Simulating impacts of alternative manure management on GHG emissions from a typical beef cattle feedlot in Brazil using Manure-DNDC

Ciniro Costa Junior, Changsheng Li, Carlos E P Cerri, Carlos C Cerri

Universidade de São Paulo
Brasil
Biogeochemistry Lab
University of New Hampshire
FAPESP

INTRODUCTION

- Biggest comercial cattle – 200 mi heads

- One of the biggest producers

- 2012 – ≈ 20% world beef production

40 million slaughters / year

$ 25 billion / year

90%

10%

INTRODUCTION

Beef Cattle Feedlot in Brazil

1.55 million in 2002

> 2x

3.76 million in 2012

INTRODUCTION

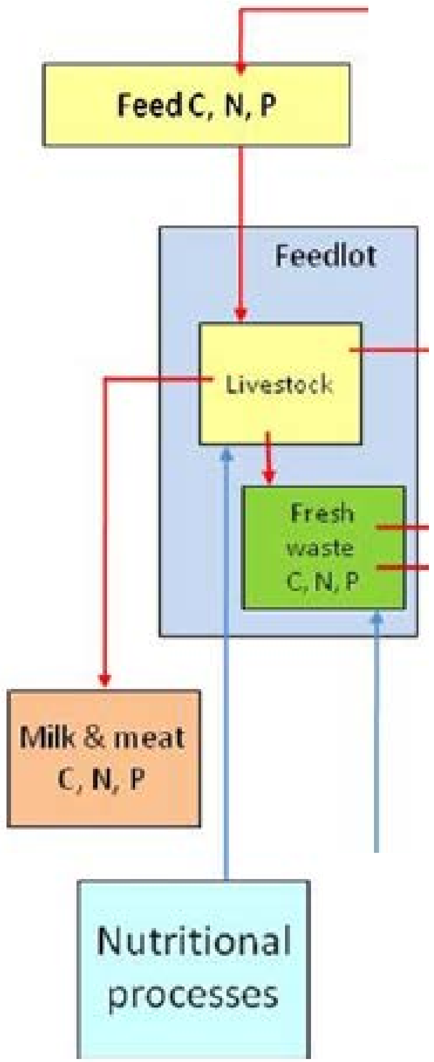
A consequence of feedlots

Large amount of manure

Manure C and N biogeochemistry cycle in Livestock Farm

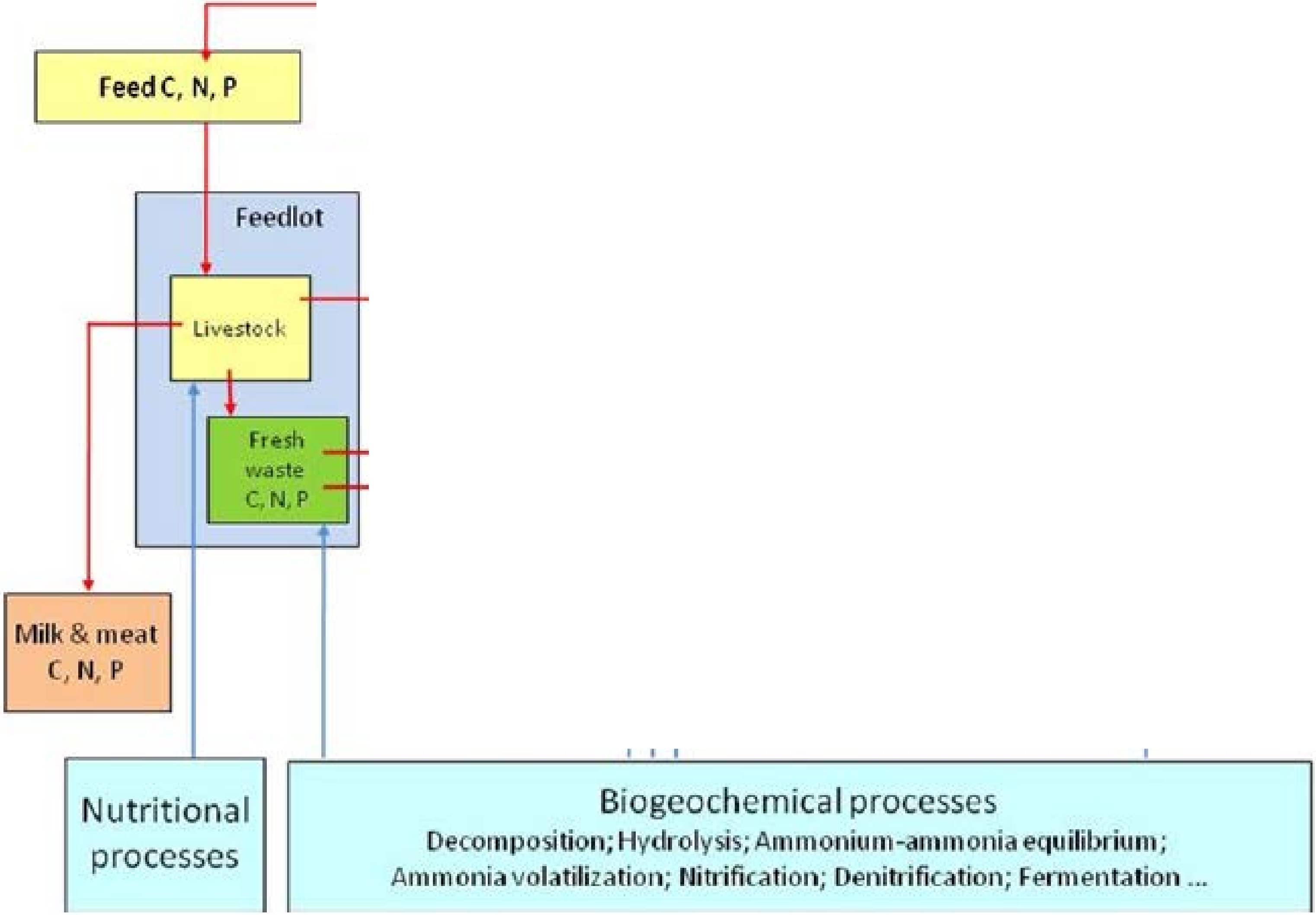
Manure = organic matter + mineral

Manure C and N biogeochemistry cycle in Livestock Farm



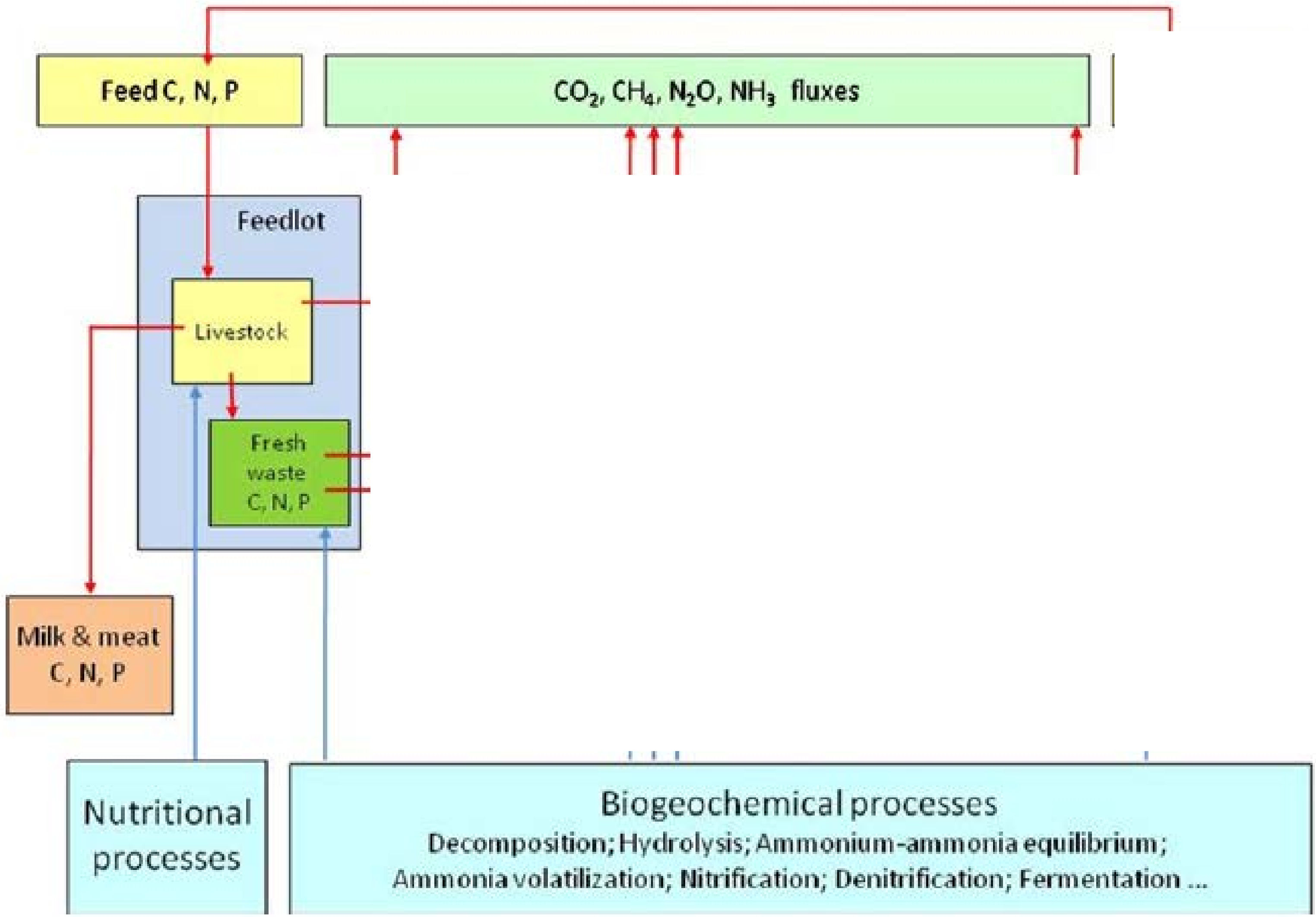
Li et al. (2012)

Manure C and N biogeochemistry cycle in Livestock Farm



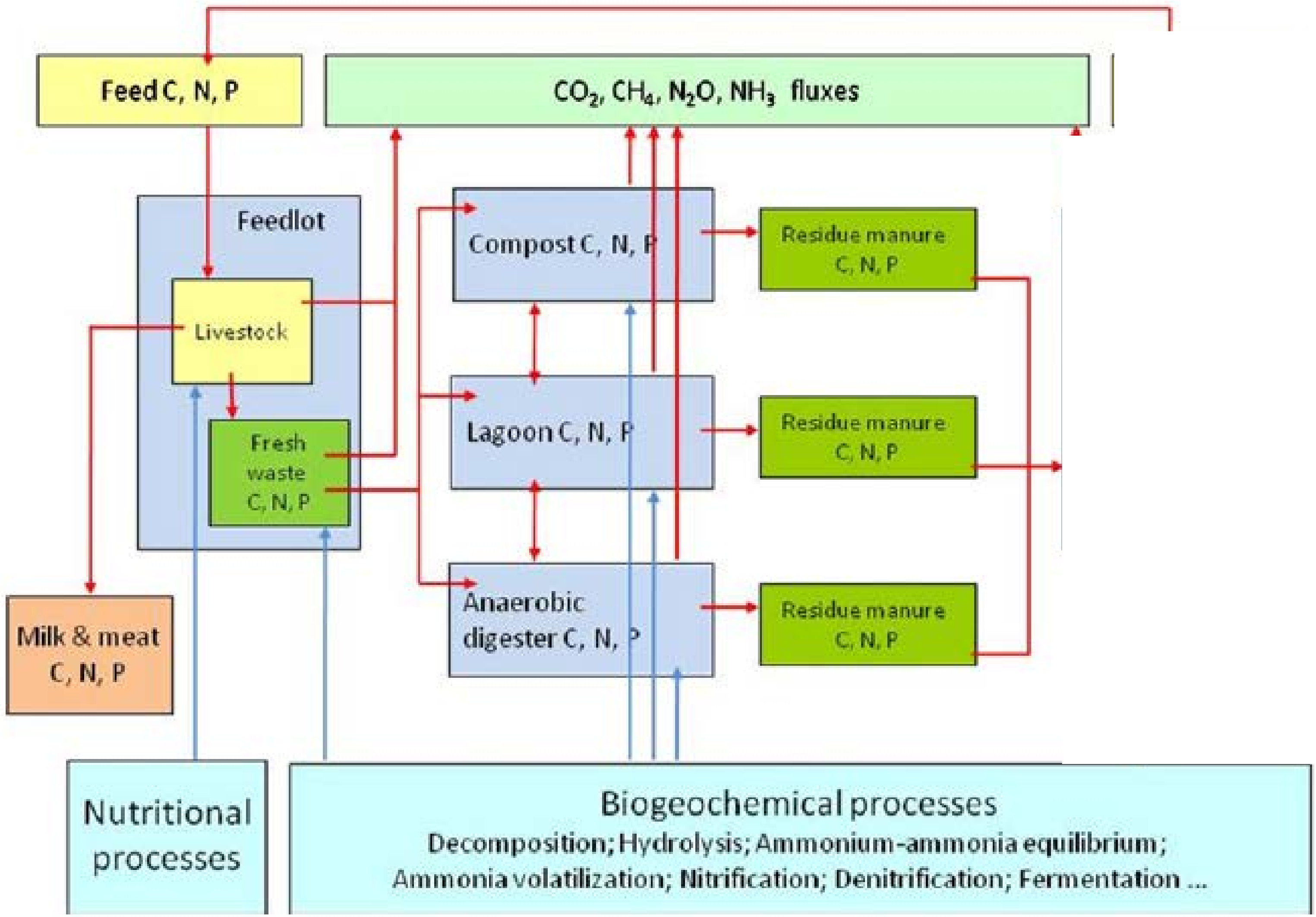
Li et al. (2012)

