



Quantifying the fertilizer value of municipal wastewater sludge

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WATER RESEARCH COMMISSION

ERWAT INNOVATIVE WASTEWATER SOLUTIONS

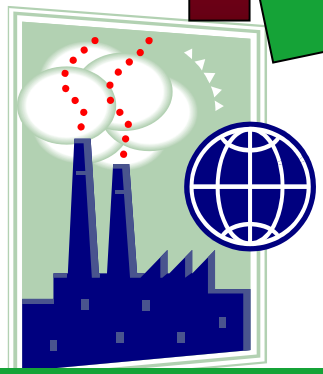
Nutrient cycle under commercial farming

Pollution, green house gas emission

?

Low fraction

Non-agricultural beneficial use

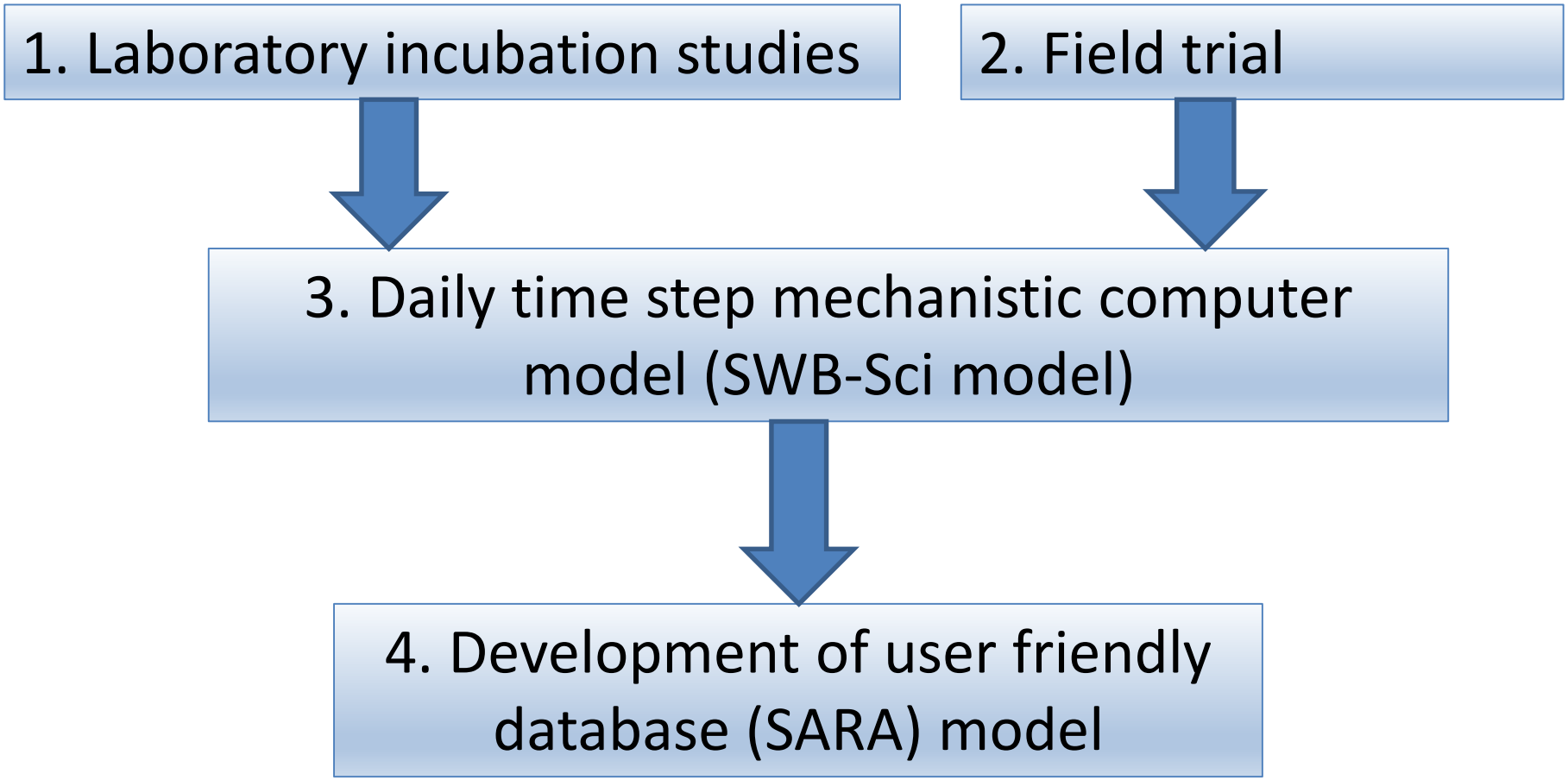


Inorganic fertilizer production

Landfills, Incineration, Disposal (land and marine)

Pollution, contribution to green house gas

Overall view of the study in flow diagram



1. Laboratory incubation study

aim

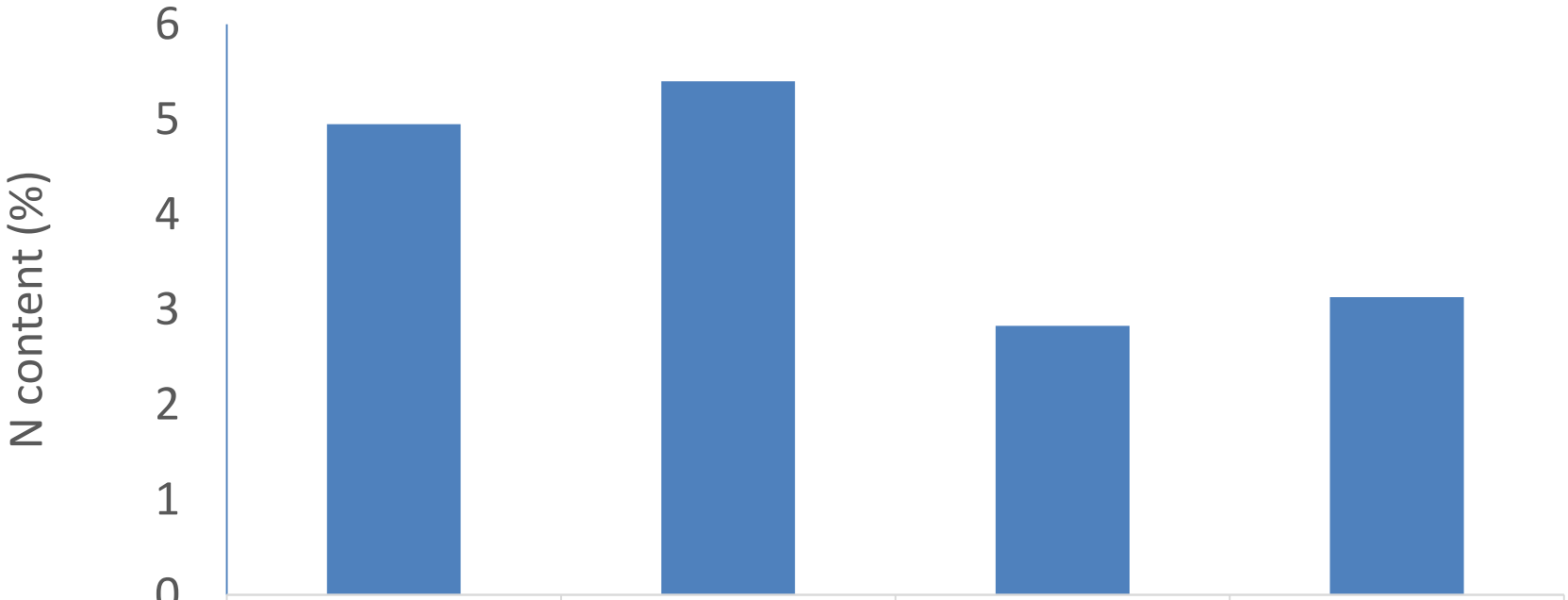
Assess the effect of wastewater treatment and post treatment dewatering techniques on:

- The nitrogen composition, and
- The fertilizer value of sludge

Generate parameters for SWB-Sci model.

1.1 Summary of findings

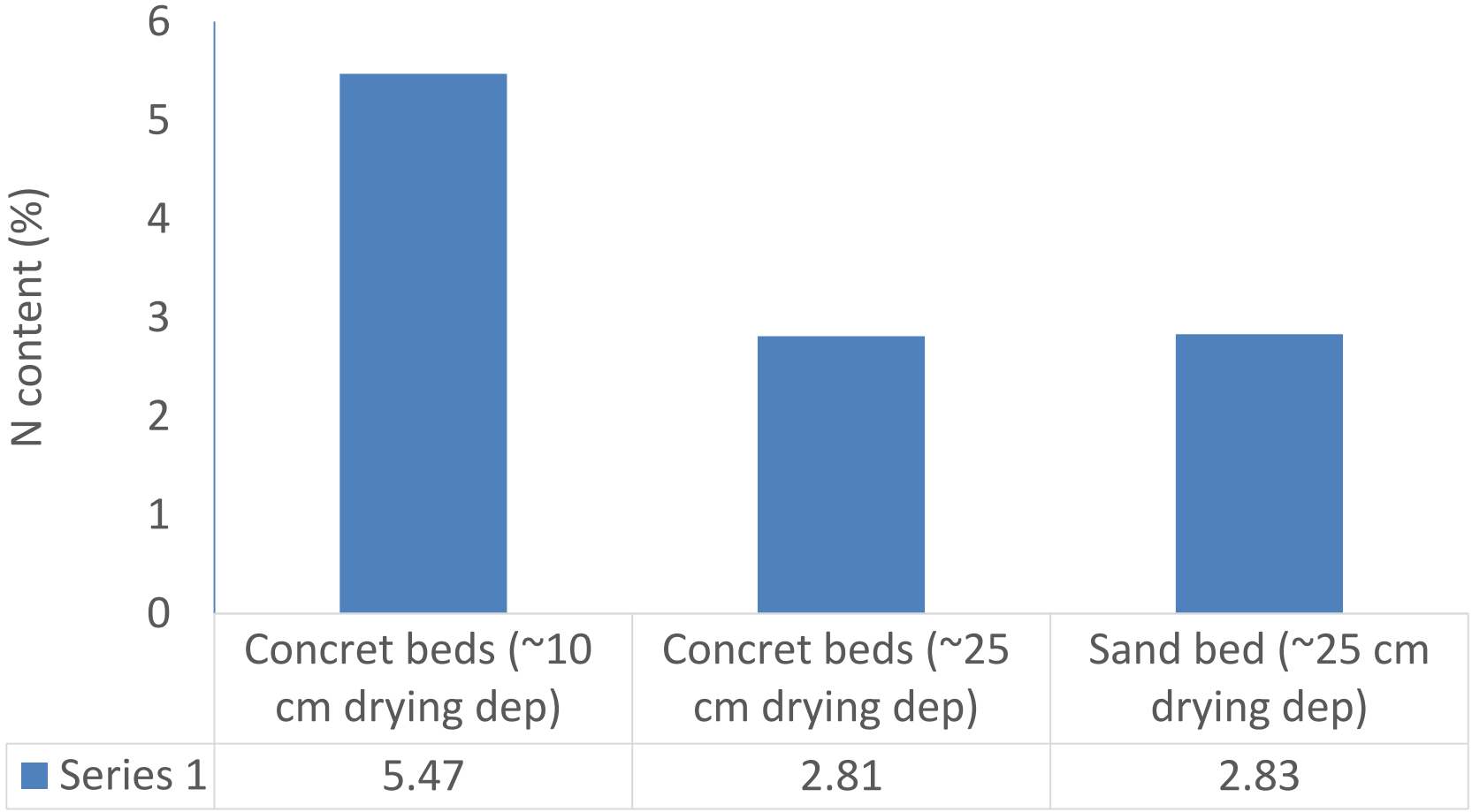
- **Effect of wastewater treatment and post treatment dewatering techniques on the total N content sludge:**



	Activated (~10 cm drying dep)	Anaer (~10 cm drying dep)	Anaer (~25 cm drying dep)	Thermally hydrolysed sludge
Series 1	4.95	5.4	2.83	3.13

