Effects of novel non-bloat legumes on C and N pools in pasture systems

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Effects of grazing on SOC

- Grazing in pastures:
  - increases SOC stock
    - stimulates aboveground production, root respiration and root exudation rates
    - increases tillering & rhizome production

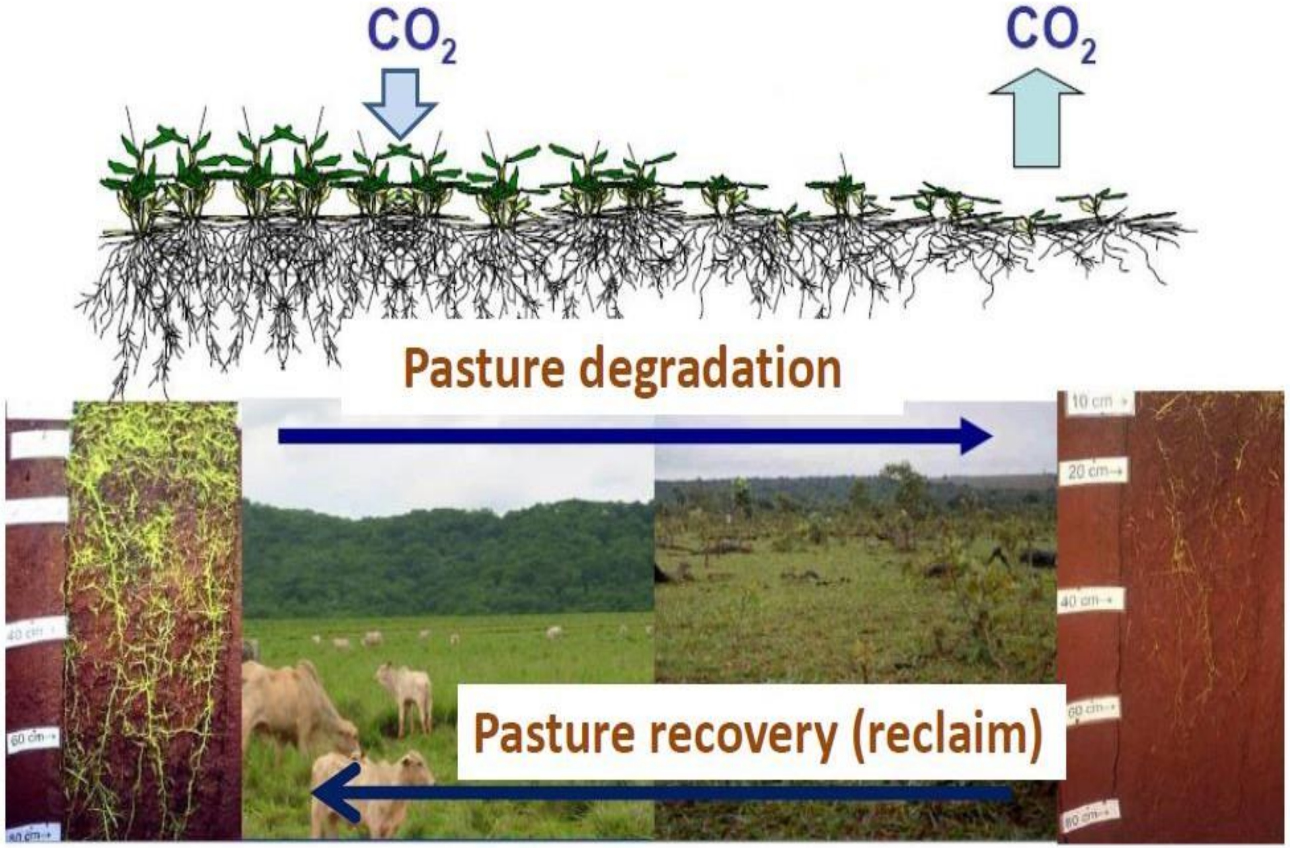
(Schnabel et al., 2001; Schuman et al., 2002)

- Overgrazing
  - decreases SOC grasslands/pastures
    - decreased primary production and increased soil erosion

(Su et al., 2005)

Pasture rejuvenation mechanisms

- Degraded pastures can be rejuvenated by:
  - ❖ Fertilization at soil-test recommended rates
  - ❖ Mechanical aeration
  - ❖ Direct/sod-seeding
  - ❖ Including legumes



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Conventional vs. sod-seeding

- Potential implications:
  - loss of wildlife habitat,
  - erosion, N leaching,
  - decreased in microbial diversity, and
  - re-salinization on marginal land
  - loss of SOC

Sod-seeding of different legumes may affect soil C and N stocks.

My PhD Research

Impacts of forage quality improvement strategies on GHG emissions and C sequestration.