Manure C and N biogeochemistry cycle in Livestock Farm



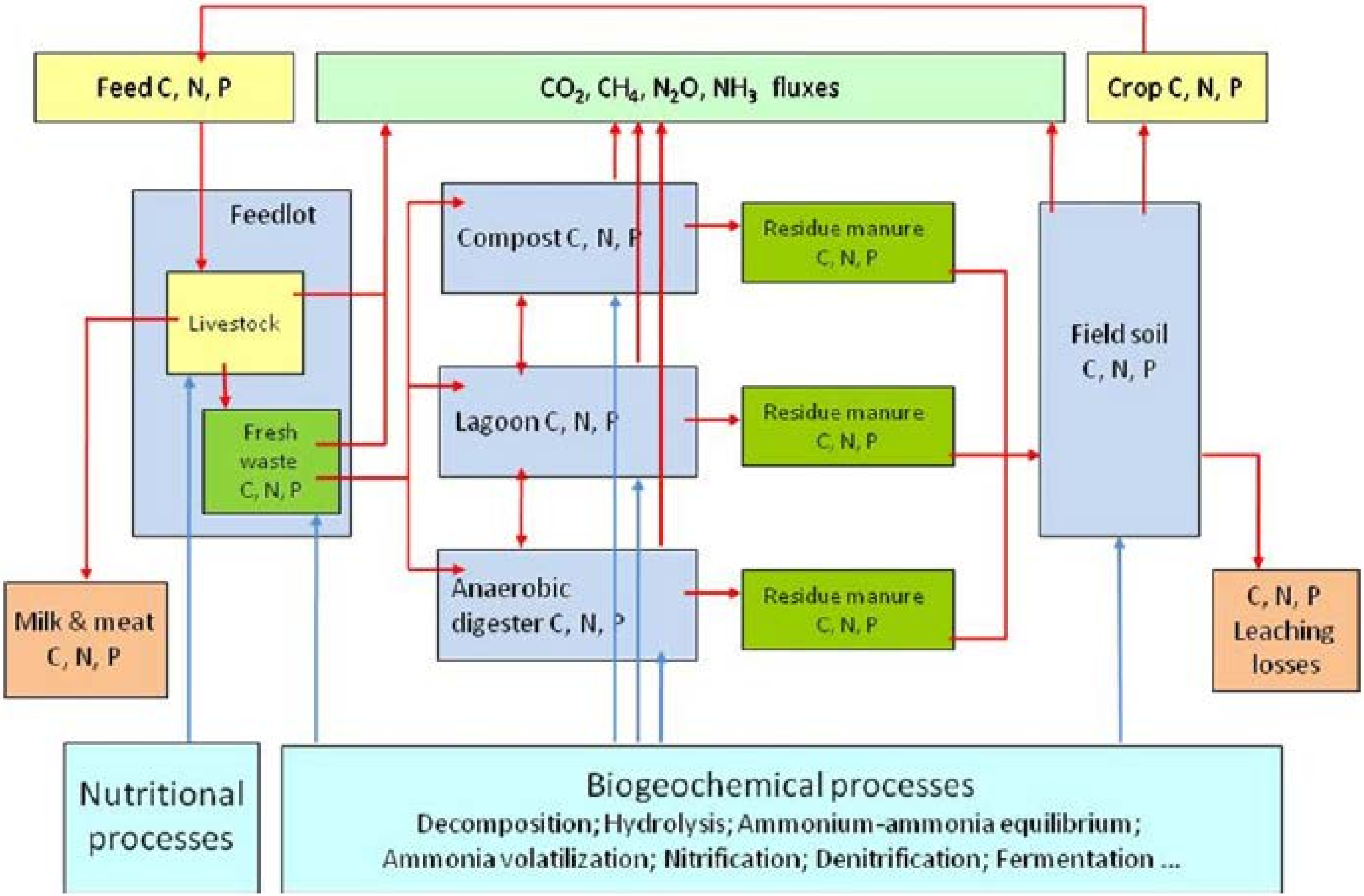
Li et al. (2012)

Manure C and N biogeochemistry cycle in Livestock Farm



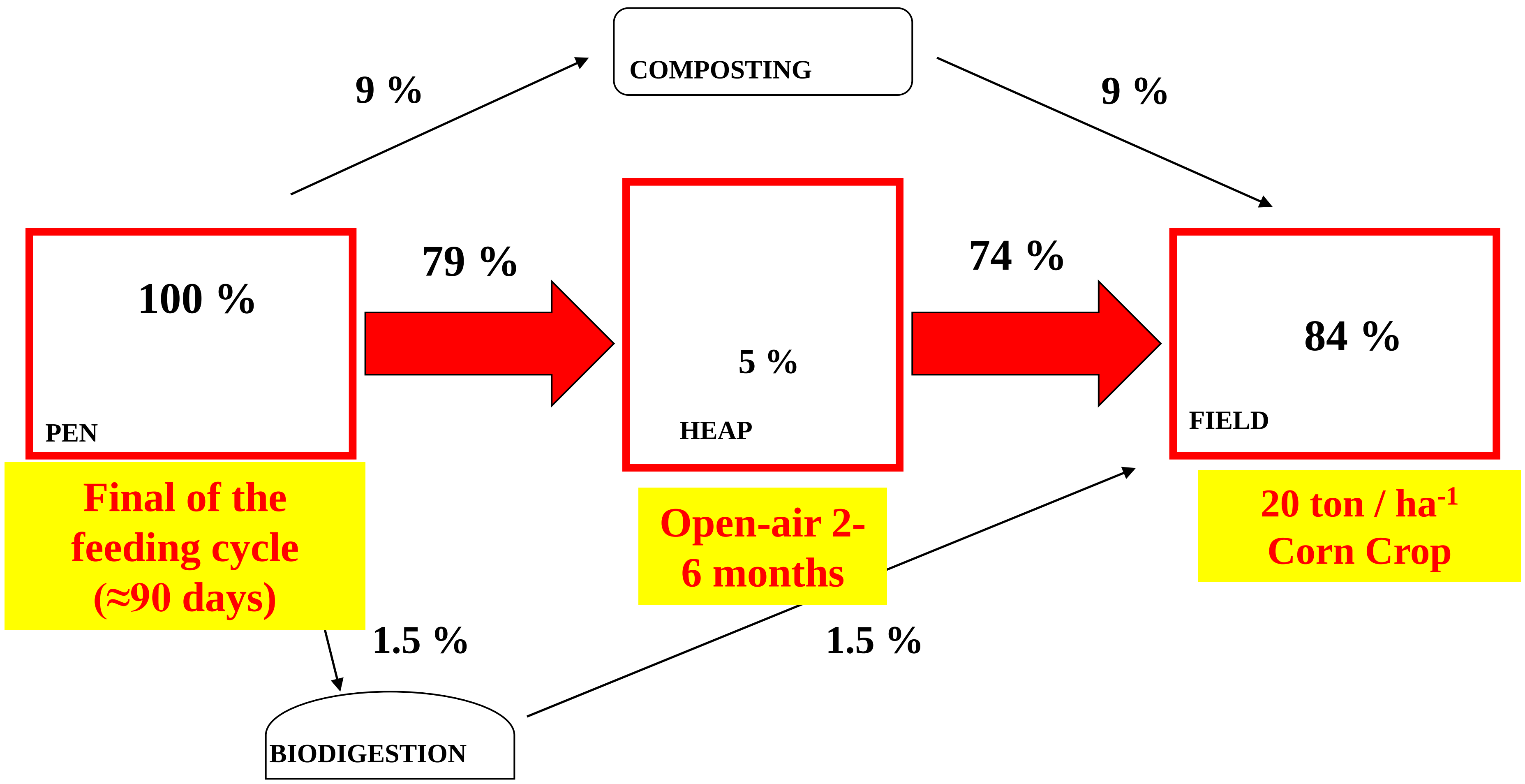
Li et al. (2012)

Manure C and N biogeochemistry cycle in Livestock Farm



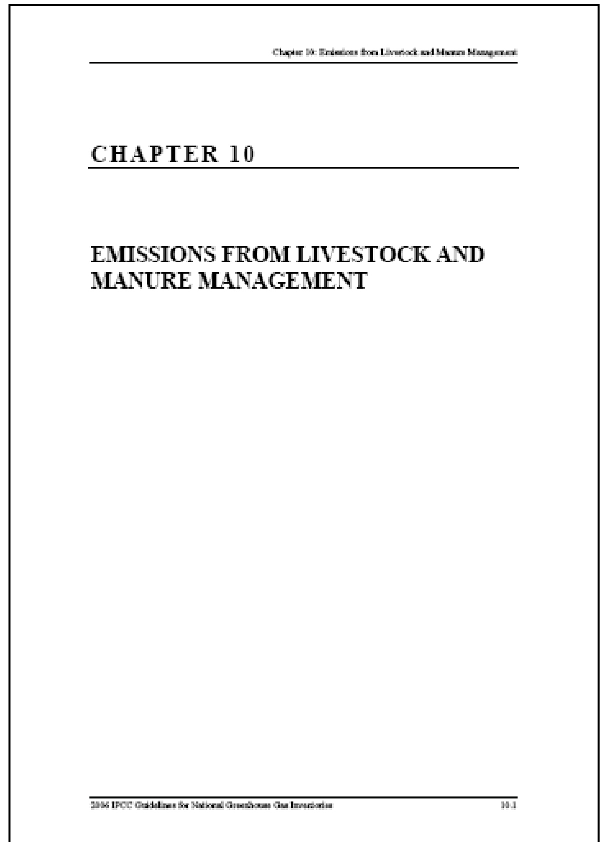
Li et al. (2012)

Manure Management in Brazilian beef cattle feedlots



Costa Junior et al. (2013)