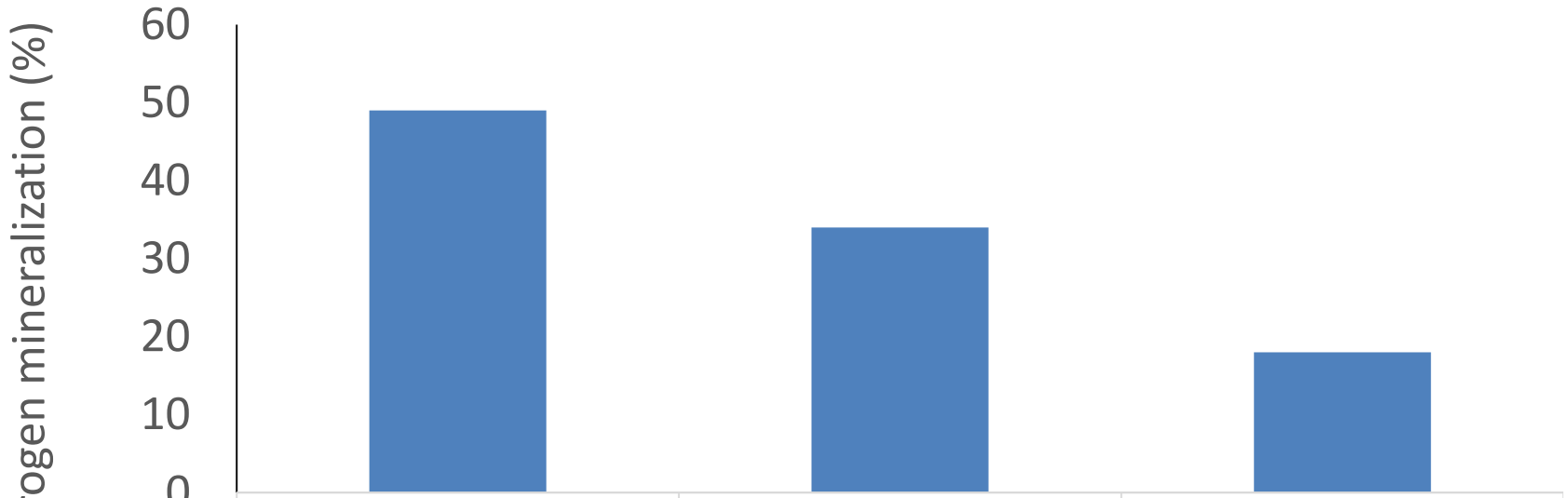
1.2 Summary of findings

- **Effect of post treatment dewatering techniques on the total N content of sludge:**



1.3 Summary of findings

- **Effect of wastewater treatment and dewatering on the release of N for use by plants:**



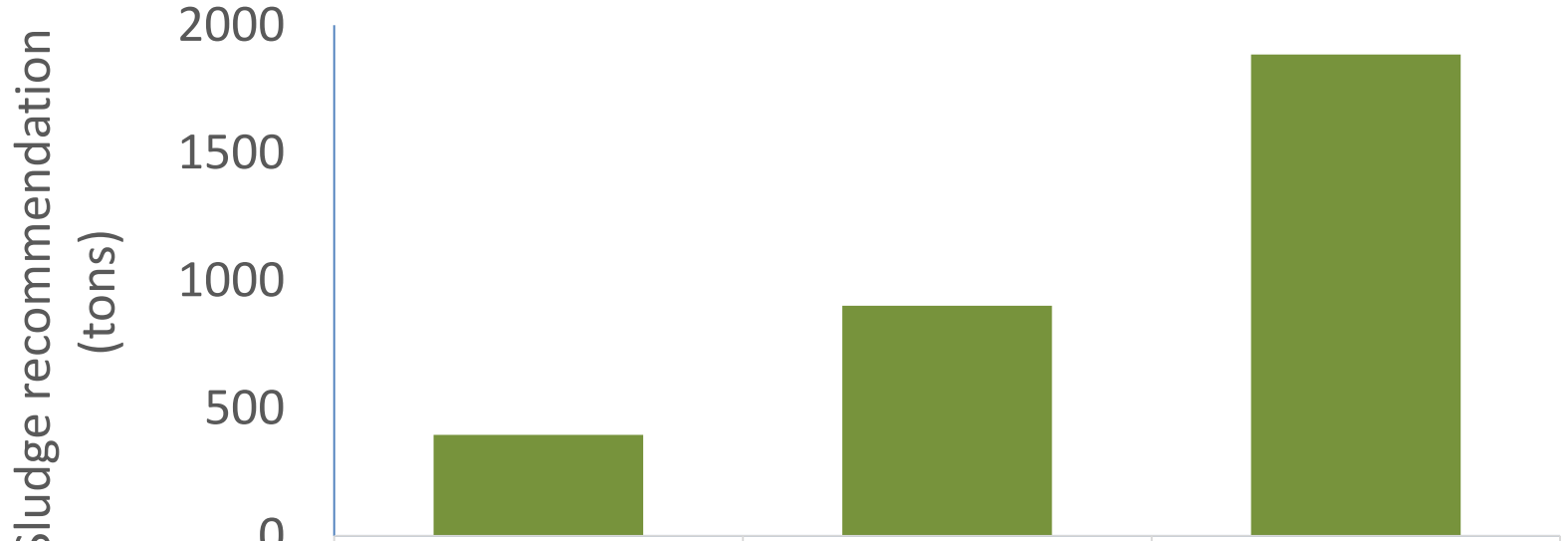
	Activated (~10 cm drying dep)	Thermally hydrolysed sludge	Anaer (~25 cm drying dep)
% N mineralized	49	34	18

1.4 Summary of findings

- What are the implications with respect to:
  - Agronomic sludge recommendation rate?
  - Fertiliser value of sludge?
- Case study:
  - Location of farm – around Johannesburg,
  - Farm distance from WTP – 10 km,
  - Farm size – 100 ha,
  - Crop - maize (rain fed),
  - N requirement – 120 kg/ha,
  - Transport – R58 per km per load (30 ton track),
  - Spreading cost – R55 per ton.

1.4.1 Summary of findings

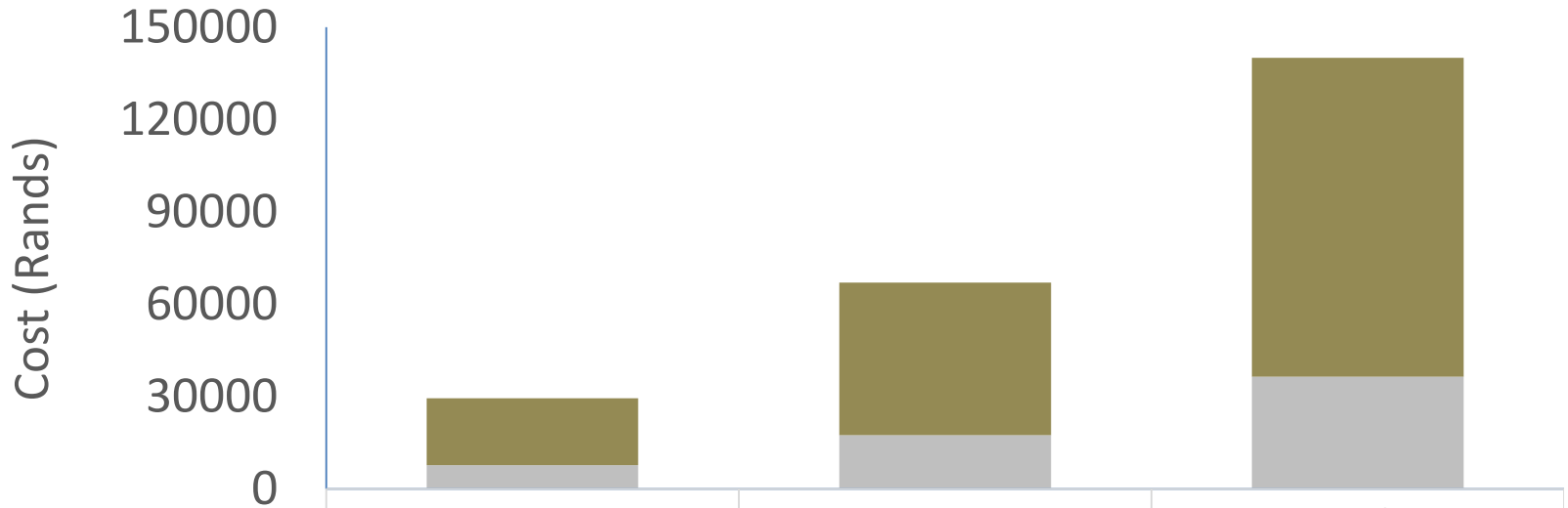
- **Total sludge recommendation to satisfy crop N requirement of the 100 ha farm.**
  - **Sludge source – different wastewater treatment and dewatering techniques**



	Activated (~10 cm drying dep)	Thermally hydrolised sludge)	Anaer (~25 cm drying dep)
Sludge recommendation	396	902	1885

1.4.1 Summary of findings

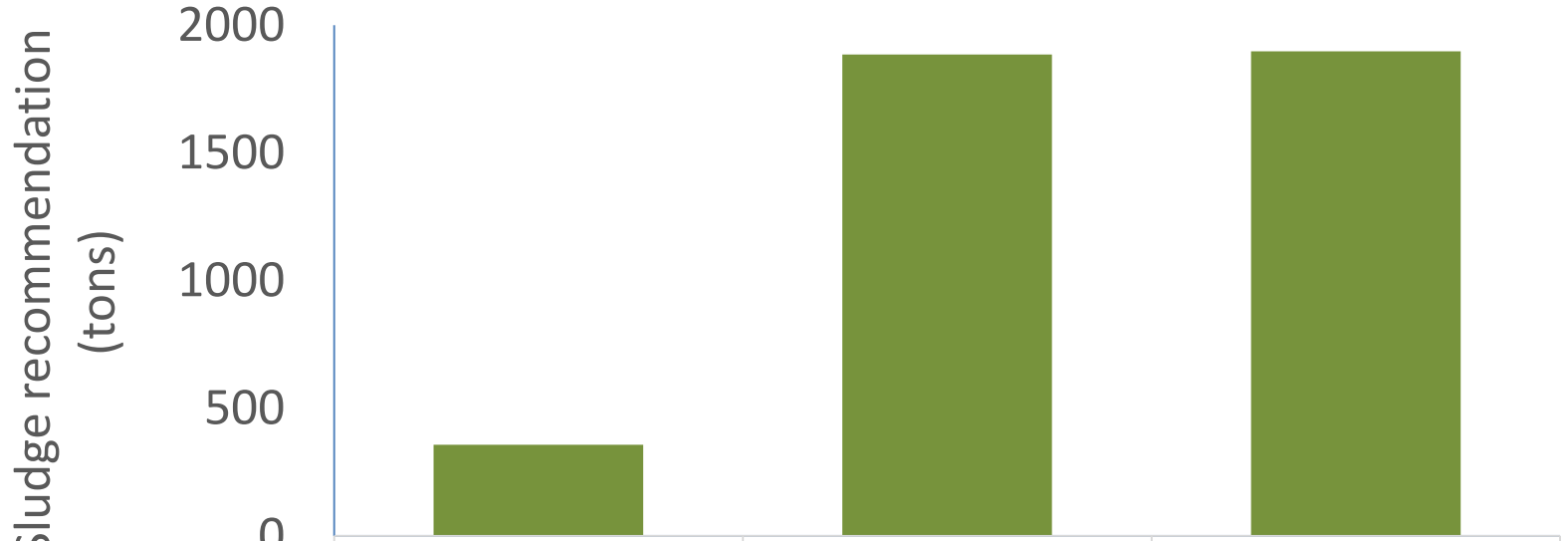
- **Total cost (transport + spreading) of sludge to the 100 ha farm 10 km away from WTP.**



	Activated (~10 cm drying dep)	Thermally hydrolised sludge)	Anaer (~25 cm drying dep)
Spreading Cost ®	21769	49615	103651
Transport cost ®	7652	17440	36435

1.4.2 Summary of findings

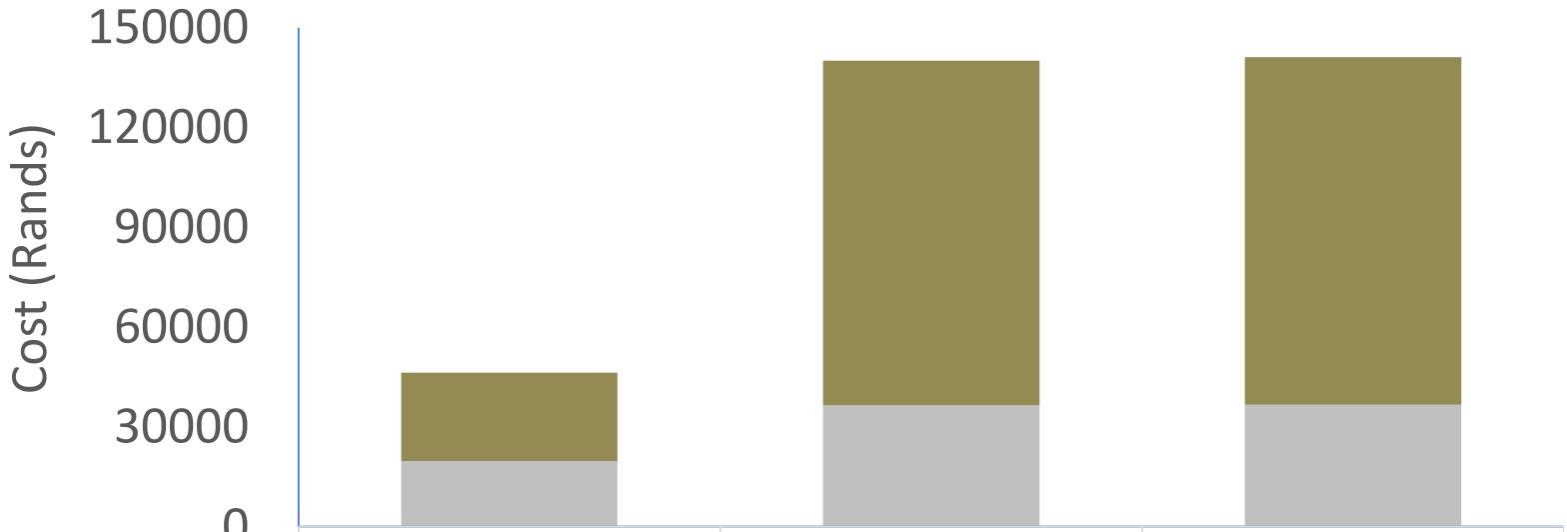
- **Total sludge recommendation to satisfy crop N requirement of the 100 ha farm.**
  - **Sludge source – similar wastewater treatment but differing drying techniques and/or depths.**



	Concrete bed (~10 cm drying dep)	Sand bed (~25 cm drying dep)	Concrete bed (~25 cm drying dep)
Sludge recommendation	358	1885	1898

1.4.2 Summary of findings

- **Total cost (transport + spreading) of sludge to the 100 ha farm 10 km away from WTP.**



	Concrete bed (~10 cm drying dep)	Sand bed (~25 cm drying dep)	Concrete bed (~25 cm drying dep)
Spreading Cost ®	26624	103651	104389
Transport cost ®	19699	36435	36694

1.4.3 Summary of findings

- The SWB-Sci mechanistic model was parameterised:
  - Using data collected from controlled incubation studies.

