

Quantifying the fertilizer value of municipal wastewater sludge



**WRC Research
Development
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Symposium &
Water-tech Summit**
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17/09/2015

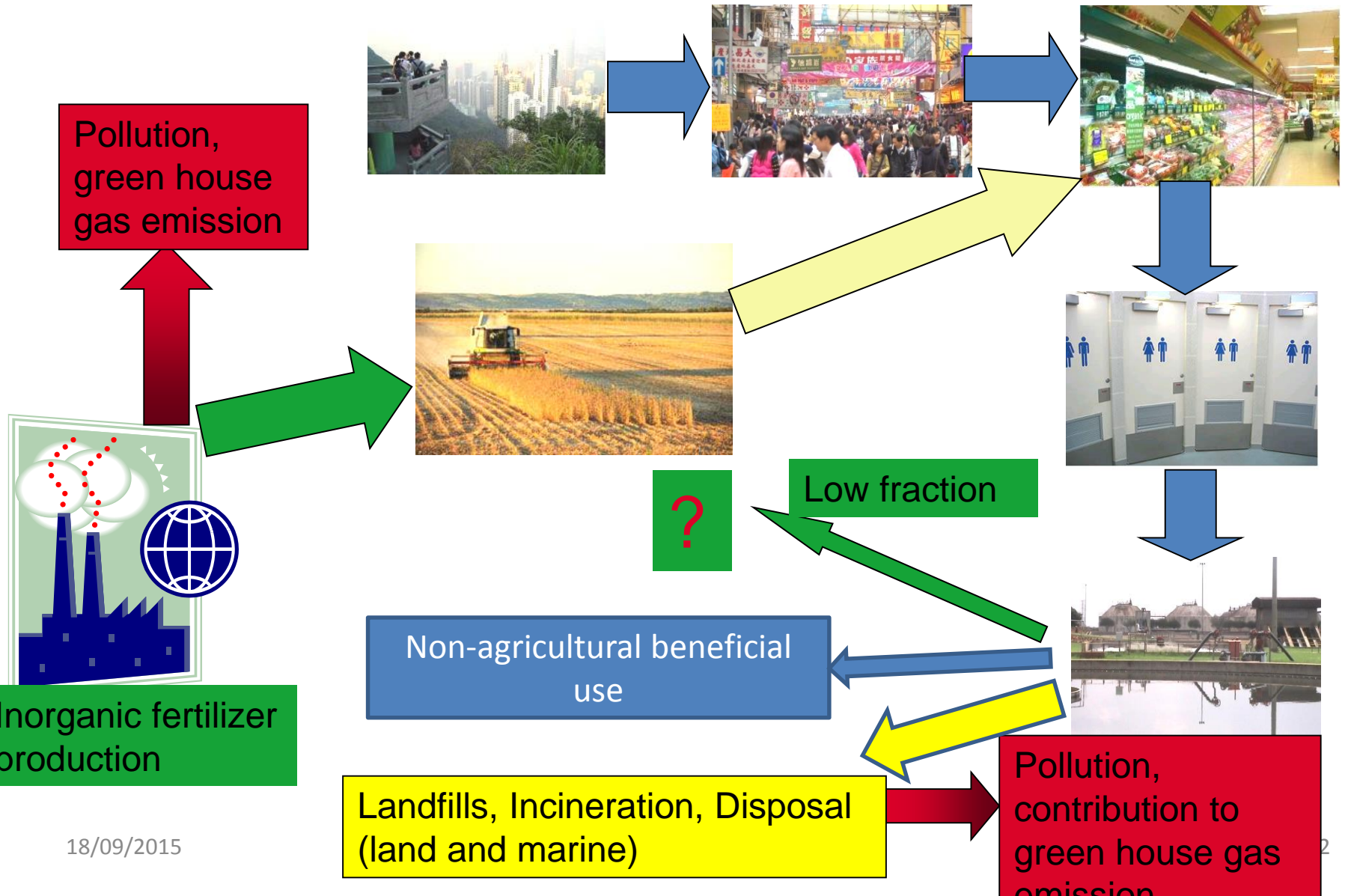
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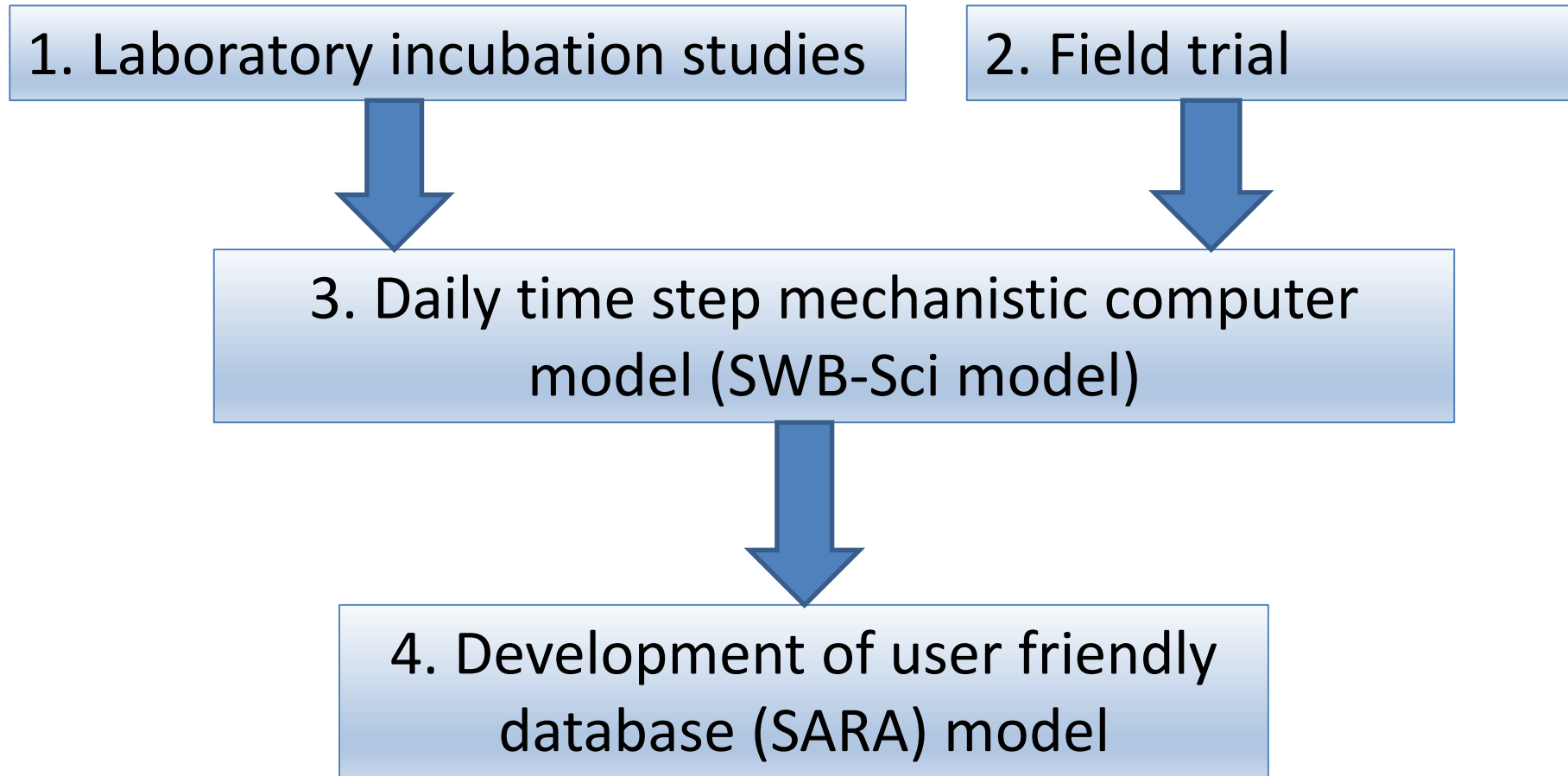
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Nutrient cycle under commercial farming



Overall view of the study in flow diagram



1. Laboratory incubation study

aim

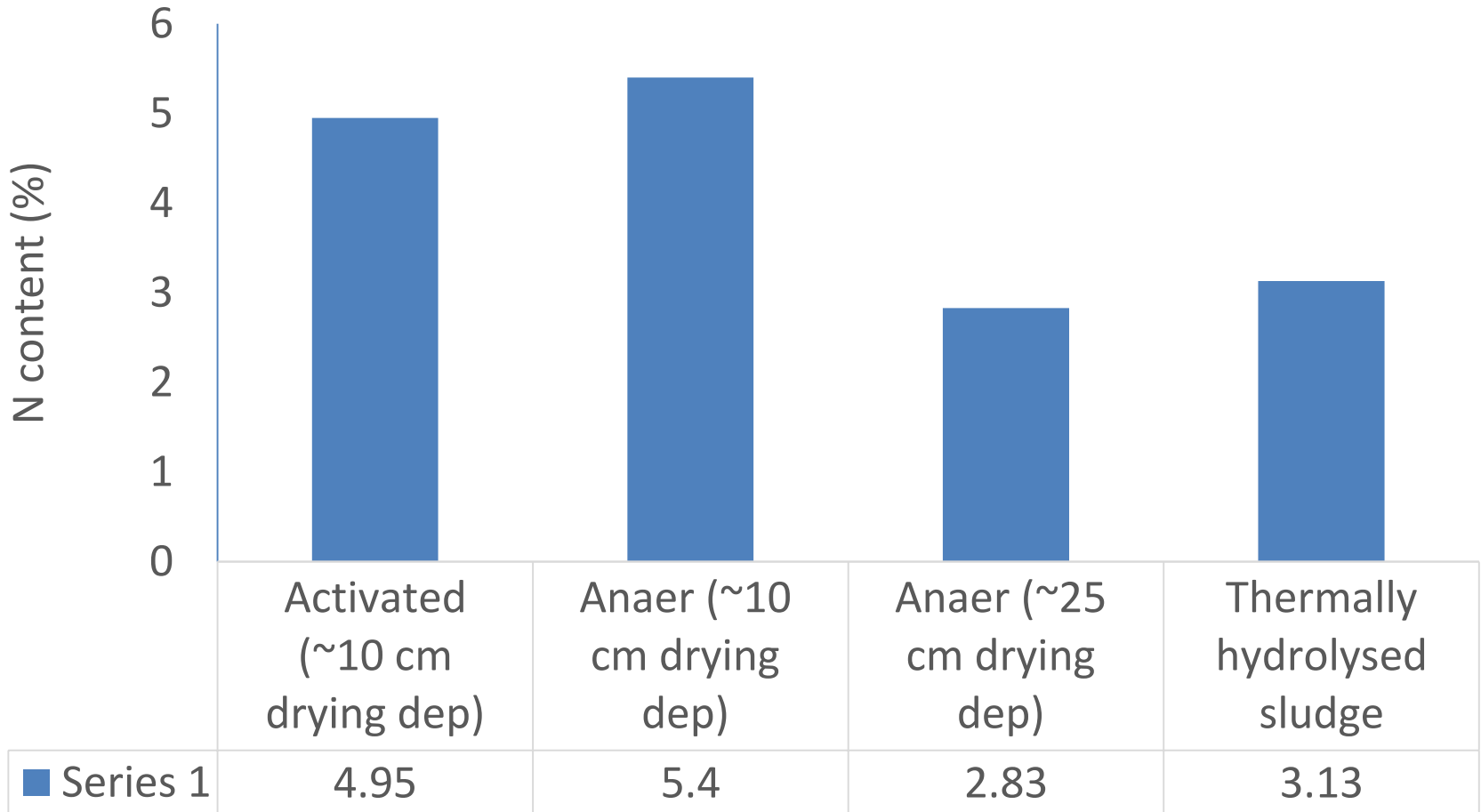
Assess the effect of wastewater treatment and post treatment dewatering techniques on:

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

Generate parameters for SWB-Sci model.