INTRODUCTION



Chapter 10: Emissions from Livestock and Manure Management

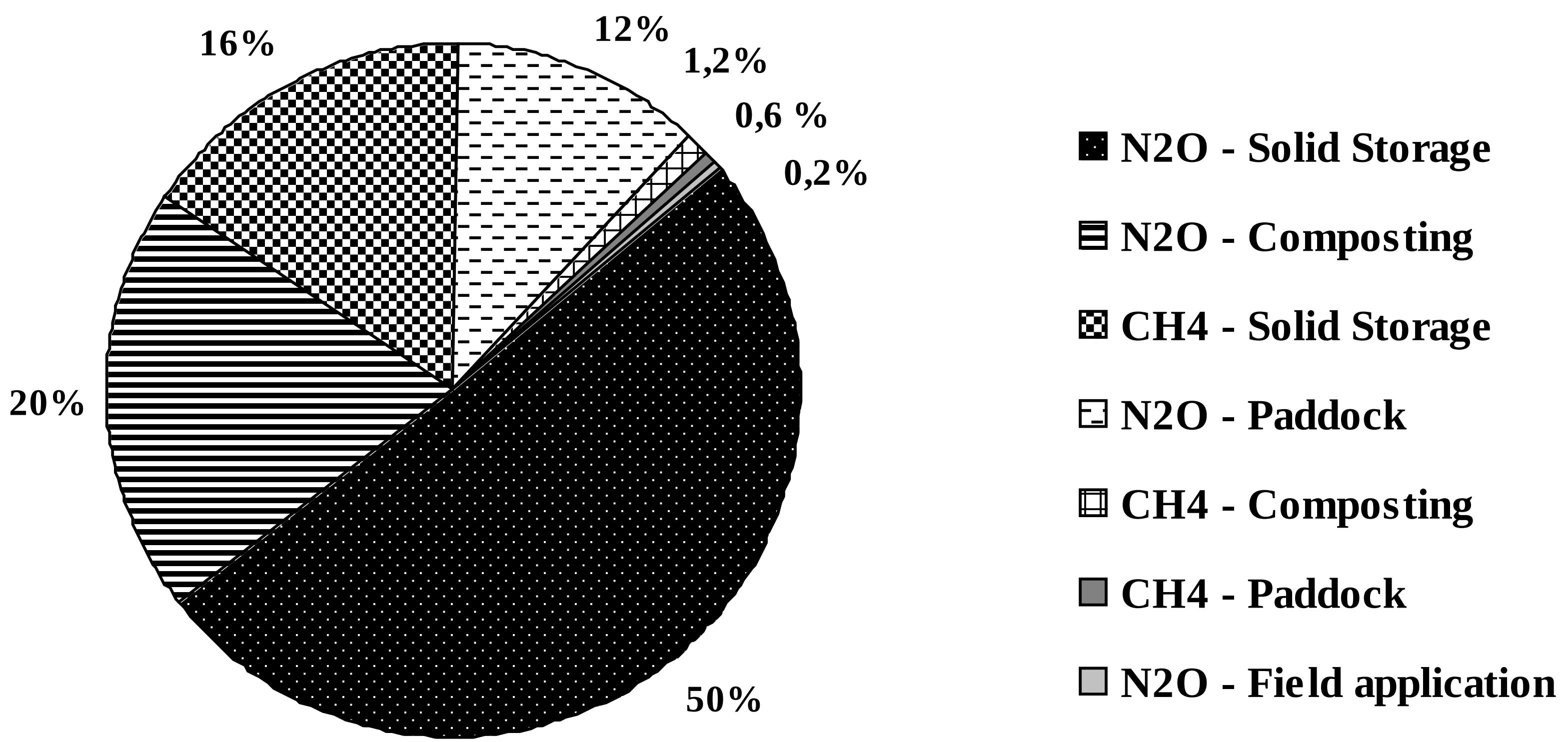
CHAPTER 10

EMISSIONS FROM LIVESTOCK AND MANURE MANAGEMENT

2006 IPCC Guidelines for National Greenhouse Gas Inventories 10.1

- the best widely applicable defaults for compiling national GHG inventories

Estimative Using IPCC Emission Factor



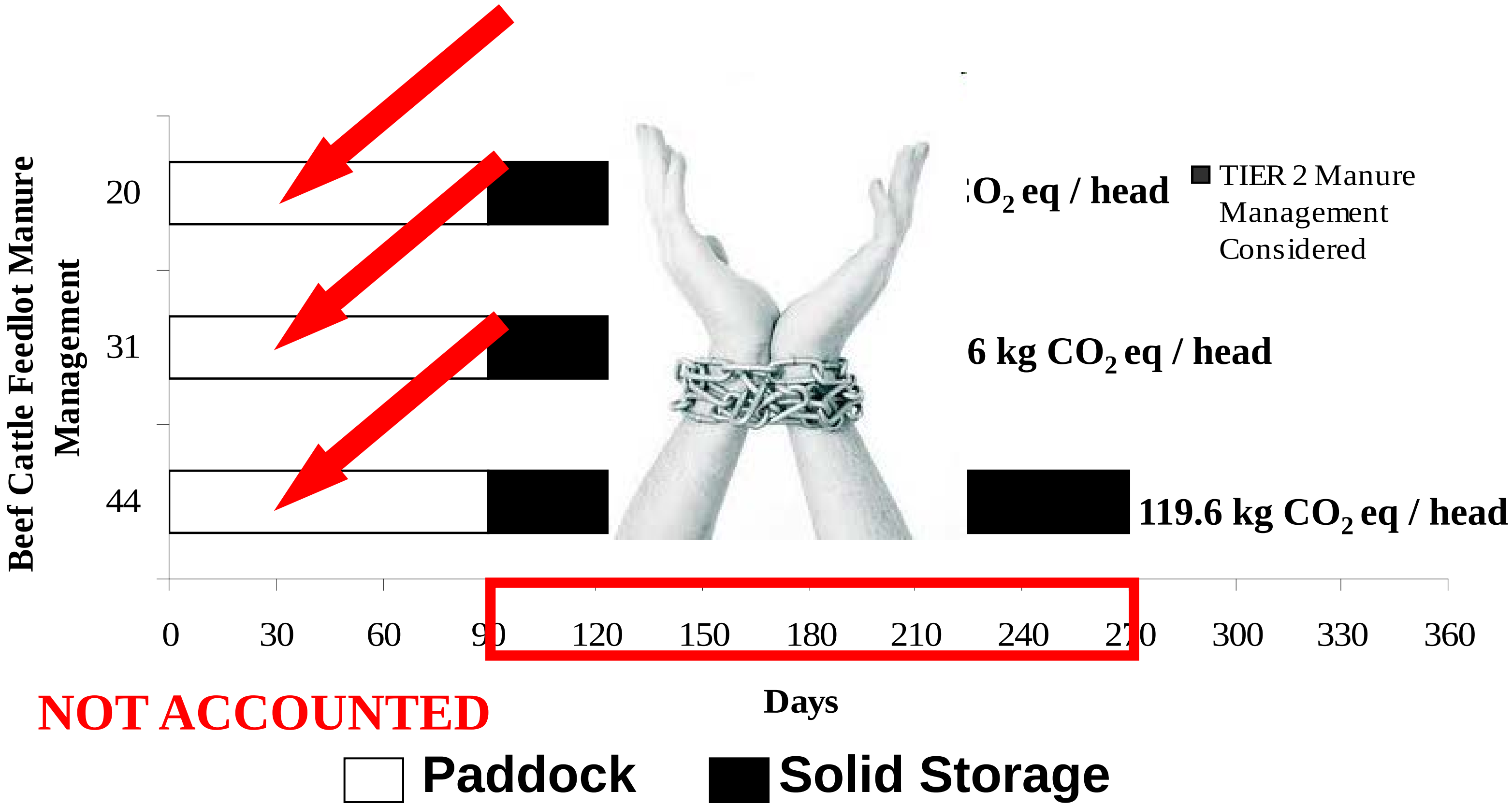
376.6 Gg CO_2 eq

Uncertainties very high –30 to 80%

Methodological Problems

Costa Junior et al. (2013)

Estimative Using IPCC Emission Factor



-Most emitter

-Assess mitigation potential

-Select cost-effectiveness

Costa Junior et al. (2013)

Specific conditions

Animal

Diet

Feedlot structure

Manure Management

Costa Junior et al. (2013)

Process-based model

Nutr Cycl Agroecosyst (2012) 93:163–200
DOI 10.1007/s10705-012-9507-z

ORIGINAL ARTICLE

Manure-DNDC: a biogeochemical process model for quantifying greenhouse gas and ammonia emissions from livestock manure systems

Changsheng Li · William Salas · Ruihong Zhang · Charley Krauter · Al Rotz · Frank Mitloehner

Received: 31 August 2011 / Accepted: 16 January 2012 / Published online: 13 May 2012

Table 1 Selected models for quantifying GHG and NH_3 emissions from livestock manure systems

Model[b]	Enteric source		Housing				Compost or heap				Lagoon or tank				Anaerobic digester				Cropland or pasture				
	CH_4	N_2O	CO_2	CH_4	N_2O	NH_3	CO_2	CH_4	N_2O	NH_3	CO_2	CH_4	N_2O	NH_3	CO_2	CH_4	N_2O	NH_3	CO_2	CH_4	N_2O	NH_3	N leach[a]
ACES						●								●									
CEFM	○																						
CONCEPT						●								●								●	
DairyGHG	○		○	○	○		○	○				●	○							○	○		
FARMIN	○	○	○		○	○														○	○	○	
FarmGHG	○			●	○	○		○	○			○	○			○					○	○	
Manure-DNDC	○	○	●	●	●	●	●	●	●	●	●	●	●	●	○	○	○	○	●	●	●	●	●
TwoFilm														●									

○ Empirical or emission factor method, ● process-based method

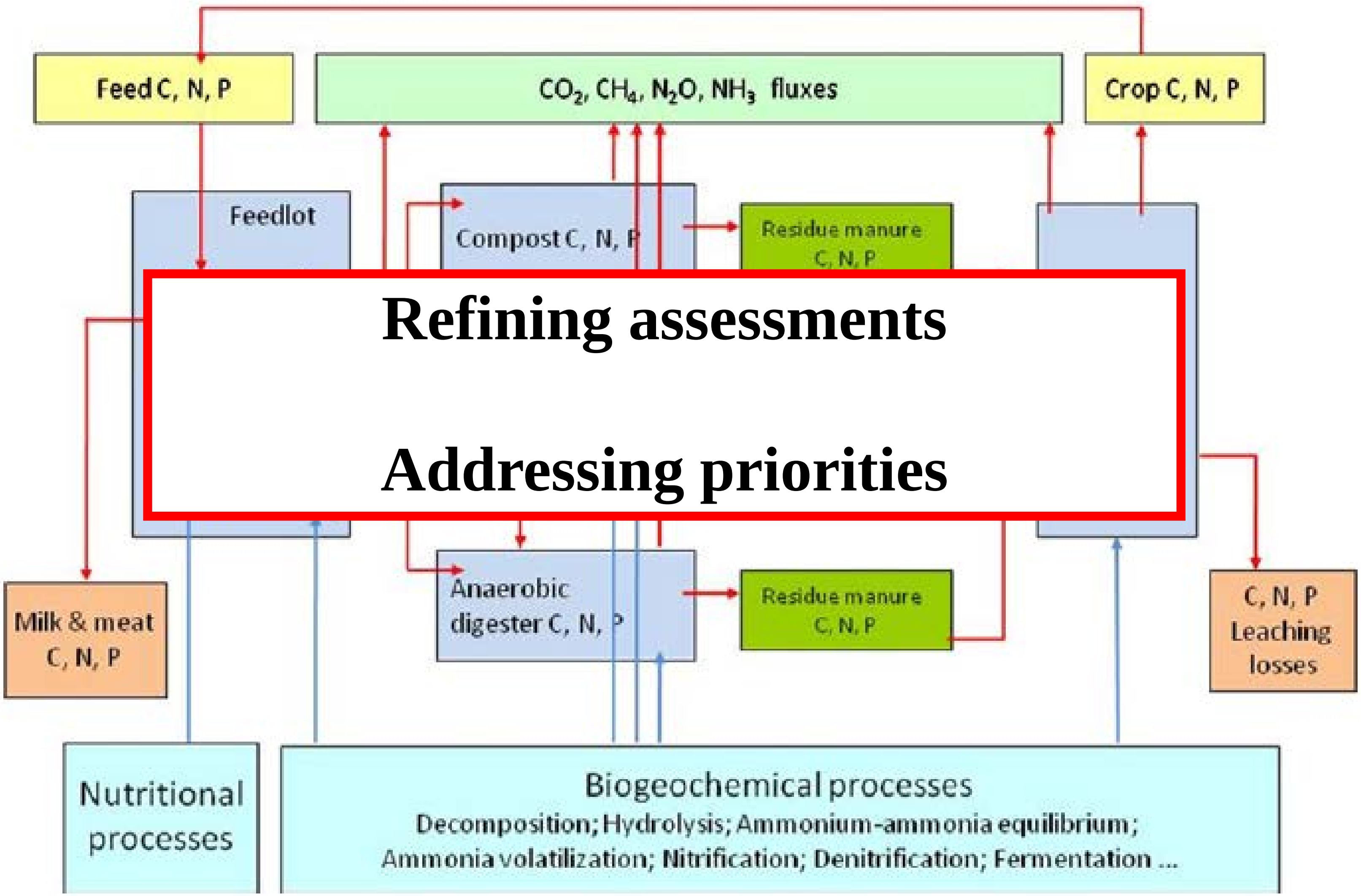
[a] N leaching loss is used to calculate indirect N_2O emissions

[b] Information sources of listed models: FARMIN: Van Evert et al. (2003), Schils et al. (2005); FarmGHG: Olesen et al. (2006), for cows and heifers; TwoFilm: De Visscher et al. (2002); CEFM: Mangino et al.; Dairy GHG: Rotz et al. (2010); CONCEPT: Zhang et al. (2005); ACES: Cortus et al. (2007)

Nutr Cycl Agroecosyst (2012) 93:163–200

Process-Based Modeling

Manure C and N biogeochemistry cycle in Livestock Farm



Objectives

- Measure CH_4 and N_2O emissions from a typical manure management

- Test the applicability of Manure-DNDC

Localization

Field Measurements (2012)

Housing
(May – August)

(n=16)
(n=2 – control)
Weekly (CH_4 / N_2O)

21 beef cattle (Bos Indicus)

Bare soil (Oxisol) - 500m^2

78 days on fed

DMI = 10 kg
CP = 12.0 %

GC

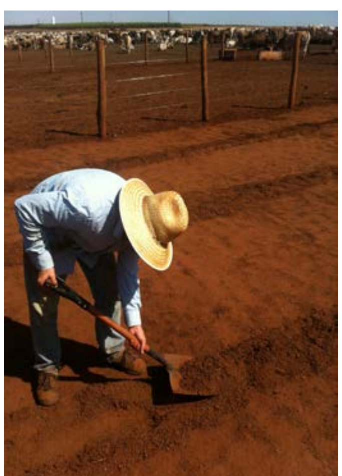
Field
(October – January 2013)

Oxisol - 20 ton (360 kgN) / ha
(n=6)

Storage -73 days
(August – October)

Porosity – 50%

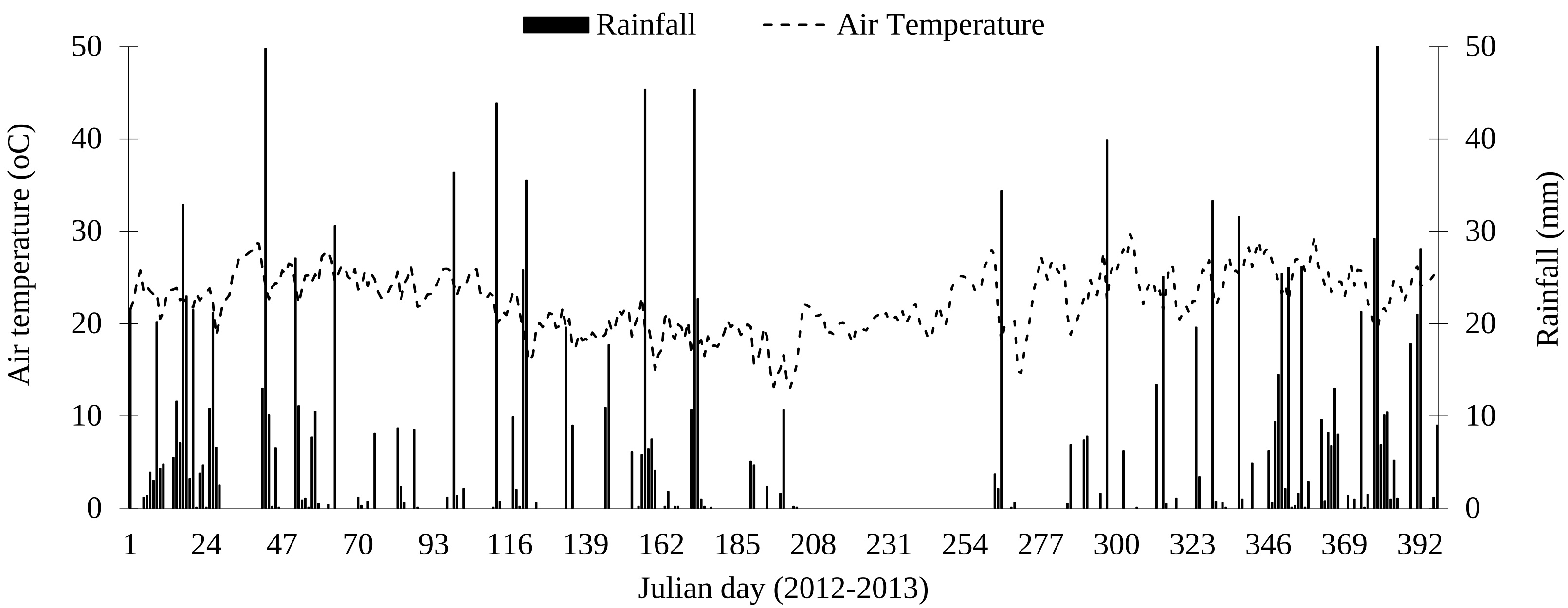
(n=12)