2. Field experiment

aim

Assess agronomic benefits and environmental impacts of using sludge as a low grade fetilizer,

To calibrate and validate the SWB-Sci model.

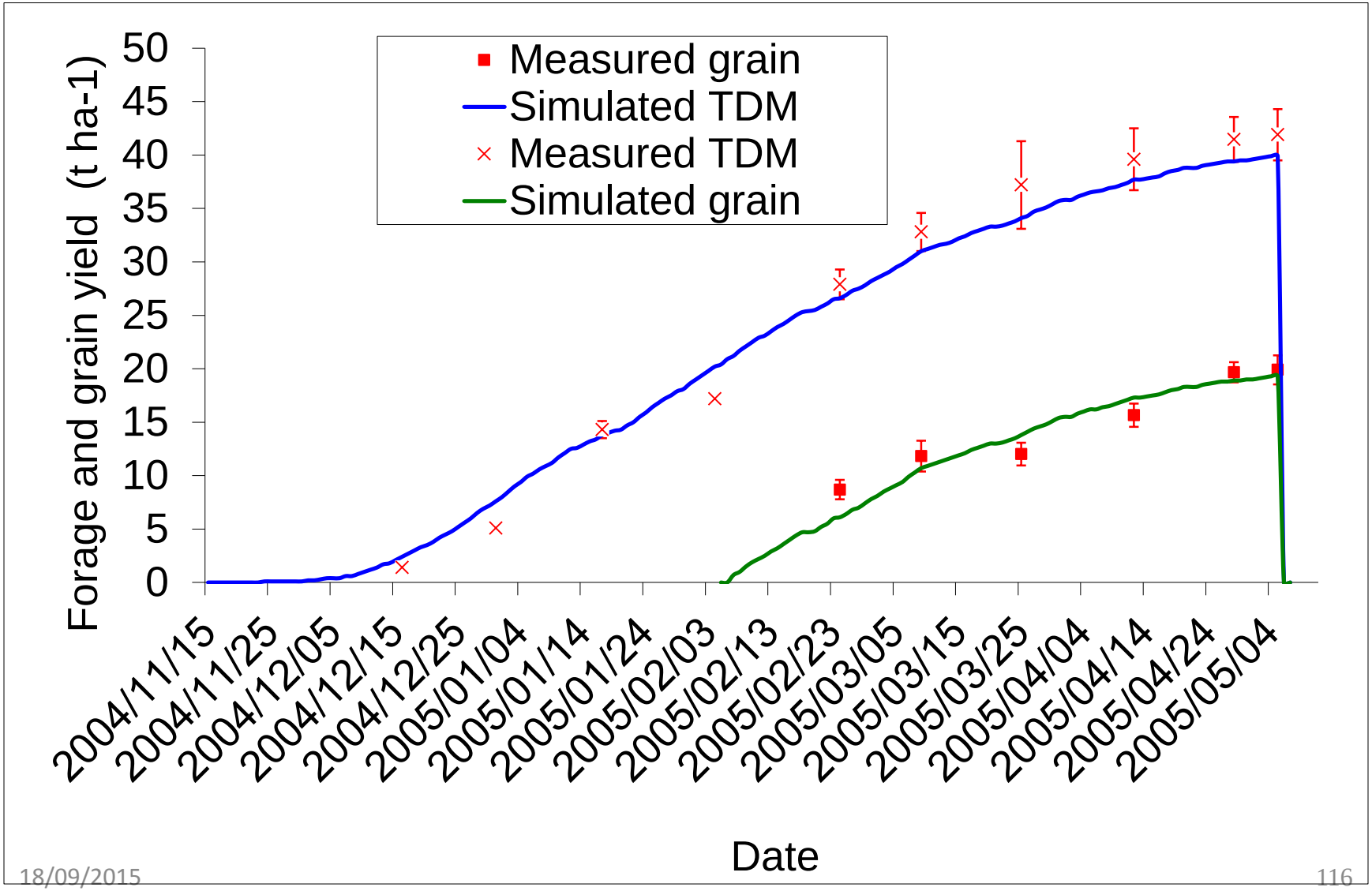
2.1 Field experiment

- Four cropping systems have been under investigation since 2004:
  - Dryland maize,
  - Irrigated maize – oat rotation,
  - Dryland pasture, and
  - Lawn sod production.



