A Decision Support System for the phyto – treatment of dairy effluent

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Phytoremediation as a for of "Phytoprevention"

Phytoremediation can come handyto solve pollution problems already existing. Is there a way it can help to prevent these problems to show up?

Agriculture is a startng point


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Dairy effluent disposal: current practice

- Directly into waterways

- Onto pasture to improve growth


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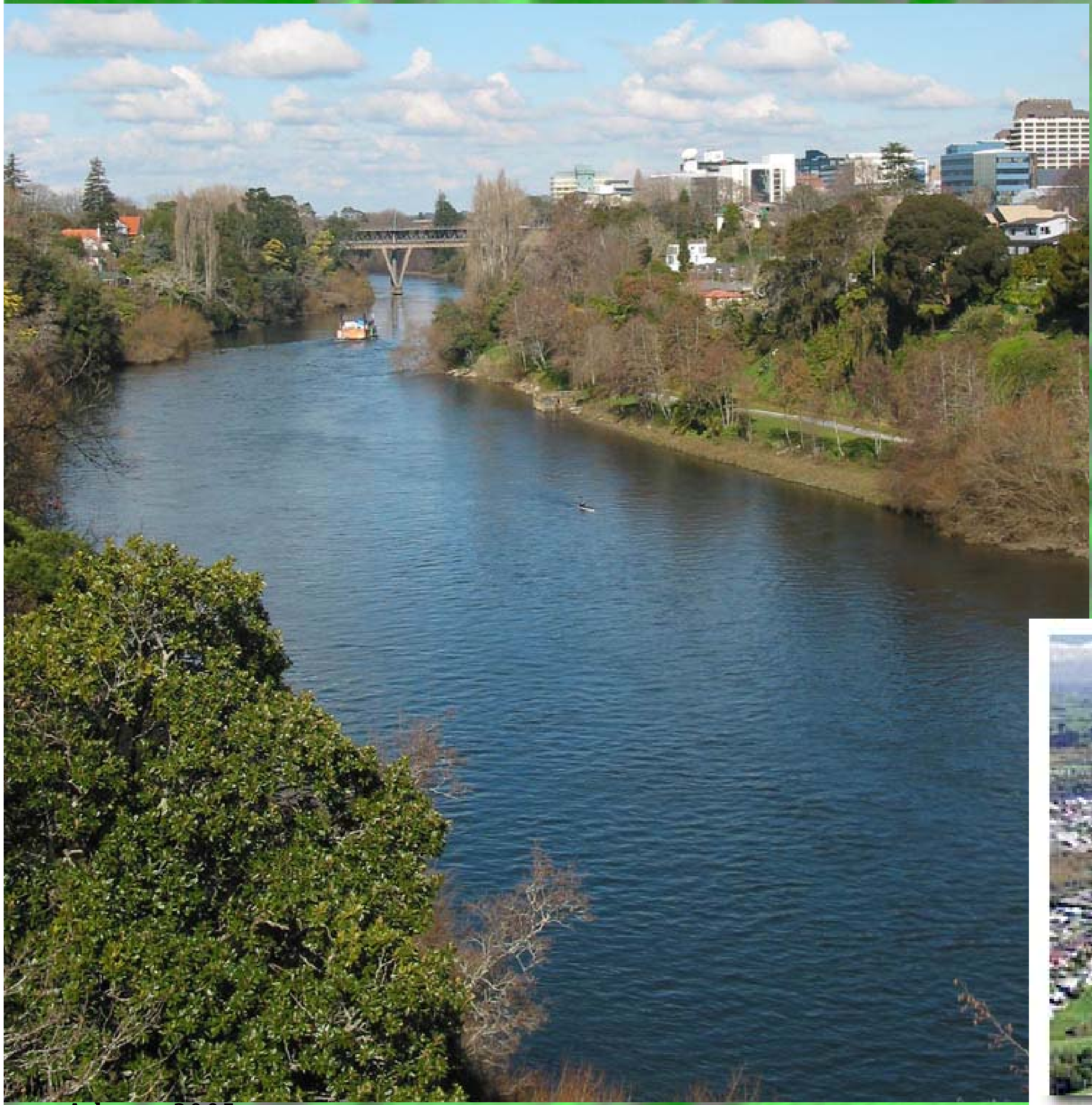
Dairy effluent in the environment

- NO3 – 100 mg/kg – **groundwater contamination**
- NH4 – 50 mg/kg – **surface runoff**
- K – 200 mg/kg – **induced Mg deficiencies**

- Pb, Cu, Zn traces – **accumulation in soils and/or crops**

- DOC – 100 mg/kg – **facilitate metal leaching**

Increasing N-loading on waterways



John Greenwood Blue-green algal bloom, Lake Hakanoa

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Financial incentives for sustainable effluent disposal

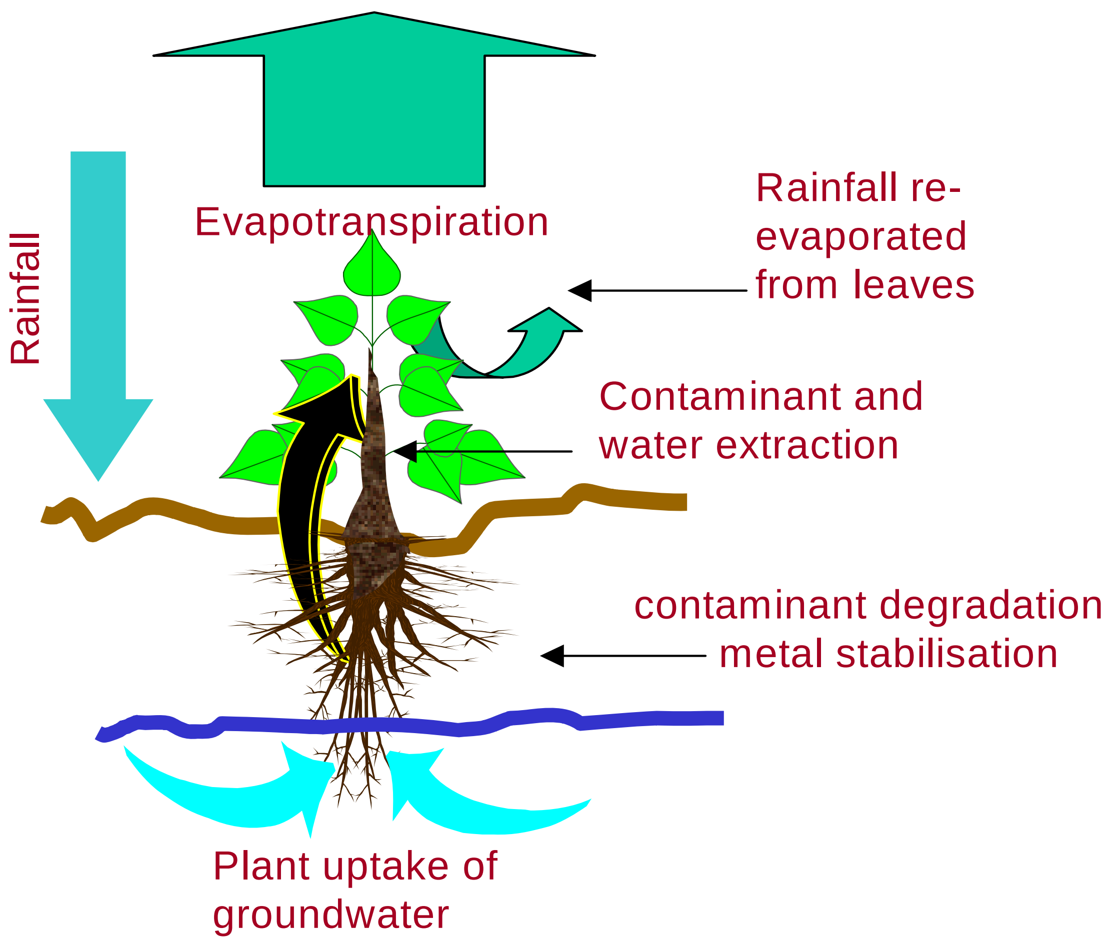
The Resource Management Act (1991)

Purpose – (1) The purpose of this Act is to promote the sustainable management of natural and physical resources

(2) In this Act, "sustainable management" means managing the use, development, and protection of natural and physical resources … while

(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment.