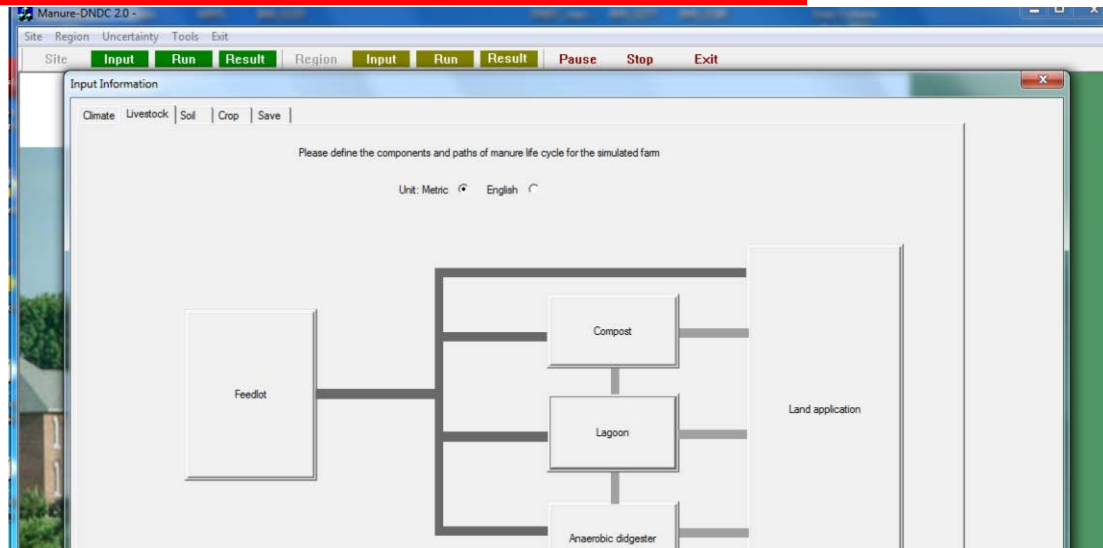
Daily – weekly (CH_4 / N_2O)

Daily – weekly (N_2O)

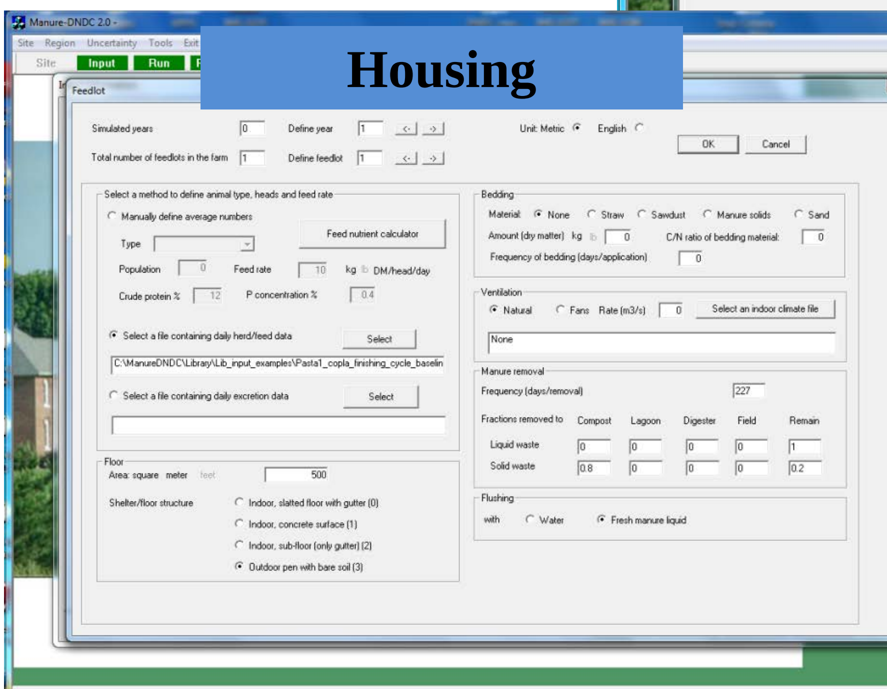
Climate Conditions



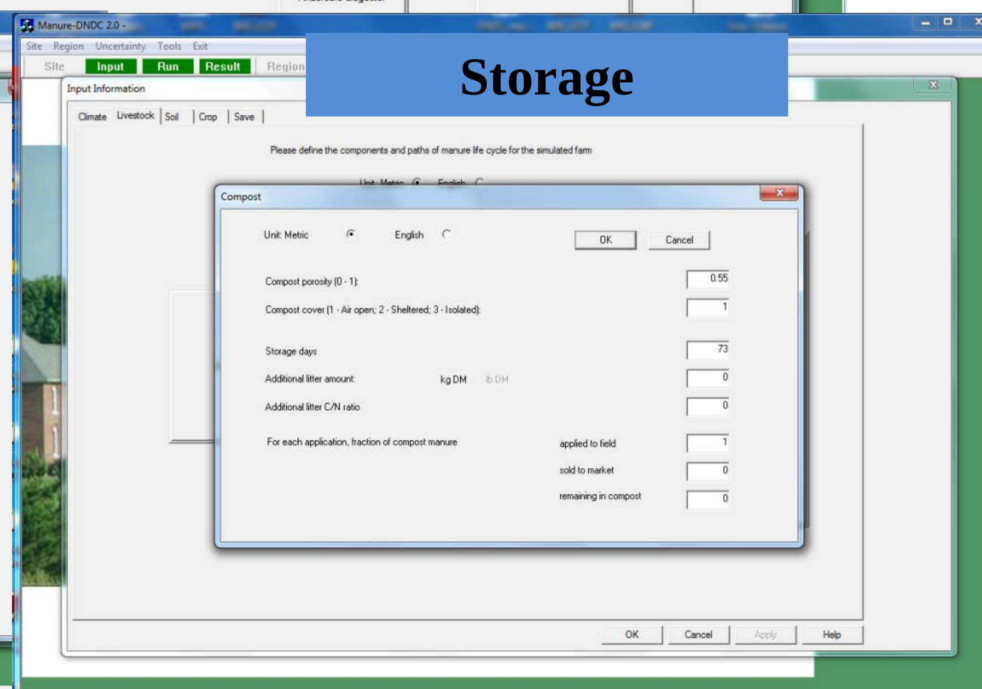
Manure DNDC - Initialization



Housing

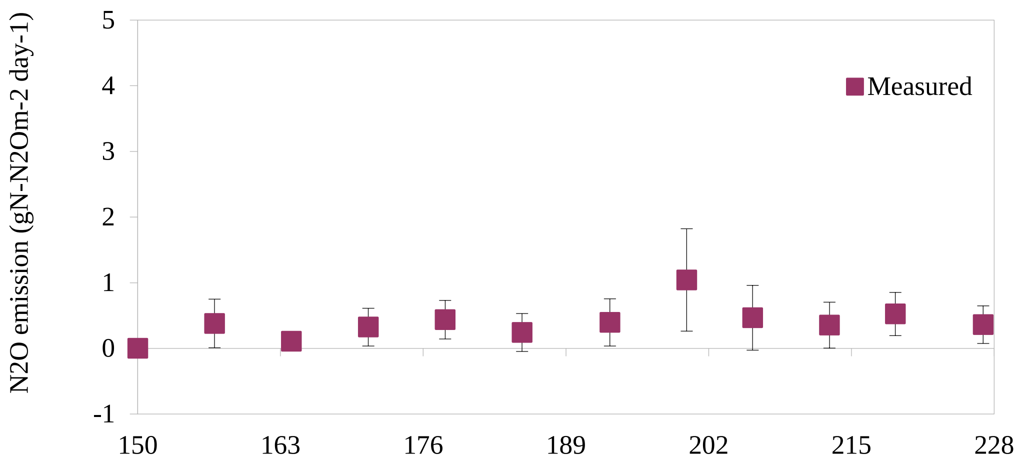


Storage

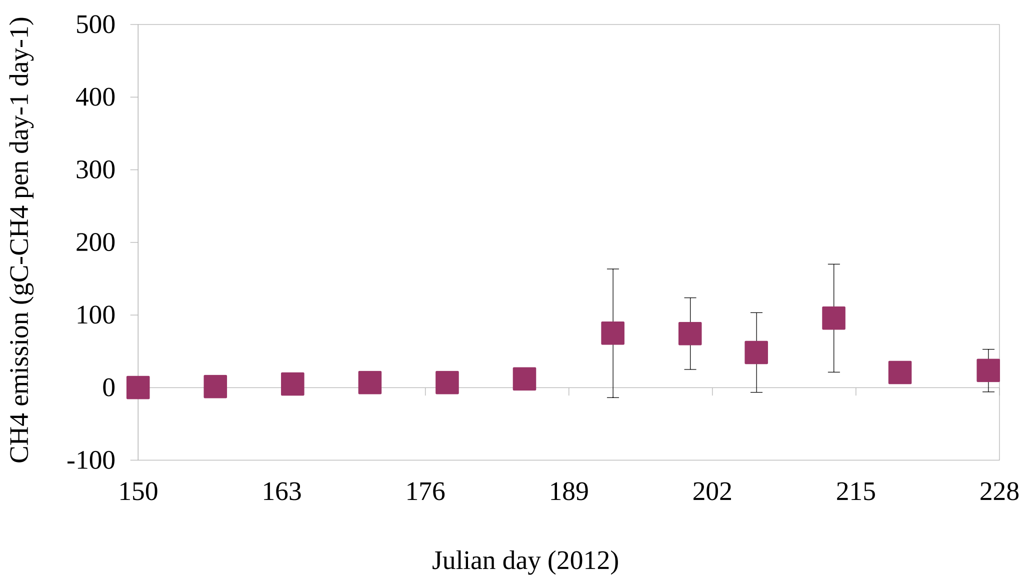


Results

Housing

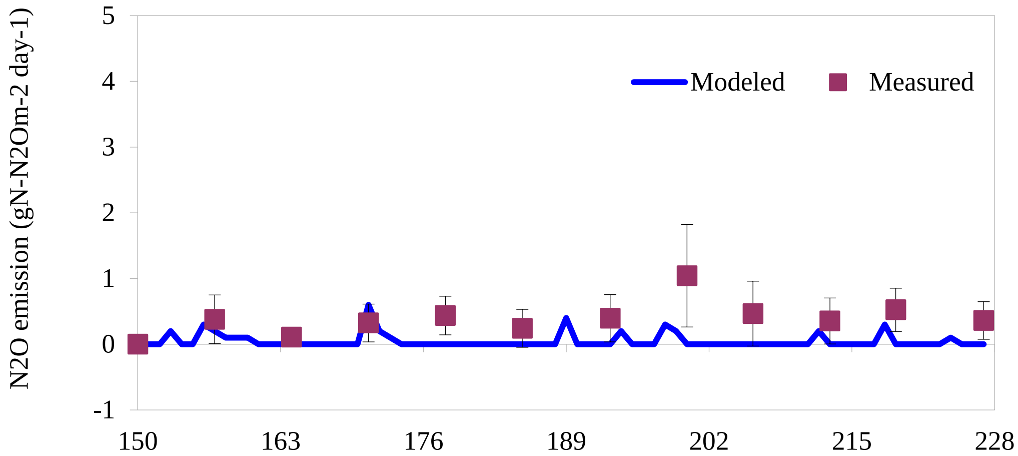


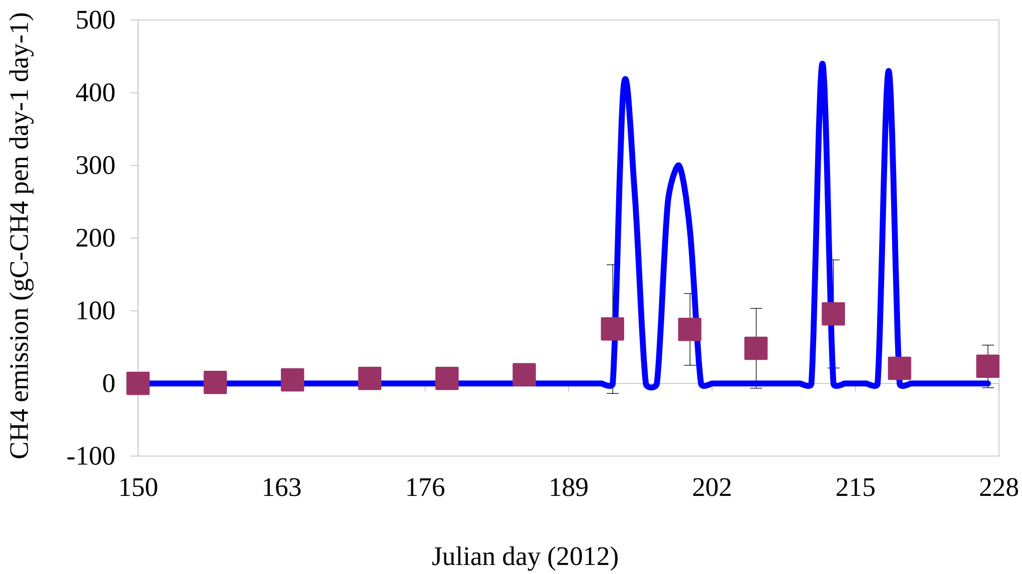
$32.7\ g \pm 27.1\ N\text{-}N_2O\ pen^{-1}$