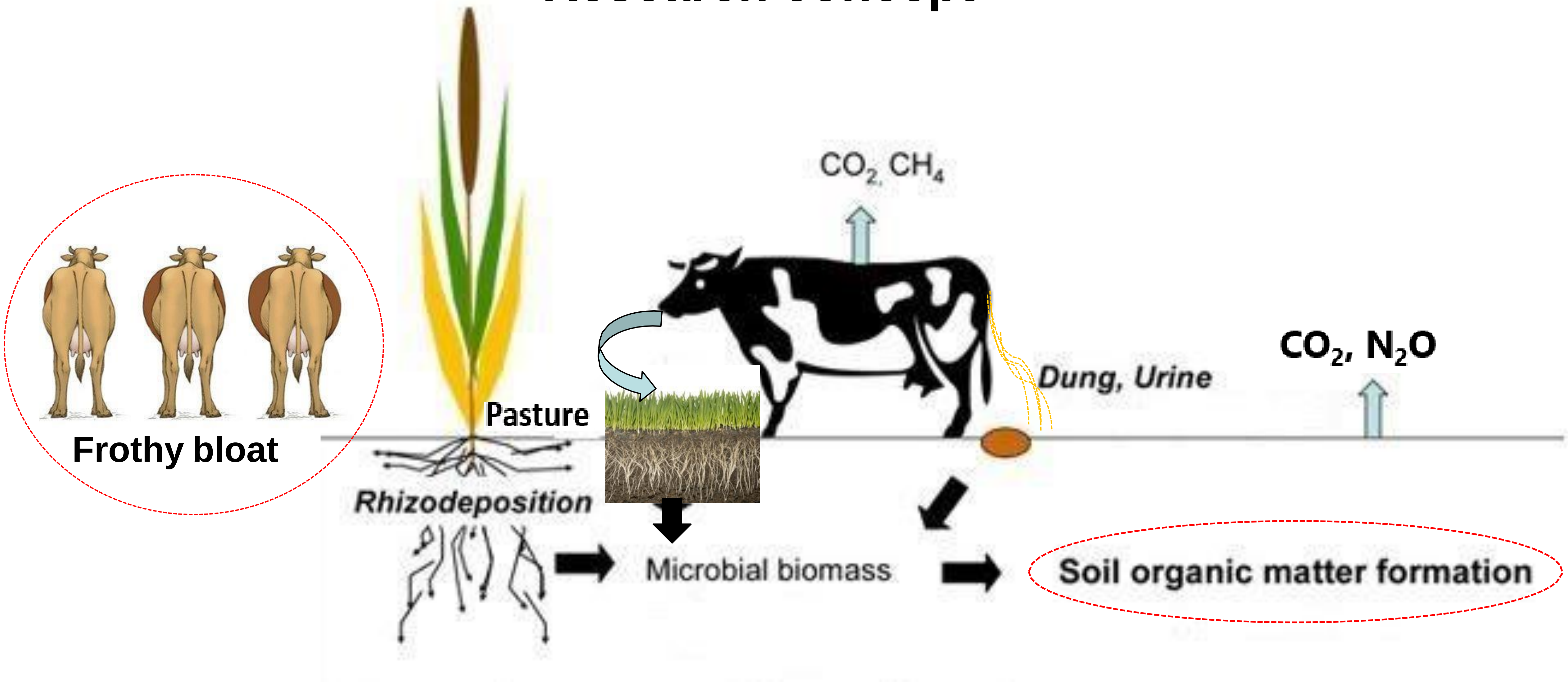
Short-term C and N dynamics study

Research Objective

To determine the impacts of novel non-bloat legumes on C and N dynamics

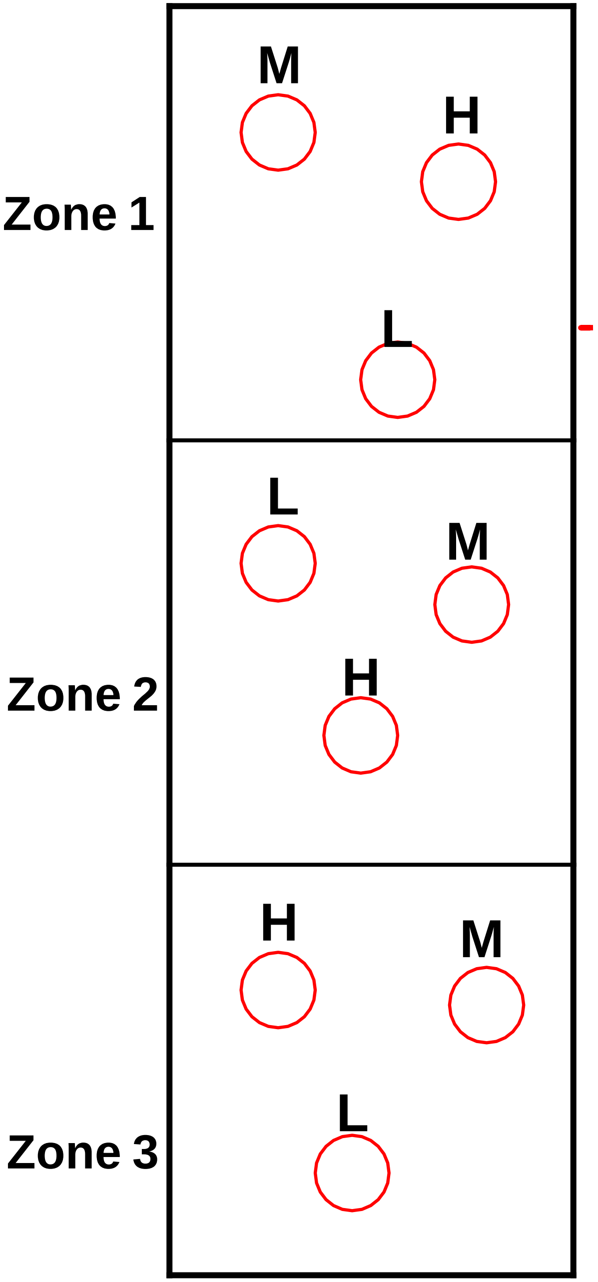
- ^{15}N-N_2-fixation study
- ^{13}C-labelling study
- Soil organic carbon study
- N cycling study using ^{15}N tracer
- Soil disturbance/forage termination study

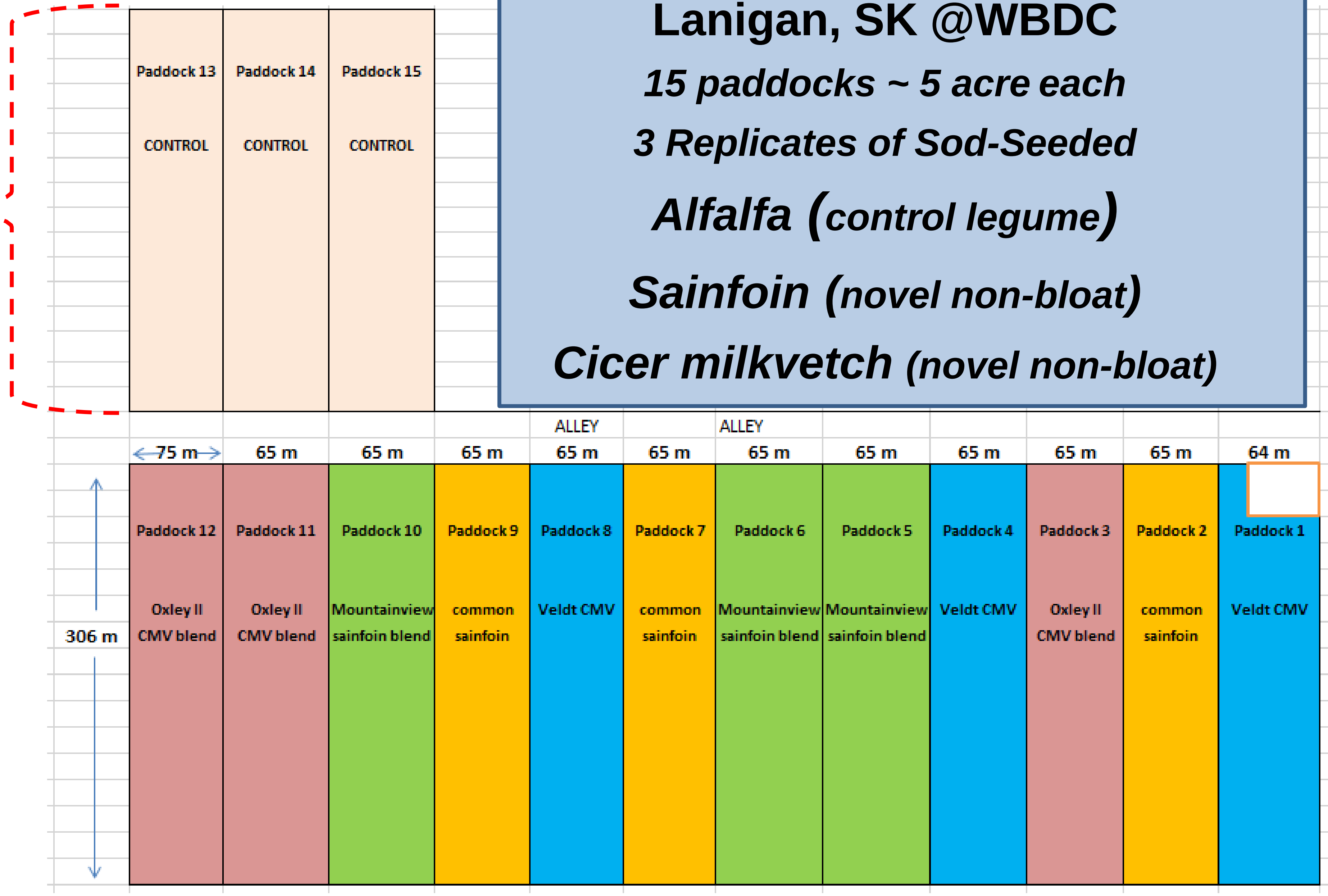
Research concept



(*Modified from Rumpel et al., 2015*)

