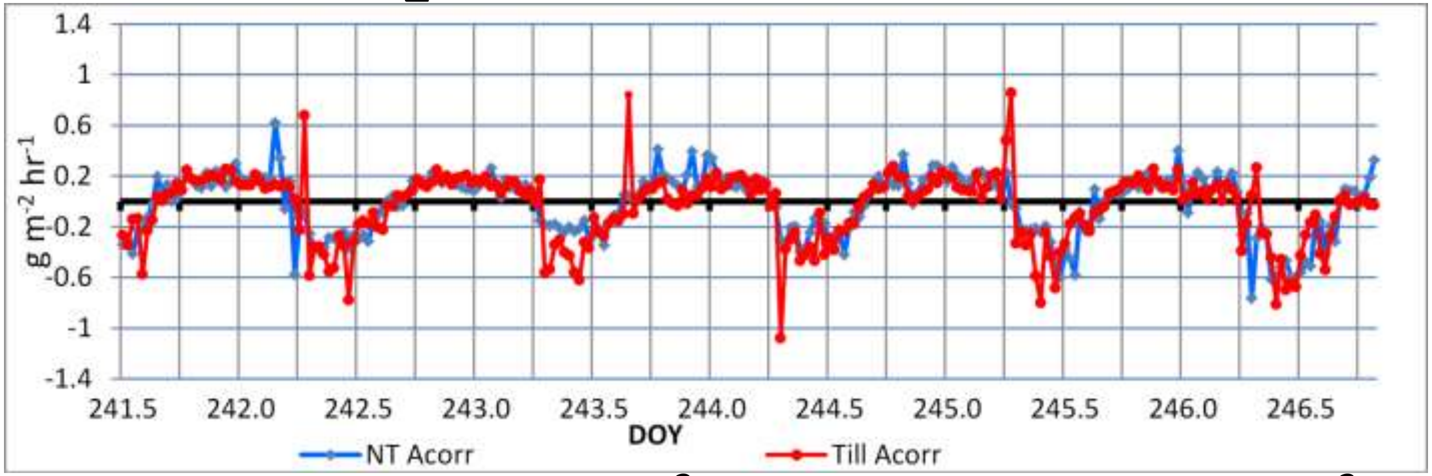
http://dx.doi.org/10.4236/ojss.2014.43012

Scientific Research

Bowen Ratio Energy Balance Measurement of Carbon Dioxide (CO_2) Fluxes of No-Till and Conventional Tillage Agriculture in Lesotho

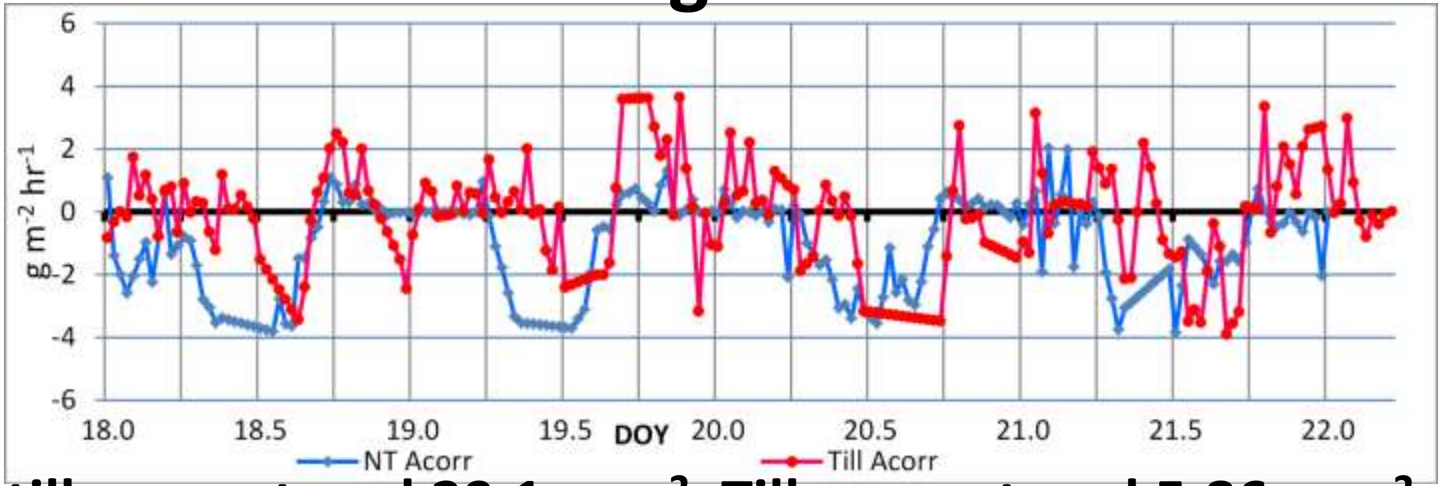
Deb O'Dell[1*], Thomas J. Sauer[2], Bruce B. Hicks[3], Dayton M. Lambert[4], David R. Smith[1], Wendy Bruns[1], August Basson[5], Makoala V. Marake[6], Forbes Walker[1], Michael D. Wilcox Jr.[7], Neal Samuel Eash[1]