$2.8\ kg \pm 2.4\ C\text{-}CH_4\ pen^{-1}$

Housing





32.7 g ± 27.1 N-N_2O pen^{-1}

4.5 g N-N_2O pen^{-1}

86%

$r^2 = 0.13$

2.8 kg ± 2.4 C-CH_4 pen^{-1}

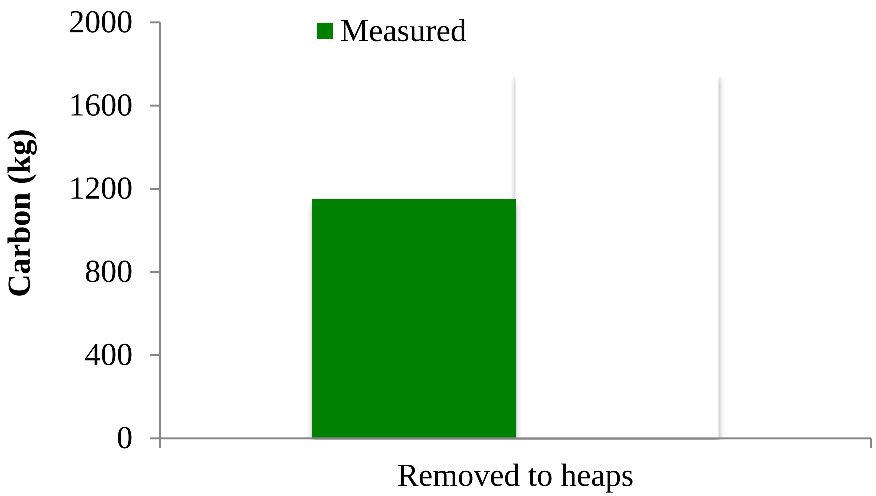
3.0 kg C-CH_4 pen^{-1}

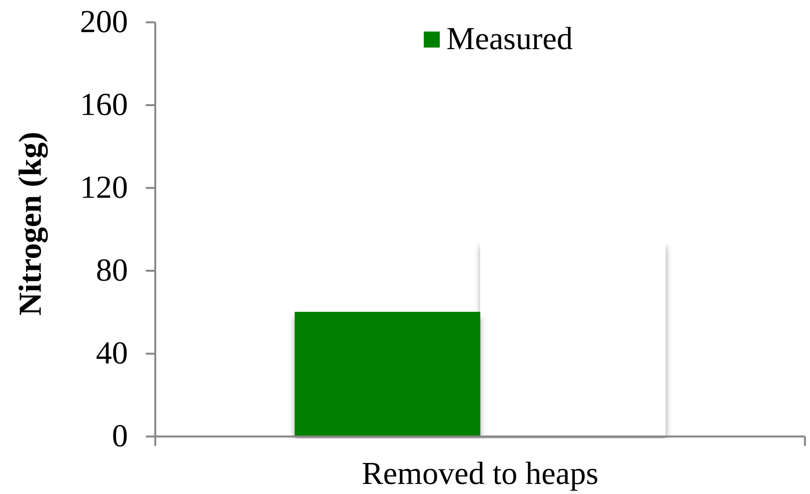
7%

$r^2 = 0.26$

Harvested manure

3 tons of manure



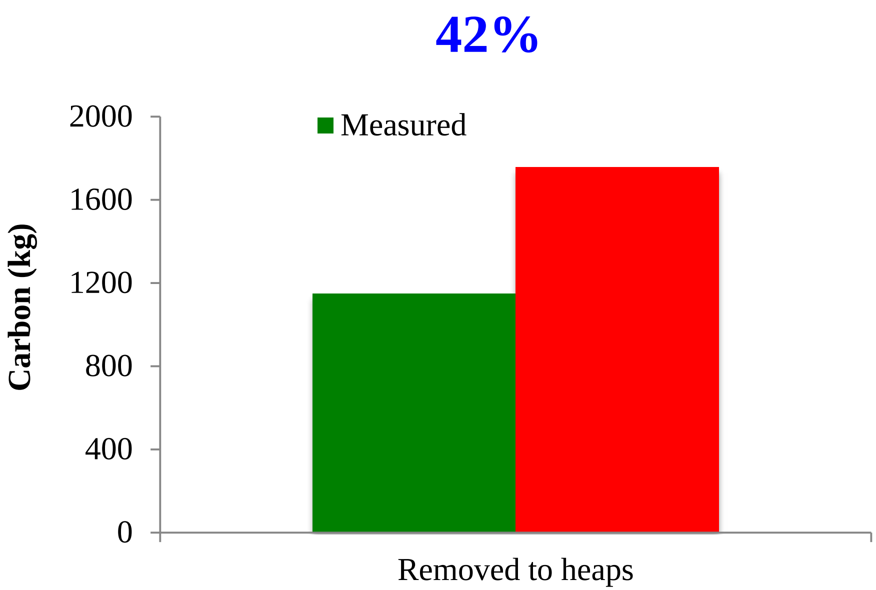


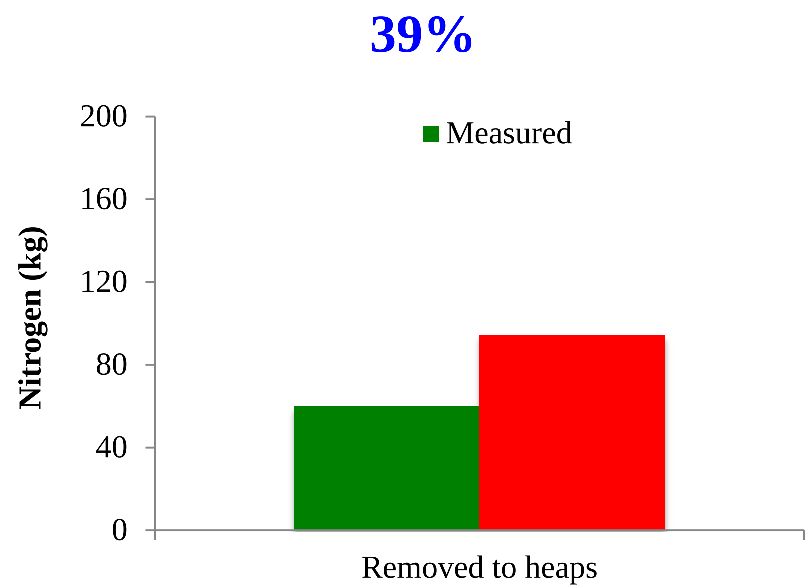
Moisture = 8%

C:N = 17.0

Harvested manure

3 tons of manure





Moisture = 8%

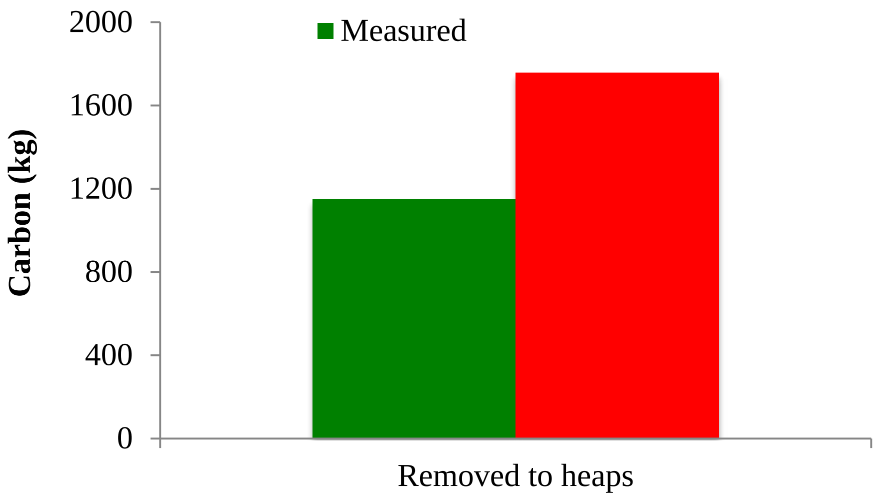
C:N = 17.0

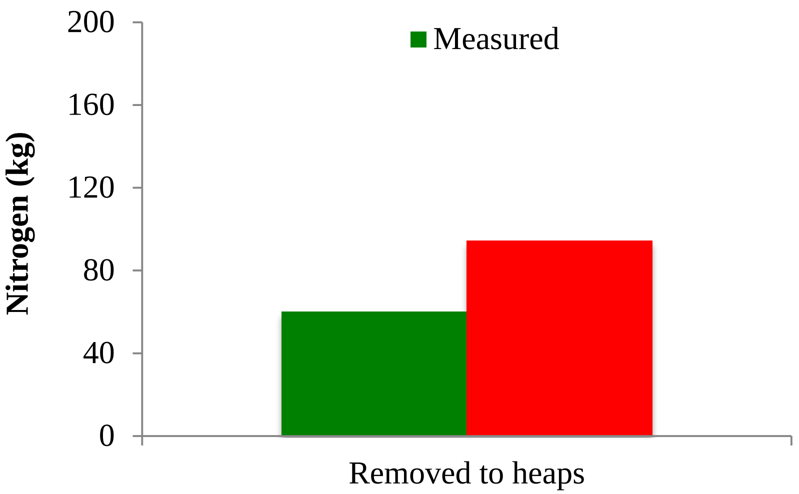
Harvested manure

3 tons of manure

42%

39%





Moisture = 8%

50%

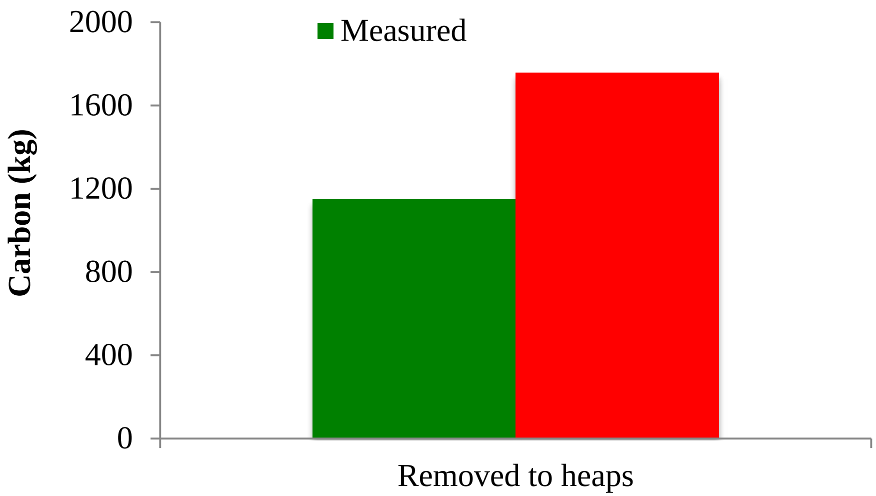
Moisture = 4%

C:N = 17.0

Harvested manure

3 tons of manure

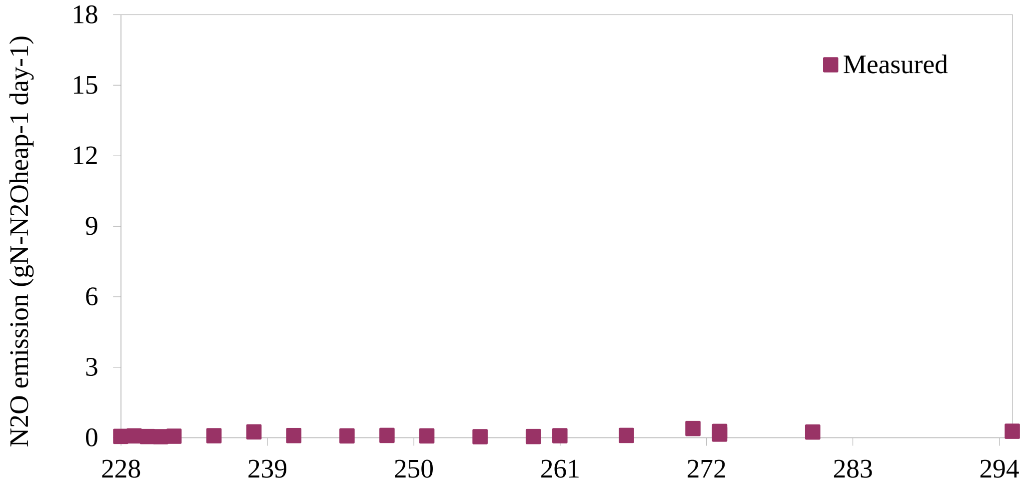
42% **39%**



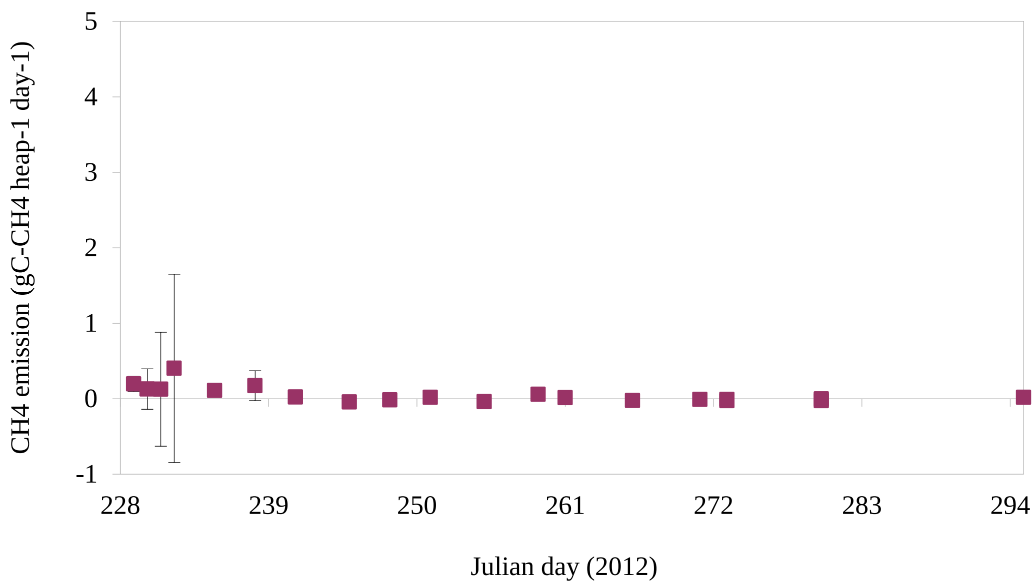
Moisture = 8% **50%** **Moisture = 4%**

C:N = 17.0 **9%** **C:N = 18.6**

Storage - Heaps

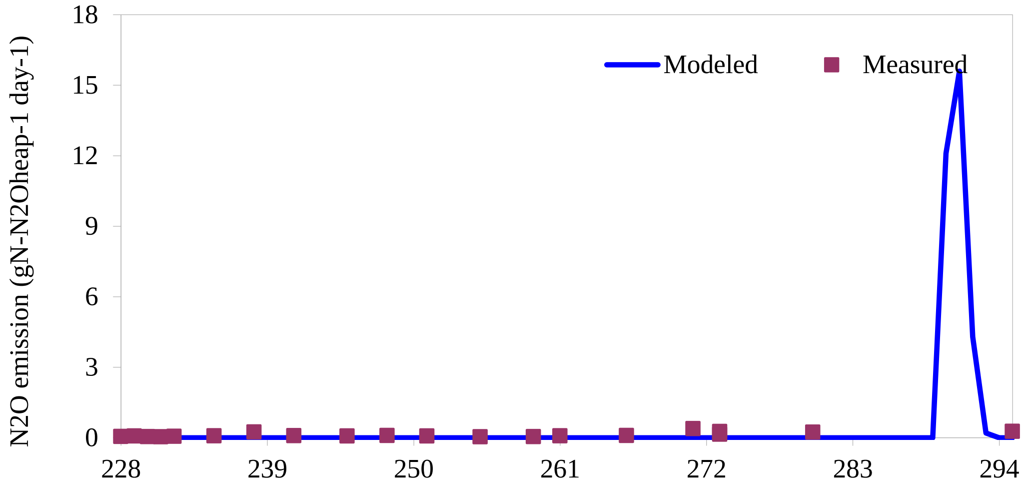


$15.7\ g \pm 7.3\ N\text{-}N_2O\ heap^{-1}$



$5.2\ g \pm 3.7\ C\text{-}CH_4\ heap^{-1}$

Storage - Heaps

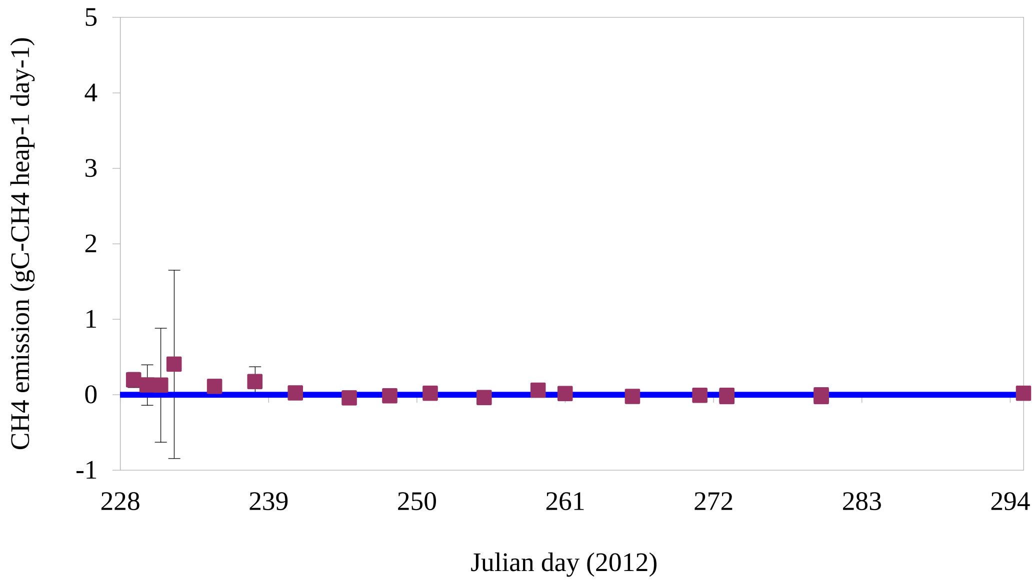


$15.7\ g \pm 7.3\ N\text{-}N_2O\ heap^{-1}$

$21.7g\ N\text{-}N_2O\ heap^{-1}$

38%

$r^2 = 0.0$



$5.2\ g \pm 3.7\ C\text{-}CH_4\ heap^{-1}$

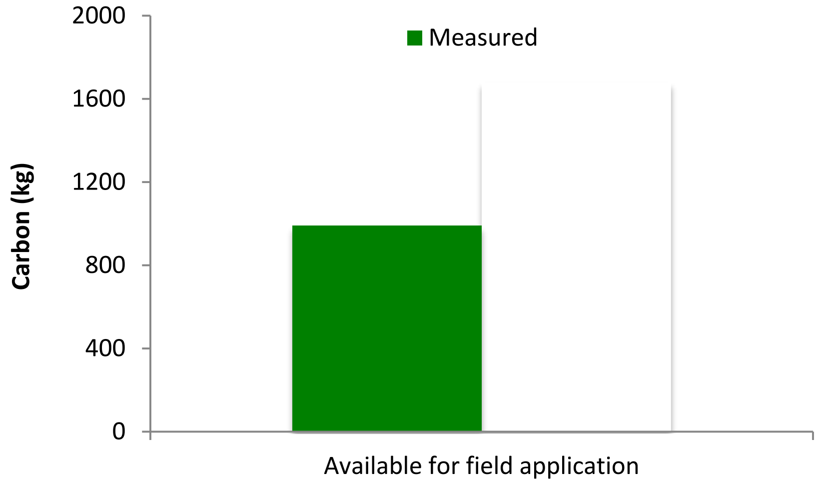
$0.5\ g\ C\text{-}CH_4\ heap^{-1}$

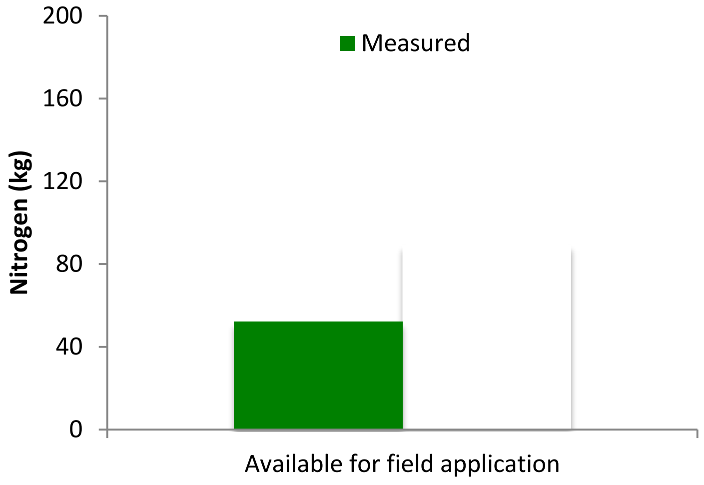
90%

$r^2 = 0.0$

C and N available for field application

2.9 tons of manure





Moisture = 18%

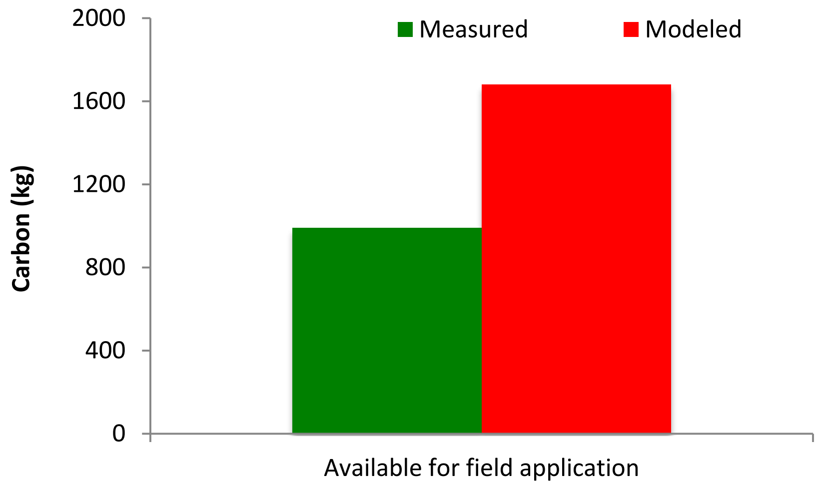
C:N = 19.0