Study Site Layout





Lanigan, SK @WBDC

15 paddocks ~ 5 acre each

3 Replicates of Sod-Seeded

Alfalfa (control legume)

Sainfoin (novel non-bloat)

Cicer milkvetch (novel non-bloat)

Today's presentation

Impact of novel non-bloat legumes on C and N dynamics

- ^{15}N-N_2-fixation study
- ^{13}C-labelling study
- Soil organic carbon study
- N cycling study using ^{15}N tracer
- Soil disturbance/forage termination study

N_2-fixation study Methodology

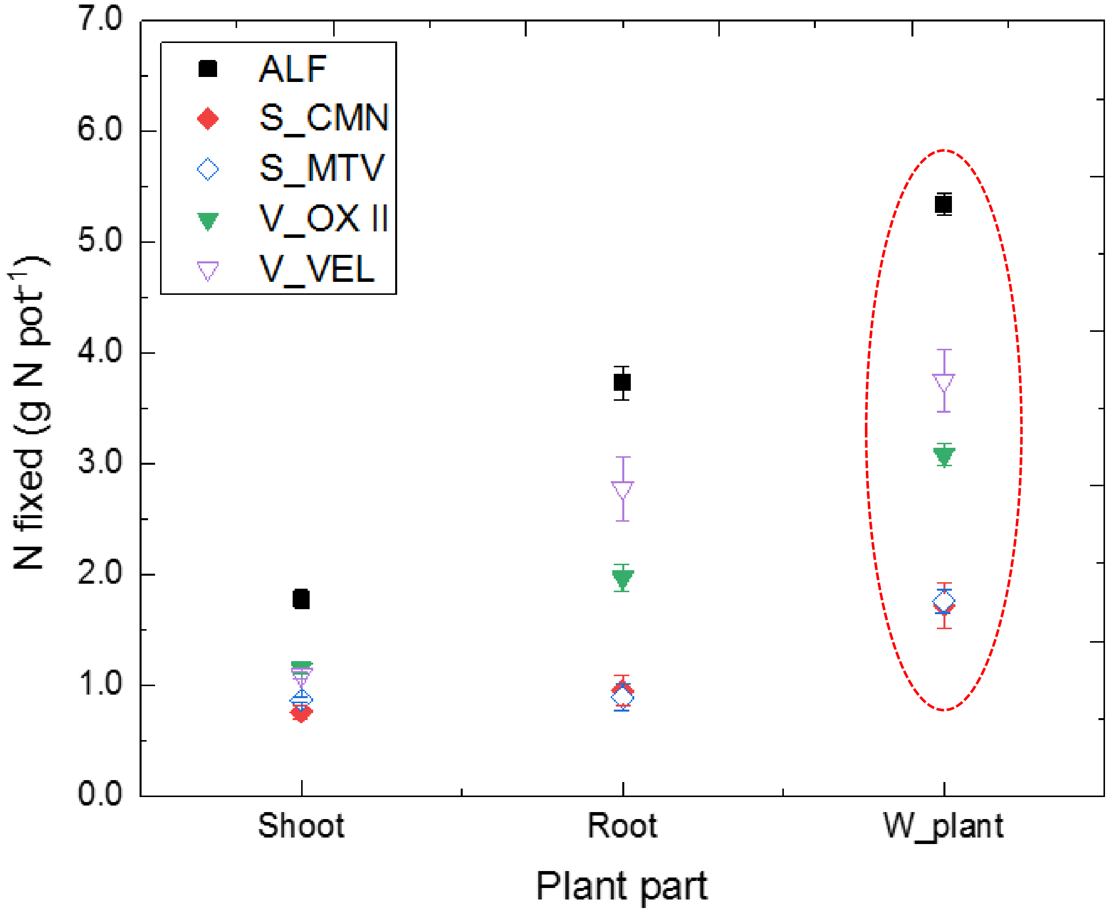
- Phytotron study.
- RCBD study in pots with soil moisture maintained at 80% of field capacity.
  - *Alfalfa (Algonquin)*
  - *Cicer Milkvetch (Veldt)*
  - *Cicer Milkvetch (Oxley II)*
  - *Sainfoin(Common)*
  - *Sainfoin(Mountainview)*
  - *Meadow bromegrass (Armada) reference sp.*

- Two months following seeding, plants were thinned to six plants per pot.
  - ^{15}N-enriched $NH_4^+NO_3^-$ (10-atom % excess) was applied at a rate of 5 kg N ha^{-1}.
- Four months after enrichment, plants were harvested from the soil level.
  - %Ndfa and total N-fixed were estimated.

$$\%Ndfa = 1 - \frac{(atom\%^{15}Nexcess_{fixingtree})}{(atom\%^{15}Nexcess_{nonfixingtree})} \times 100\%$$

All data were analyzed using ANOVA by the PROC MIXED procedure

N_2-fixation study Results



- Alfalfa fixed significantly more atmospheric N_2 than the other species in all the plant parts measured.
  - ***Alfalfa > Cicer Milkvetch > Sainfoin***

    %Ndfa: 92% vs 87% vs 81%

    g N pot^{-1}: 5.3 vs 3.4 vs 1.7

    kg N ha^{-1} fixed: 200 vs 128 vs 65
- No significant difference between cultivars of sainfoin.

C and N dynamics Methodology

- **Soil sampling: 0-15 cm, 15-30 cm, 30-60 cm and 60-100 cm in 2017 and 2018.**

  - Total soil organic carbon (SOC) using LECO C632 after acid pre-treatment.
  - Water extractable C and N (DOC and TDN) determined in *5mM* $CaCl_2$ extract.