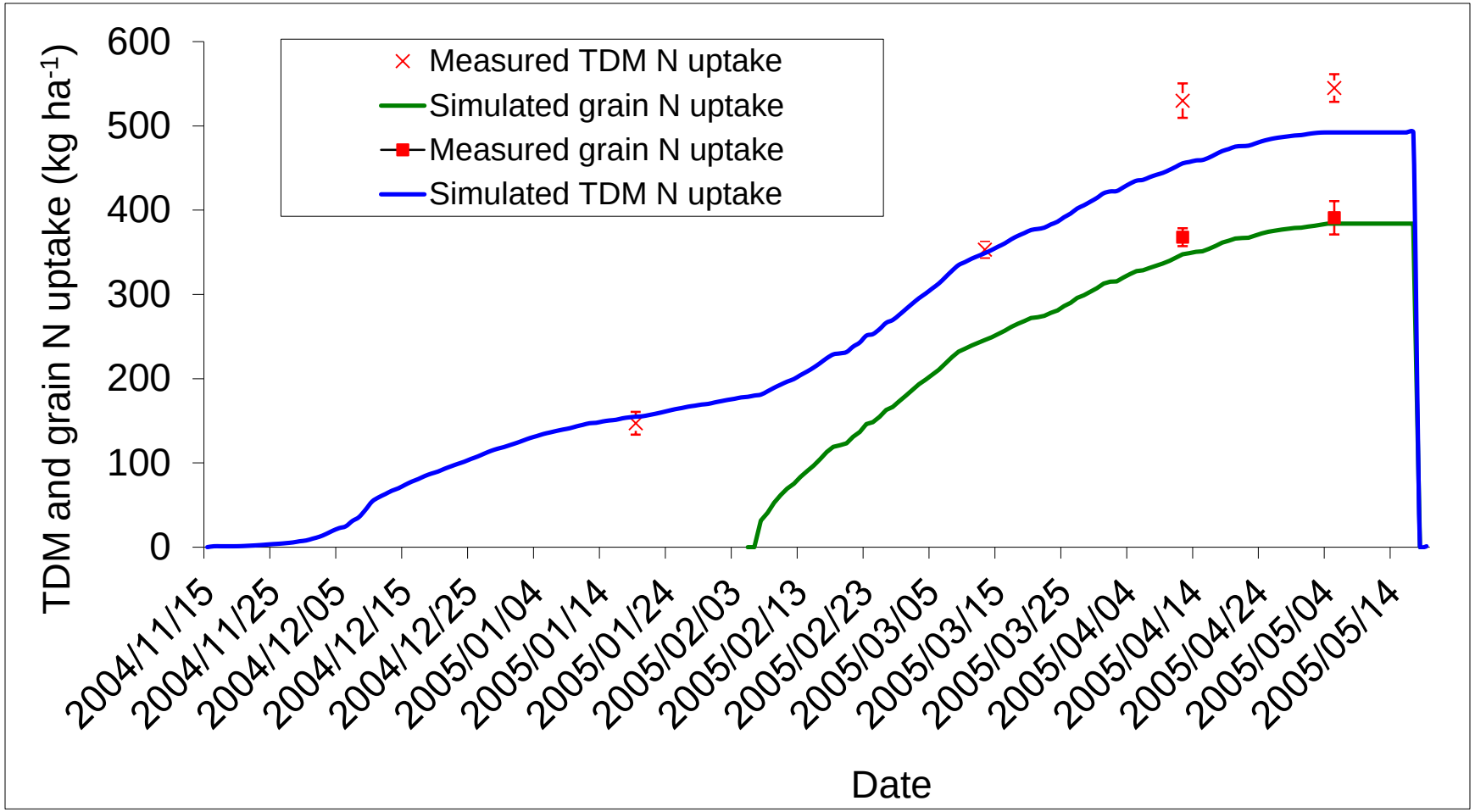
2.2 SWB-Sci model calibration

Forage and grain yield



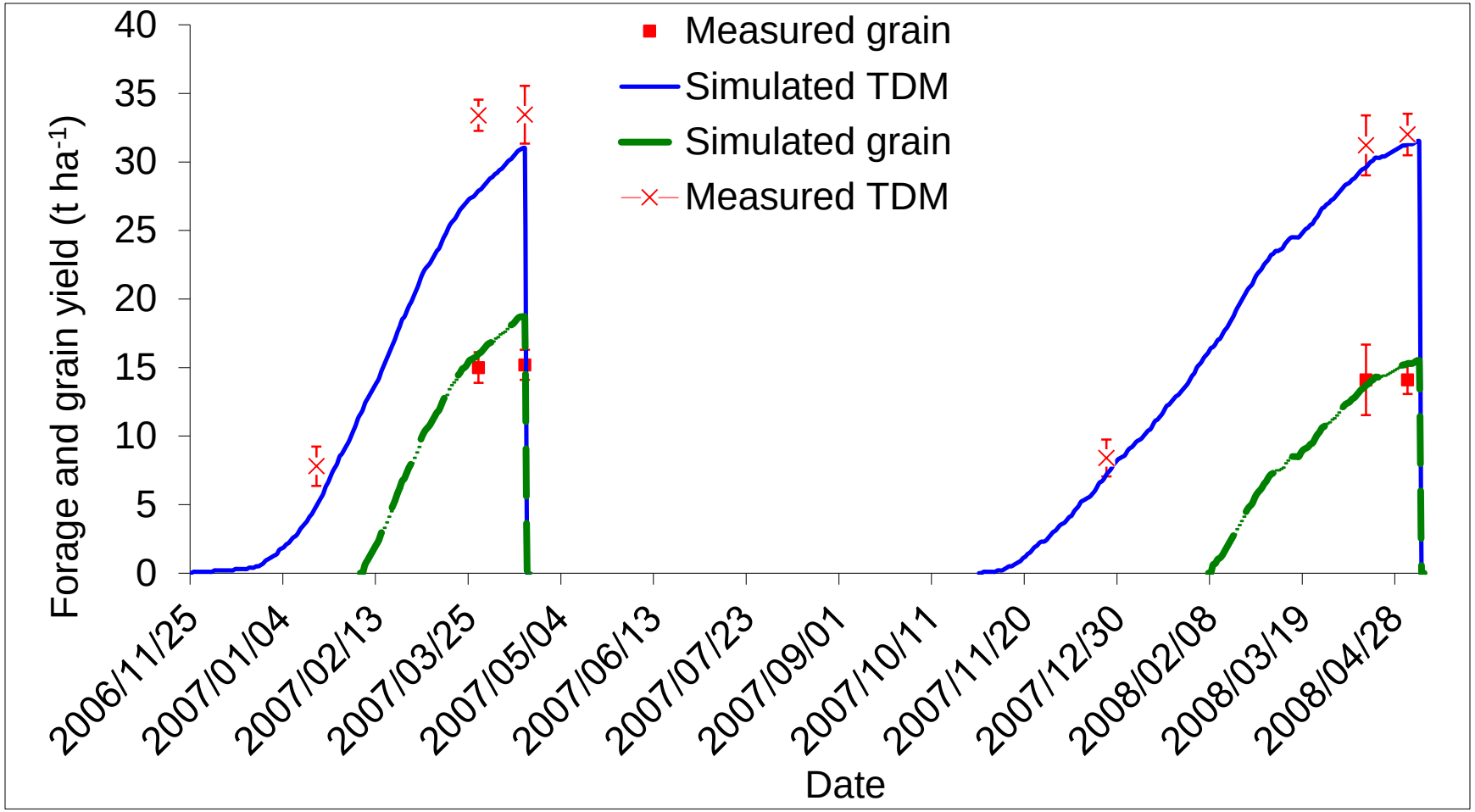
2.2 SWB-Sci model calibration

Forage and grain N uptake



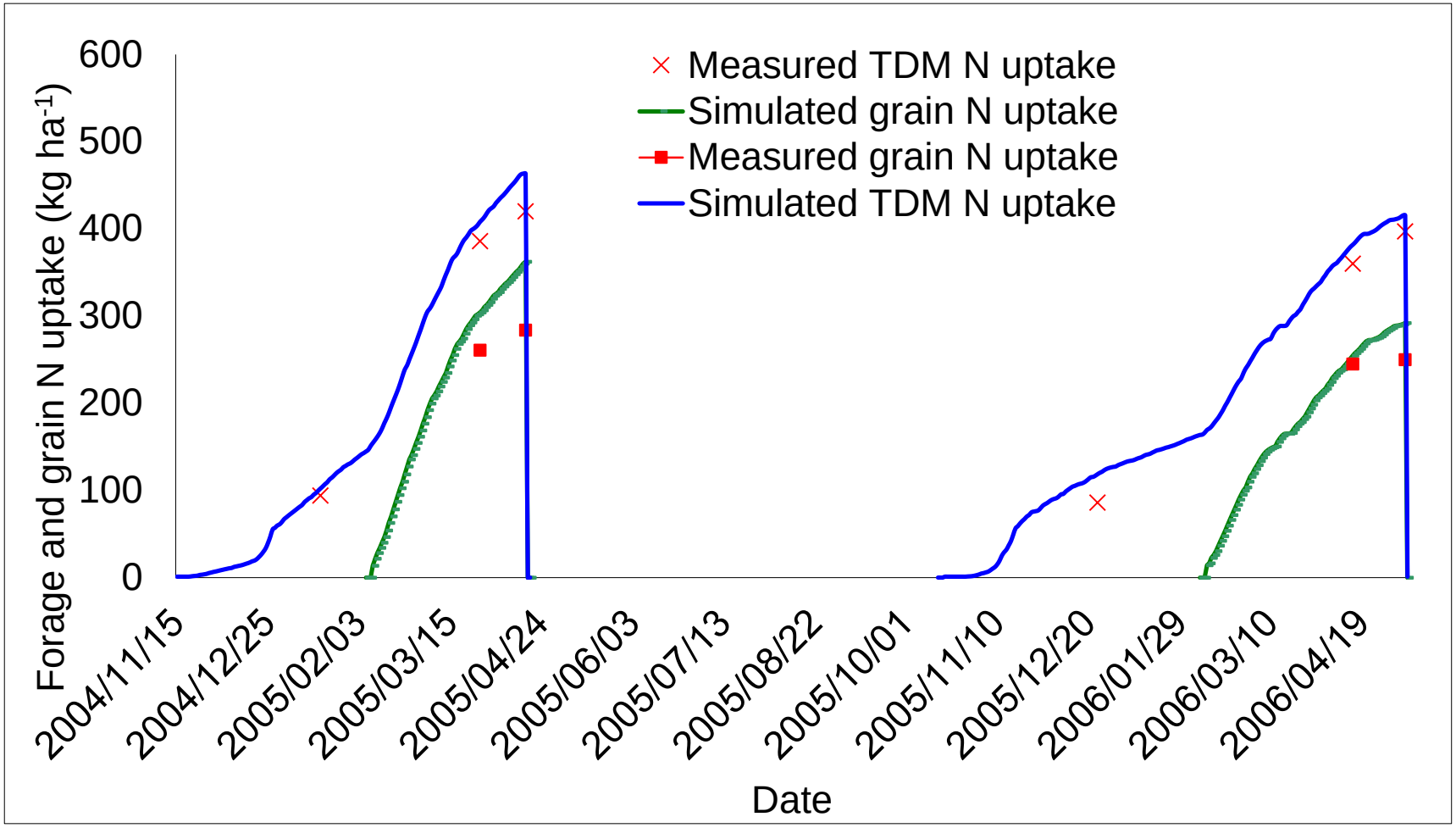
2.3 SWB-Sci model validation

Maize forage and grain yield



2.3 SWB-Sci model validation

Maize forage and grain yield



3. Daily time step mechanistic computer model (SWB-Sci model) Scenario simulations

aim

To investigate whether a single generic annual N release rate could be used across sites within an agro-ecological zone,

To generate sludge N mineralization rate data base across South African agro-ecological zones.

3.1 Hypotheses tested

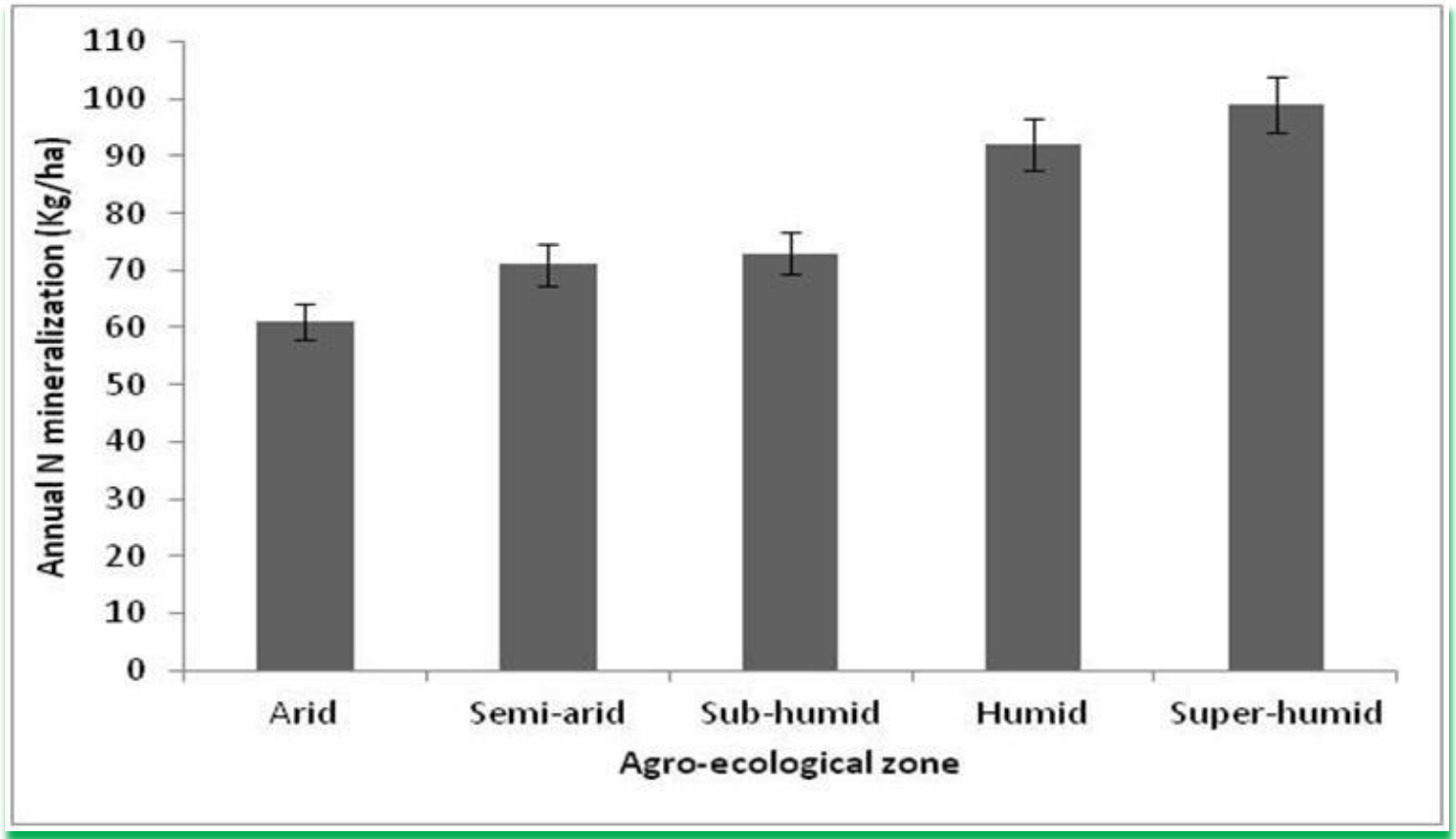
- To achieve the stated aims, the following hypotheses were tested:

  Under rainfed farming, cumulative annual N mineralization from sludge-amended soils:

  - Will remain unchanged across agro-ecological zones,
  - Will not vary between seasons at a specific site, and
  - Will not vary across soil textures within a site.

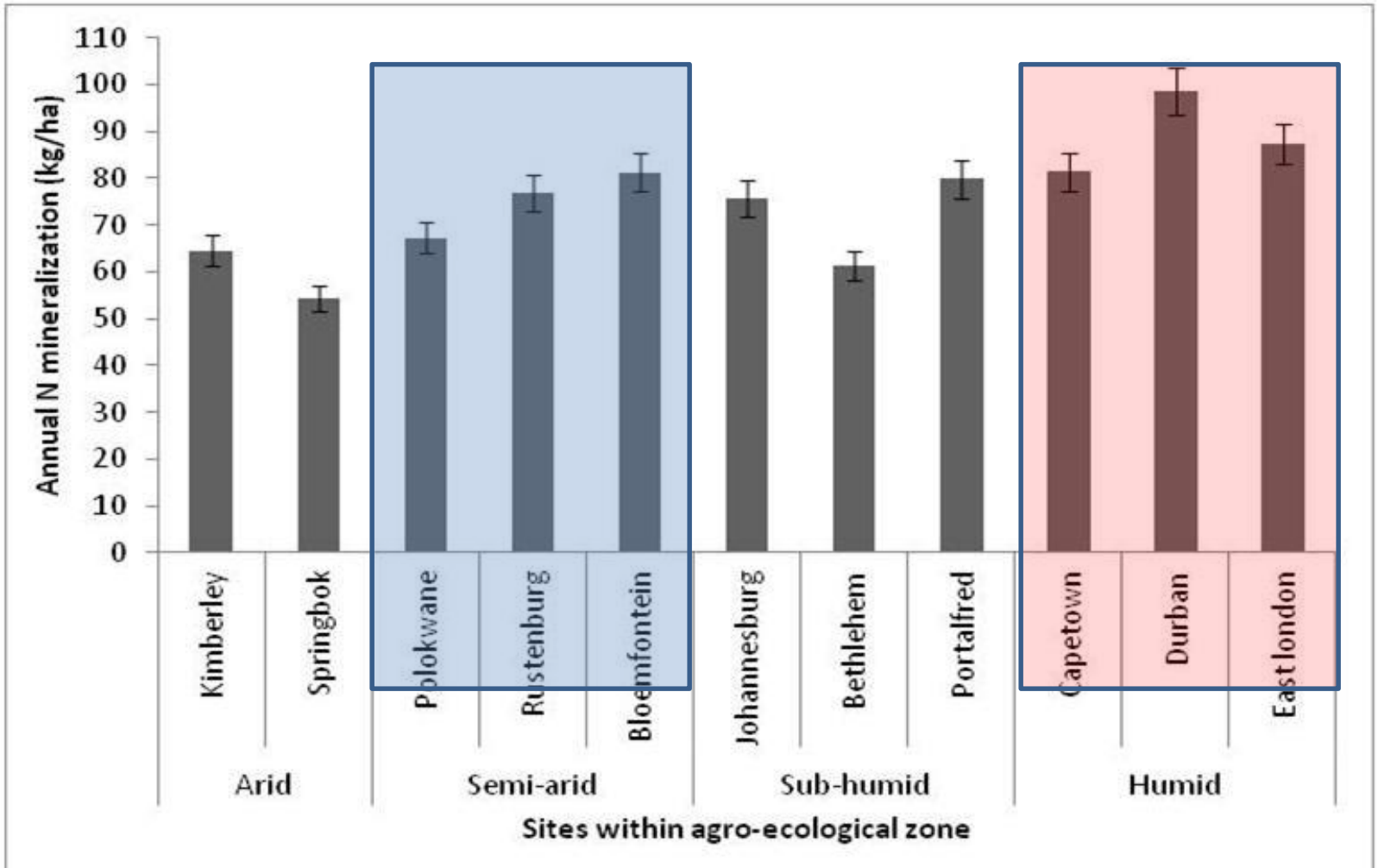
3.1 Hypotheses 1a – Can a single annual N mineralization rate be used across agro-ecological zones?

- N mineralization varied significantly across agro-ecological zones.
  - Therefore no single recipe across agro-ecological zones.