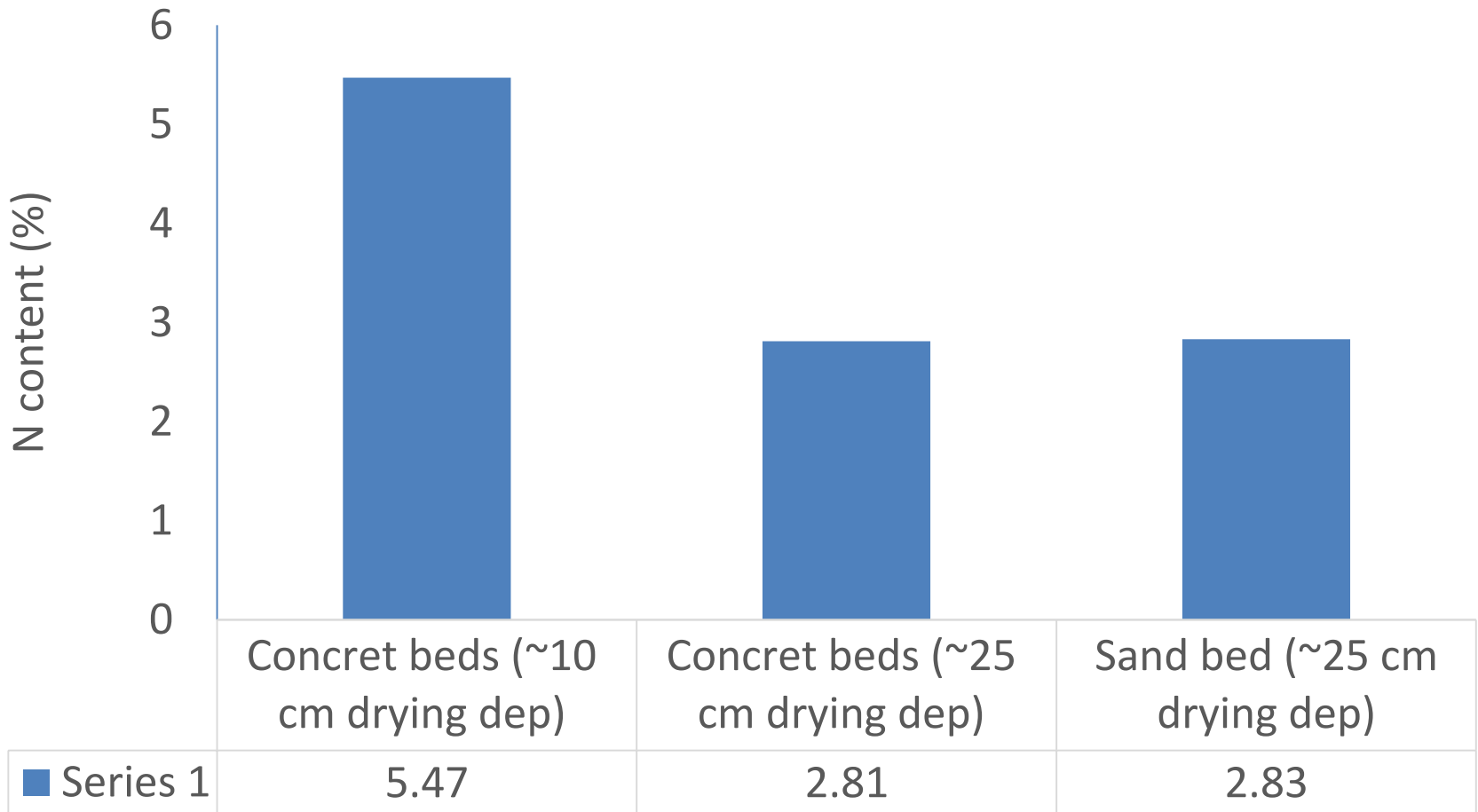
1.1 Summary of findings

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



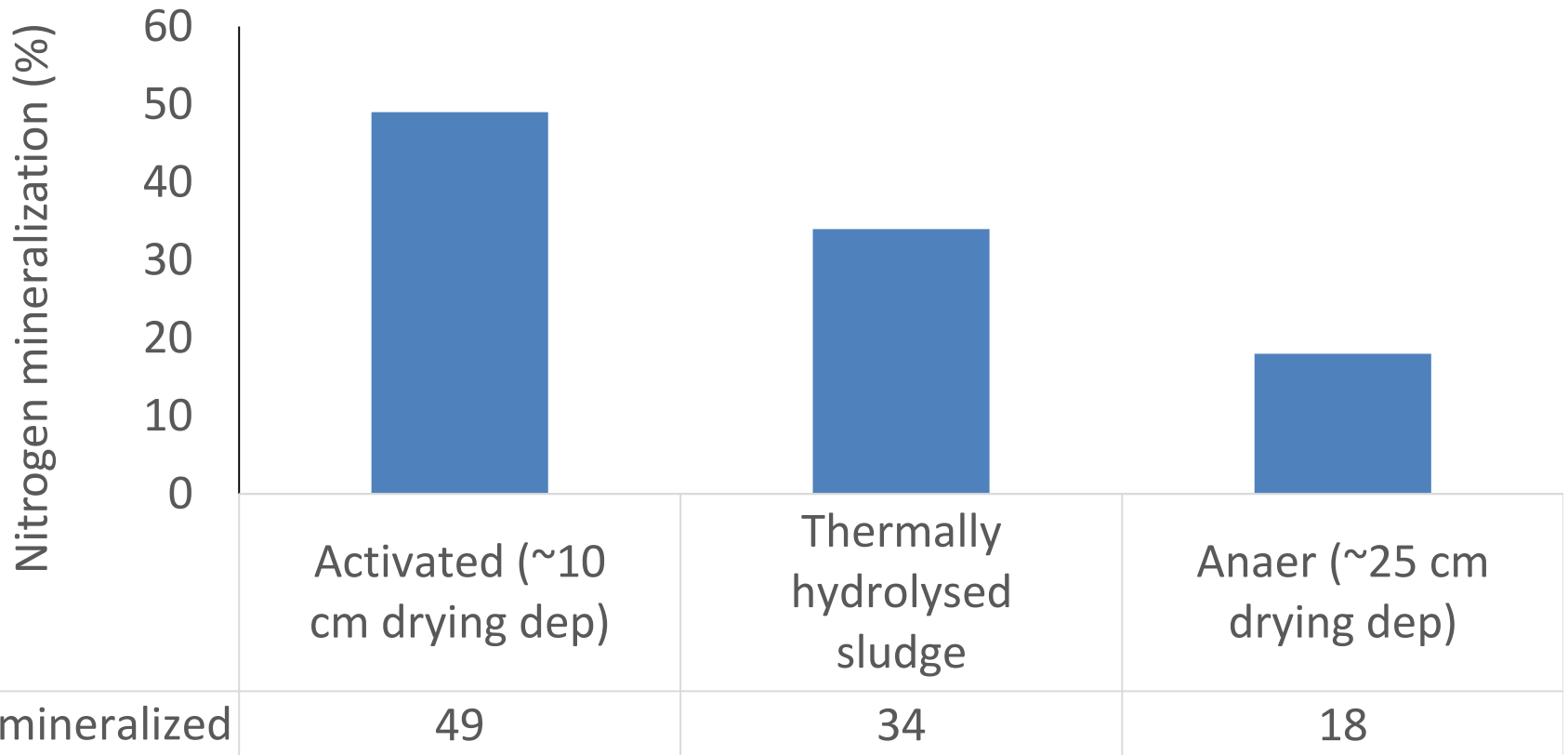
1.2 Summary of findings

- 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:**

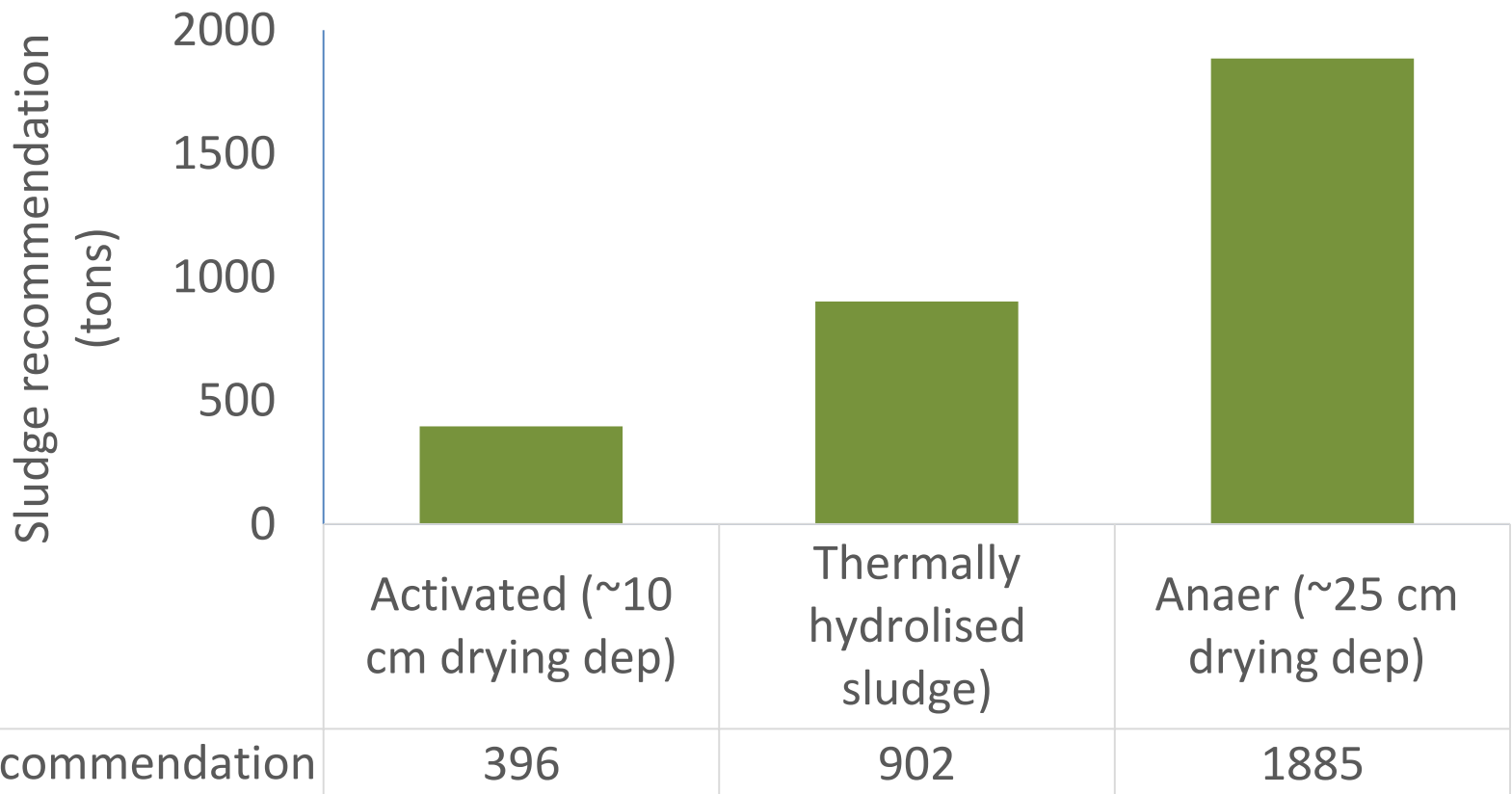


1.4 Summary of findings

- 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.