Could fast-growing tree species be used?



- **Tolerant to local conditions**
- **Rapid growth**
- **High water use**
- **Extract or enhance the degradation of the target contaminant**

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Other problems related to Agriculture and farming can span from…

...rough Bison in US

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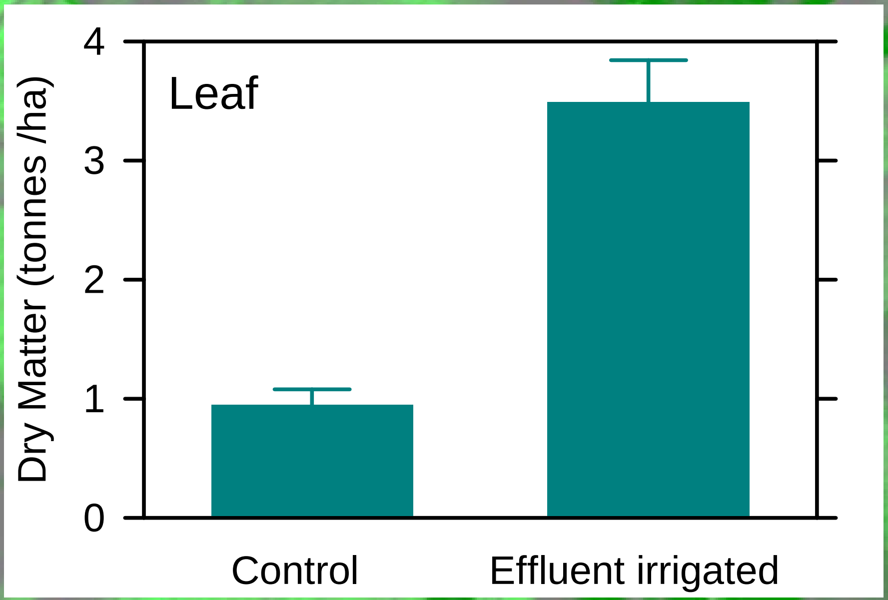
to disciplined cows in New Zealand

So it is important to train the cows when to urinate

effect of dairy effluent on growth



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Salix branches and leaves are palatable fodder for cows. They also supply minerals as Mg and Ca

Green house experiment

- 18 lysimeters
- 12 planted with Salix kanayunagy clones (a species very resistant to pathogens)
- 6 control non planted lysimeters
- Treatments: 2L effluent a day=T1, 1L effluent a day=T2, 0,5L of effluent a day=T3, only water=T0; three replicates for each treatment
- Effluent collected from Massey dairy farm N°4, Palmerston North, NZ

Green house experiment

- Water for irrigaton was supplied according to the seasonal and growth needs.
- Effluent was applied for 100 days, after leaving the plants stand for 35 days in the buckets for acclimation
- Weekly activities: collect leachates, measure shoot length, count leaves, collect leaves samples
- Destructive final sample: 14 Feb. 2005

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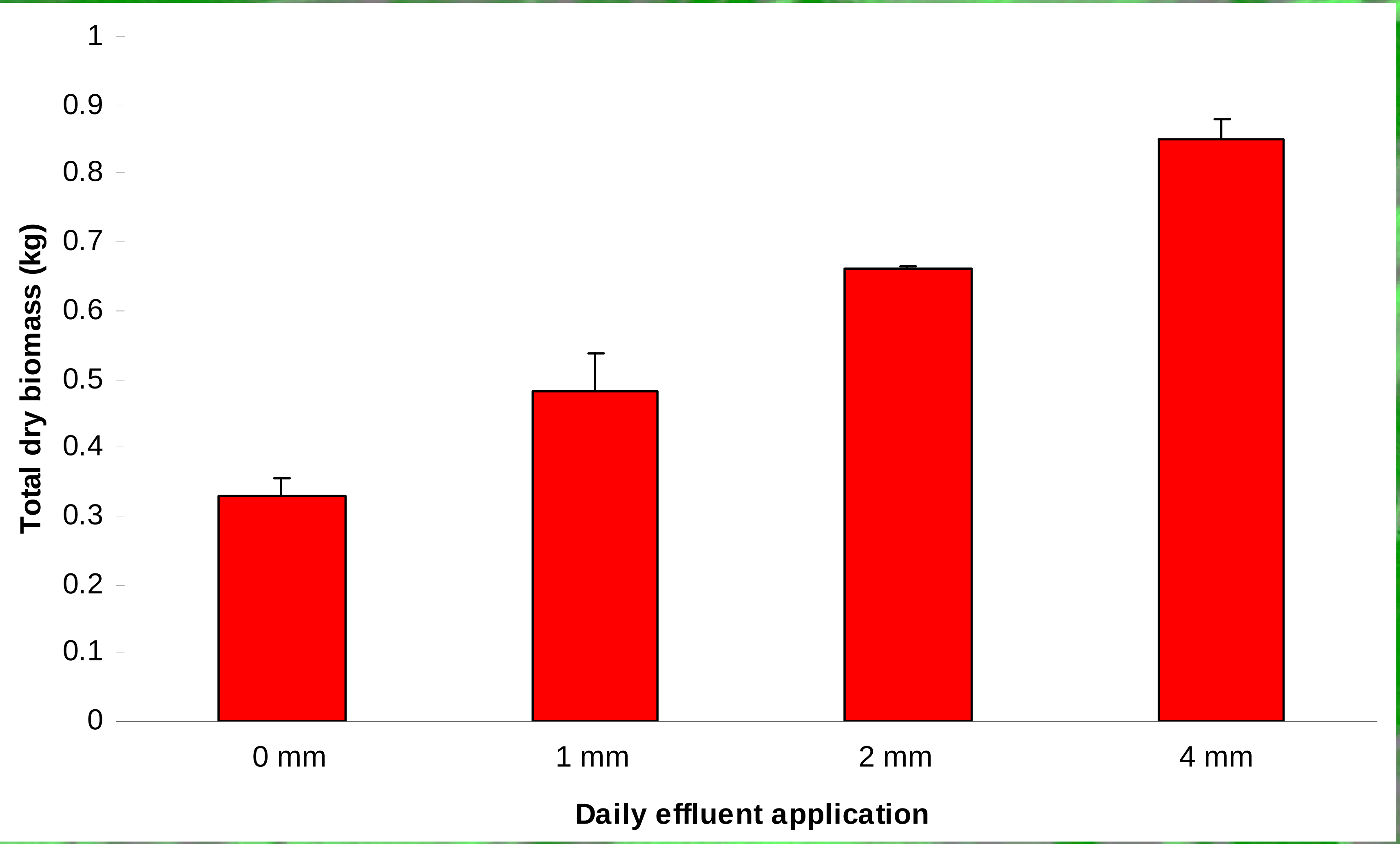
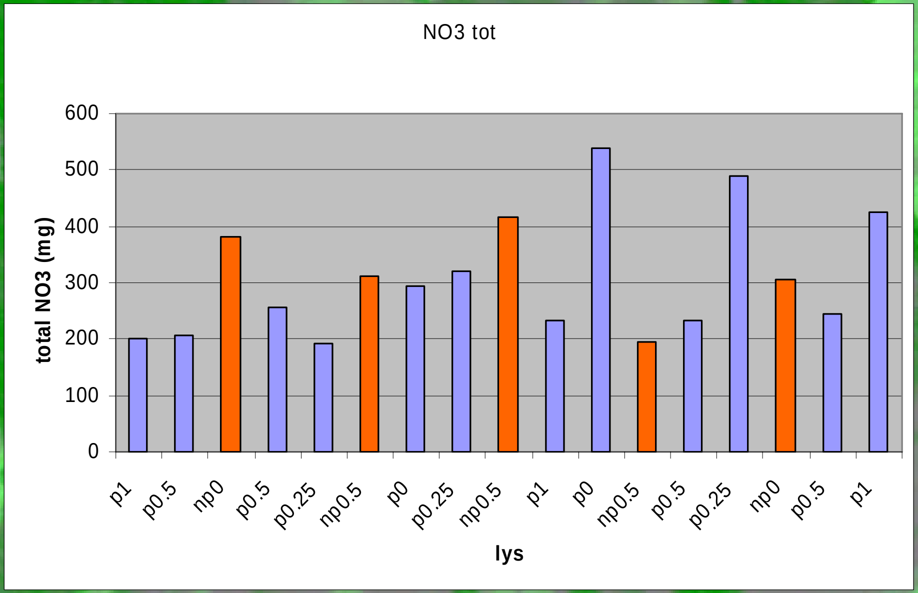
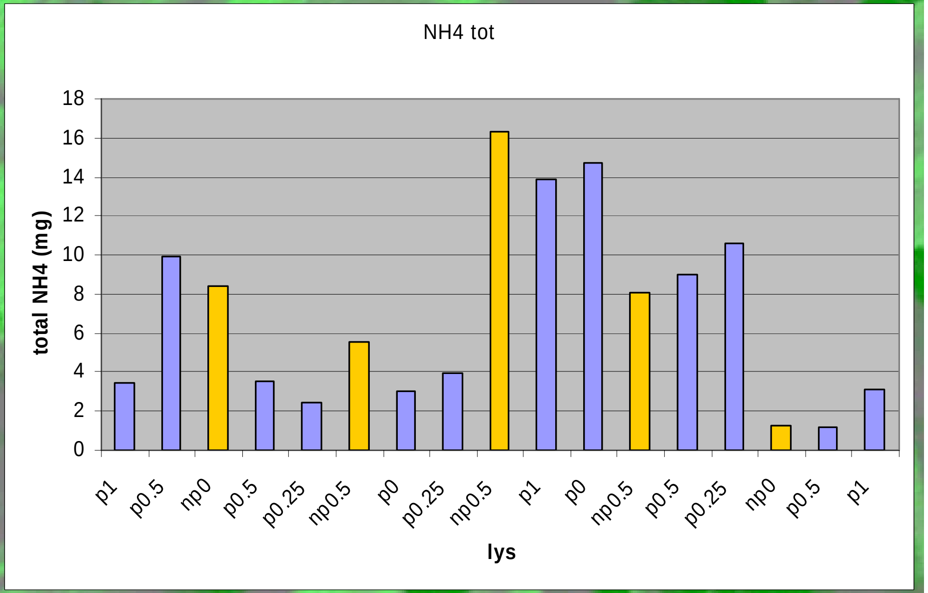
Effect of effluent on willow biomass