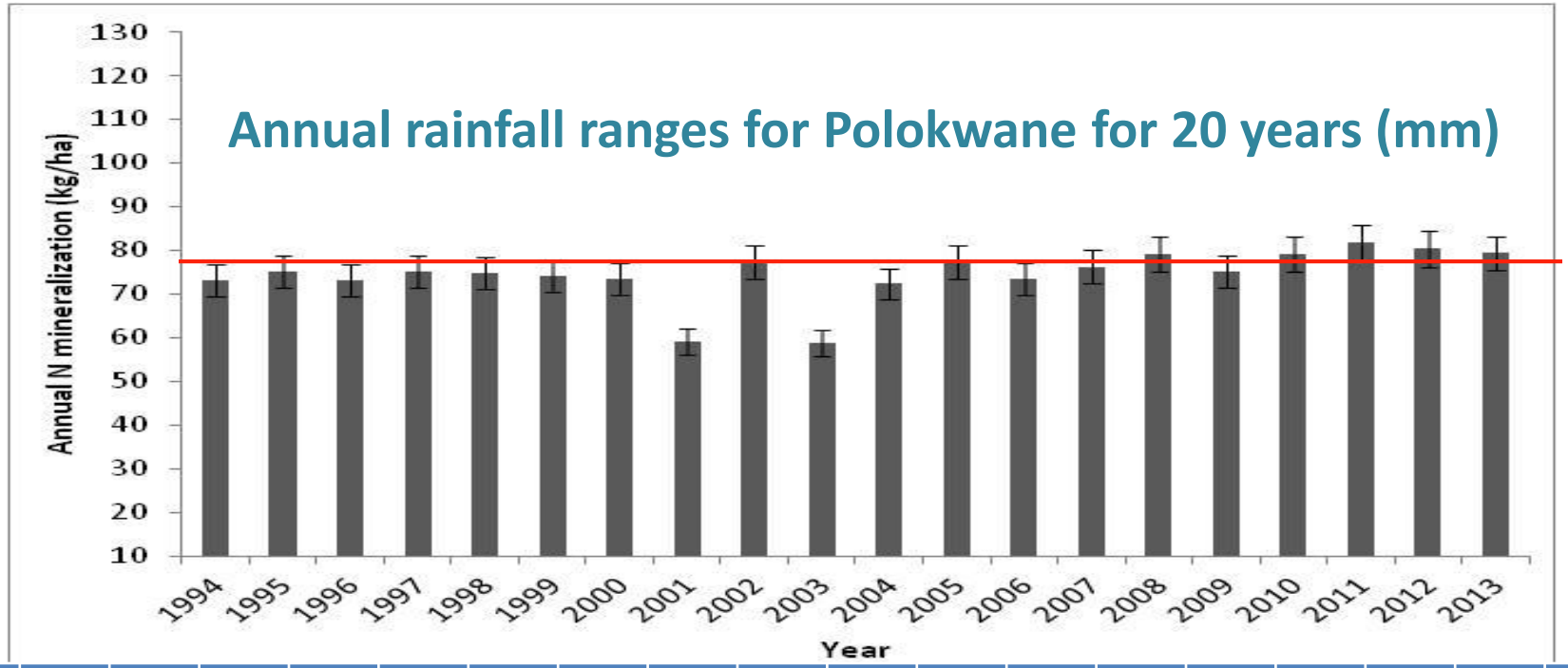
3.1 Hypothesis 1b – Can a single annual N mineralization rate be used across sites within an agro-ecological zone?

- No



3.2 Hypothesis 2 - Does annual N mineralization vary across years within a site? Eg. Polokwane

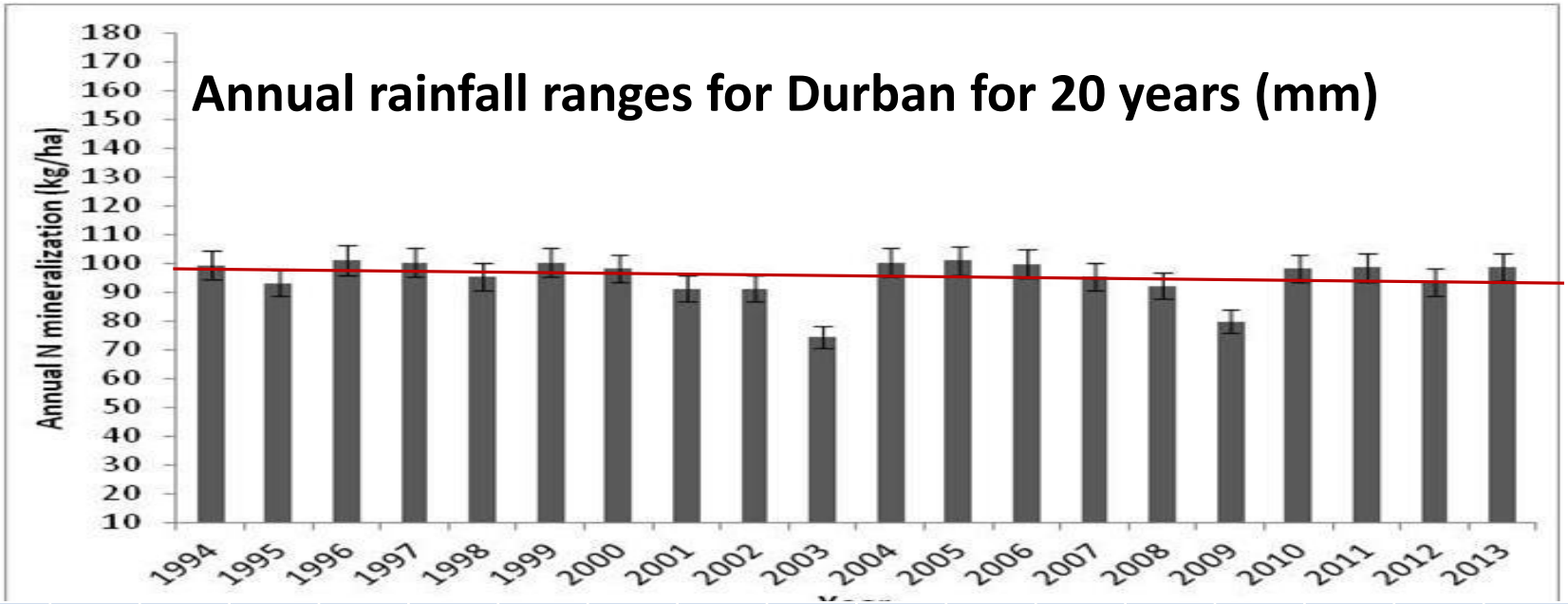
- N mineralization remained similar for 80% of the years.
  - Exceptions - anomalous dry years.
- Therefore site specific generic annual N mineralization rate can be used.



94	95	96	97	98	99	00	01	02	03	04	05	06	08	08	09	10	11	12	13
380	395	440	465	390	410	487	272	478	223	388	341	513	341	420	389	440	490	432	410

3.2 Hypothesis 2 - Does annual N mineralization vary across years within a site? Eg. Durban

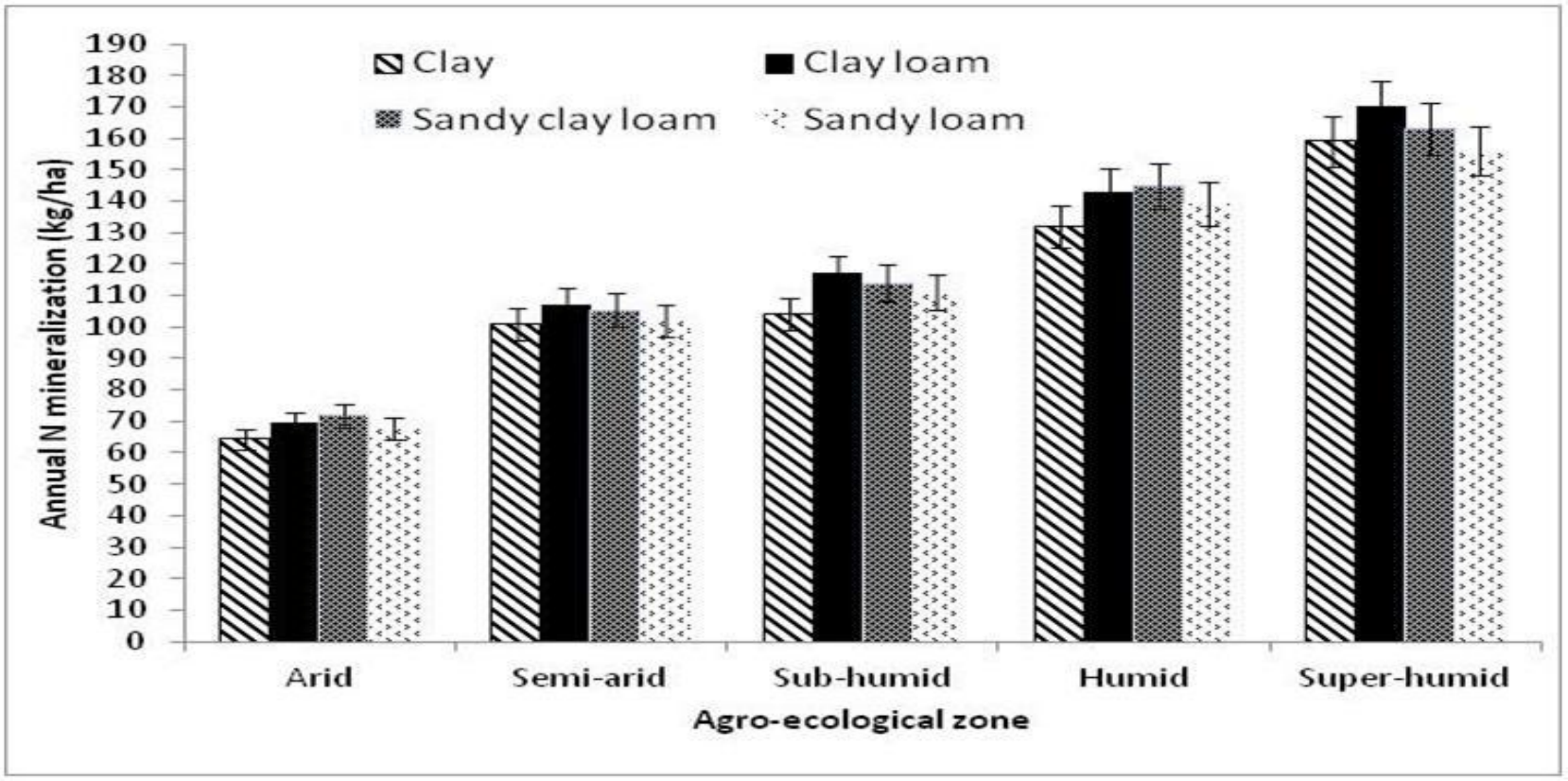
- N mineralization remained similar for 80% of the years.
  - Exceptions - anomalous dry years.
- Therefore site specific generic annual N mineralization rate can be used.



94	95	96	97	98	99	00	01	02	03	04	05	06	08	08	09	10	11	12	13
980	1065	940	865	990	870	840	885	880	620	1004	1049	997	924	1006	587	980	990	1082	910

3.3 Hypothesis 3 - Does annual N mineralization vary across soil textures within a site?

- N mineralization remained similar across soil textures in all agro-ecological zones.
- Therefore site specific single generic N mineralization rate can be used across soil textures.



4. Development of user friendly database (SARA) model

aim

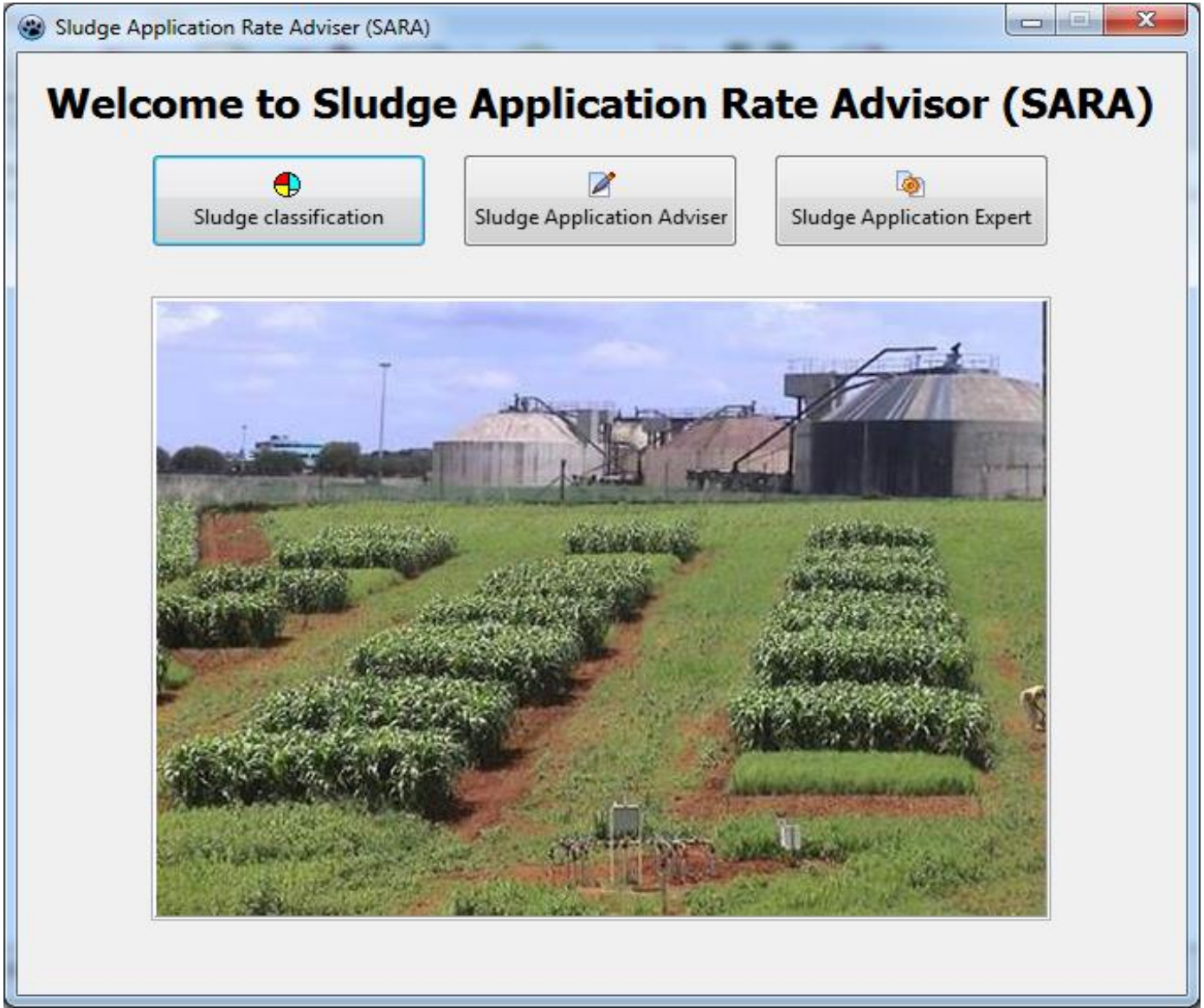
Estimate crop and site specific sludge application rate recommendations,