Results – CO_2 Flux for Non-growing Season



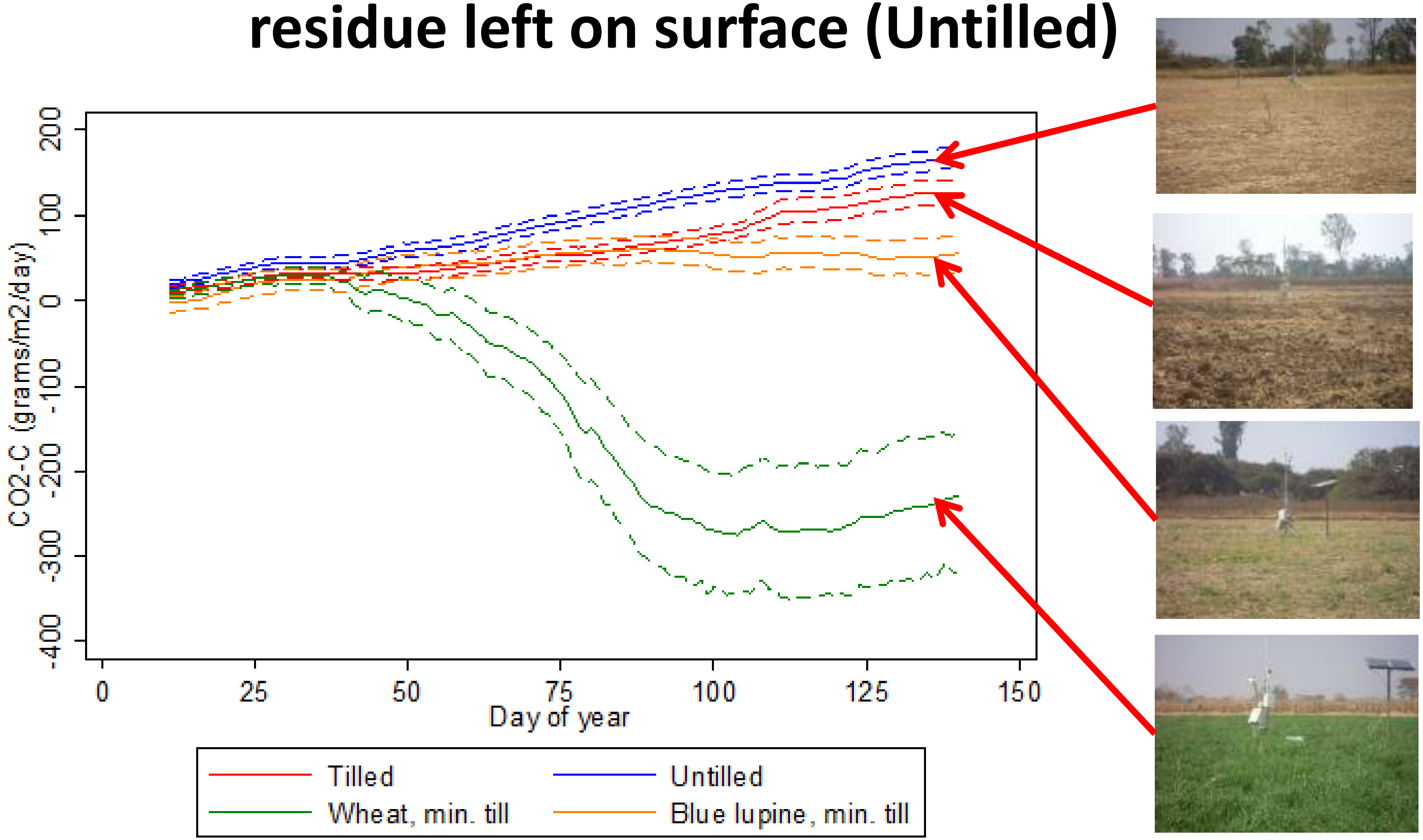
No-till sequestered 0.03 g m^{-2}, Till sequestered 0.01 g m^{-2} for 7 days in Aug and Sep 2011