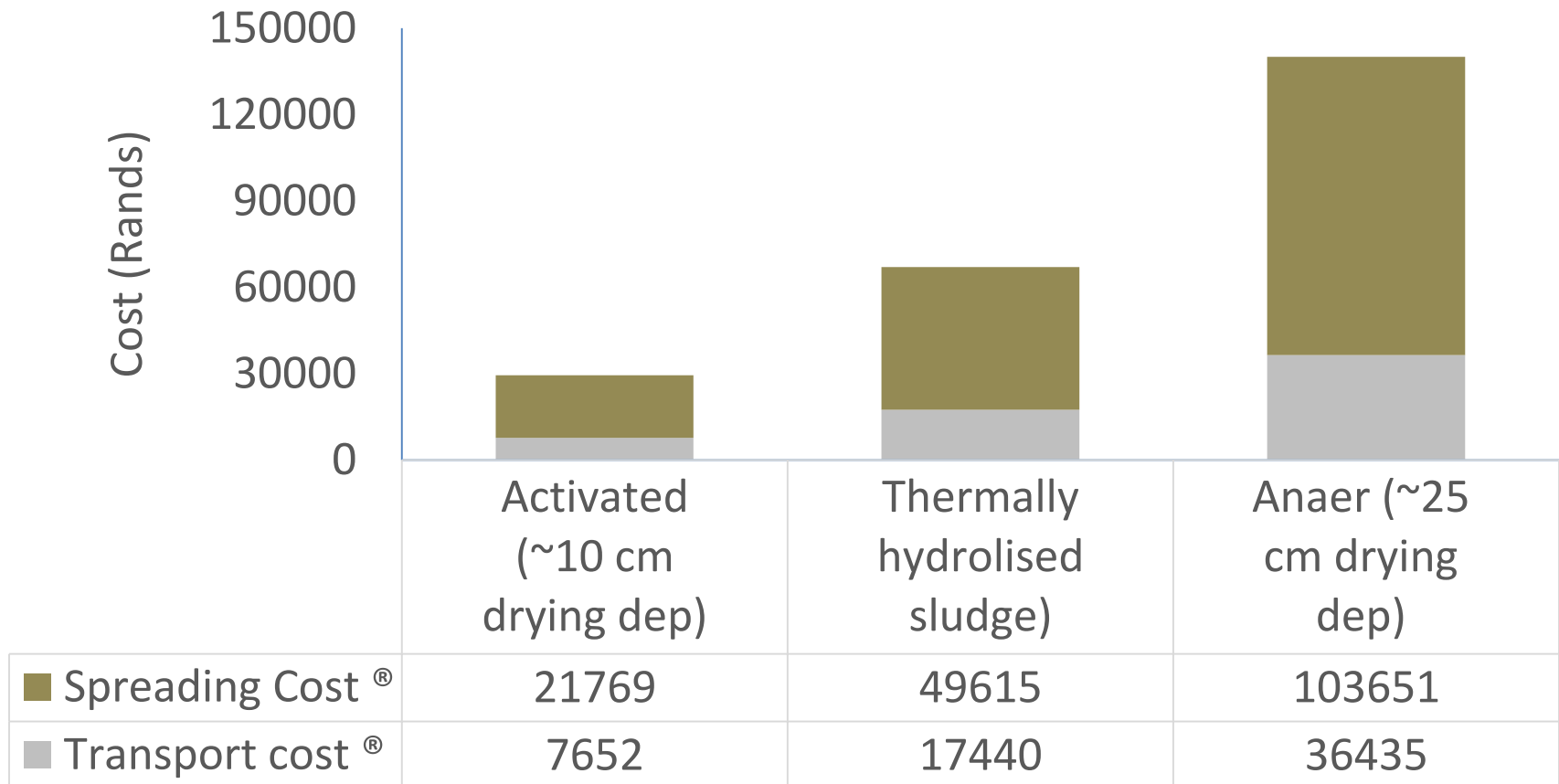
1.4.1 Summary of findings

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



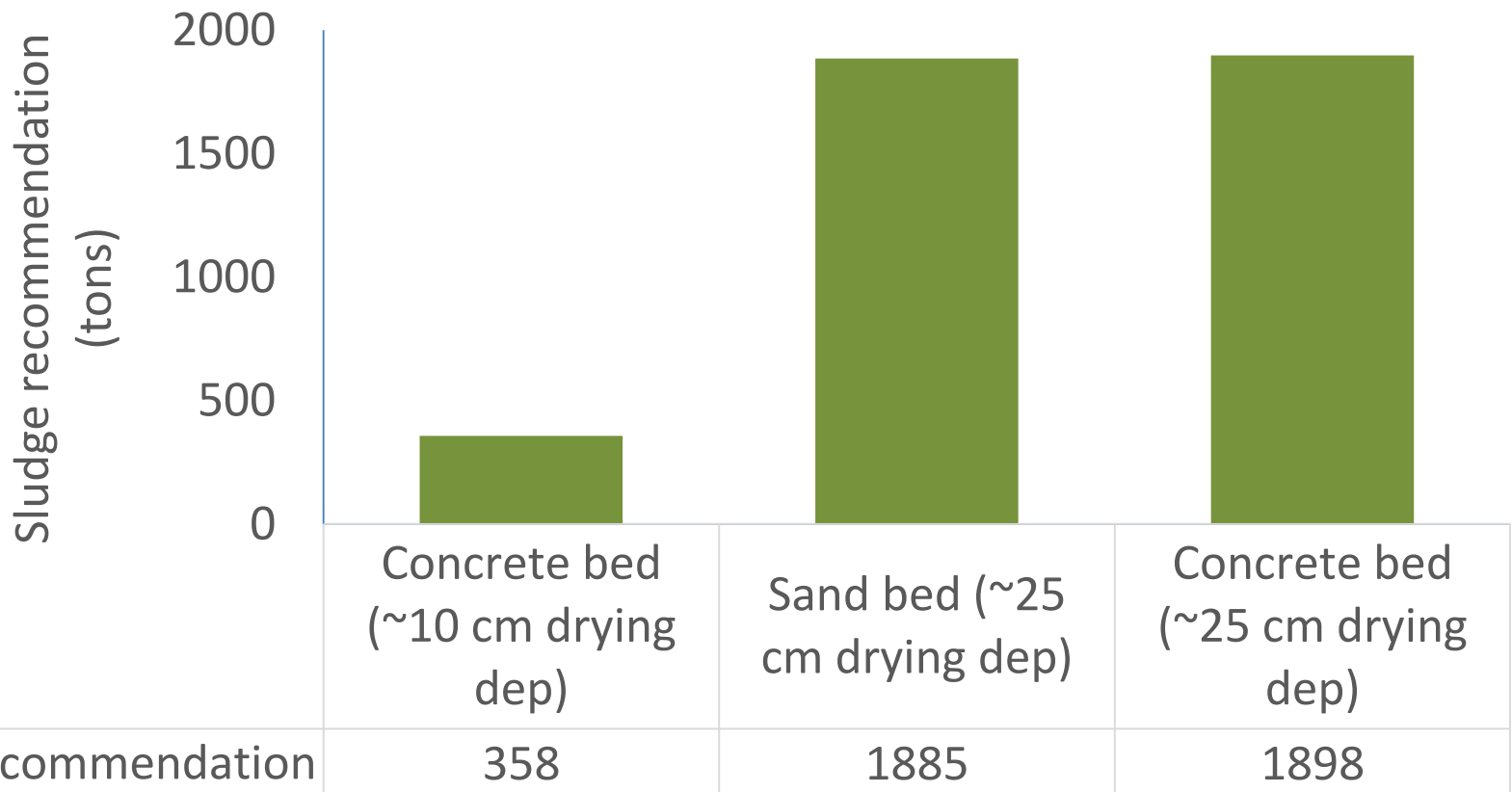
1.4.1 Summary of findings

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



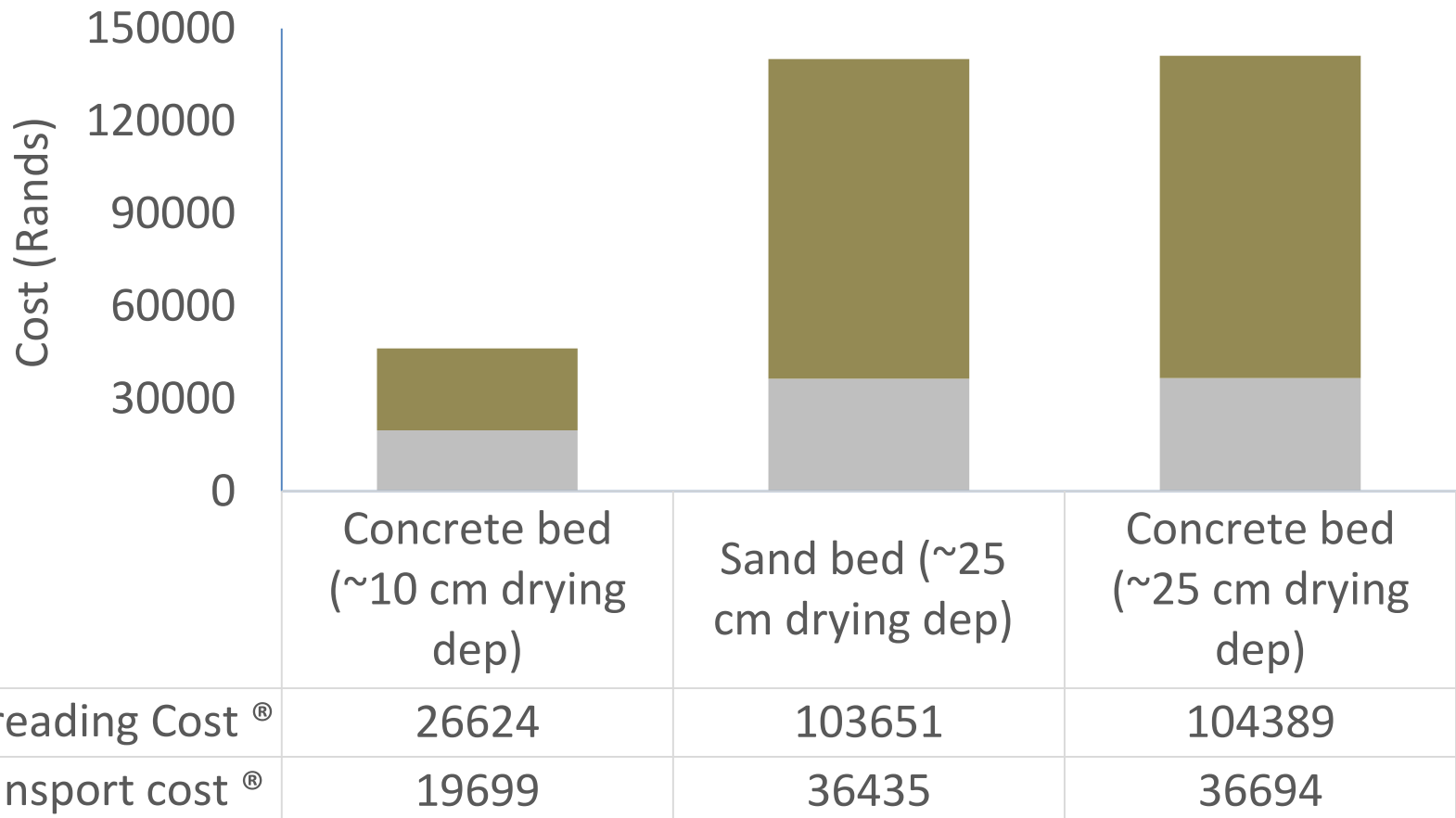
1.4.2 Summary of findings

- **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.**



1.4.2 Summary of findings

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



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 fertilizer,

To calibrate and validate the SWB-Sci model.