NO3 and NH4 from lysimeter lecheates after 100 days of effluent appication





Total NO3 is almost 100 times higher than total NH4

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Critical questions

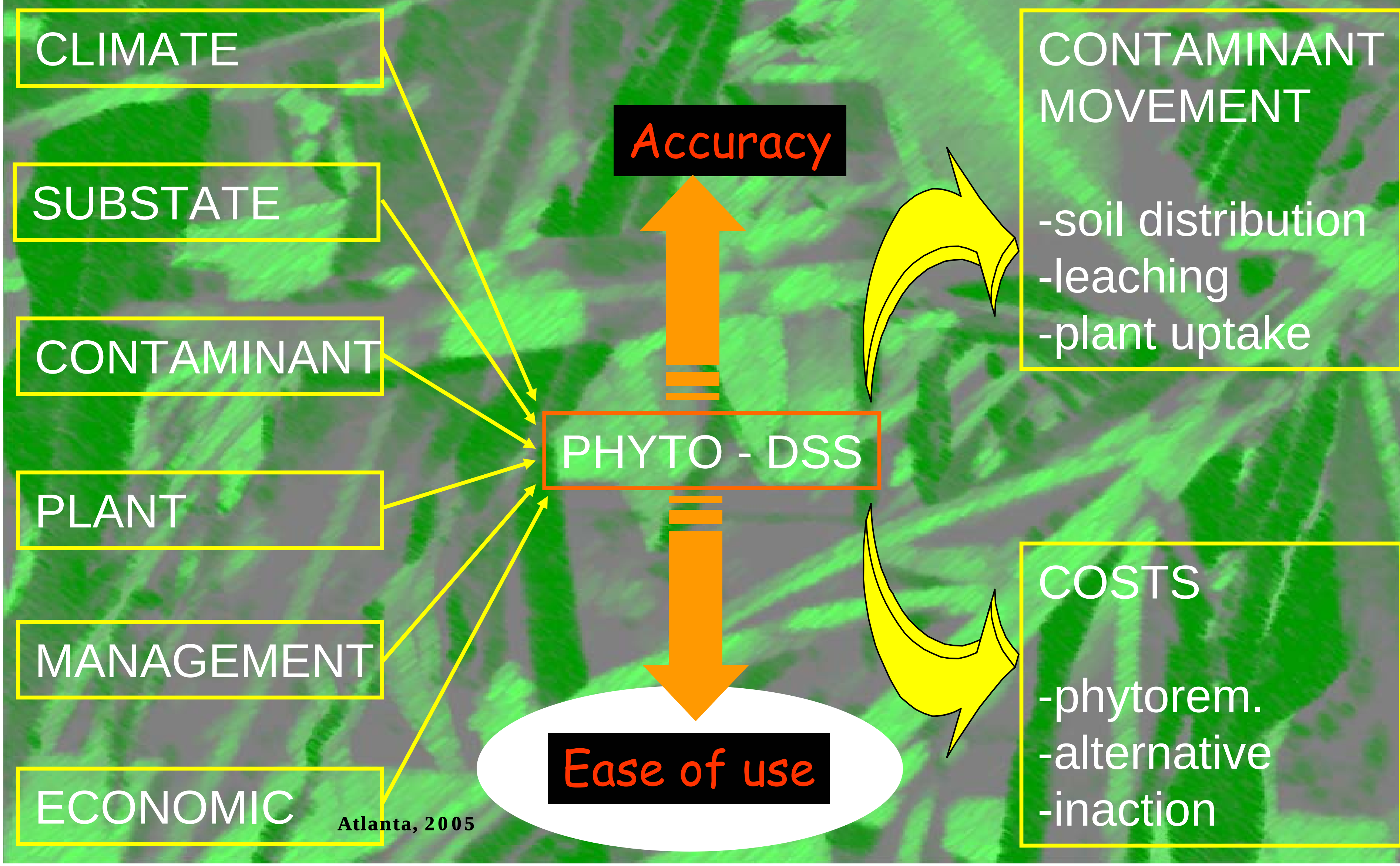
- Poplar and willow (phreatophytes) are palatable forage species that have a positive growth response to dairy effluent.
- What area of trees is needed to dispose of the effluent?
- How do the costs compare to pasture disposal?
- What are the likely long-term effects?