Growing Season

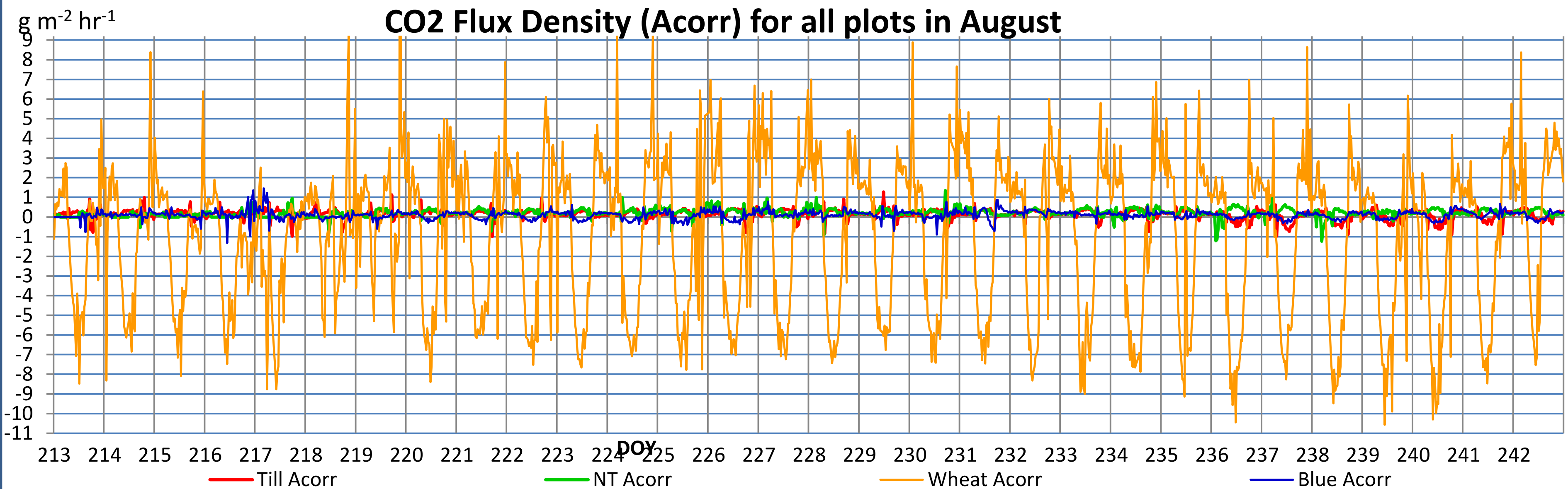


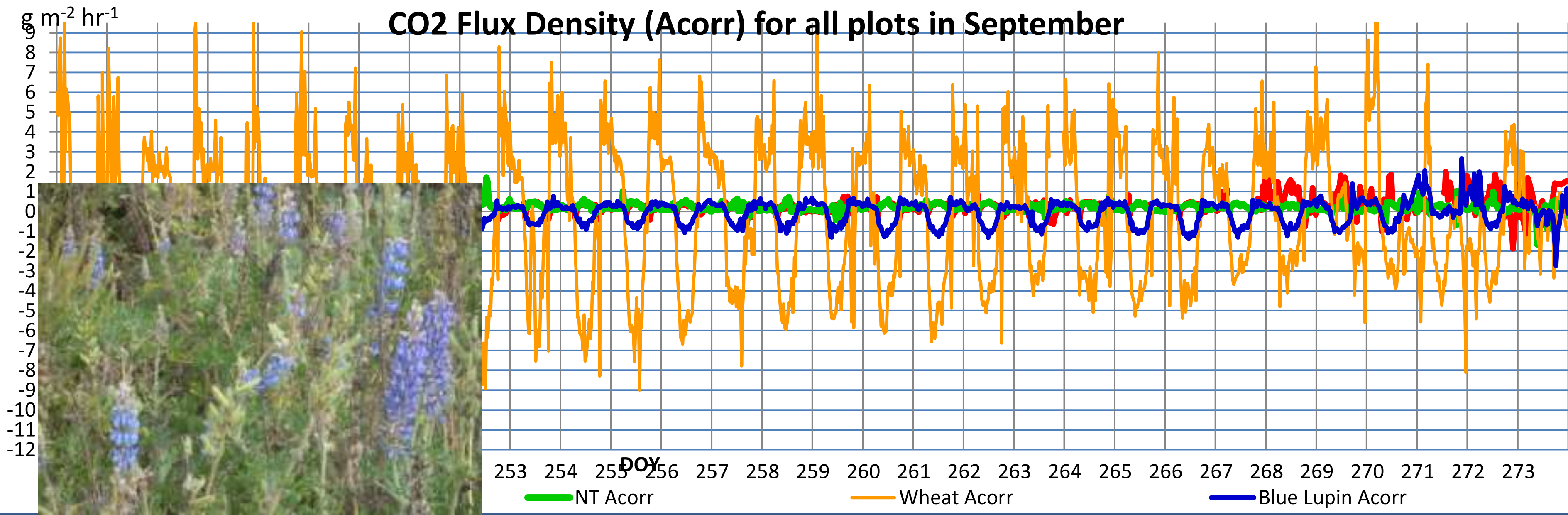
No-till sequestered 29.1 g m^{-2}, Till sequestered 5.86 g m^{-2} for 5.5 days in Jan 2012

Phase 2 - We compared:
2 Winter Cover Crops (Wheat and Blue Lupin) with 2 Fallow: residue incorporated (Tilled) and residue left on surface (Untilled)



CO2 half hour flux during Aug and Sep 2013





Research Results:

- No-till sequesters more carbon than Till during growing season
- Winter wheat cover crop sequestered C
- Sparse blue lupin legume did not sequester, but emitted less than fallow
- Till fallow emitted less than no-till fallow
  - Dry winter till had very little moisture - any cover better than none
- These results show that even a short term cover crop can mitigate greenhouse gas emissions

Knowledge/Technology Output:

- Micrometeorology Instrumentation and Processes
  - Developed and Refined
  - Can install and train personnel in Africa
- Measure CO_2 emissions in real time
- Evaluate and compare the mitigation potential of any agricultural practice
- Demonstrates potential for small holder farmers to receive carbon credits for conservation agriculture practices
- Build capacity for CO_2 measurement in Africa - developing countries

Technology Transfer

- Build Capacity: University students and engineers
- Climate networks and policy (Fluxnet, UNFCCC)
- Collaborations with climate organizations for measurement (World Agroforestry Centre)
- Carbon markets
- NGOs

Thank you!