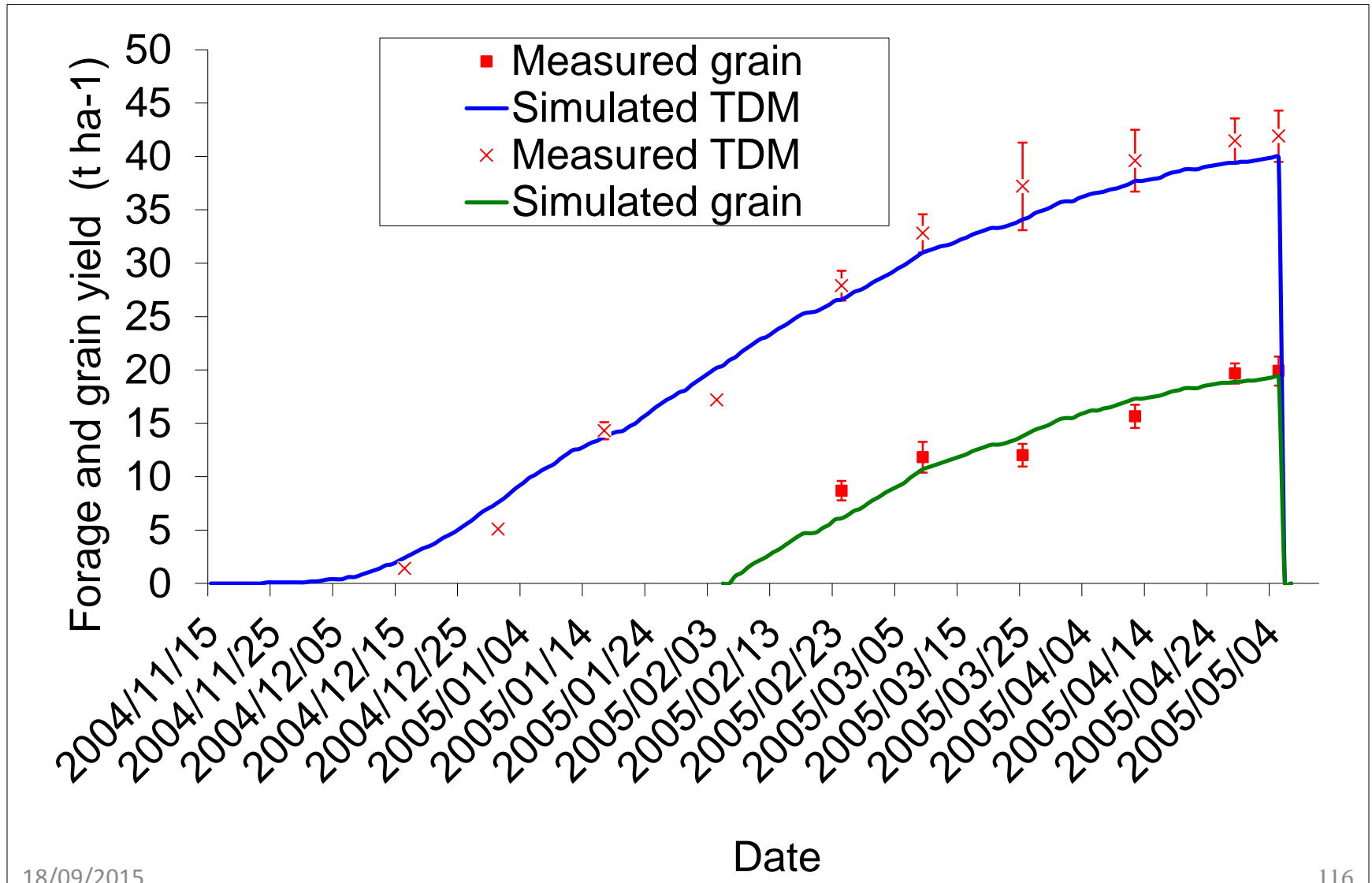
2.1 Field experiment

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



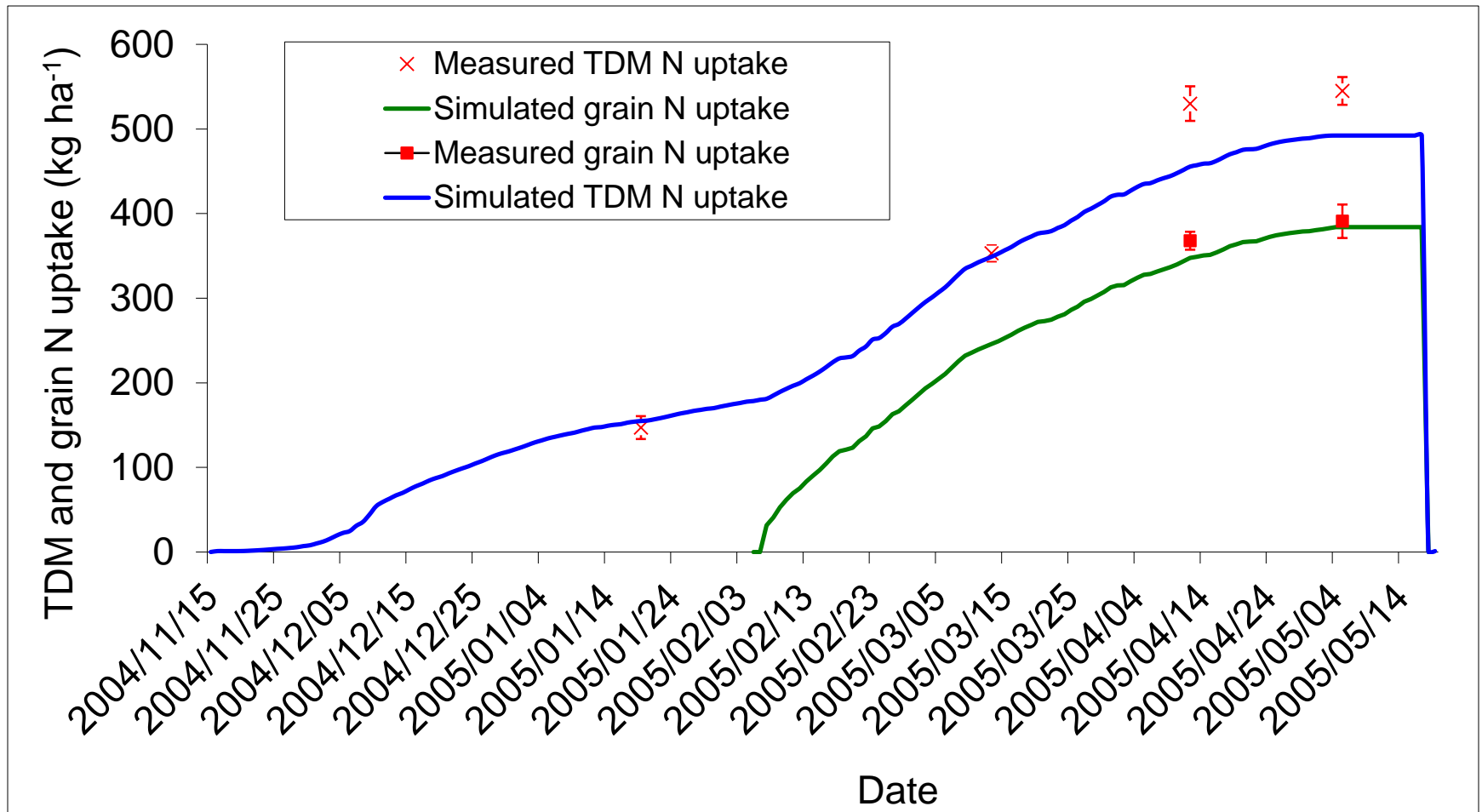
2.2 SWB-Sci model calibration

Forage and grain yield



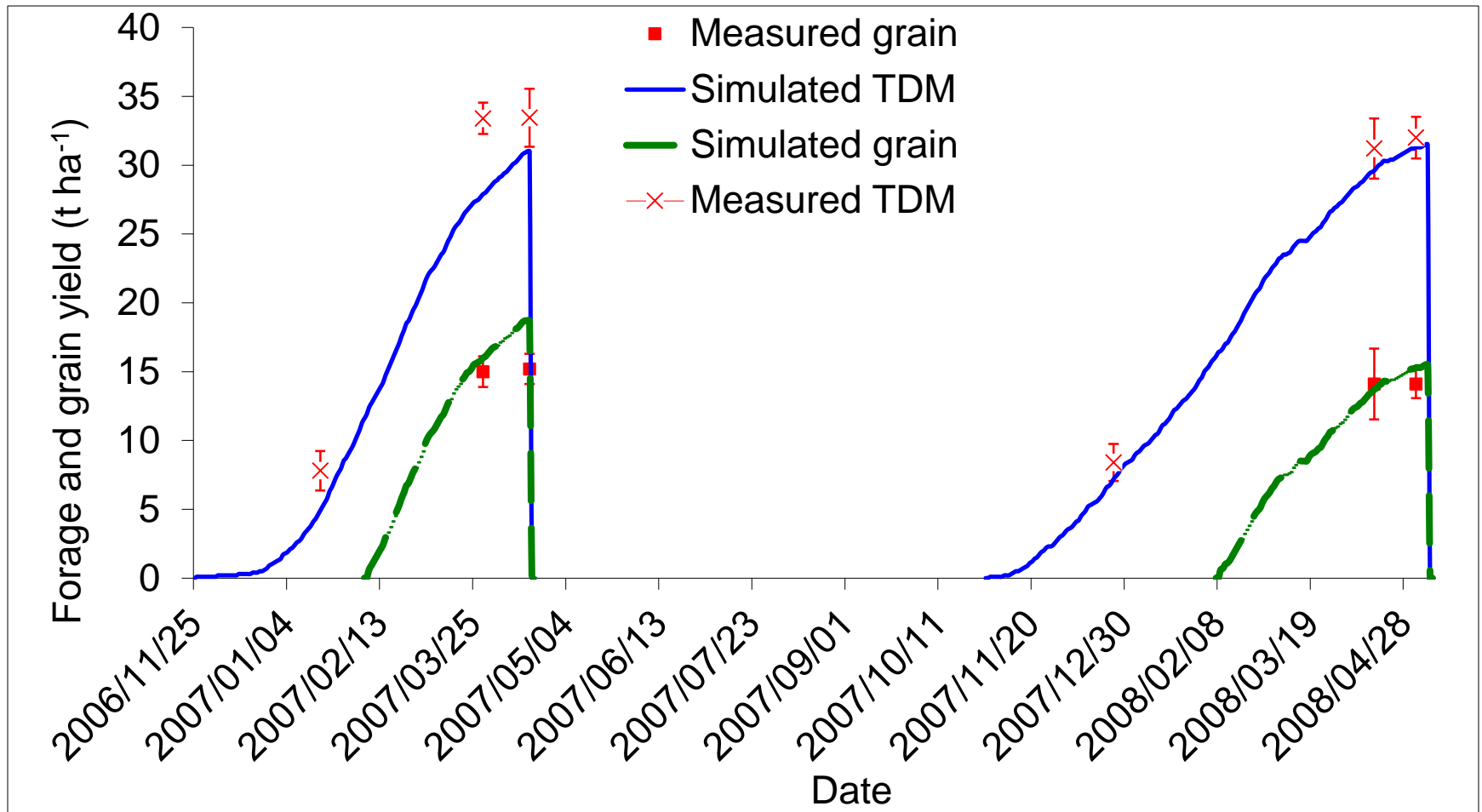
2.2 SWB-Sci model calibration

Forage and grain N uptake