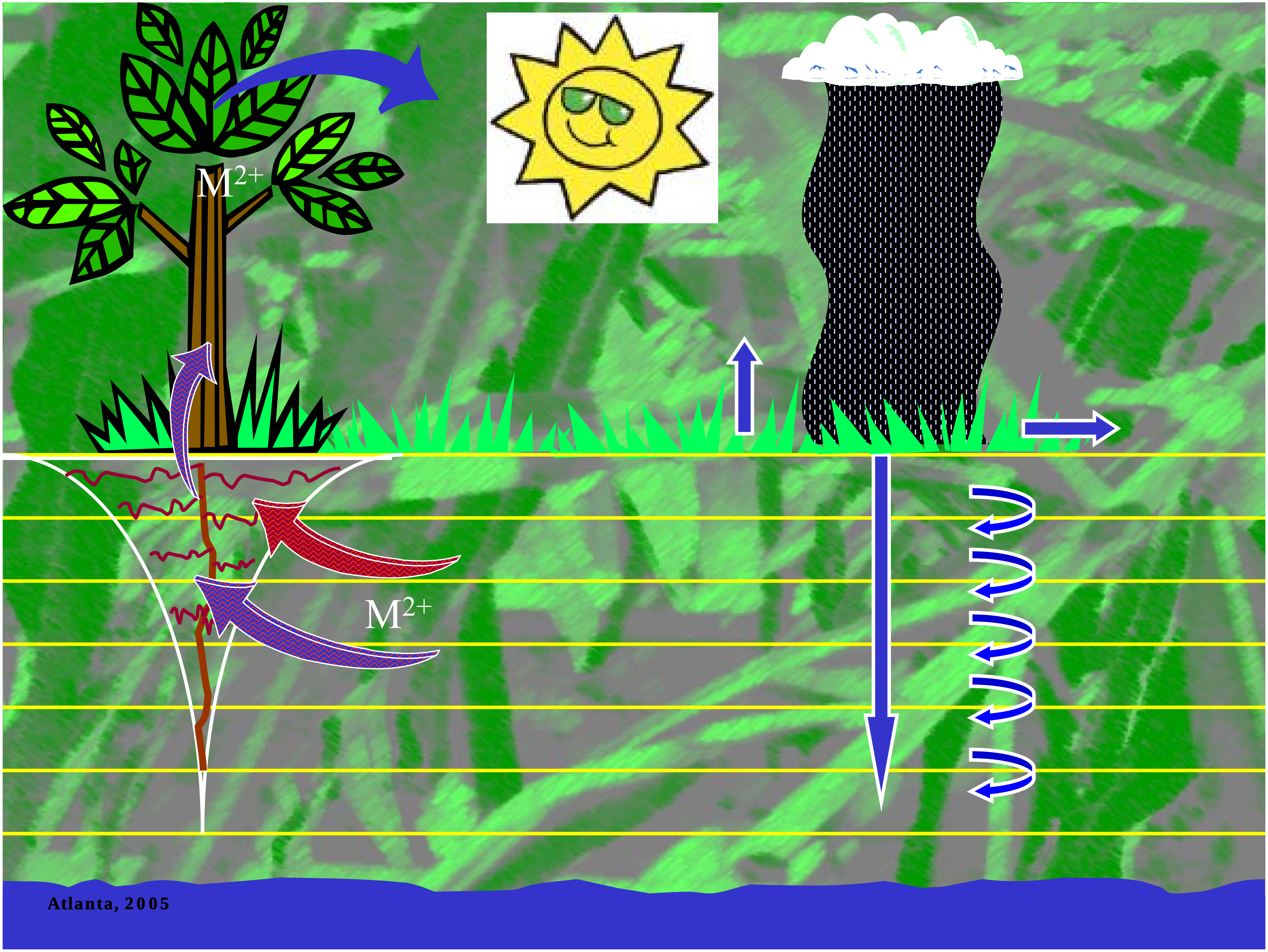
Decision Support System

- Supple technical program that works for gold, and works just as well for wastewaters: how to dispose of "something" (metal, nutrient, ecc..) and have back a revenue

- For dairy shed effluent we can just say "pecunia non olent"

DSS design


CLIMATE
SUBSTATE
CONTAMINANT
PLANT
MANAGEMENT
ECONOMIC
Accuracy
PHYTO - DSS
Ease of use
CONTAMINANT MOVEMENT
-soil distribution
-leaching
-plant uptake
COSTS
-phytorem.
-alternative
-inaction


M^{2+}
M^{2+}
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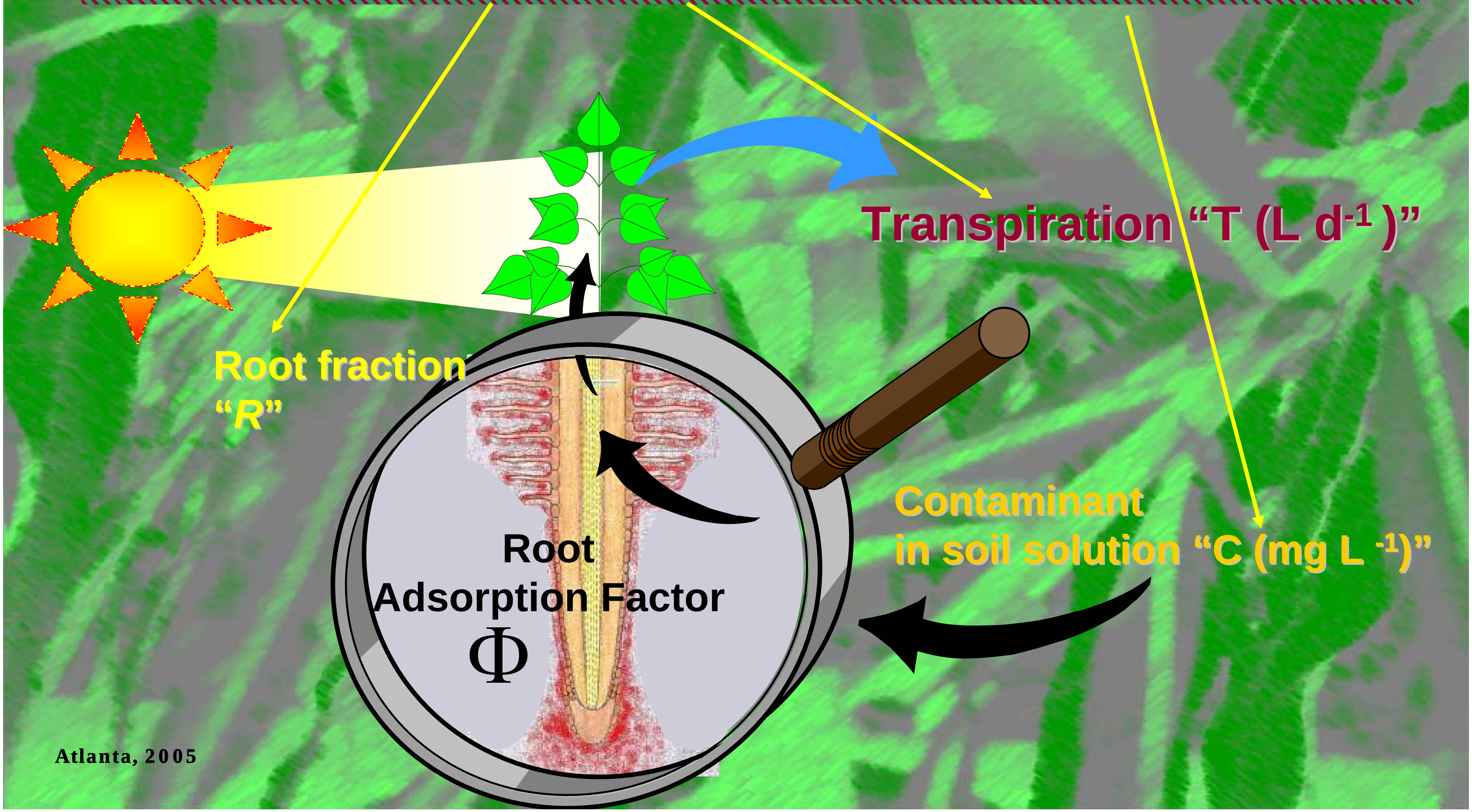
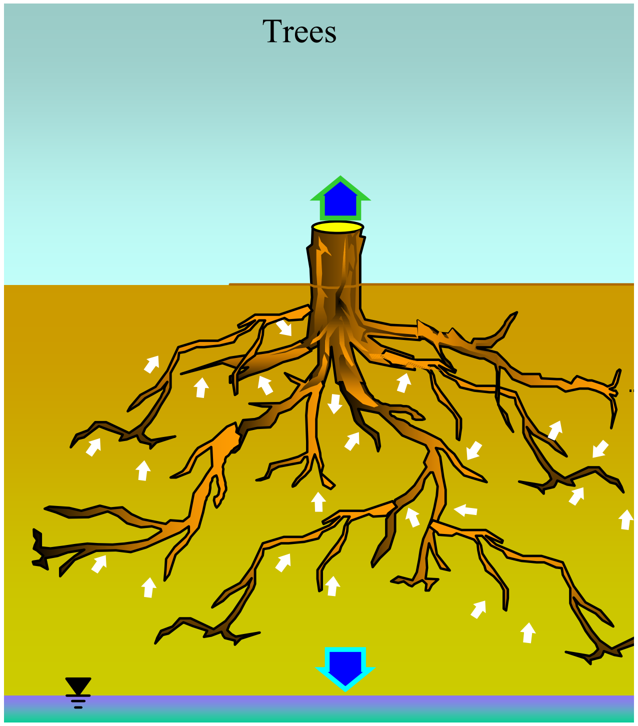
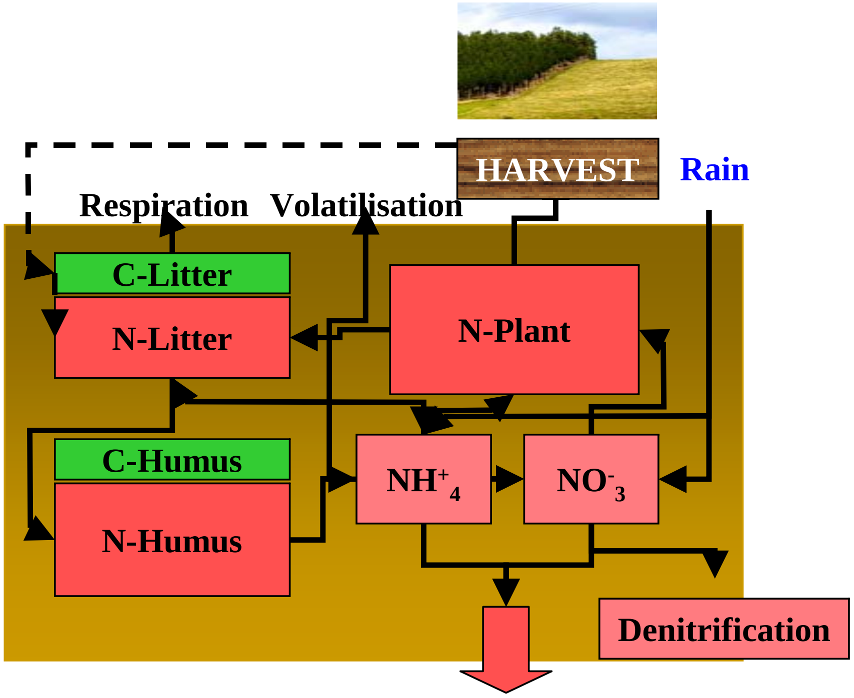
The process of phytoextraction