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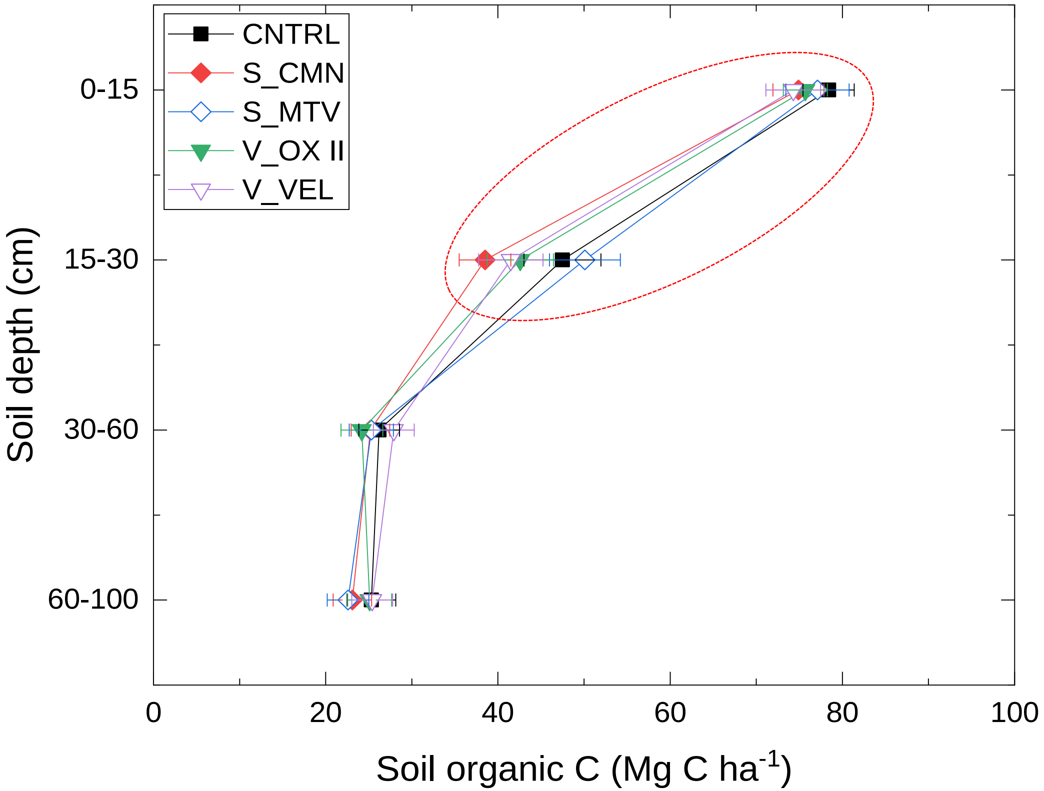
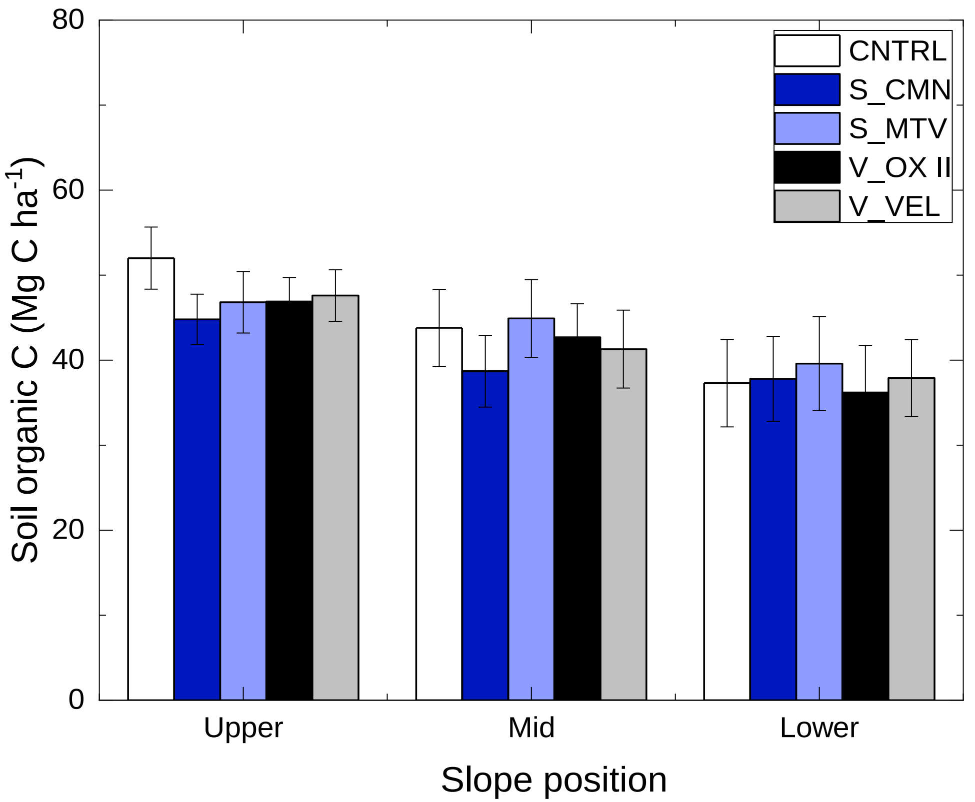
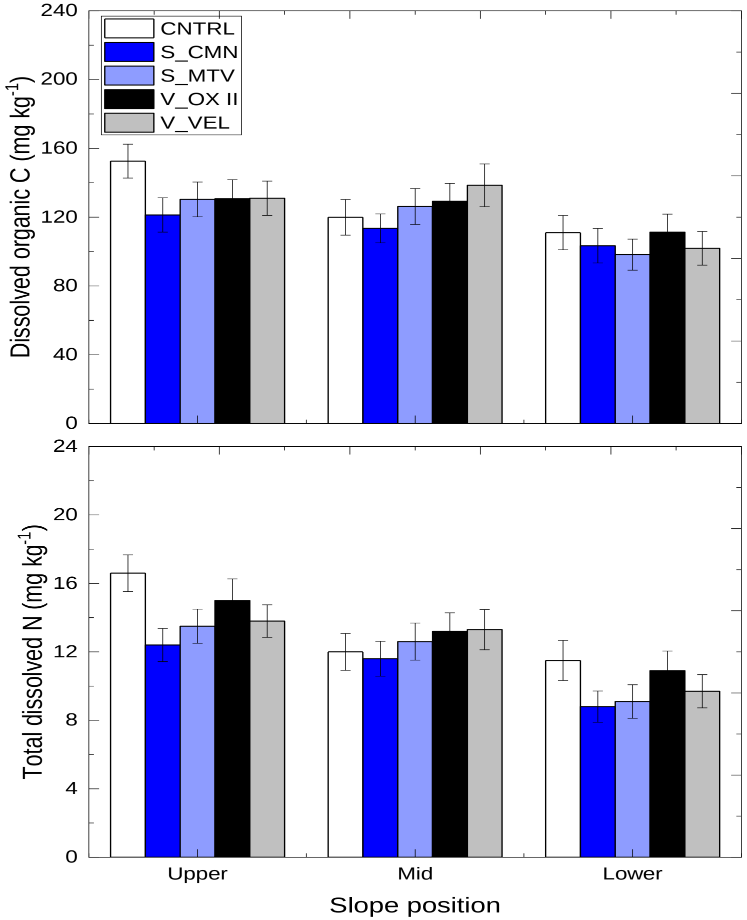
Soil Organic Carbon Results