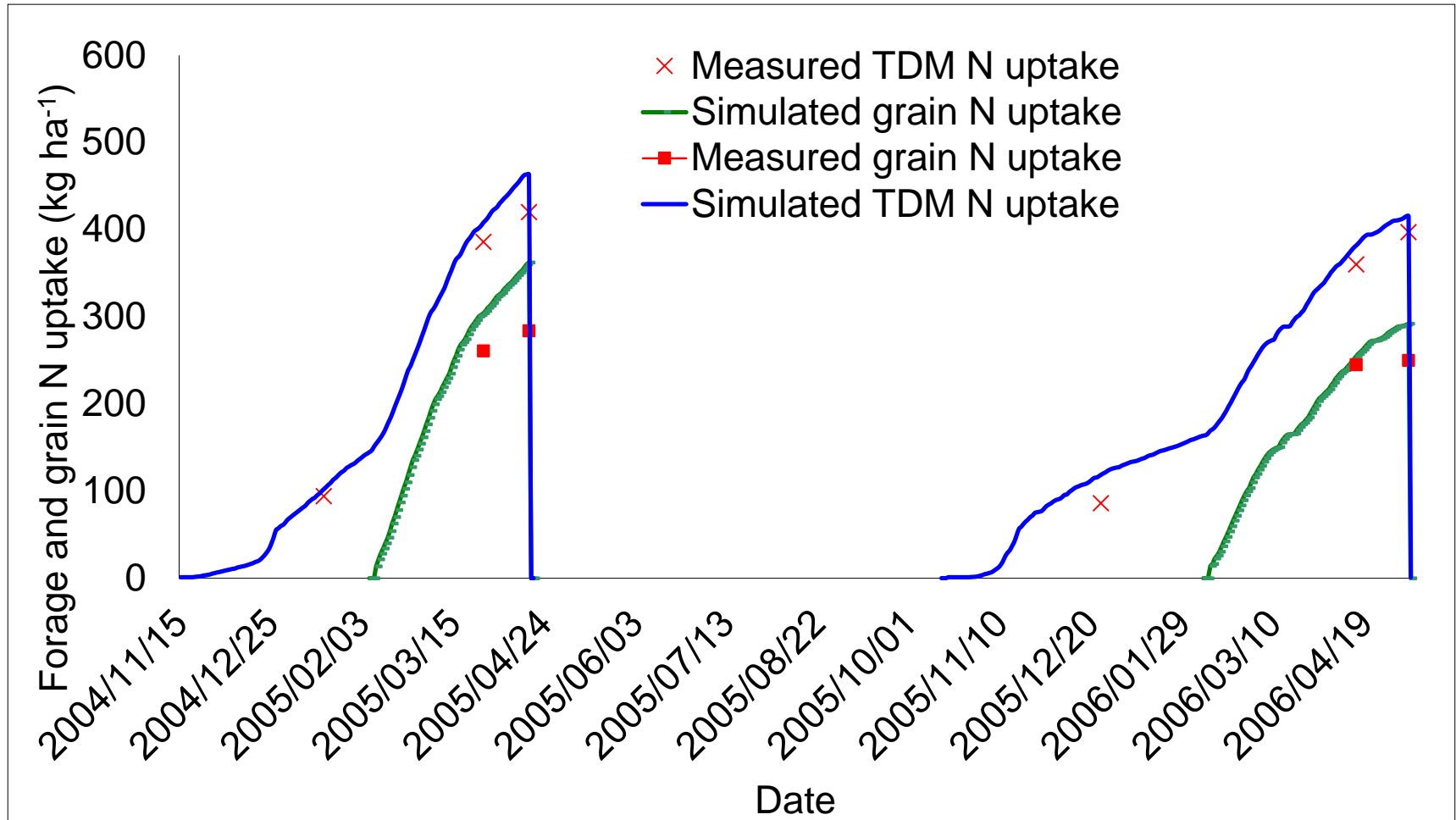
2.3 SWB-Sci model validation

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

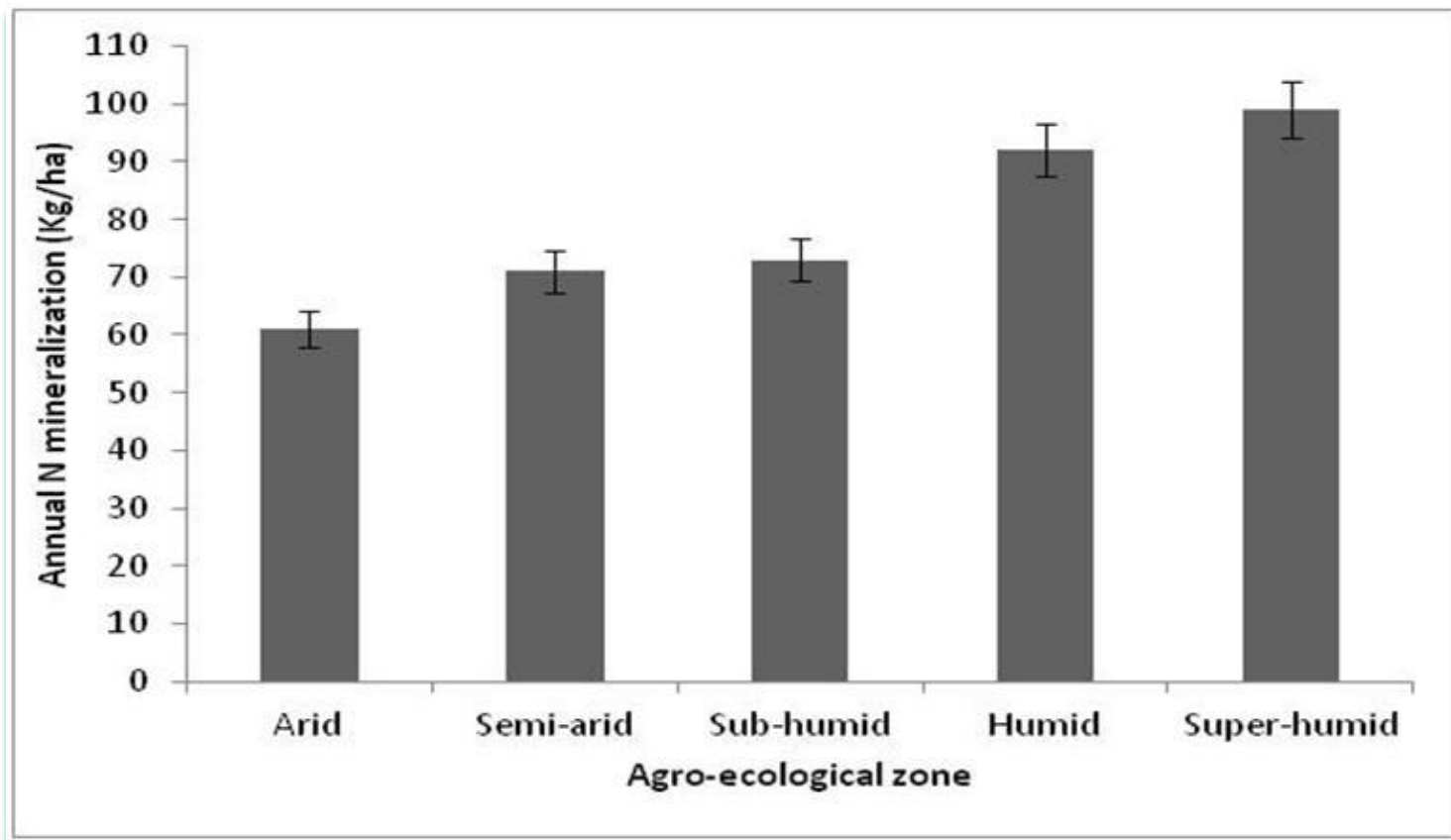
- To achieve the stated aims, the following hypotheses were tested:

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.