$$M(t) = \int_0^{z_R} \int_0^t R(t`, z)\, T(t`)\, C(t`z)\, \phi\left(C\left(t`z\right)\right) \; dt \; dz$$



Nitrogen in soil is affected by plants roots, microbes, humic substances, DOC and climate





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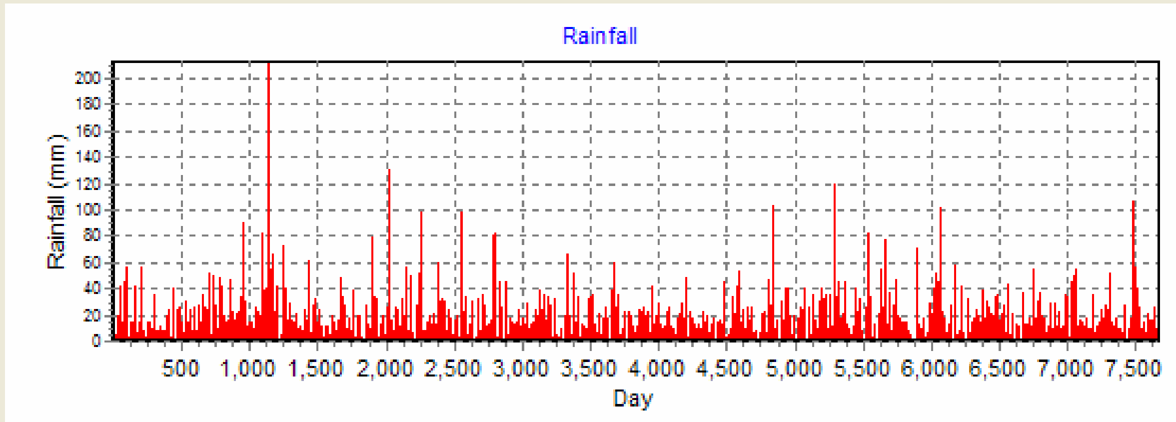
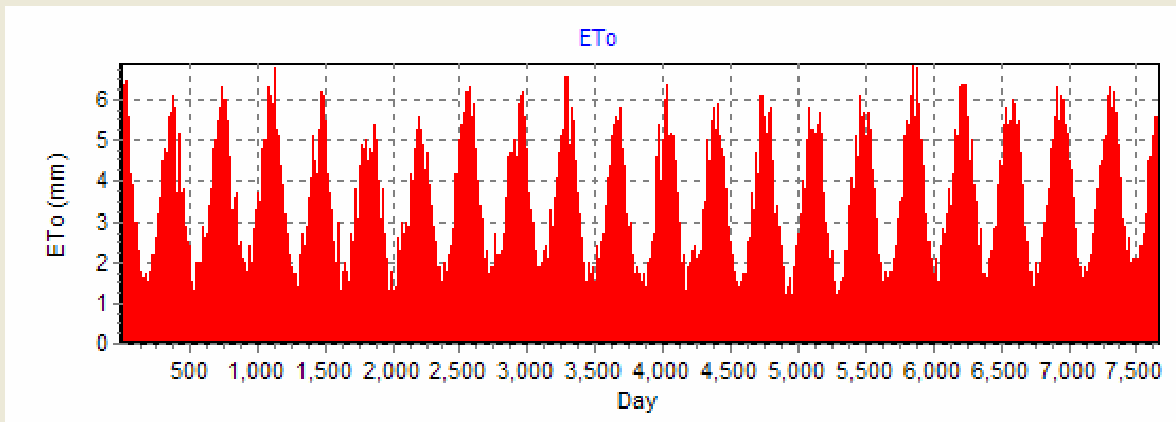
Parameterisation: climate

Substrate and management | Climate | Inputs | Outputs

Copy screen to clip-board

Date	Rainfall	ETo
1982001	0	4.6
1982002	0	5.0
1982003	15.6	4.8
1982004	0	5.0
1982005	1.3	4.6
1982006	9.4	4.3
1982007	4.2	4.4
1982008	0	5.9
1982009	0	5.1
1982010	0	5.7
1982011	0	6.0
1982012	0	5.4
1982013	0	6.2
1982014	1.1	3.1
1982015	0	6.4
1982016	0	4.3
1982017	0	5.4
1982018	0.6	5.9
1982019	0.1	4.6
1982020	0	5.9
1982021	0	5.1
1982022	0	4.1
1982023	4.8	4.0
1982024	1.4	3.8