C and N available for field application

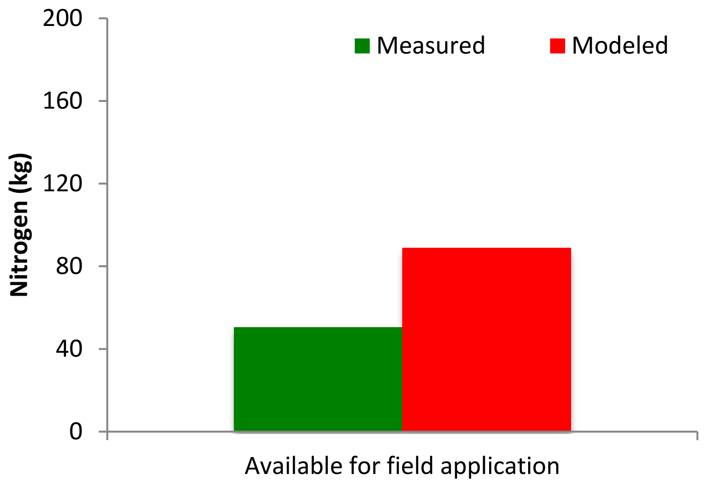
2.9 tons of manure

0.15 ha
360 kg N / ha

41%



42%



Moisture = 18%

50%

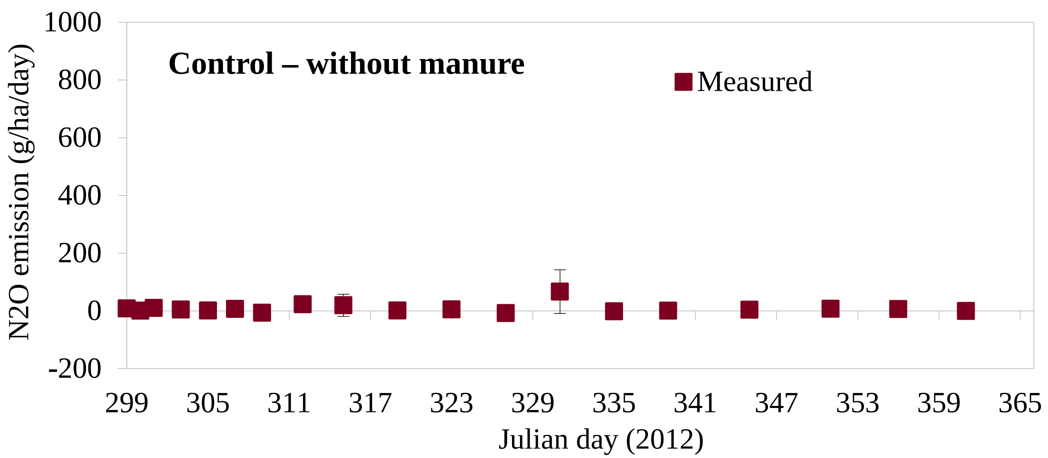
Moisture = 9%

C:N = 19.0

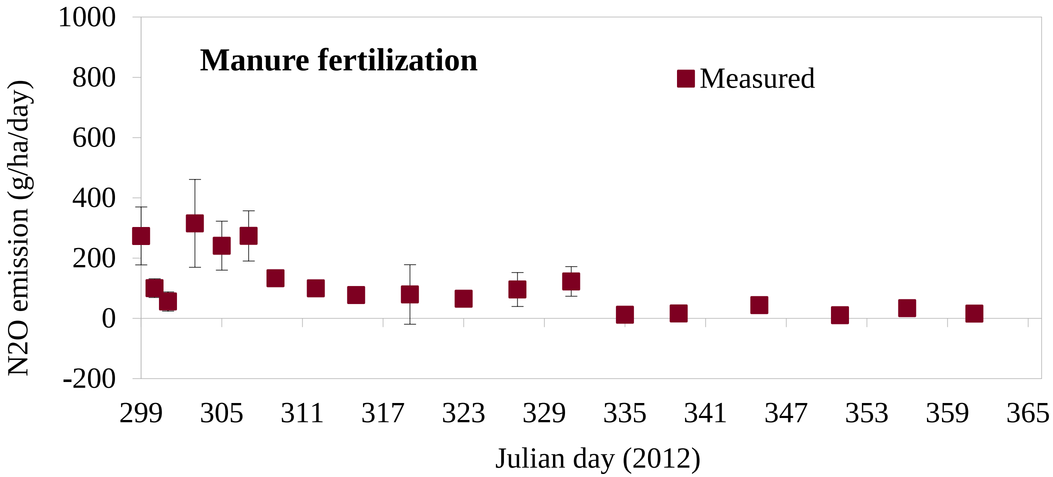
0%

C:N = 18.9

Manure application to soil

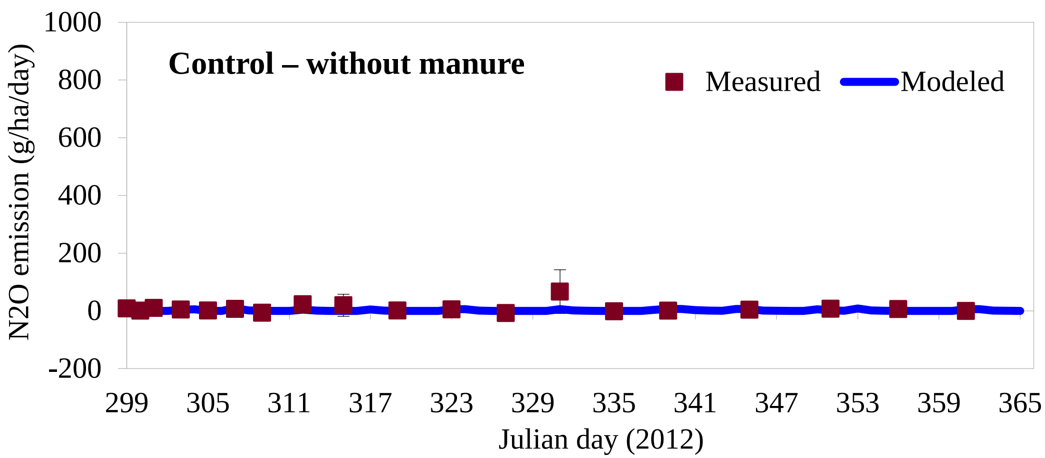


0.5 kg ± 0.3 N-N_2O ha^{-1}



4.6 ± 2.1 kg N-N_2O ha^{-1}

Manure application to soil

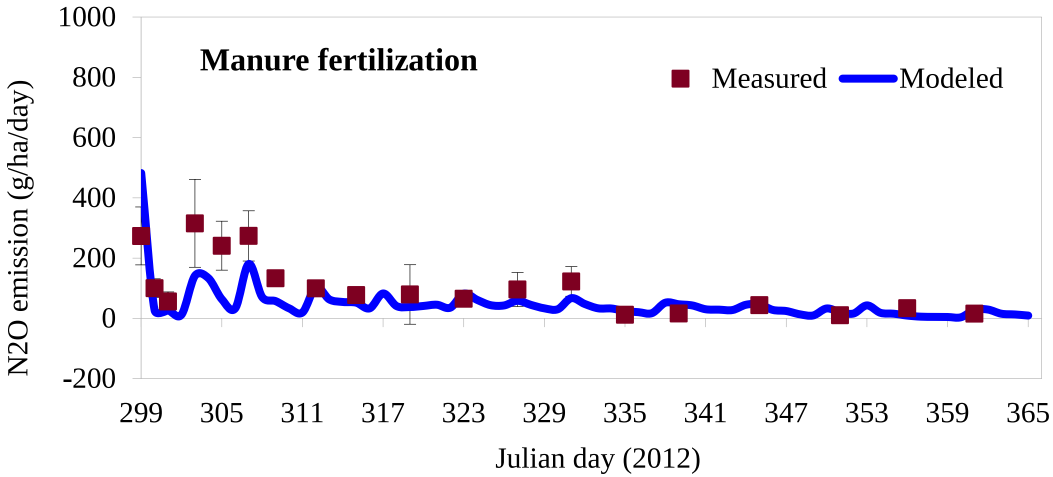


0.5 kg ± 0.3 N-N_2O ha^{-1}

0.3 kg N-N_2O pen^{-1}

40%

r2 = 0.35



4.6 ± 2.1 kg N-N_2O ha^{-1}

3.1 kg N-N_2O ha^{-1}

32%

r2 = 0.44

Emission Balance

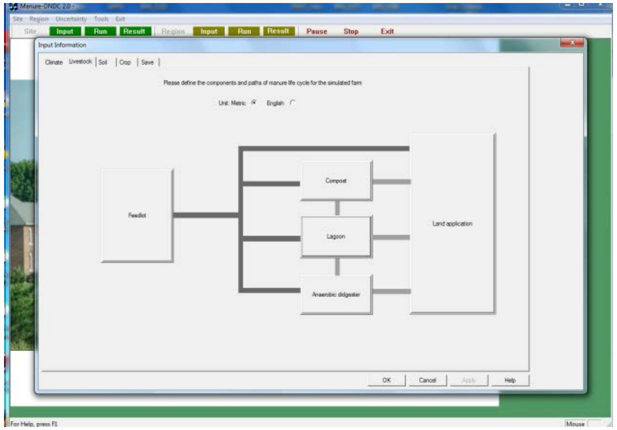
Greenhouse gas emissions (GHG), in equivalents of carbon dioxide (CO_2eq), from one complete manure management (housing to field application) of a typical beef cattle feedlot in Brazil*

	GHG emissions		Relative emissions by manure management compartments		Model deviation
	Measured	Modeled	Measured	Modeled	
	----kg CO_2eq†----		%		%
Housing	108.9 ±95.0	101.3	24.7	31.7	-7.0
Storage	6.6 ±3.9	14.5	1.5	4.5	+119.7
Field	325.2 ±137.6	204.0	73.8	63.8	-37.3
Total emissions	440.7 ±236.6	319.8	-	-	-27.4

*Emissions of methane and nitrous oxide from manure excreted by 21 beef cattle held in an open-air pen (500 m^2) during 78 days on fed, removed in the final of the feeding period and storage in one open-air heap for 73 before field application (360 kg N ha^{-1}).

†Assuming a global warming potential of 25 and 298 for methane and nitrous oxide, respectively.