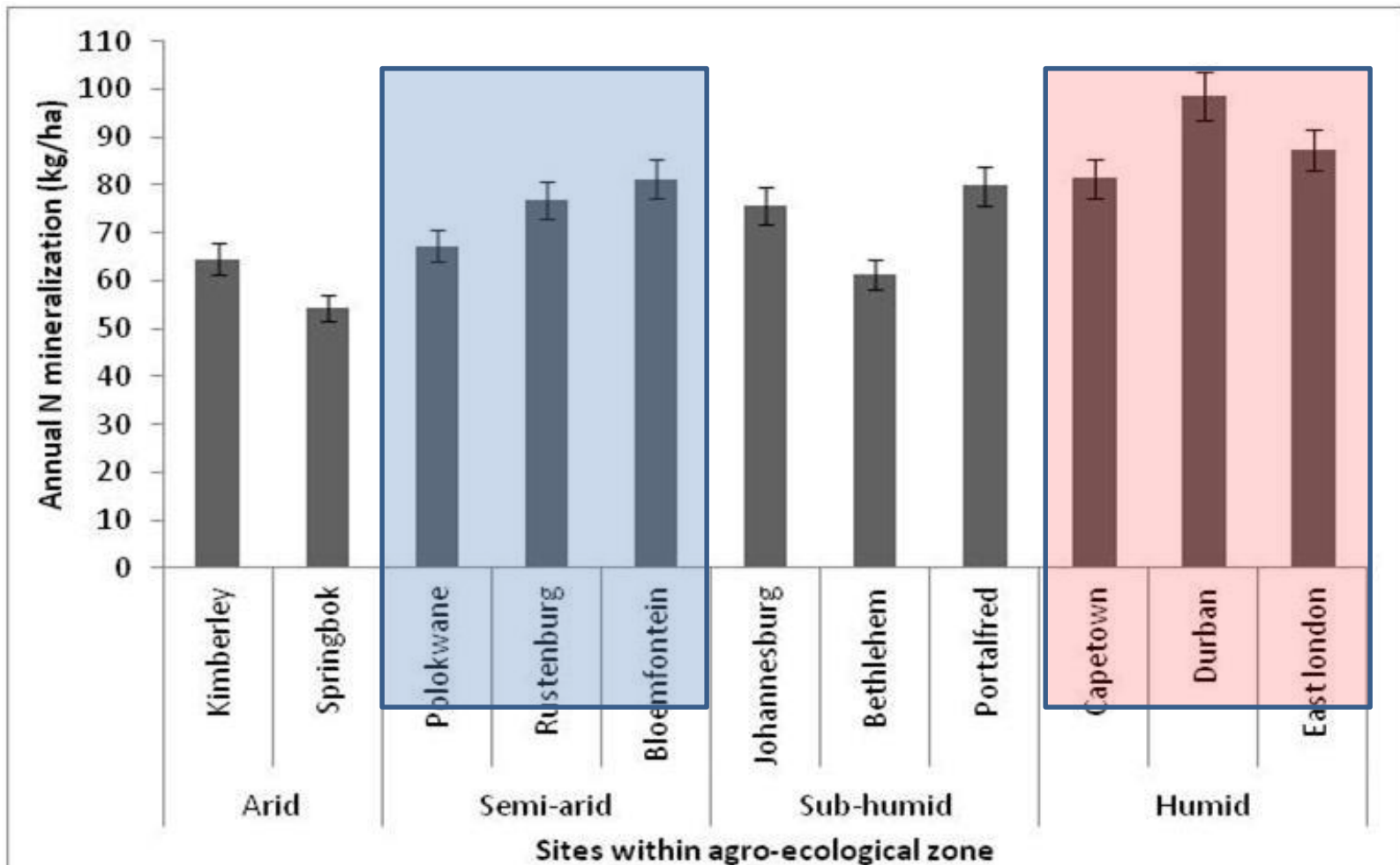
3.1 Hypotheses 1a – Can a single annual N mineralization rate be used across agro-ecological zones?

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



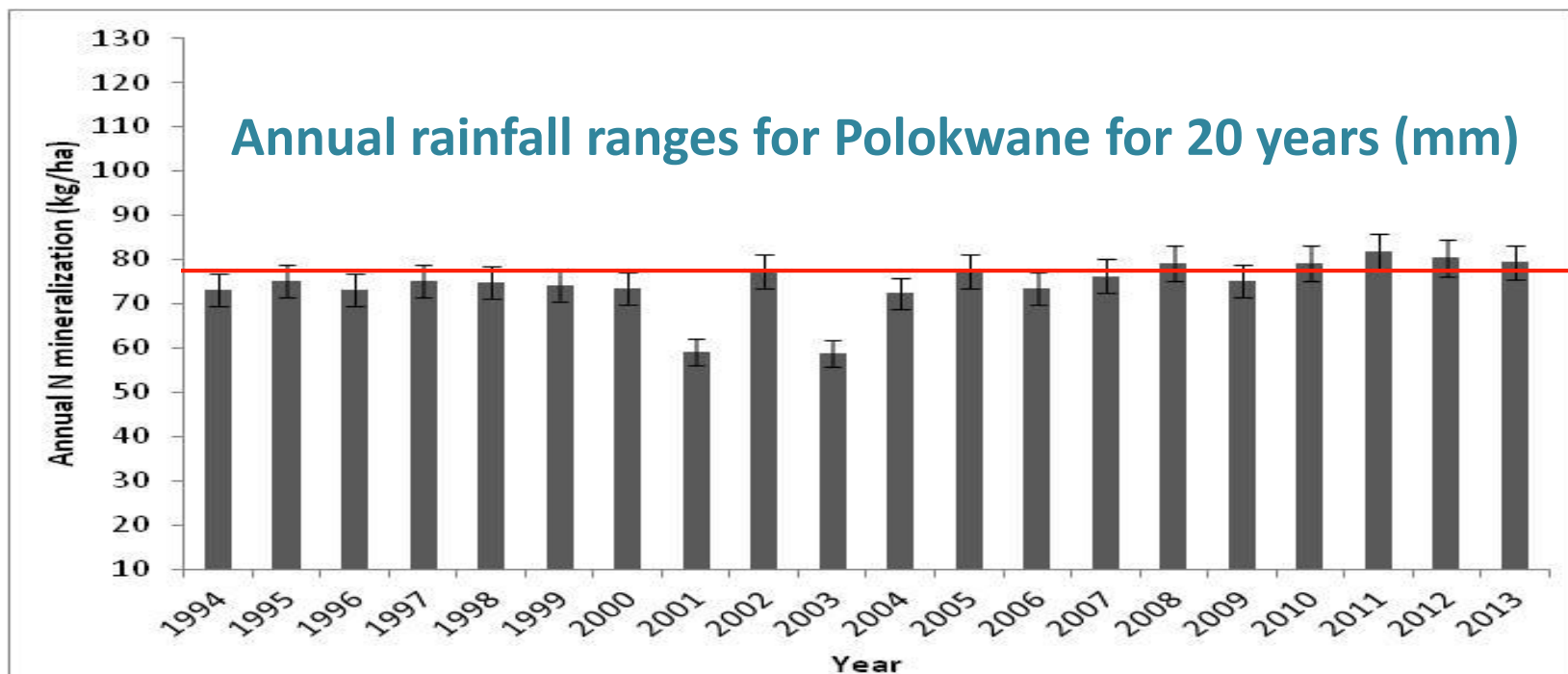
3.1 Hypothesis 1b – Can a single annual N mineralization rate be used across sites within an agro-ecological zone?

- No



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

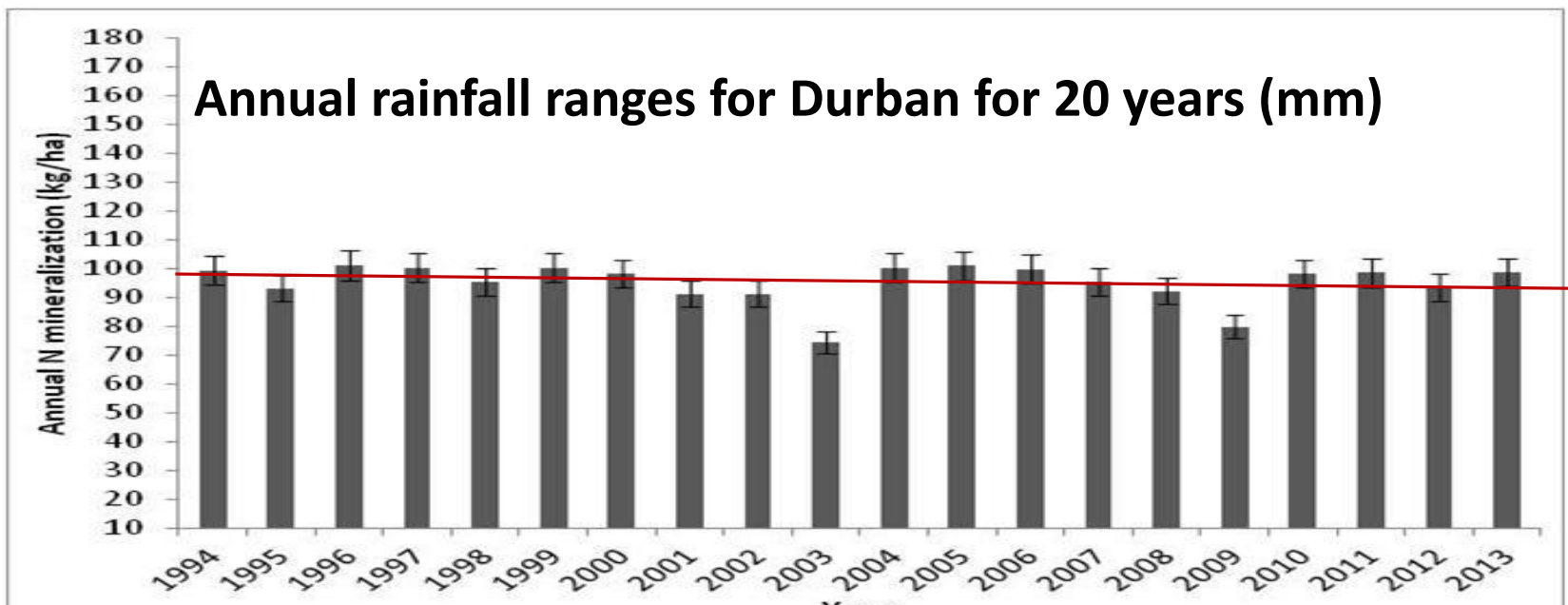
- N mineralization remained similar for 80% of the years.
 - Exceptions - anomalous dry years.
- Therefore site specific generic annual N mineralization rate can be used.