Estimate the economical distance that a sludge can be transported using commercial fertilizer as bench mark,

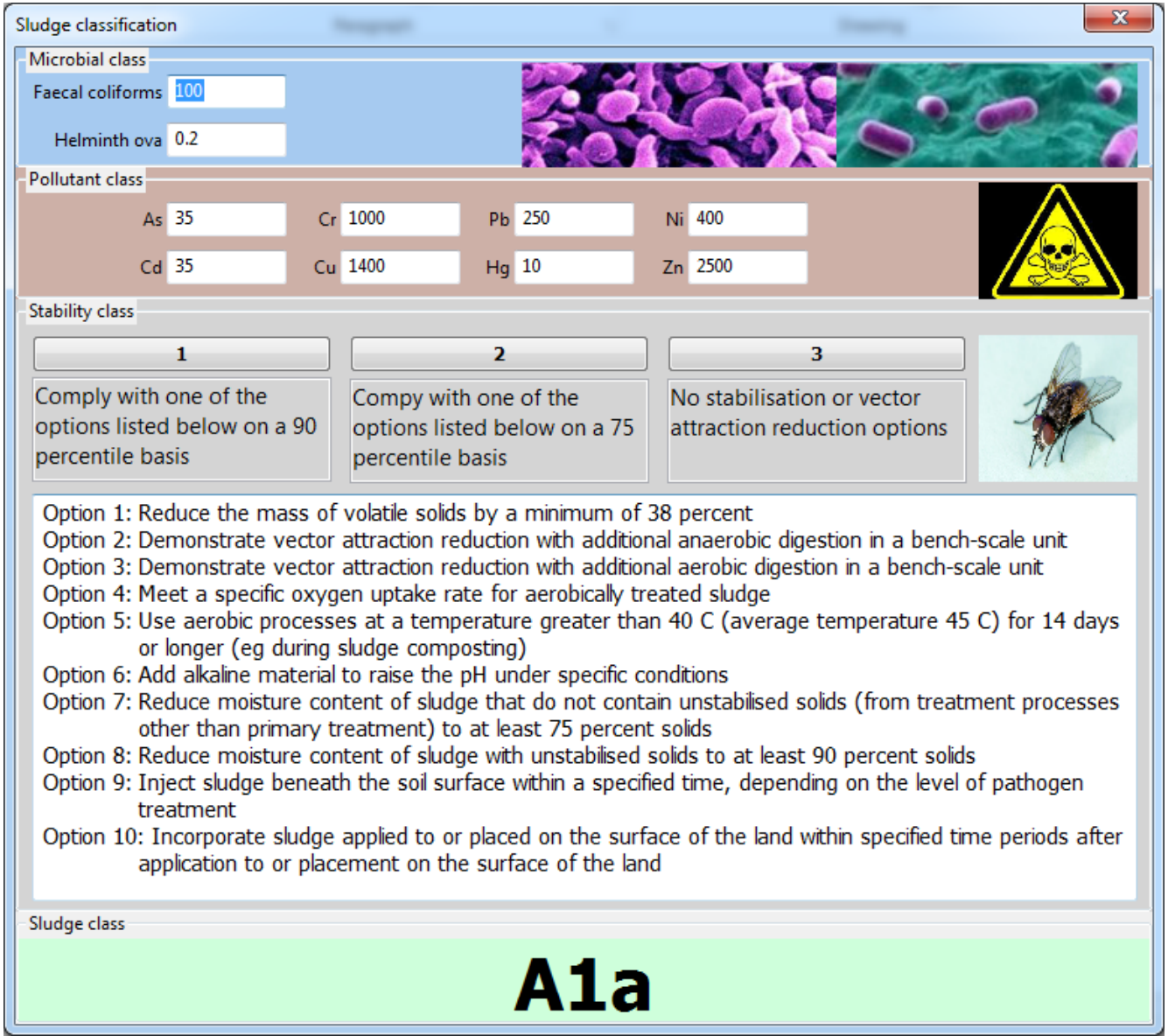
Assess environmental impact from heavy metal accumulation.