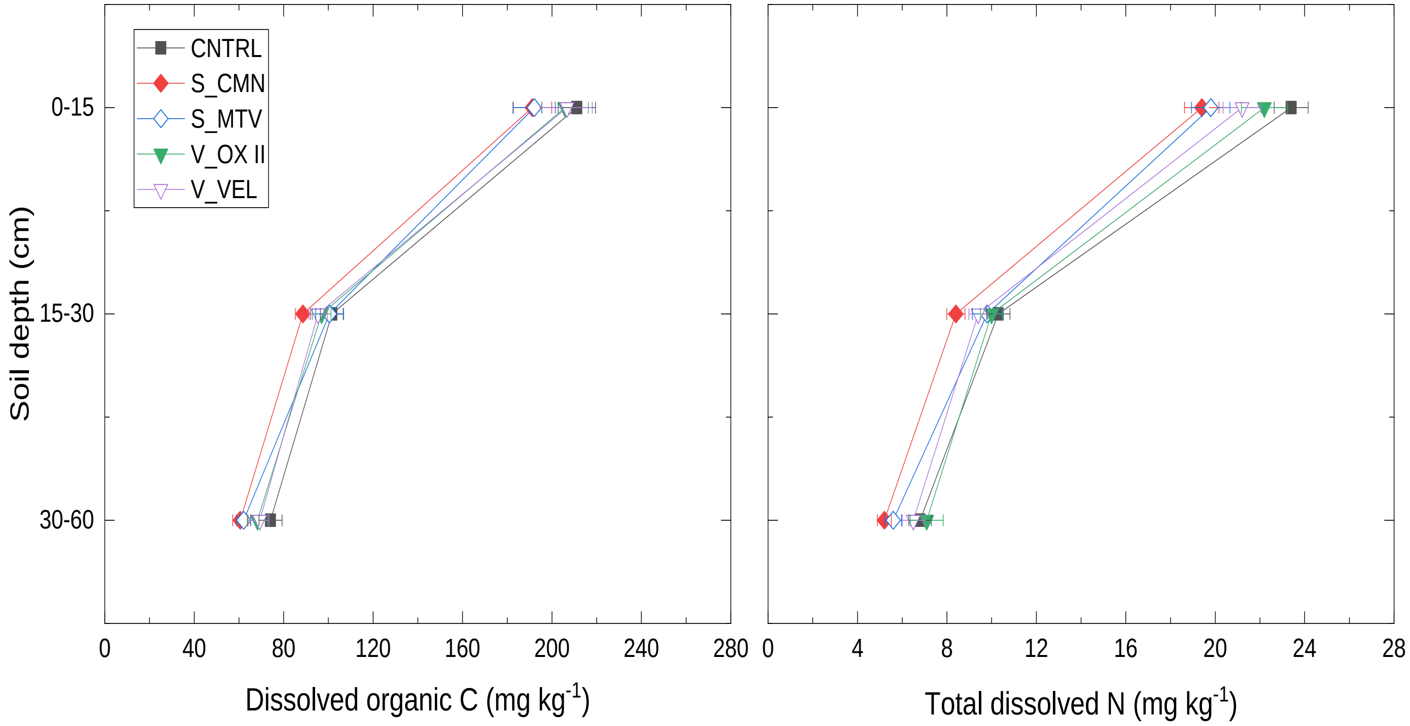




- No significant effects of legume type or varieties on total SOC.
- As expected, slope and depth had significant effect on SOC.
  - upper >> Lower; Surface >> subsurface (70 % SOC within 0-30 cm)

Water-extractable Organic Matter

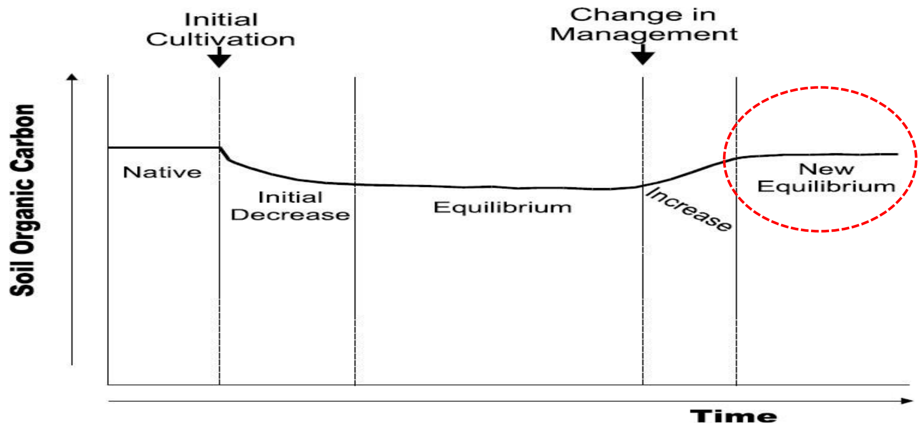




- Soil under alfalfa had highest water extractable C and N on upslopes, milkvetch higher on mid.
- Both slope position and soil depth had significant effects on DOC and TDN.
    - upper >> Lower; Surface >> subsurface

Discussion

- Introduction of legumes did not significantly affect total SOC:
  - C status of soil before sod-seeding was high



- Short period of the experiment
  - detect management effects (WEOM/LFOM).

- N_2 fixation, easily decomposable organic matter (WEOM) higher under alfalfa than novel non-bloat legumes.

- Similar C and N values compared to previous studies.
  - efficiency of C and N cycling due perennial legumes.
  - similar inputs and outputs.

- Reverse trend in SOC/WEOM
  - Upper slope >> Lower slope

Continued measurements over longer time would be useful to reveal any SOM changes.

Conclusion and Take Home Message

- Alfalfa fixed more atmospheric N than Cicer Milkvetch and Sainfoin.
- Cicer Milkvetch and Sainfoin are viable alternatives to alfalfa for pasture rejuvenation:
  - No adverse impact on C and N pools compared to alfalfa.
  - Efficient protein utilization (absence of frothy bloat).
  - Considering the whole system, the non-bloat legumes (milkvetch and sainfoin) may have lower GHG emission footprint due to:
    - Reduced enteric methane (CH_4) emission.
    - Lowered soil GHG (CO_2, N_2O, and CH_4) emissions.
    - Efficient protein utilization.
    - No negative impact on soil C and N stores and cycling.
  - Preliminary ranking for pasture rejuvenation and lower GHG footprint:
    - *Cicer Milkvetch > Sainfoin > Alfalfa*