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

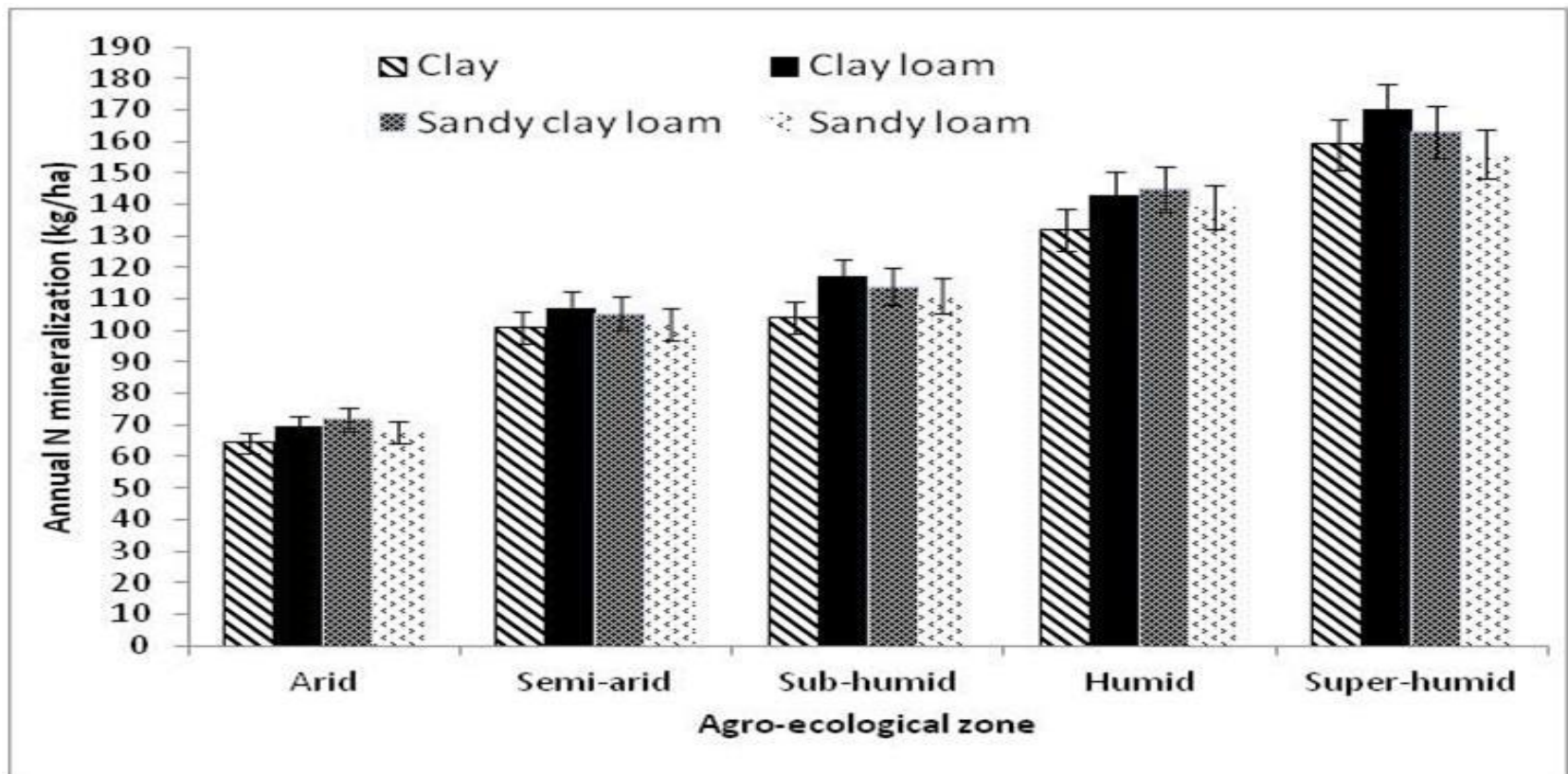
- N mineralization remained similar for 80% of the years.
 - Exceptions - anomalous dry years.
- Therefore site specific generic annual N mineralization rate can be used.



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

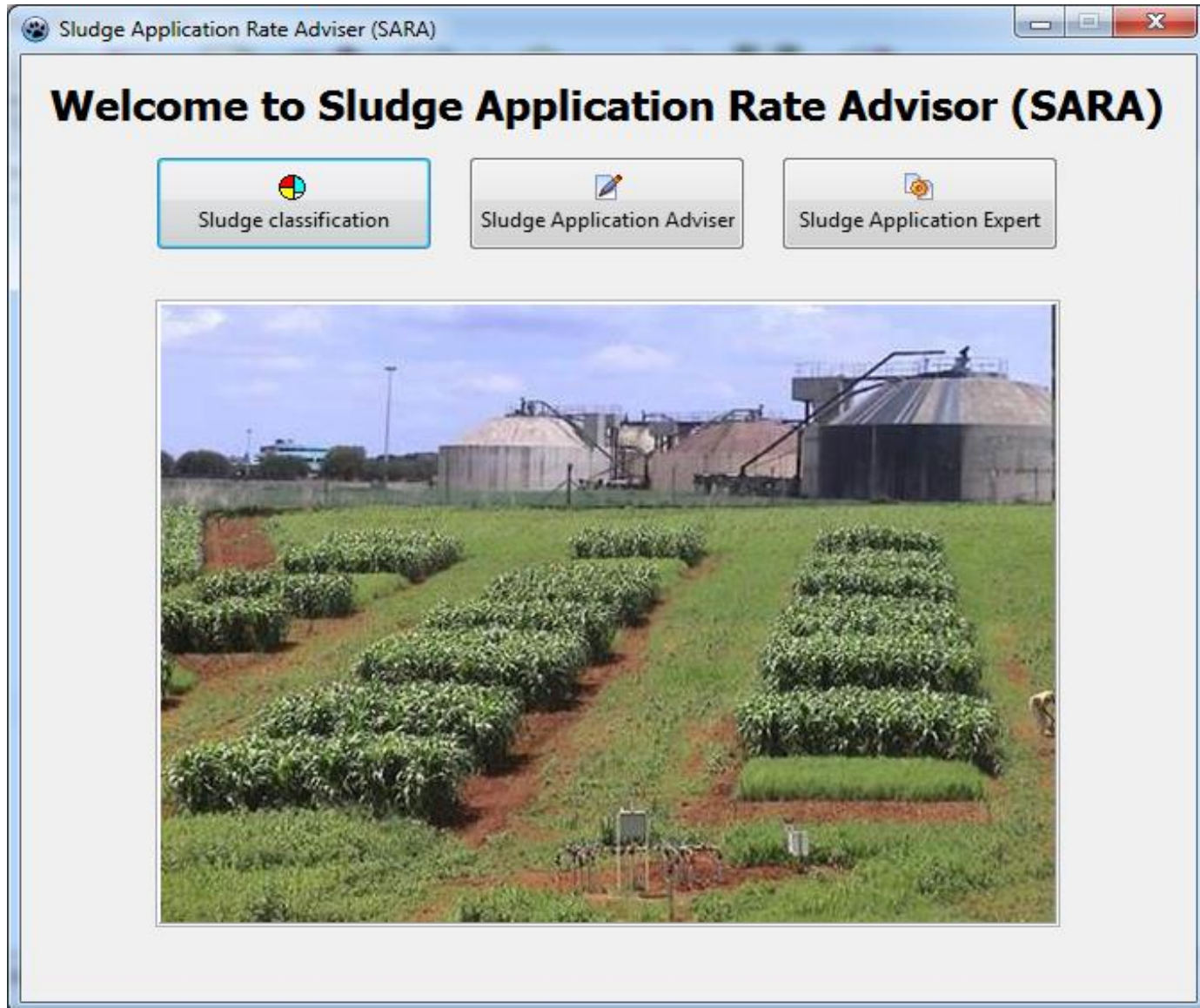
Estimate crop and site specific sludge application rate recommendations,

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

Sludge classification

Microbial class


Faecal coliforms

Helminth ova




Pollutant class

As	<input type="text" value="35"/>	Cr	<input type="text" value="1000"/>	Pb	<input type="text" value="250"/>	Ni	<input type="text" value="400"/>
Cd	<input type="text" value="35"/>	Cu	<input type="text" value="1400"/>	Hg	<input type="text" value="10"/>	Zn	<input type="text" value="2500"/>



Stability class

1	2	3	
Comply with one of the options listed below on a 90 percentile basis	Comply with one of the options listed below on a 75 percentile basis	No stabilisation or vector attraction reduction options	

Option 1: Reduce the mass of volatile solids by a minimum of 38 percent
Option 2: Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit
Option 3: Demonstrate vector attraction reduction with additional aerobic digestion in a bench-scale unit
Option 4: Meet a specific oxygen uptake rate for aerobically treated sludge
Option 5: Use aerobic processes at a temperature greater than 40 C (average temperature 45 C) for 14 days or longer (eg during sludge composting)
Option 6: Add alkaline material to raise the pH under specific conditions
Option 7: Reduce moisture content of sludge that do not contain unstabilised solids (from treatment processes other than primary treatment) to at least 75 percent solids
Option 8: Reduce moisture content of sludge with unstabilised solids to at least 90 percent solids
Option 9: Inject sludge beneath the soil surface within a specified time, depending on the level of pathogen treatment
Option 10: Incorporate sludge applied to or placed on the surface of the land within specified time periods after application to or placement on the surface of the land

Sludge class

A1a

4.3 Farm, farmer and field entry interface

Adviser expert: Field ✕

Fields

Farm-id Field-id

Province City

Farmer's name

Farm size (ha)

Crop Target yield (t/ha)

Cropping system

Sludge application method

4.4 Field soil information input interface

Adviser expert: Soil ✕

Soil

Soil textural class

Soil bulk density

Clay (%)

Soil Nitrate & Ammonium (mg/kg)

Ammonium acetate extractable potassium (mg/kg)

Soil plant available Phosphorus (mg/kg) Analytical method

4.4 Sludge properties input nterface

Adviser expert: Sludge ✕

Sludge

Application year

Application round

Sludge type

Water content (%)

Total Nitrogen content (%)

Nitrate content (mg/kg)

Ammonium content (mg/kg)

Phosphorus content (%)

Potassium content (%)

4.5 Sludge and inorganic fertilizer (K) recommendation

Adviser expert: Recommendation

Farm-id	Field-id	Farm name	Year	Round	Type	Moist
1	1	John	2014	1st year	Anaerobically digested paddy dried for more than 20 days	
1	2	John	2014	1st year	Anaerobically digested paddy dried for 10 or less days	

Sludge (ton) 370.5 Potassium (ton) 1.4

Back Next Cancel

4.6 Sludge fertilizer value interface


Adviser expert: Economic adviser ✕

Input

Farm distance from wastewater treatment plant (km) Spreading cost per ton

Rate per km

Number of loads




Commercial inorganic fertilizer price information

Nitrogen price per kg (R)

Phosphorus price per kg (R)

Potassium price per kg (R)

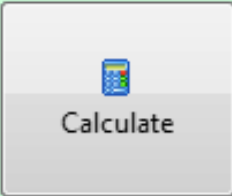
Distance from commercial fertilizer source to farm (km)




Total cost of commercial fertilizer (fertilizer + transport costs) (R)

Transport cost of municipal sludge (R)

Net margin (R)

 **Calculate**



4.7 Heavy metal accumulation interface

model

Adviser expert: Trace metal adviser

Heavy metal accumulation

	Sludge (mg/kg)	Soil (mg/kg)	
Cu	<input type="text" value="336.37"/>	<input type="text" value="0.103"/>	Application method <input type="text" value="Incorporated"/>
Zn	<input type="text" value="2451"/>	<input type="text" value="1.006"/>	Plough depth (m) <input type="text" value="0.5"/>
Hg	<input type="text" value="0.85"/>	<input type="text" value="0.154"/>	Sludge application rate (t/ha) <input type="text"/>
Pb	<input type="text" value="66.76"/>	<input type="text" value="0.015"/>	
Cd	<input type="text" value="8.96"/>	<input type="text" value="0.029"/>	
Ni	<input type="text" value="81.11"/>	<input type="text" value="0.743"/>	
Cr	<input type="text" value="237.81"/>	<input type="text" value="0.012"/>	
As	<input type="text" value="6.21"/>	<input type="text" value="0.004"/>	

Duration to reach environmental threshold level

Element that will reach environmental threshold level before others

Time to reach environmental threshold level (years)