4. Model interface

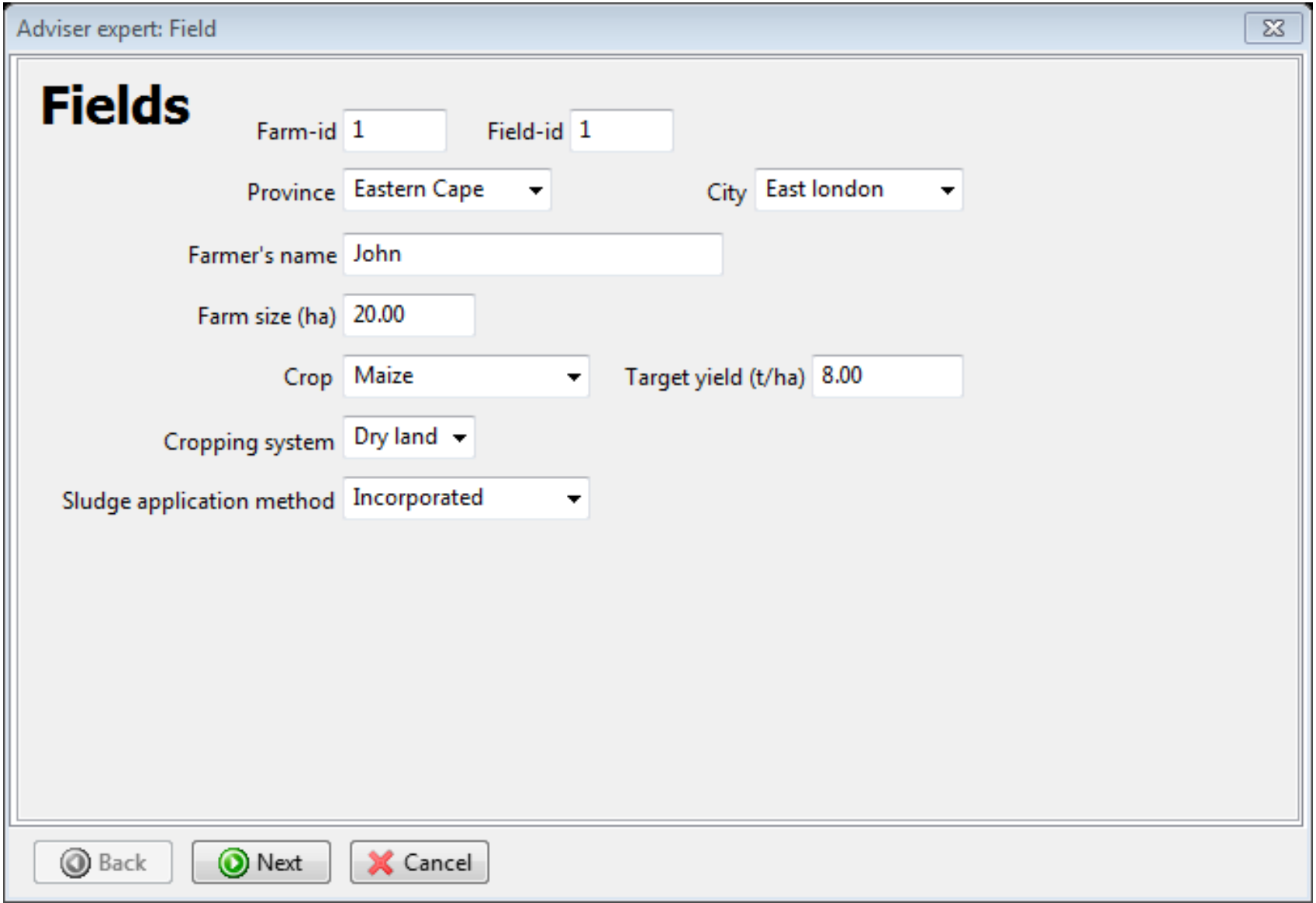
4.1 First interface



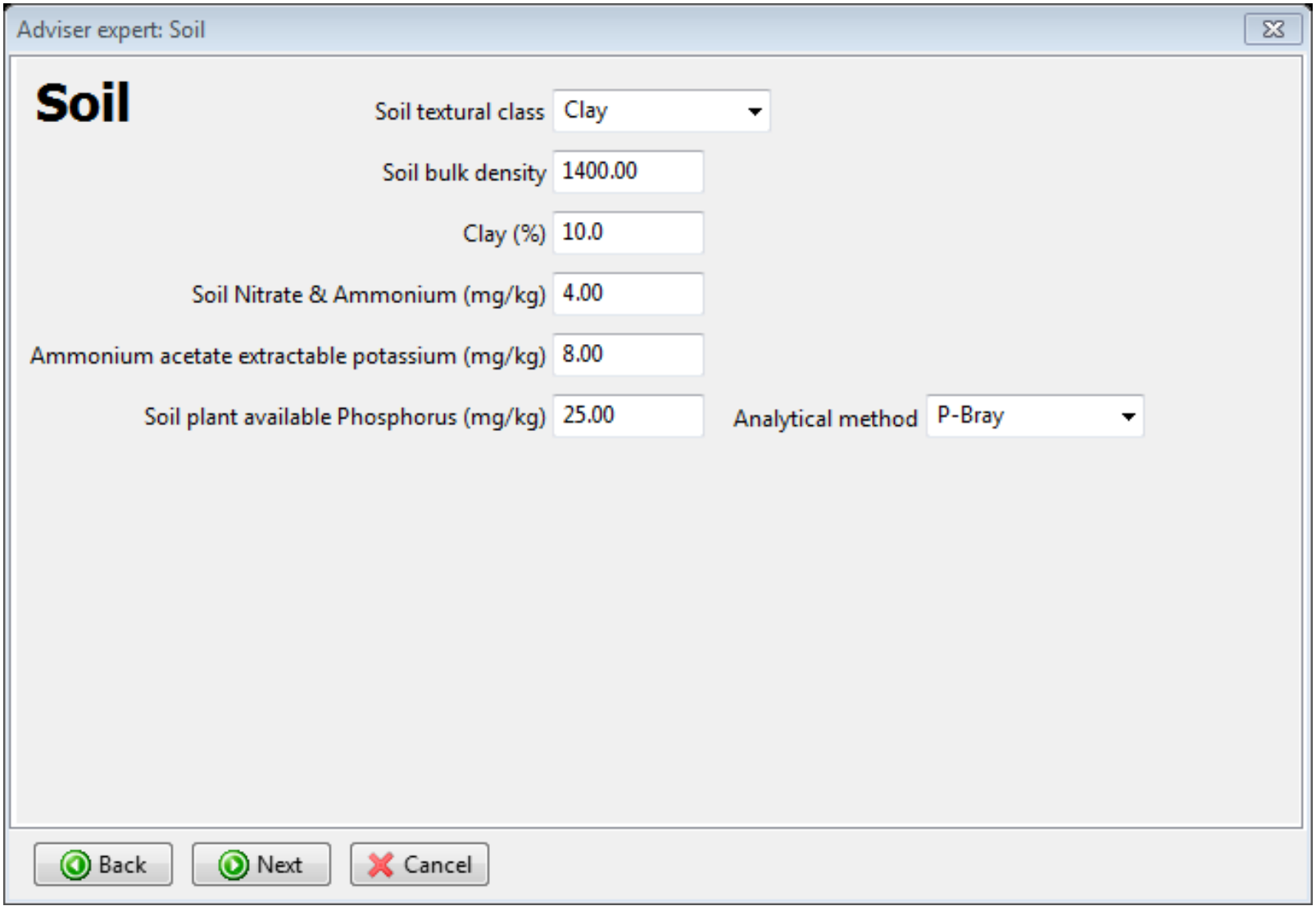
4.2 Sludge classification interface



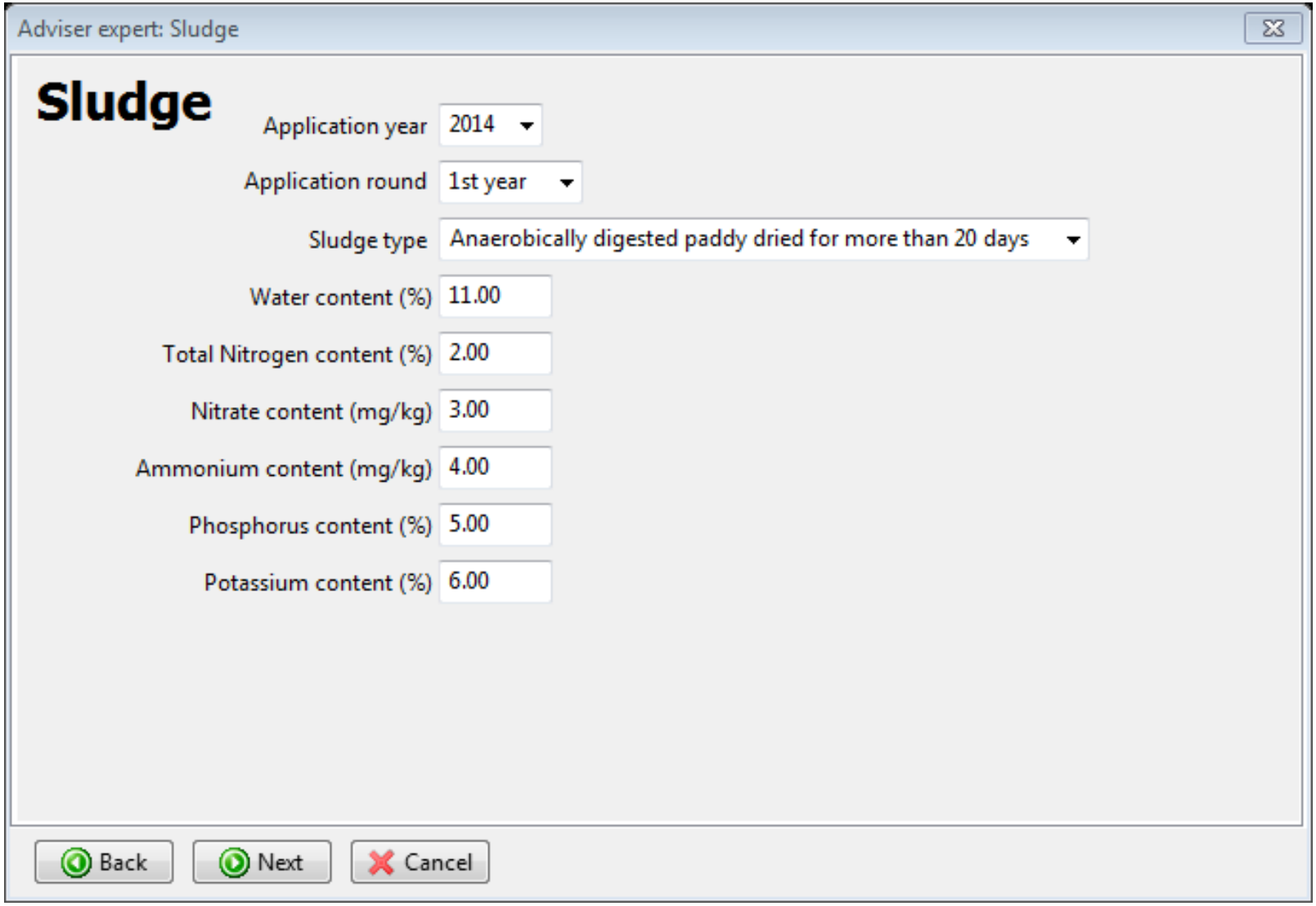
4.3 Farm, farmer and field entry interface



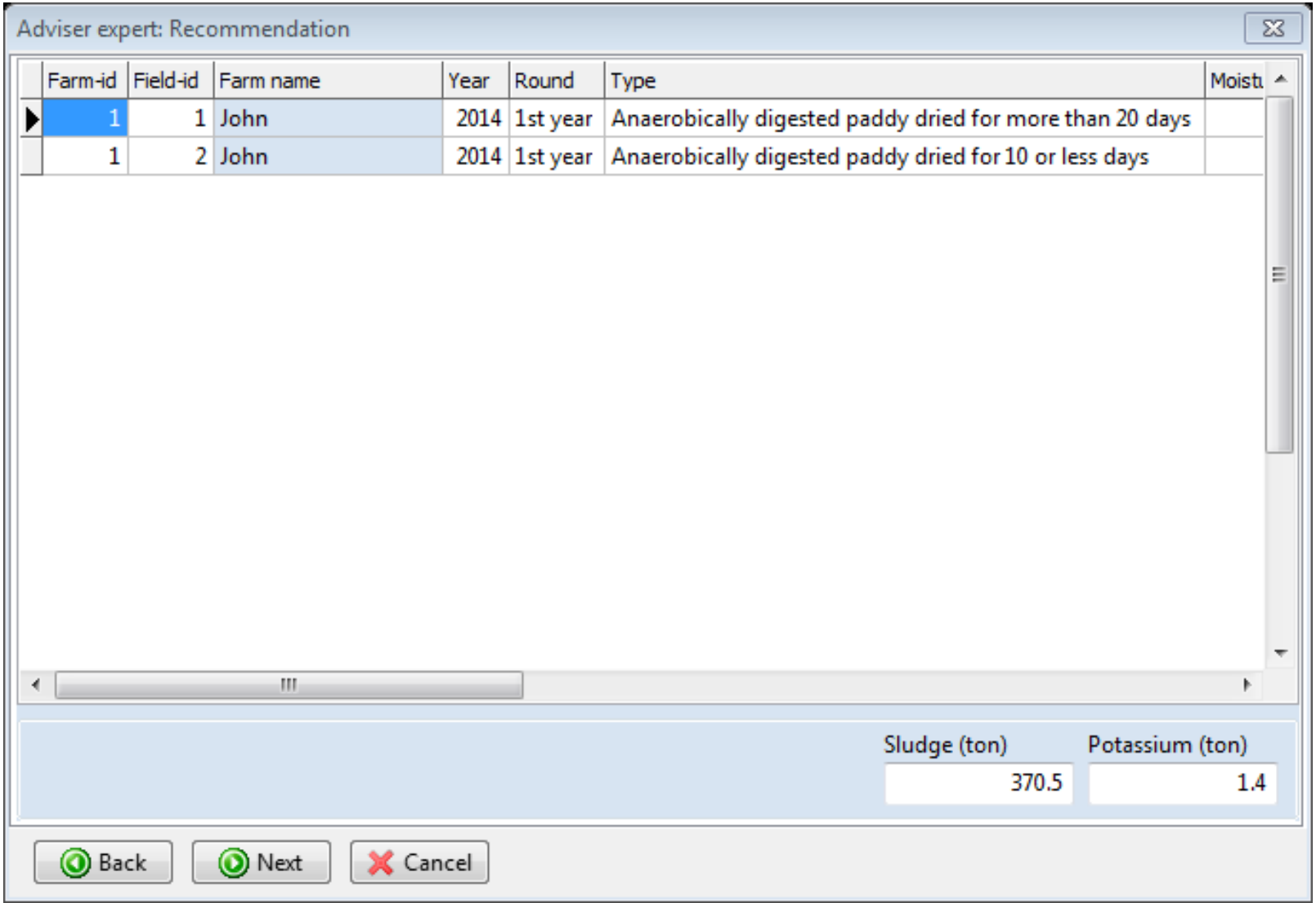
4.4 Field soil information input interface