Load Climate

Launch Climate Simulator

Climate data

Climate data file: KopuMetData82-02.prn

Total number of days: 7665

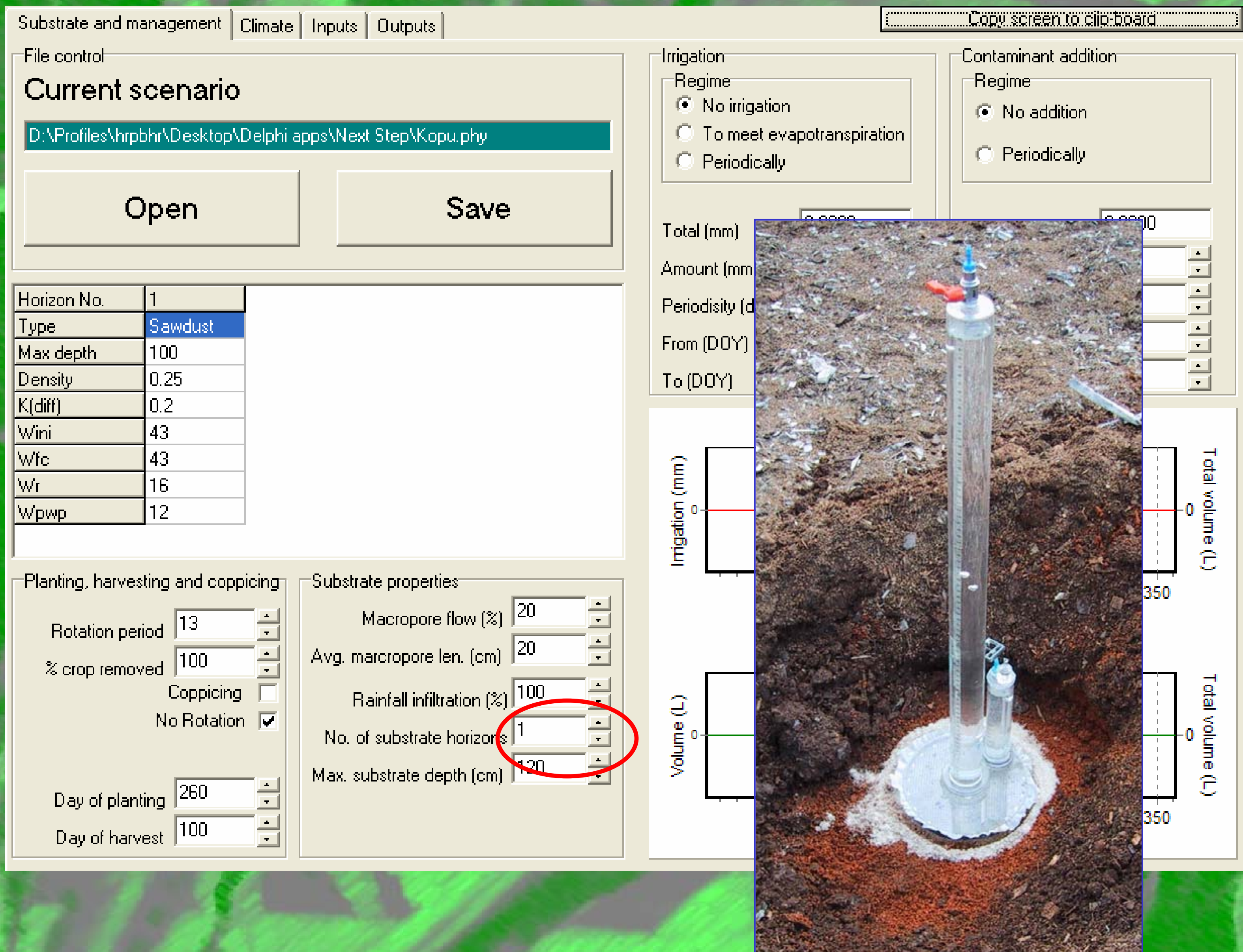
Average annual rainfall (mm): 1169

Total Rainfall (mm): 24933

Average annual ETo (mm): 856

Total ETo (mm): 18278

Parameterisation: substrate



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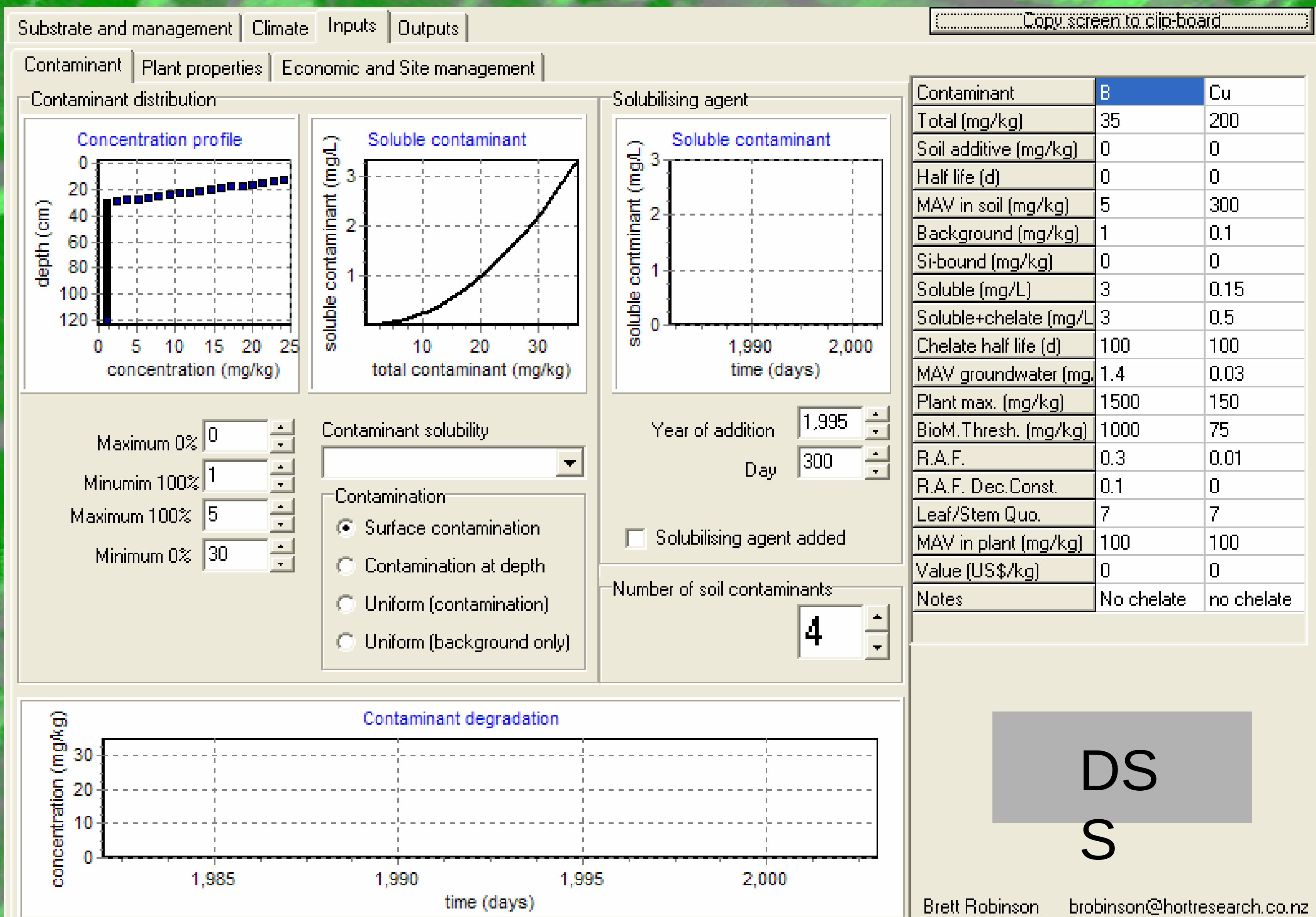
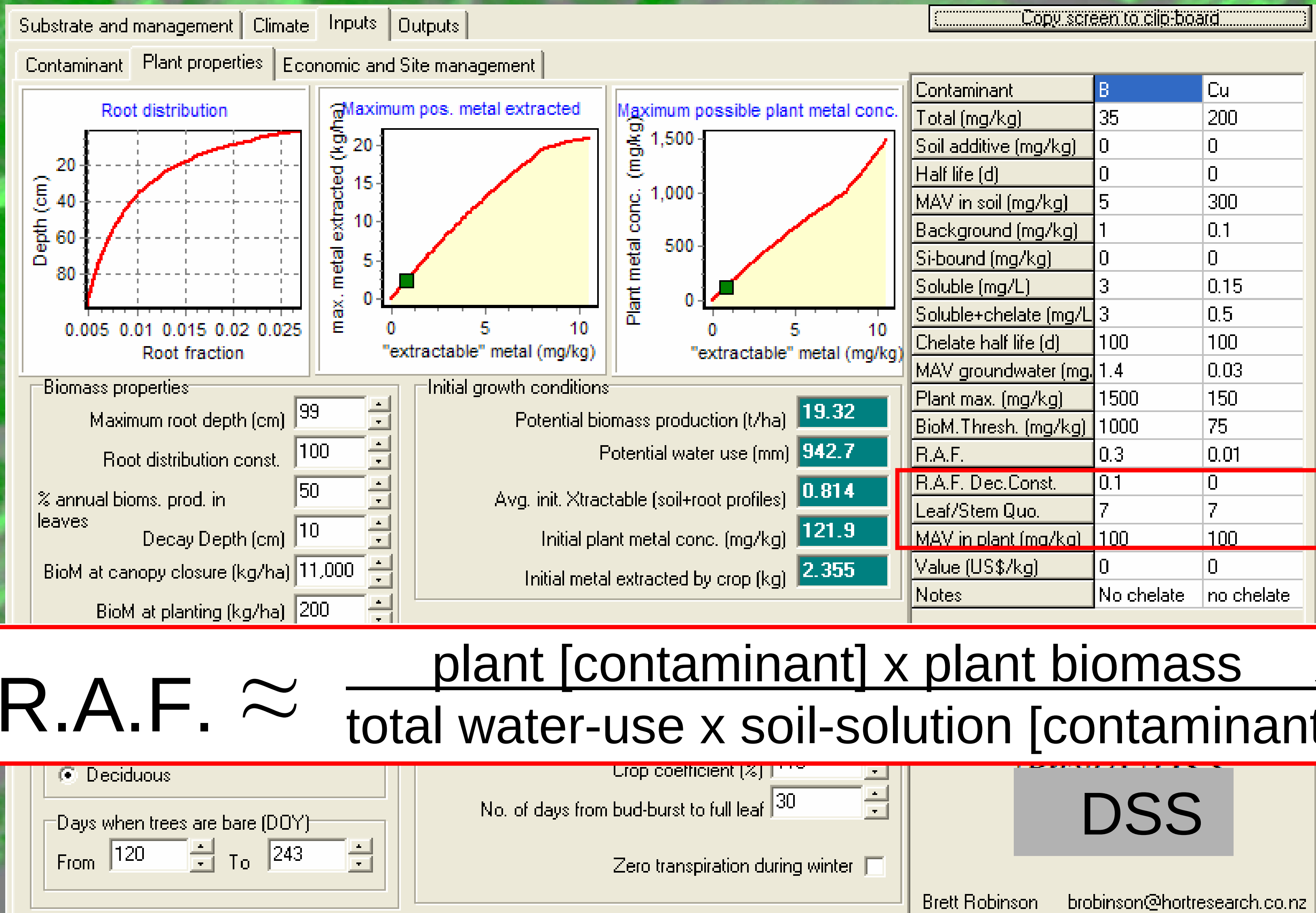
Parameterisation: contaminants