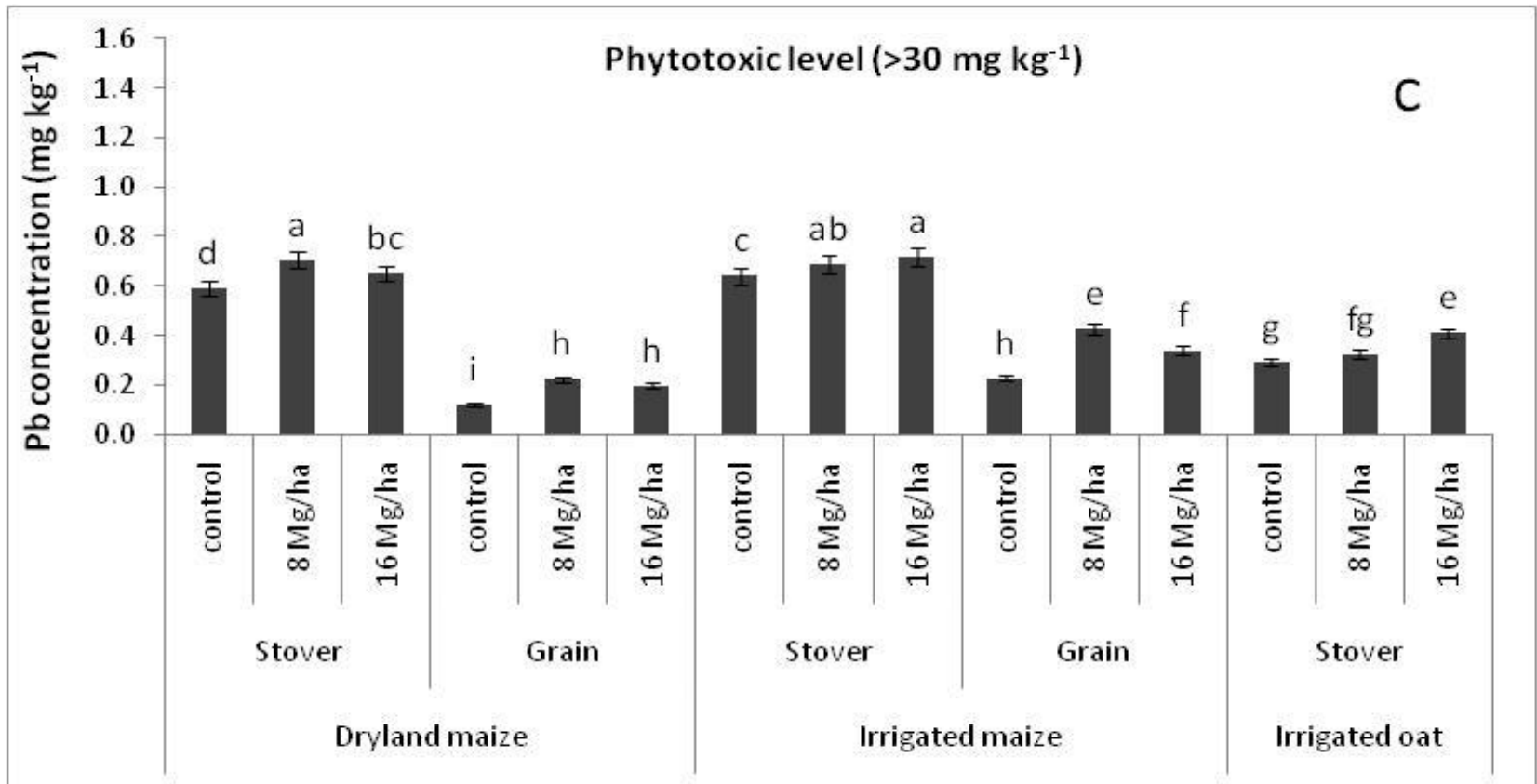
THANK YOU



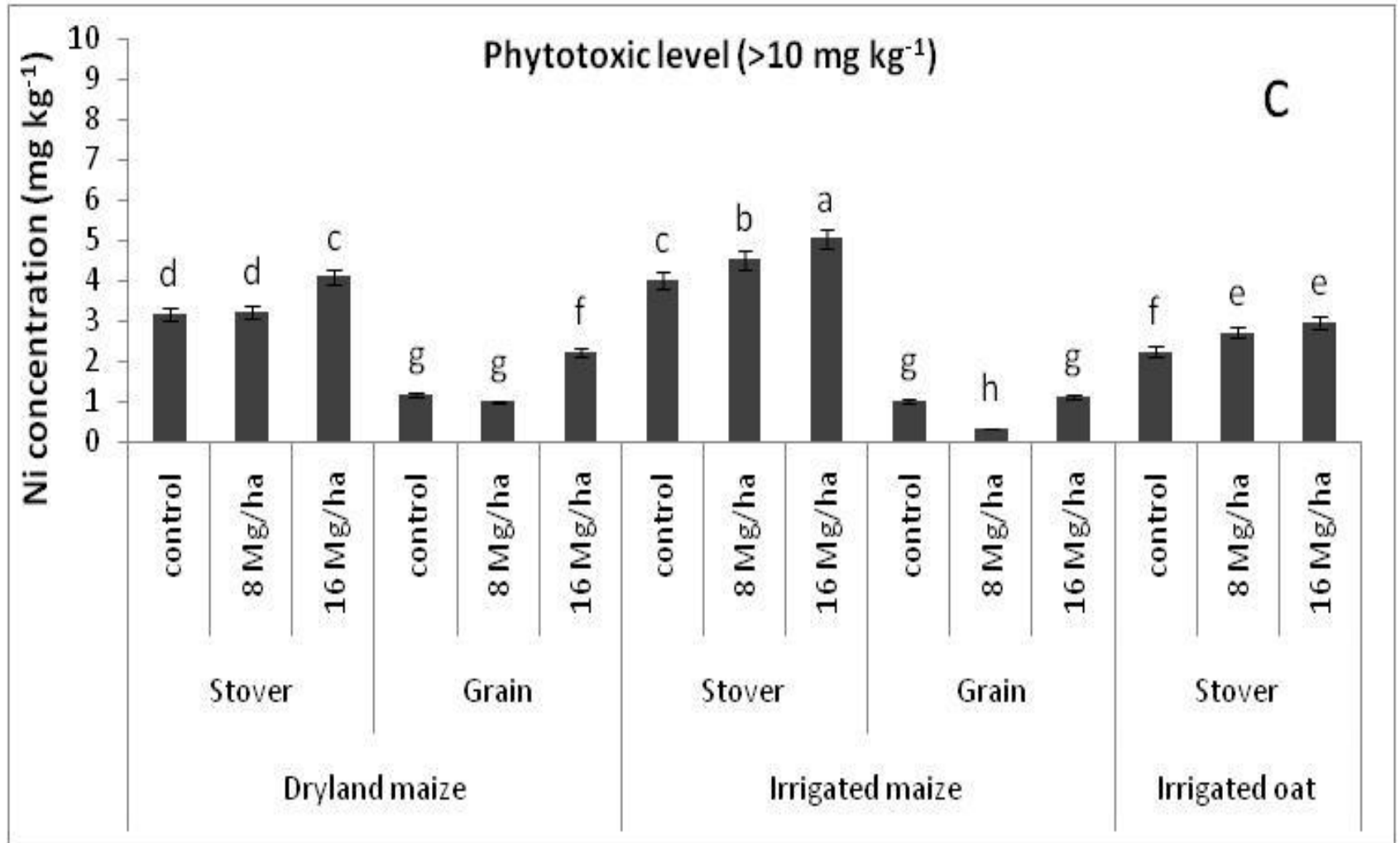
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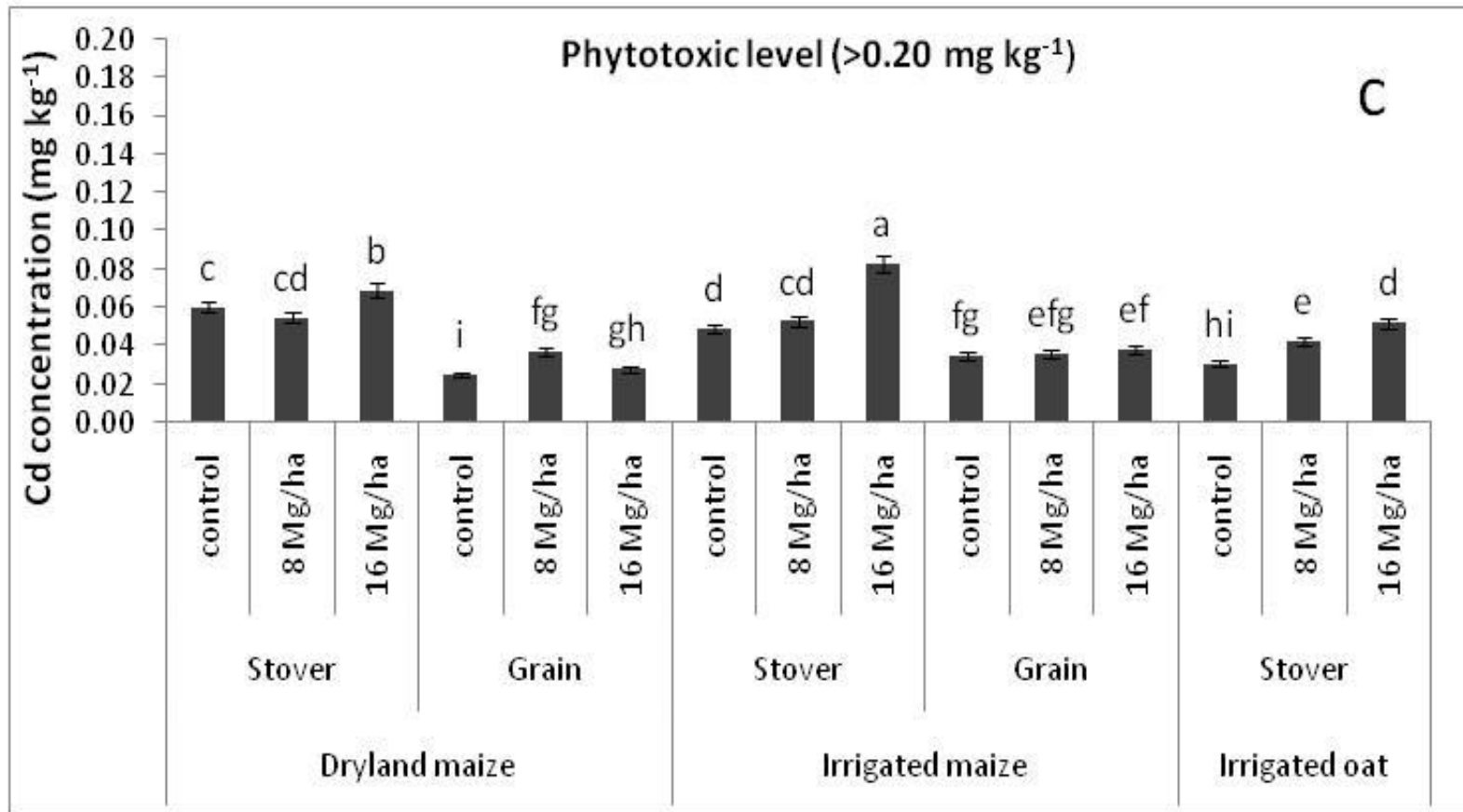
Lead



Nickel



Cadmium



Field experiment