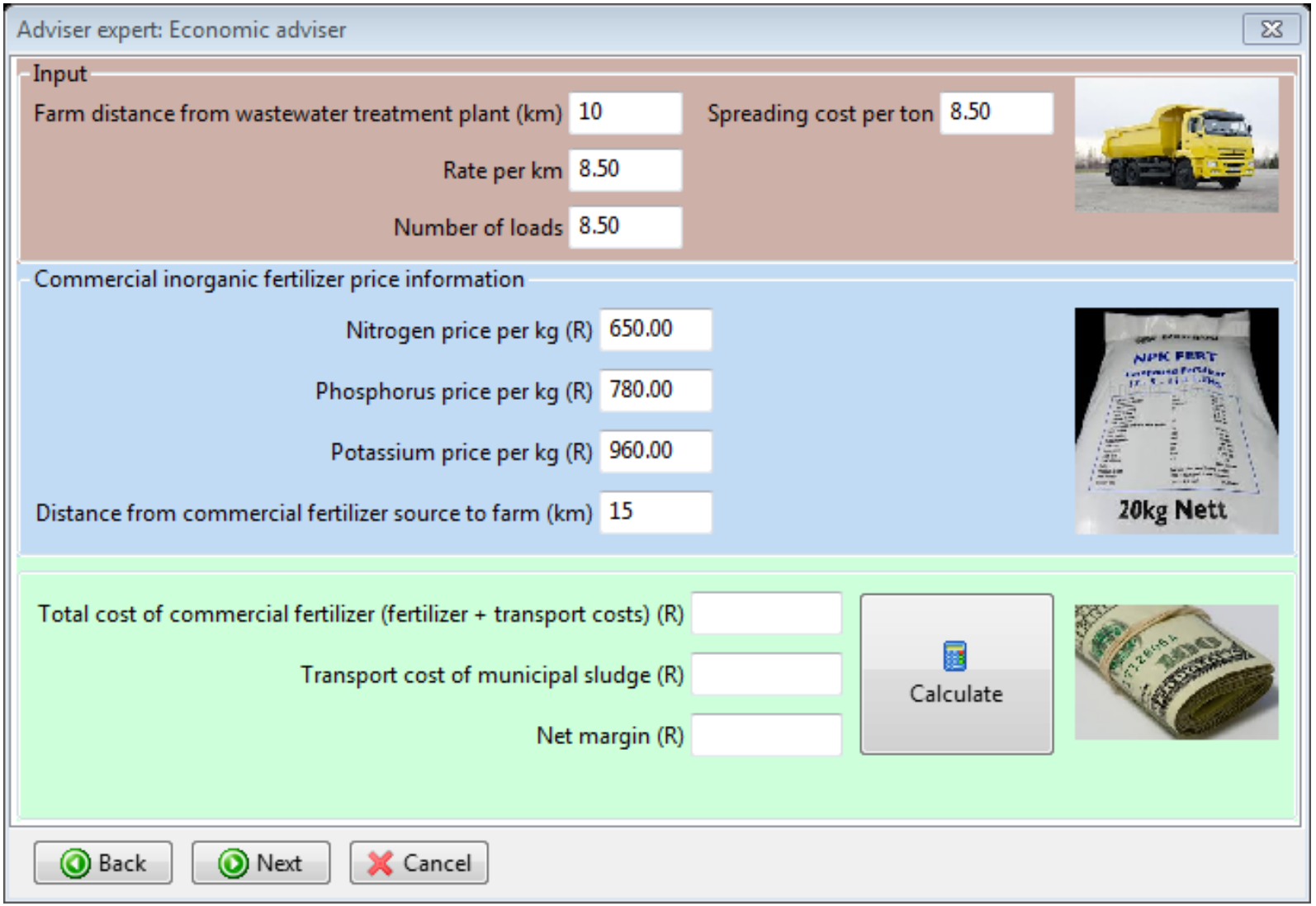
4.4 Sludge properties input nterface



4.5 Sludge and inorganic fertilizer (K) recommendation

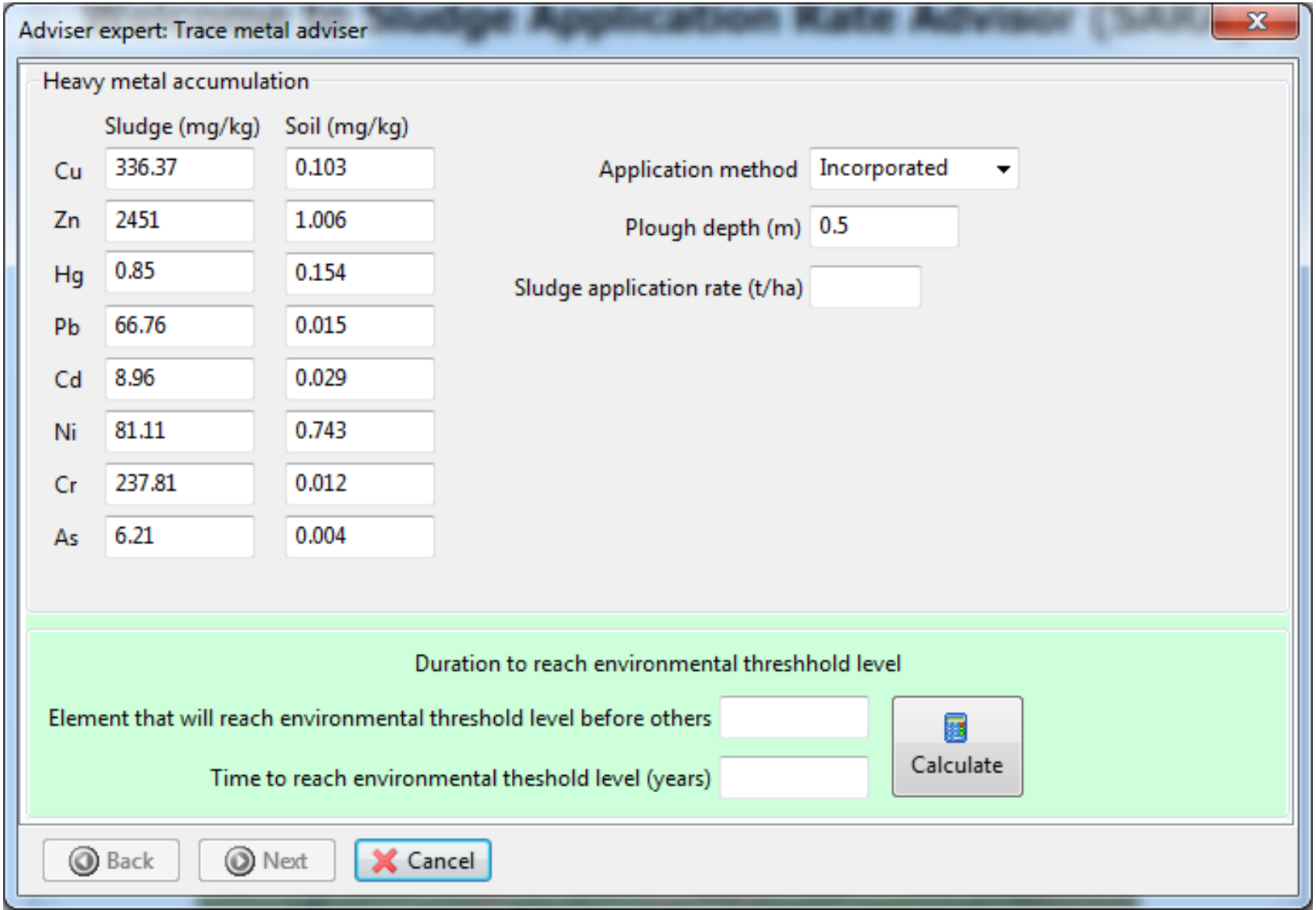


4.6 Sludge fertilizer value interface



4.7 Heavy metal accumulation interface

model



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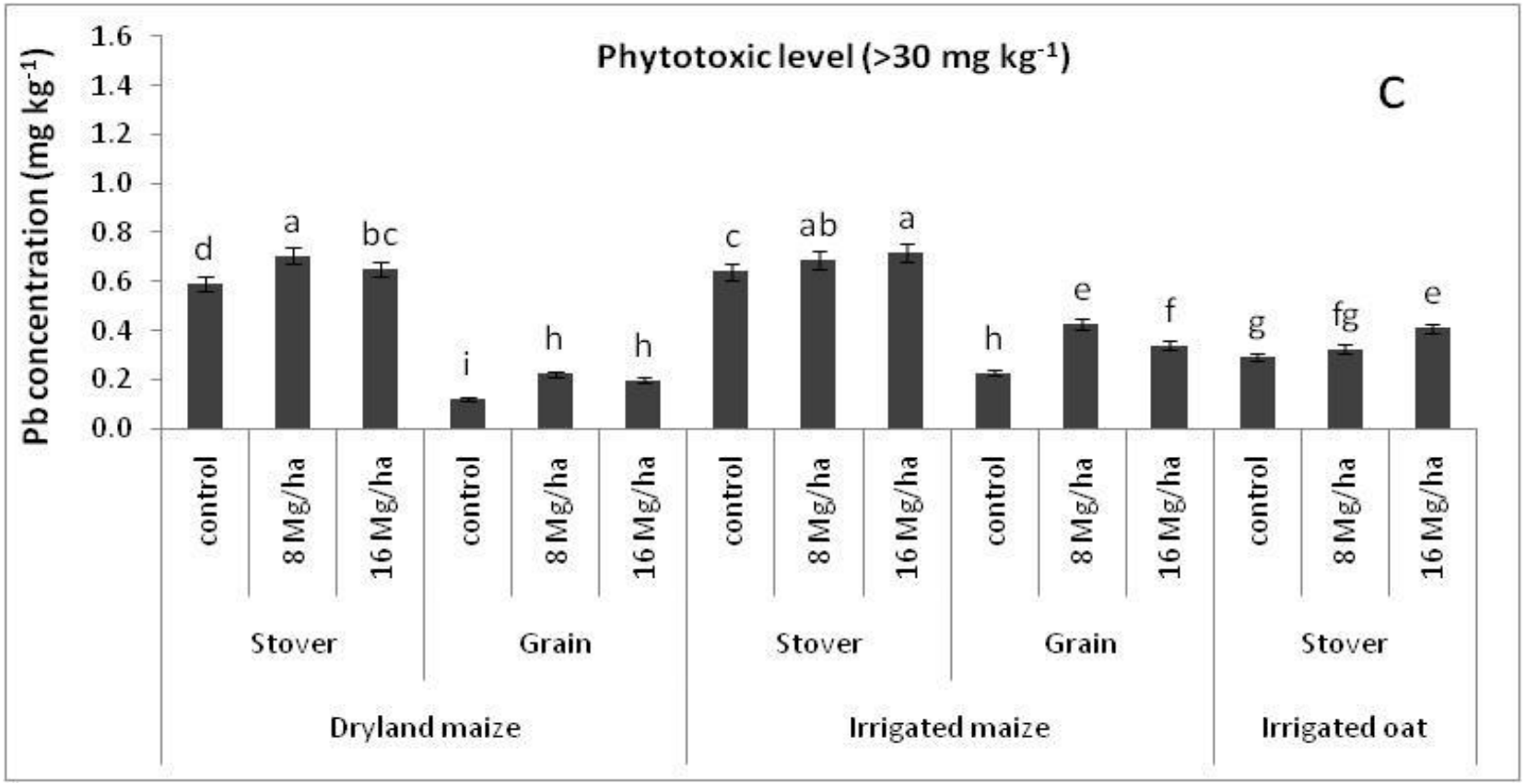
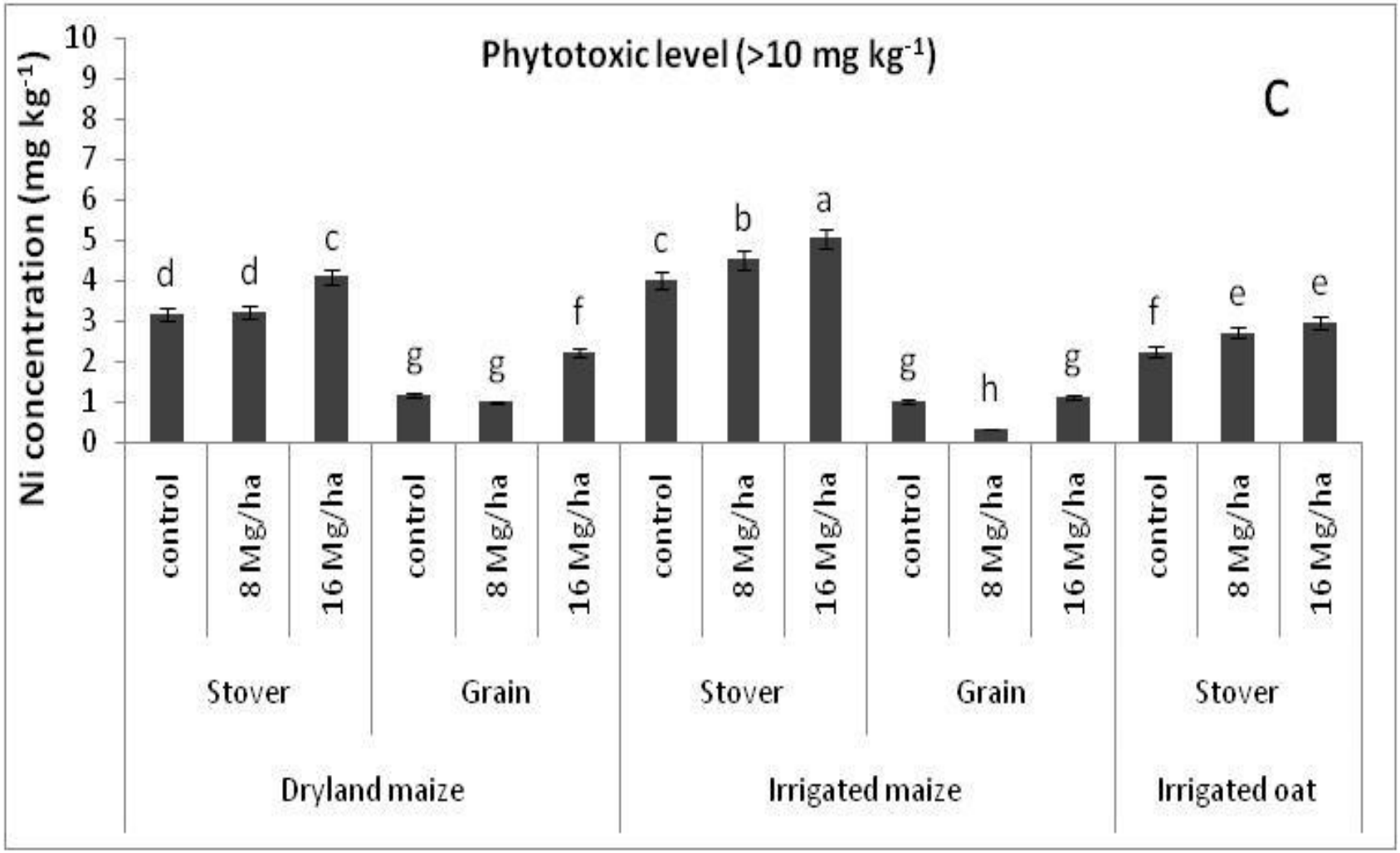
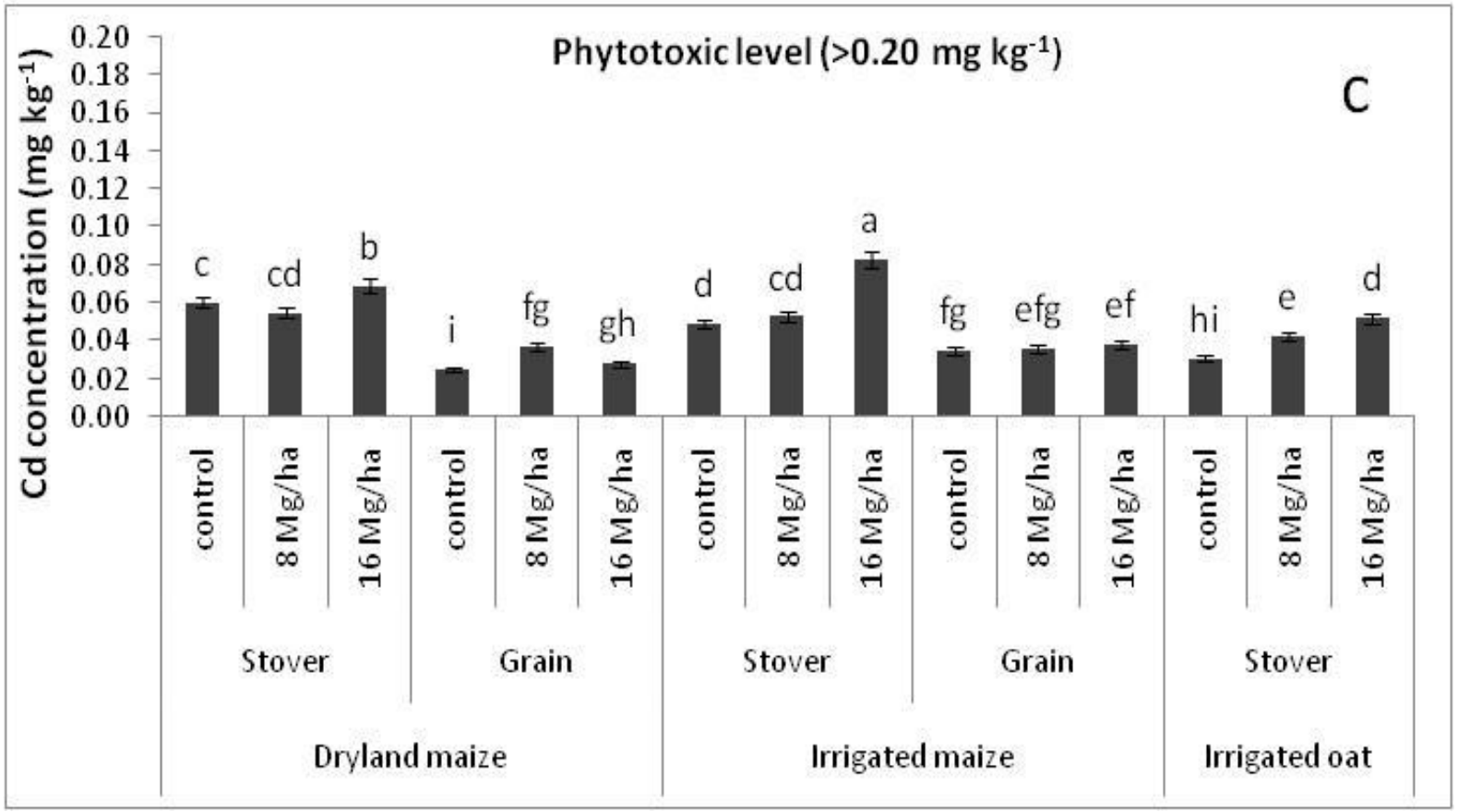
Lead


Pb concentration (mg kg-1)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Phytotoxic level (>30 mg kg-1)
C
d
a
bc
i
h
h
c
ab
a
h
e
f
g
fg
e
control
8 Mg/ha
16 Mg/ha
Stover
Grain
Dryland maize
Irrigated maize
Irrigated oat

Nickel


Phytotoxic level (>10 mg kg-1)
C
Ni concentration (mg kg-1)
10
9
8
7
6
5
4
3
2
1
0
d
d
c
g
g
f
c
b
a
g
h
g
f
e
e
control
8 Mg/ha
16 Mg/ha
Stover
Grain
Dryland maize
Irrigated maize
Irrigated oat

Cadmium


Phytotoxic level (>0.20 mg kg-1)
C
Cd concentration (mg kg-1)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
c
cd
b
i
fg
gh
d
cd
a
fg
efg
ef
hi
e
d
control
8 Mg/ha
16 Mg/ha
Stover
Grain
Dryland maize
Irrigated maize
Irrigated oat

Field experiment