Sensitivity Tests

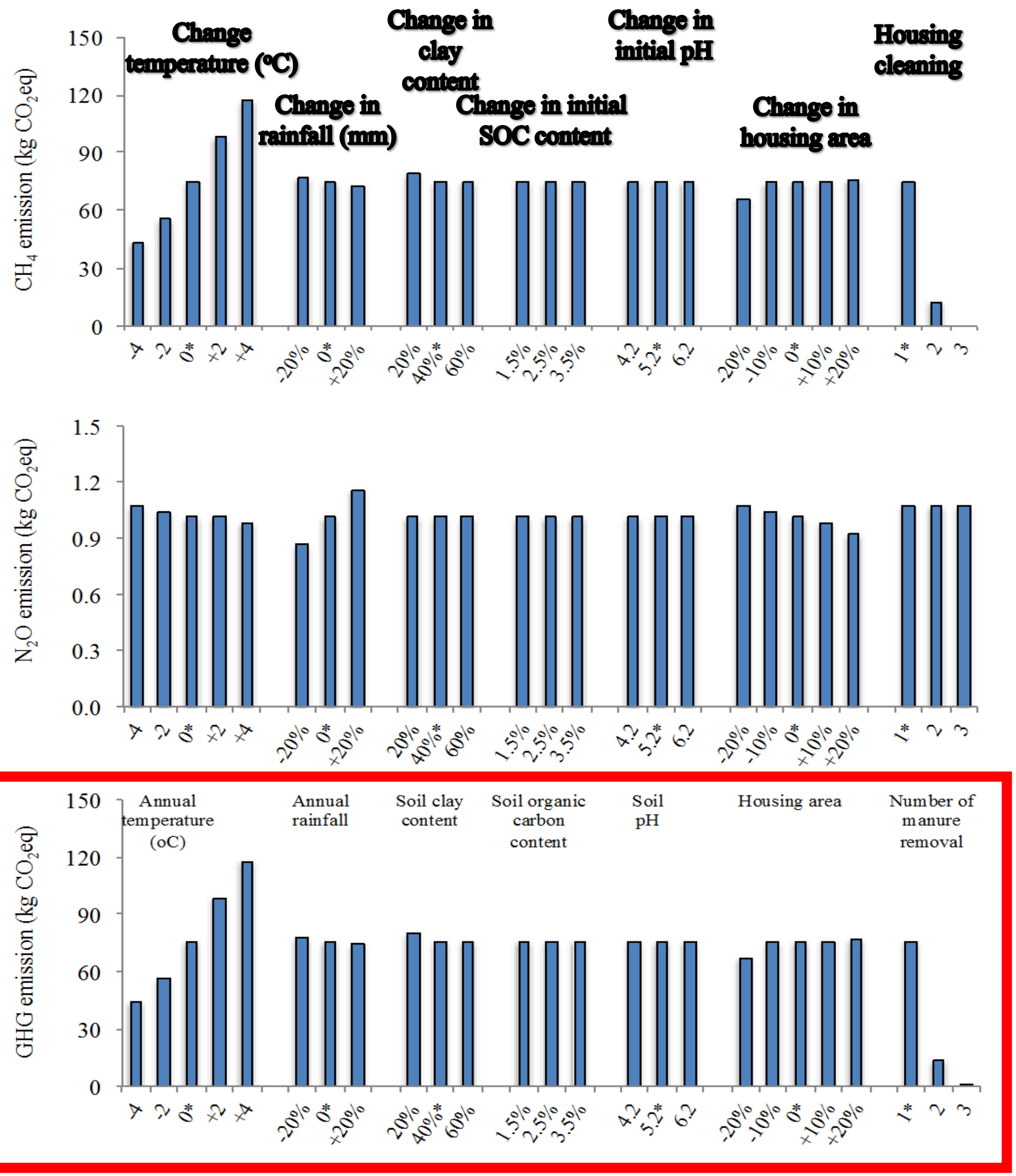


Environmental

Management

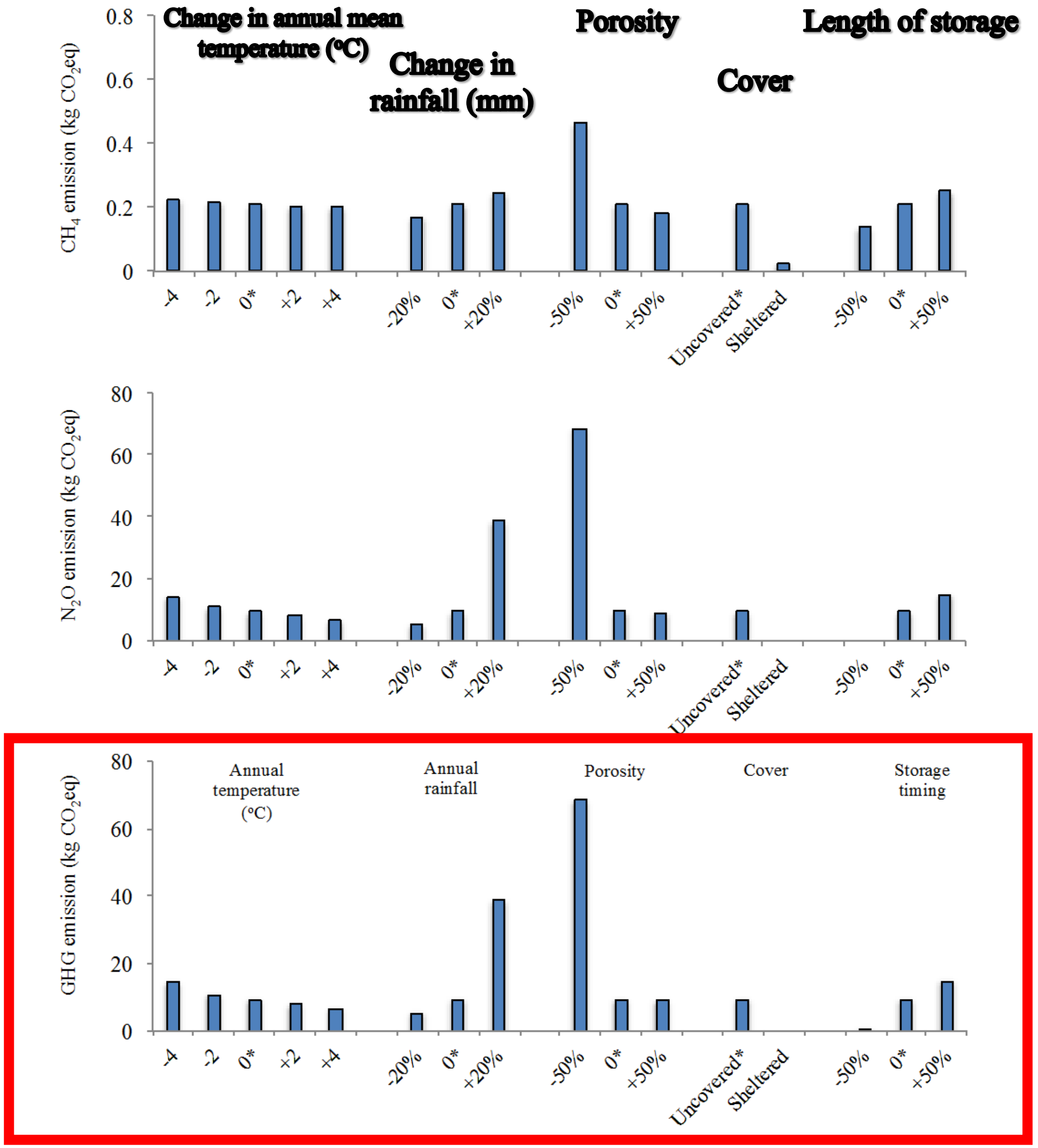
Scenarios

Sensitivity tests - Housing



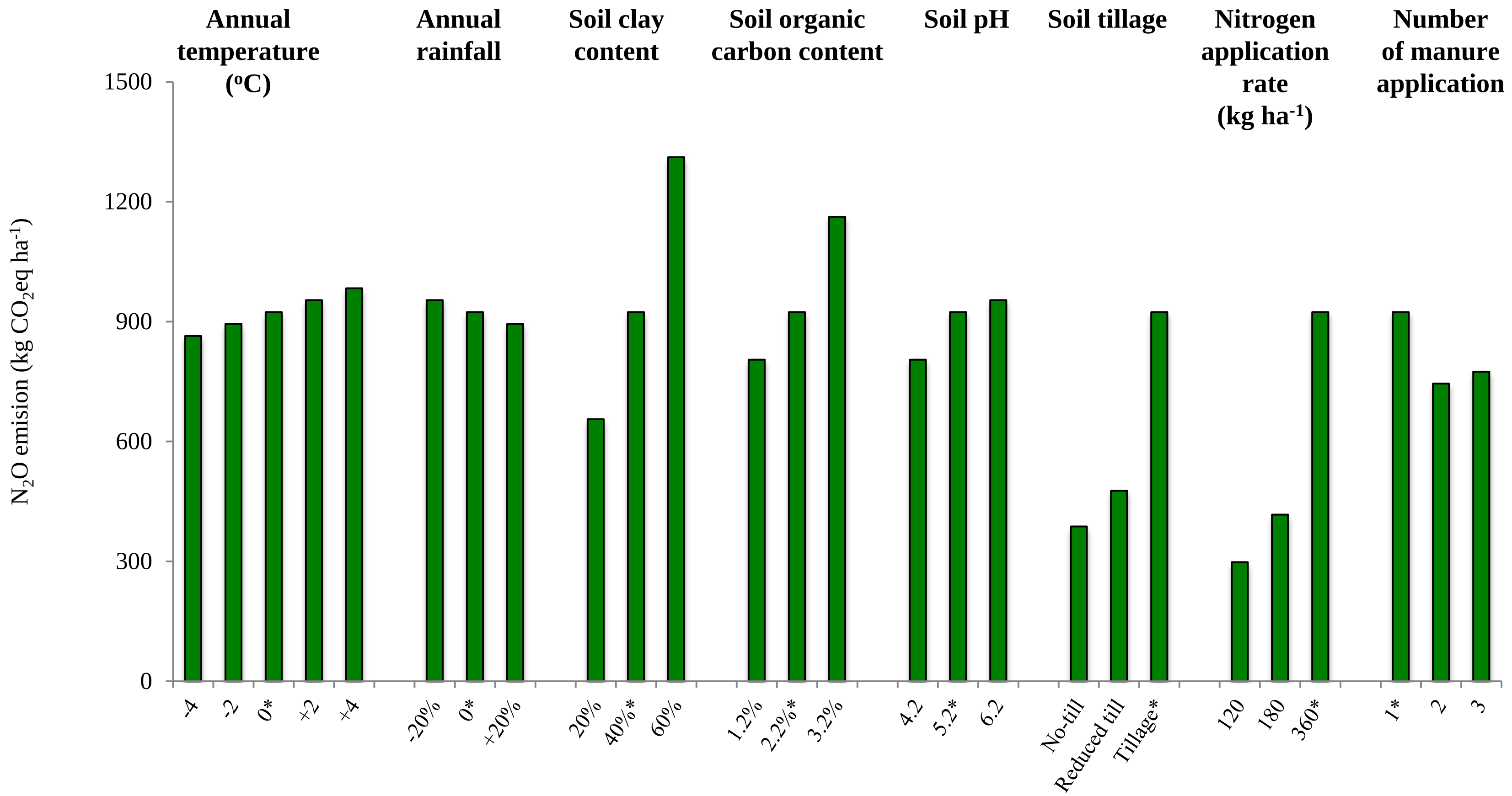
* baseline

Sensitivity tests - Storage



* baseline

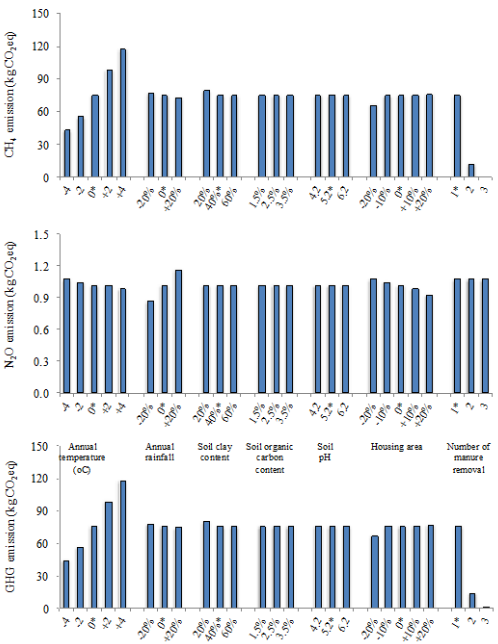
Sensitivity tests - Field



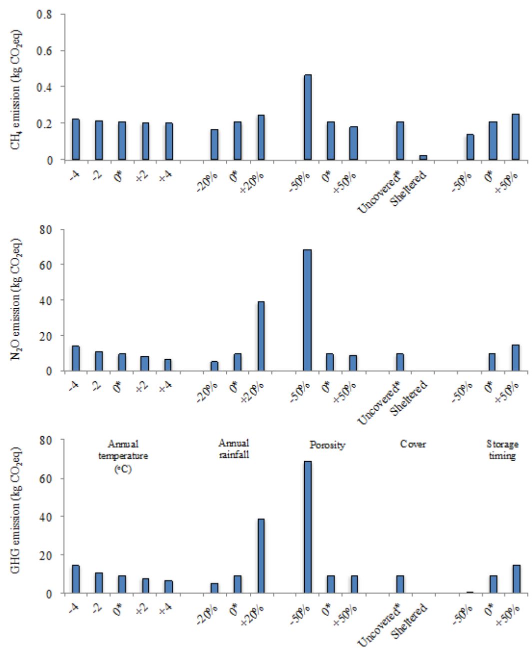
* baseline

Scenarios

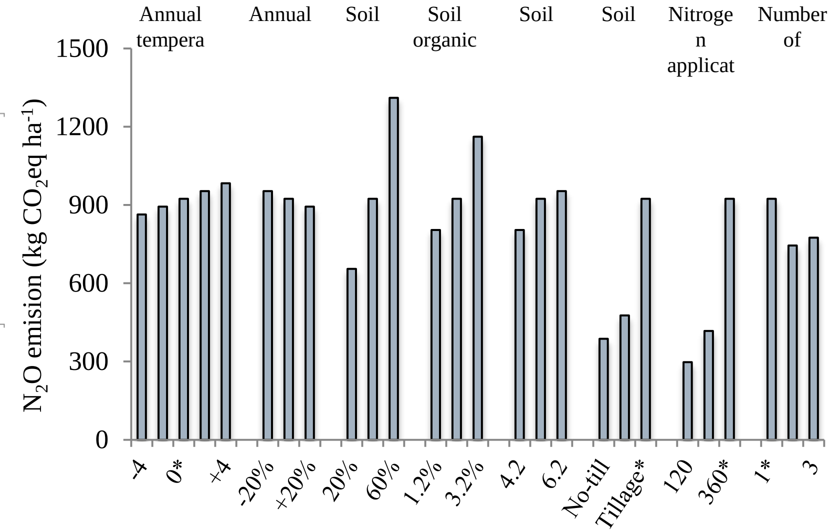
Increasing manure removal

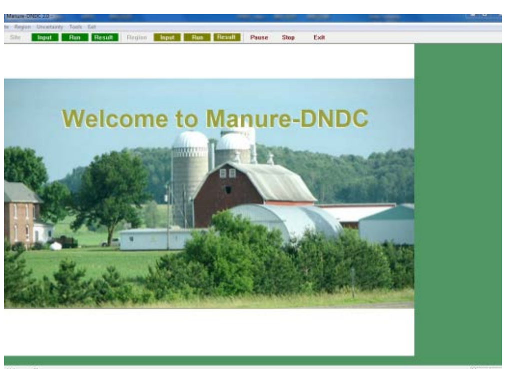


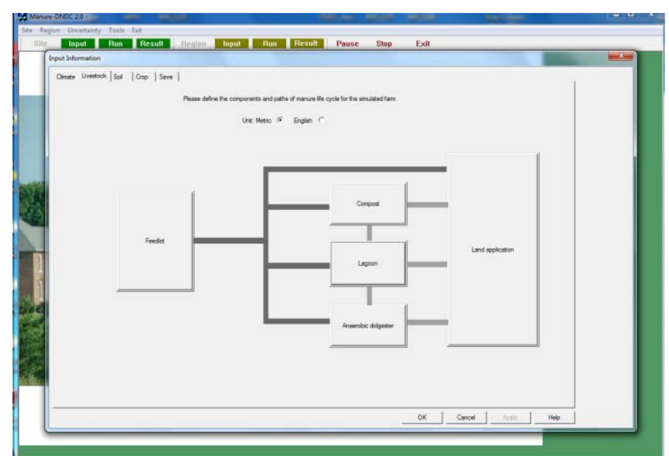
Constant



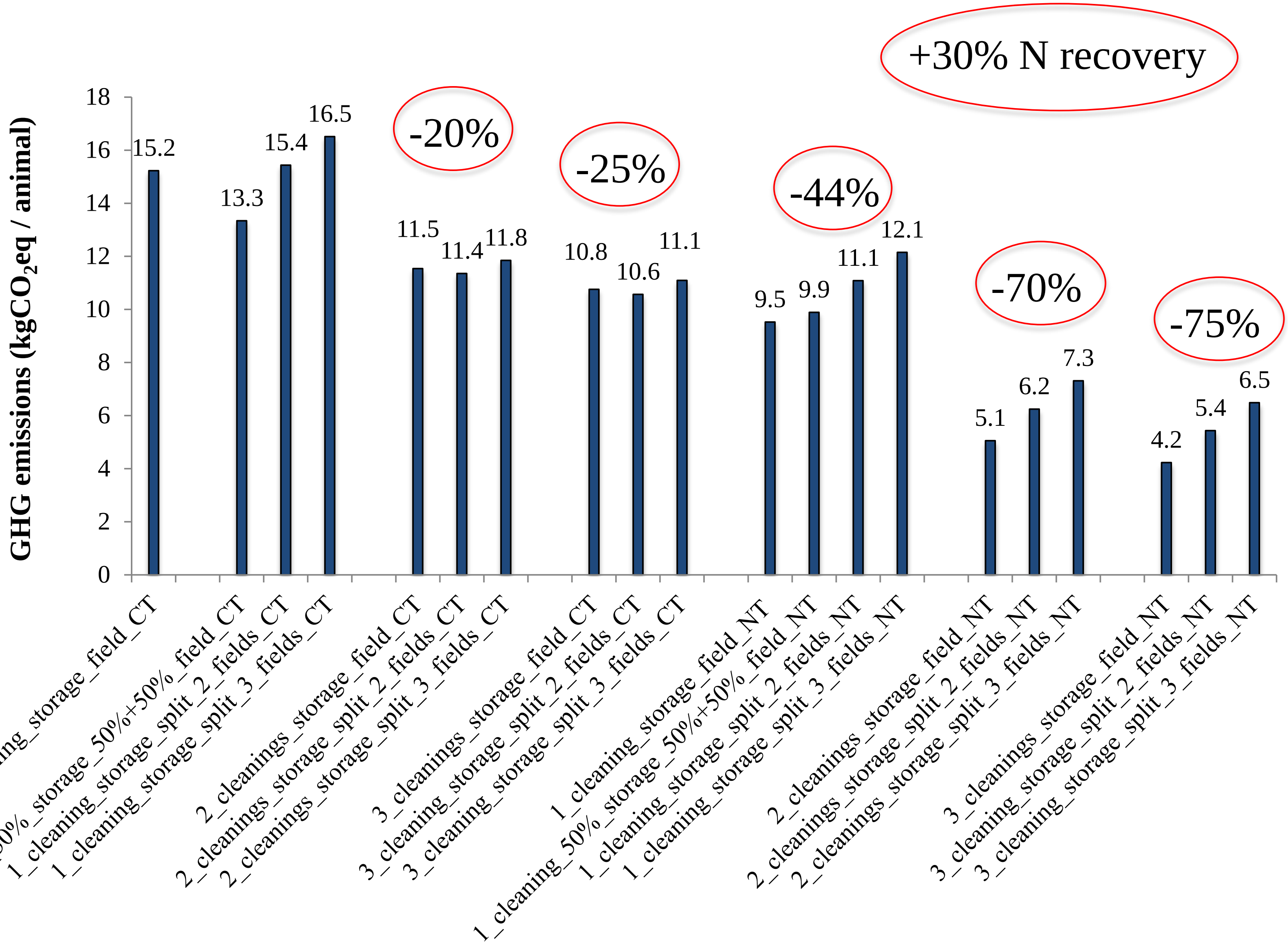
Adopting NT and splitting manure into more fields







Scenarios


+30% N recovery
-20%
-25%
-44%
-70%
-75%
GHG emissions ($kgCO_2eq$ / animal)
0
2
4
6
8
10
12
14
16
18
15.2
13.3
15.4
16.5
11.5
11.4
11.8
10.8
10.6
11.1
9.5
9.9
11.1
12.1
5.1
6.2
7.3
4.2
5.4
6.5
Baseline - 1_cleaning_storage_field_CT
1_cleaning_50%_storage_50%+50%_field_CT
1_cleaning_storage_split_2_fields_CT
1_cleaning_storage_split_3_fields_CT
2_cleanings_storage_field_CT
2_cleanings_storage_split_2_fields_CT
2_cleanings_storage_split_3_fields_CT
3_cleanings_storage_field_CT