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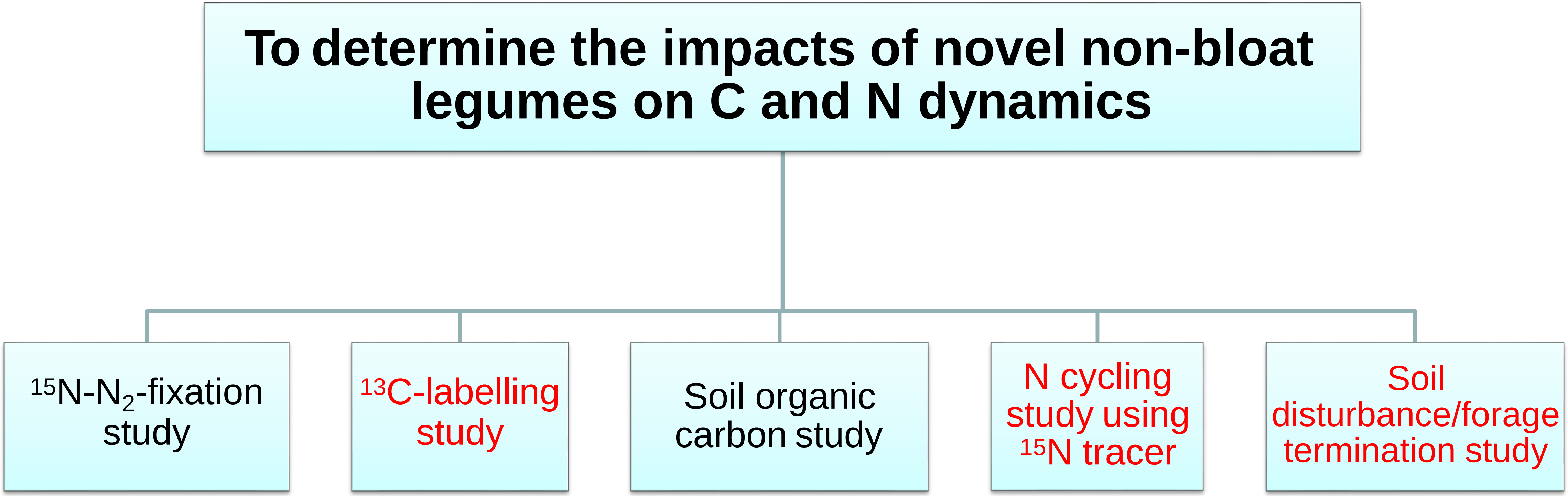
Future Studies



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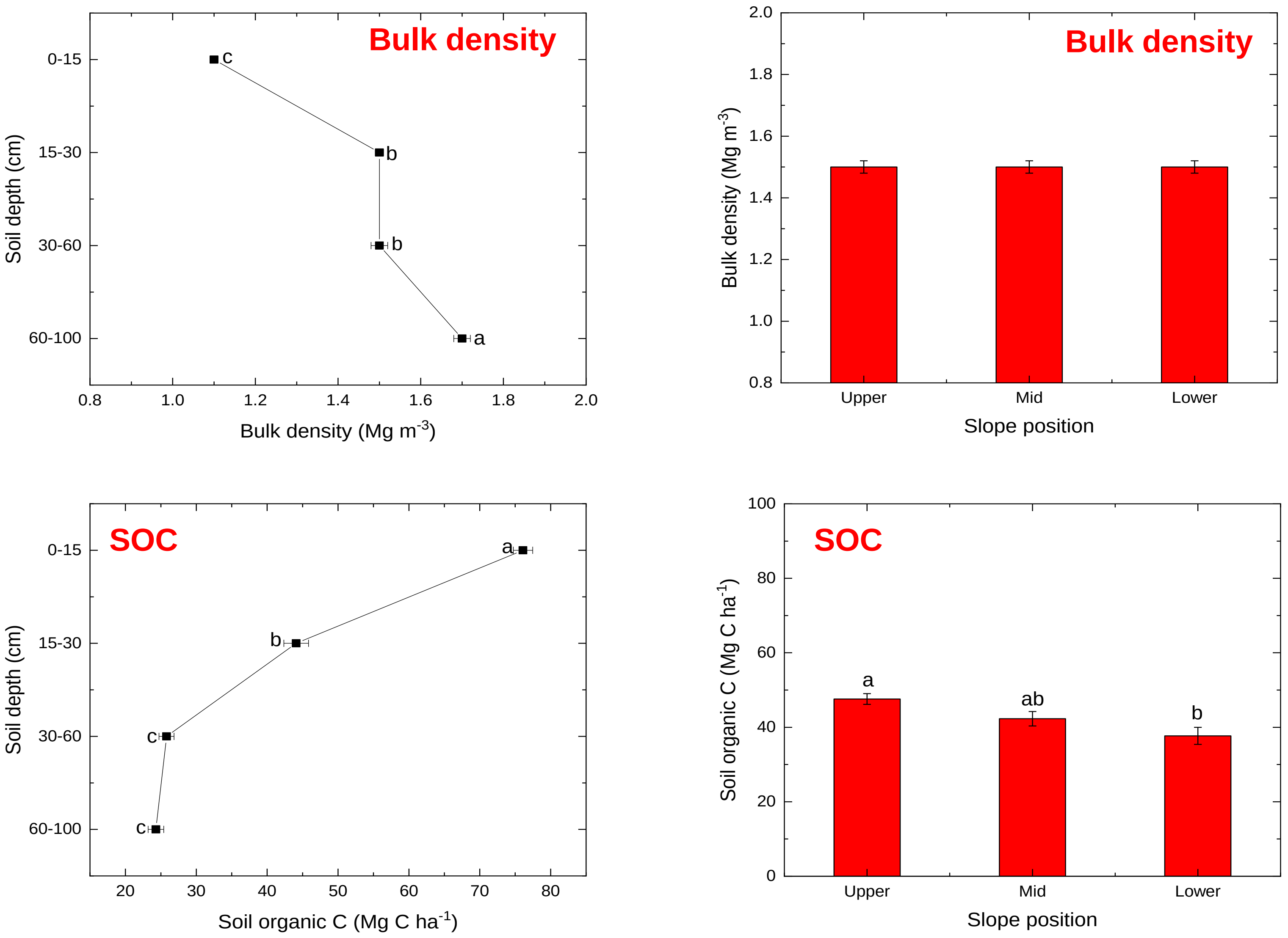
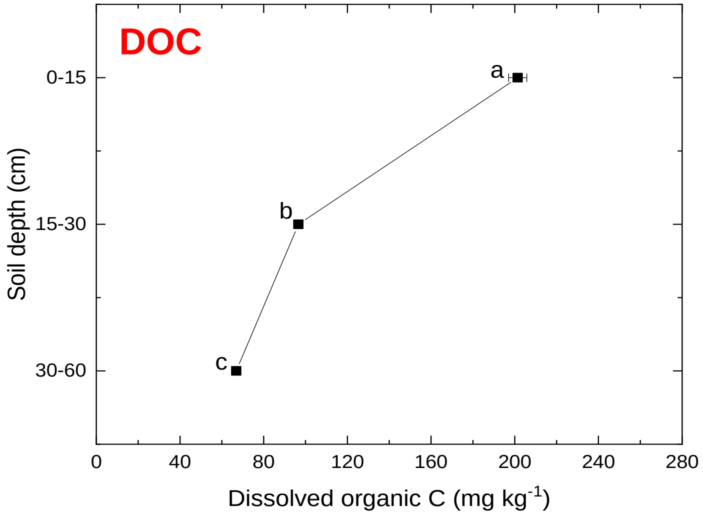
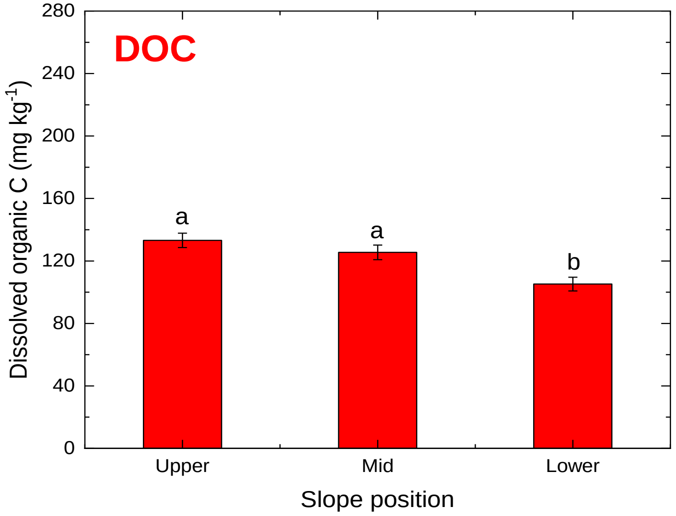
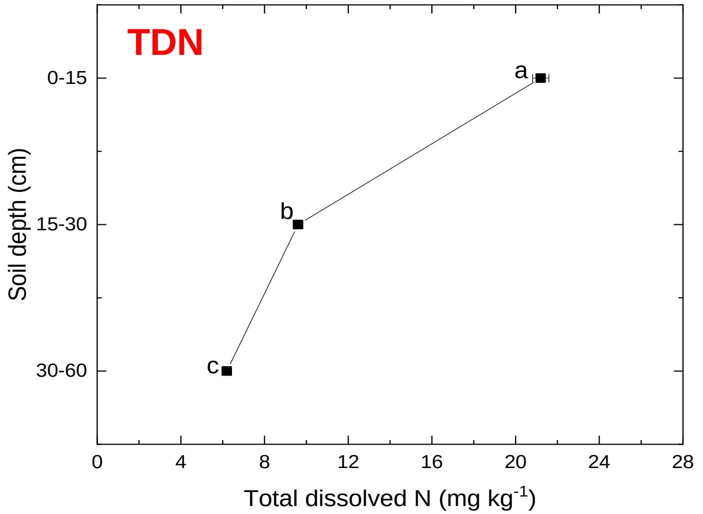
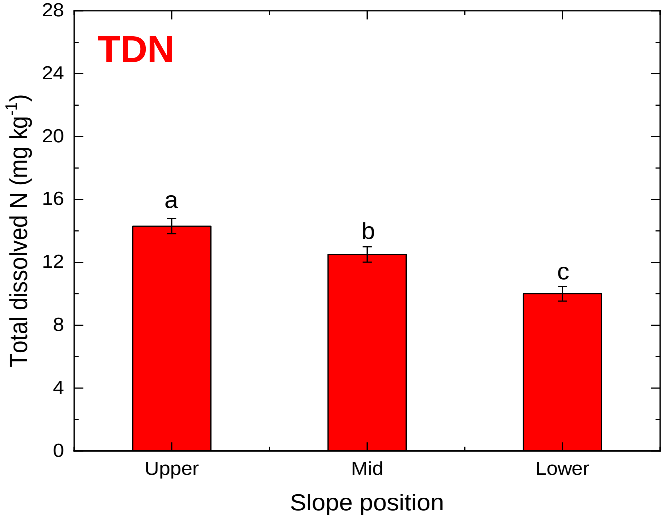
Questions?

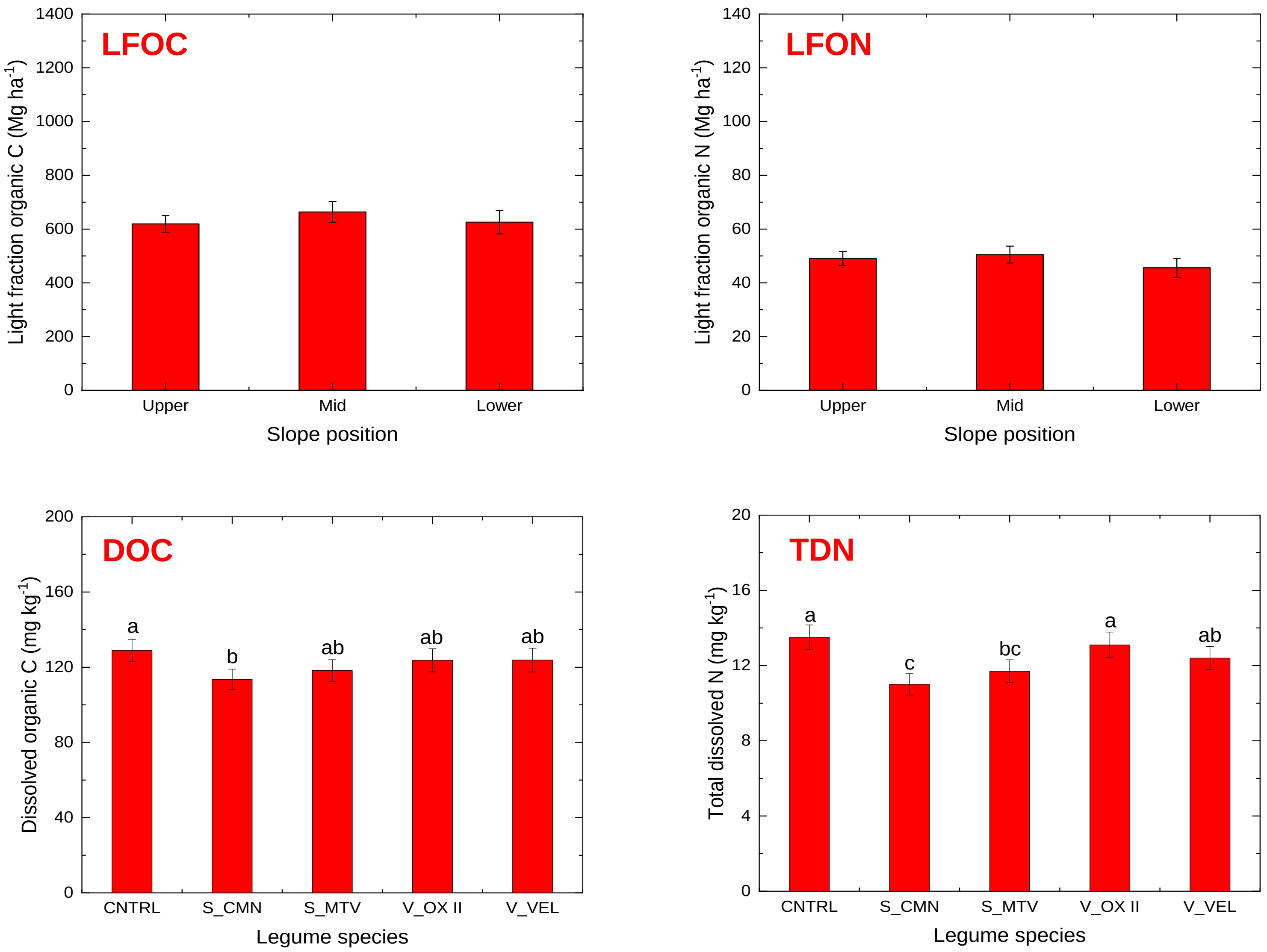

Bulk density
Soil depth (cm)
0-15
15-30
30-60
60-100
c
b
b
a
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Bulk density (Mg m-3)
Bulk density
Bulk density (Mg m-3)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
Upper
Mid
Lower
Slope position
SOC
Soil depth (cm)
0-15
15-30
30-60
60-100
a
b
c
c
20
30
40
50
60
70
80
Soil organic C (Mg C ha-1)
SOC
Soil organic C (Mg C ha-1)
100
80
60
40
20
0
a
ab
b
Upper
Mid
Lower
Slope position