3_cleaning_storage_split_2_fields_CT
3_cleaning_storage_split_3_fields_CT
1_cleaning_storage_field_NT
1_cleaning_50%_storage_50%+50%_field_NT
1_cleaning_storage_split_2_fields_NT
1_cleaning_storage_split_3_fields_NT
2_cleanings_storage_field_NT
2_cleanings_storage_split_2_fields_NT
2_cleanings_storage_split_3_fields_NT
3_cleanings_storage_field_NT
3_cleaning_storage_split_2_fields_NT
3_cleaning_storage_split_3_fields_NT

STILL A LOT OF WORK !!!

Conclusion

-A typical manure management emitted 15.2 kg CO_2eq animal^{-1}. About 24.7, 1.5 and 73.8% came from housing, storage and field application of manure, respectively.

-In spite of discrepancies, applicability of Manure-DNDC in the context of the entire manure management cycle was acceptable.

-More frequent manure removal from housing and adoption of no-tillage system would be more effective mitigating total GHG emissions (up to 75%).

-Furthermore, the continuous measurements are also valuable for refinements and calibration of the process-based model estimation.

谢谢

Thank you!

Ciniro Costa Junior

cinirojr@hotmail.com

Questions?

Ciniro Costa Junior

cinirojr@cena.usp.br

cena
USP