DOC
Soil depth (cm)
0-15
15-30
30-60
a
b
c
0
40
80
120
160
200
240
280
Dissolved organic C (mg kg-1)


DOC
Dissolved organic C (mg kg-1)
280
240
200
160
120
80
40
0
a
a
b
Upper
Mid
Lower
Slope position


TDN
Soil depth (cm)
0-15
15-30
30-60
a
b
c
0
4
8
12
16
20
24
28
Total dissolved N (mg kg-1)


TDN
Total dissolved N (mg kg-1)
28
24
20
16
12
8
4
0
a
b
c
Upper
Mid
Lower
Slope position



LFOC
Light fraction organic C (Mg ha^{-1})
0
200
400
600
800
1000
1200
1400
Upper
Mid
Lower
Slope position
LFON
Light fraction organic N (Mg ha^{-1})
0
20
40
60
80
100
120
140
Upper
Mid
Lower
Slope position
DOC
Dissolved organic C (mg kg^{-1})
0
40
80
120
160
200
a
b
ab
ab
ab
CNTRL
S_CMN
S_MTV
V_OX II
V_VEL
Legume species
TDN
Total dissolved N (mg kg^{-1})
0
4
8
12
16
20
a
c
bc
a
ab
CNTRL
S_CMN
S_MTV
V_OX II
V_VEL
Legume species

Table 1: ANOVA on the effects of Slope position (SLP), Legume varieties (LEG) and their combined interactions on bulk density and short-term C and N changes in the 2017 and 2018 growing seasons in a pasture system sod-seeded with novel non-bloat legumes.

[1]Analysis of variance						
			Water-extractable OM		Light Fraction	
	Bulk density	**SOC**	**DOC**	**DTN**	**C**	**N**
	Mg m⁻³	*Mg C ha⁻¹*	---------*mg kg⁻¹*--------		--------*Mg ha⁻¹*--------	
[2]SLP	NS	NS	NS	*	NS	NS
[3]LEG	NS	***	****	****	NS	NS
SLP x LEG	NS	NS	NS	NS	NS	NS

[1]Asterisk indicates significant difference between treatment means according to Tukey's HSD ($P < 0.10$; *$P<0.10$, **$P<0.01$, ***$P<0.001$, ****$P<.0001$; NS, not significant at $P<0.10$). [2]Slope position refers to upper, mid and lower slope positions. [3]Legume refers to the annual non-bloat cultivars and alfalfa seeded in the paddocks. Data were pooled across slope position ($n = 9$) and for each individual treatment (slope position; $n = 9$ and legume; $n = 3$).

Table 2: ANOVA on the effects of Soil depth (DEP), Legume varieties (LEG) and their combined interactions on bulk density and short-term C and N changes in the 2017 and 2018 growing seasons in a pasture system sod-seeded with novel non-bloat legumes.

[1]Analysis of variance						
			Water-extractable OM		Light Fraction	
	Bulk density	**SOC**	**DOC**	**DTN**	**C**	**N**
	Mg m⁻³	*Mg C ha⁻¹*	---------*mg kg⁻¹*--------		--------*Mg ha⁻¹*--------	
[2]DEP	NS	NS	**	****	-	-
[3]LEG	****	****	****	****	NS	NS
DEP x LEG	NS	NS	NS	NS	-	-

[1]Asterisk indicates significant difference between treatment means according to Tukey's HSD ($P < 0.10$; *P<0.10, **P<0.01, ***P<0.001, ****P<.0001; NS, not significant at $P<0.10$). [2]Soil depth refers to 0-15 cm, 15-30 cm, 30-60 cm and 60-100 cm, based on the parameter. [3]Legume refers to the annual non-bloat cultivars and alfalfa seeded in the paddocks. Data were pooled across soil depth (n = 9) and for each individual treatment (soil depth; n = 9 and legume; n = 3).

Table 3: ANOVA on the effects of Slope position (SLP), Legume varieties (LEG) and their combined interactions on bulk density and short-term C and N changes in the 2017 and 2018 growing seasons in a pasture system sod-seeded with novel non-bloat legumes.

[1]Analysis of variance						
			Water-extractable OM		Light Fraction	
	Bulk density	**SOC**	**DOC**	**DTN**	**C**	**N**
	Mg m^{-3}	*Mg C ha^{-1}*	---------*mg kg^{-1}*--------		--------*Mg ha^{-1}*--------	
[2]SLP	NS	NS	NS	0.0402	NS	NS
[3]LEG	NS	0.0017	<.0001	<.0001	NS	NS
SLP x LEG	NS	NS	NS	NS	NS	NS

[1]Asterisk indicates significant difference between treatment means according to Tukey's HSD (P < 0.10; *P<0.10, **P<0.01, ***P<0.001, ****P<.0001; NS, not significant at P<0.10). [2]Slope position refers to upper, mid and lower slope positions. [3]Legume refers to the annual non-bloat cultivars and alfalfa seeded in the paddocks. Data were pooled across slope position (n = 9) and for each individual treatment (slope position; n = 9 and legume; n = 3).

Table 4: ANOVA on the effects of Soil depth (DEP), Legume varieties (LEG) and their combined interactions on bulk density and short-term C and N changes in the 2017 and 2018 growing seasons in a pasture system sod-seeded with novel non-bloat legumes.

[1]Analysis of variance						
			Water-extractable OM		Light Fraction	
	Bulk density	**SOC**	**DOC**	**DTN**	**C**	**N**
	Mg m^{-3}	*Mg C ha^{-1}*	---------*mg kg^{-1}*--------		--------*Mg ha^{-1}*--------	
[2]DEP	NS	NS	0.0159	<.0001	-	-
[3]LEG	<.0001	<.0001	<.0001	<.0001	NS	NS
DEP x LEG	NS	NS	NS	NS	-	-

[1]Asterisk indicates significant difference between treatment means according to Tukey's HSD (P < 0.10; *P<0.10, **P<0.01, ***P<0.001, ****P<.0001; NS, not significant at P<0.10). [2]Soil depth refers to 0-15 cm, 15-30 cm, 30-60 cm and 60-100 cm, based on the parameter. [3]Legume refers to the annual non-bloat cultivars and alfalfa seeded in the paddocks. Data were pooled across soil depth (n = 9) and for each individual treatment (soil depth; n = 9 and legume; n = 3).