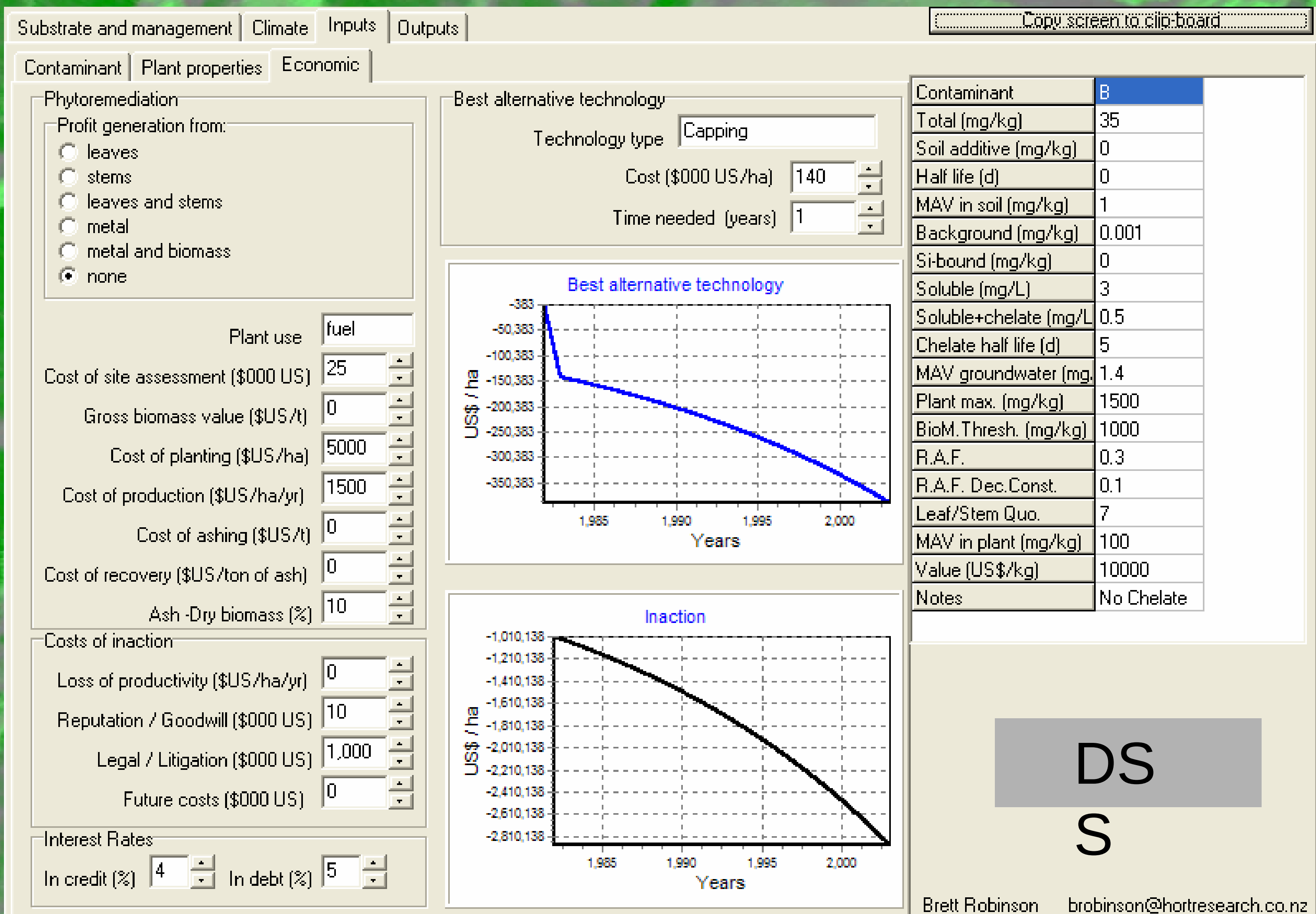


Parameterisation: plant properties

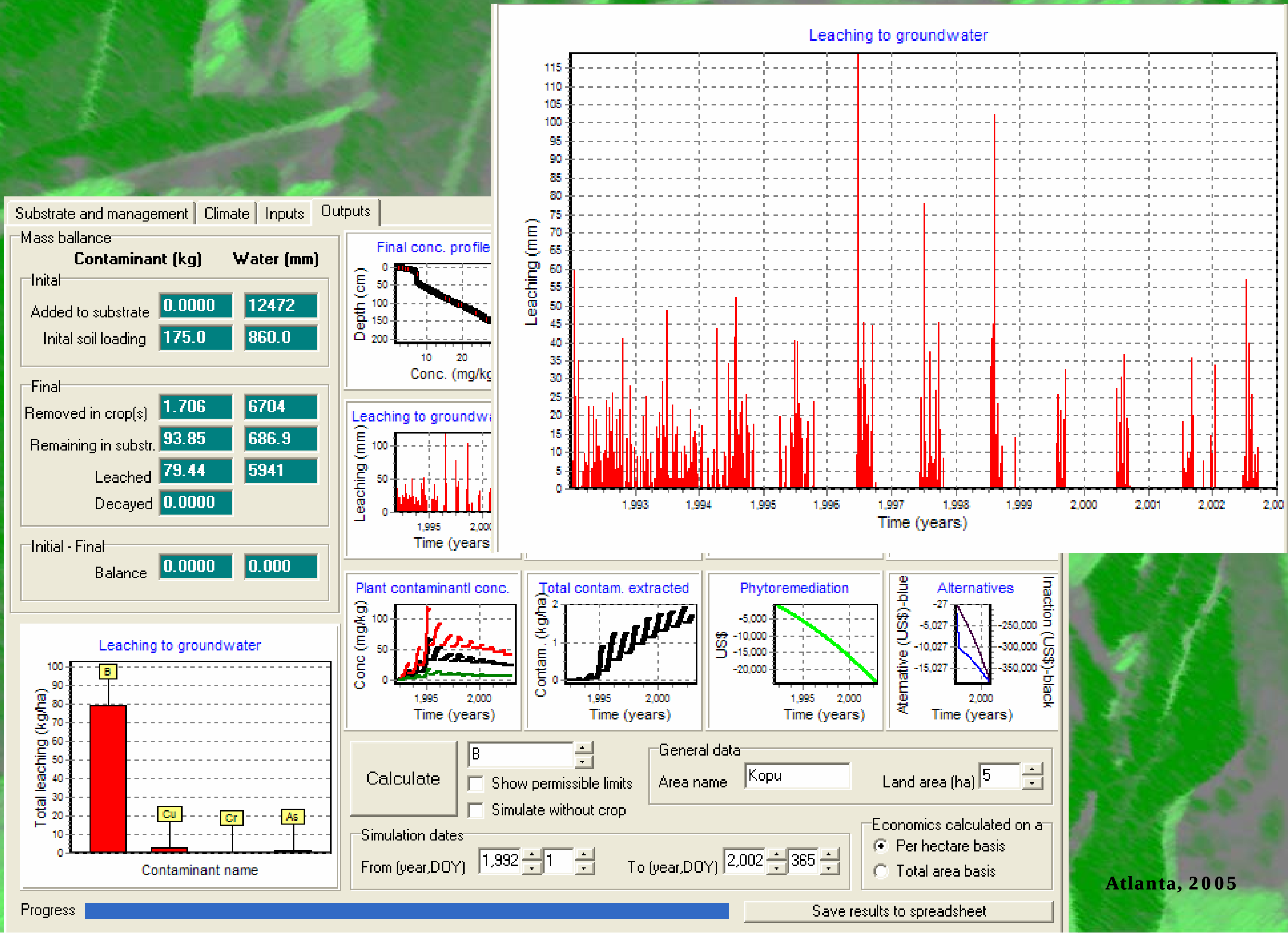


$$\text{R.A.F.} \approx \frac{\text{plant [contaminant] x plant biomass}}{\text{total water-use x soil-solution [contaminant]}}$$

Parameterisation: economic variables



PhytoDSS - outputs



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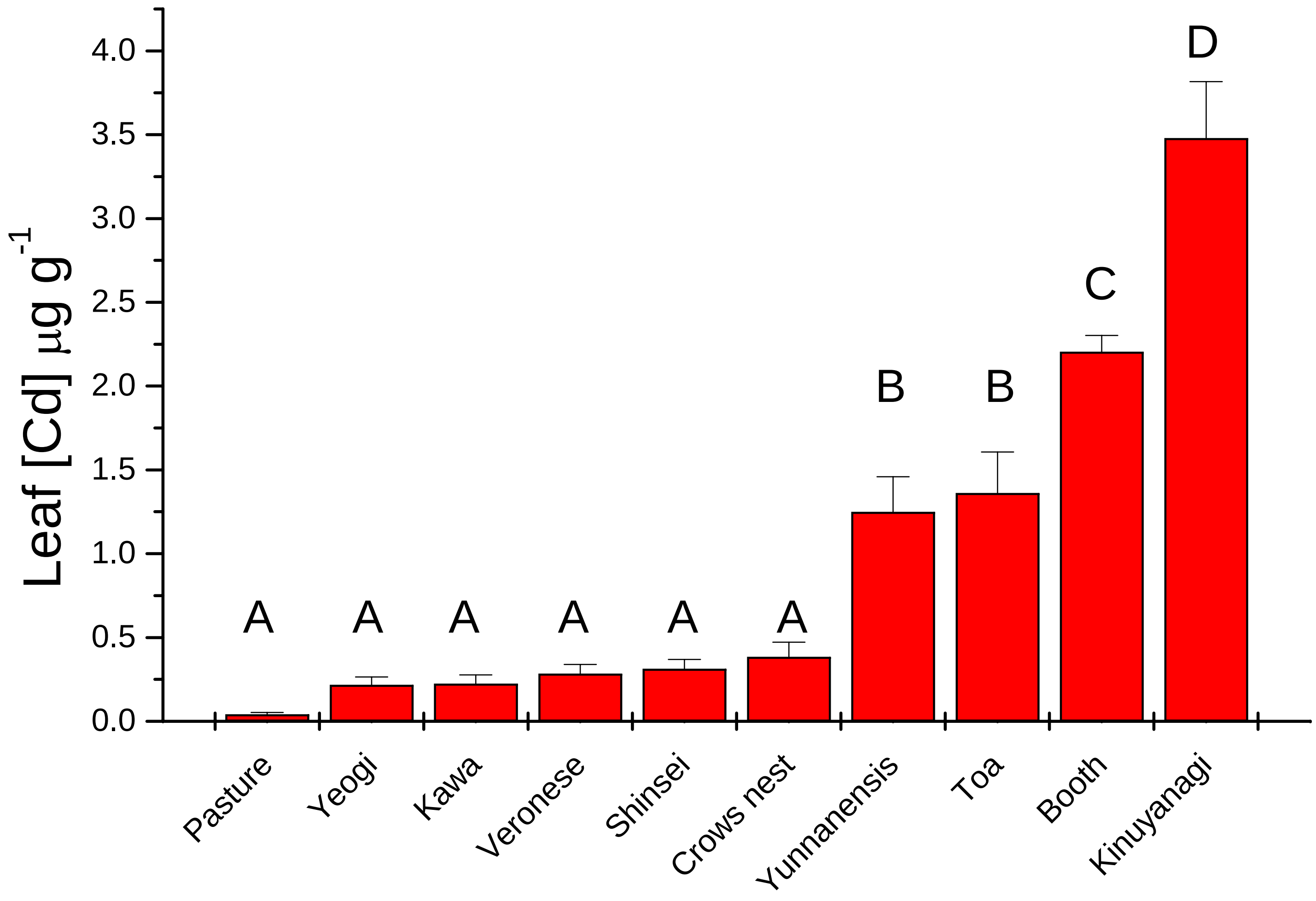
Conclusions

- Each farm is unique in the characteristics of soil, agronomical practice and climate
- The DSS is a mechanistic model that takes into consideration the main variable affecting Nitrogen and metal leaching into soil and water due to wastewater disposal onto agricultural land
- Existing models may not be suitable for dairy effluents because they do not consider DOC and N
- There may also be concerns for metals transport from soil to groundwater

Willows may provide an exposure pathway for Cd



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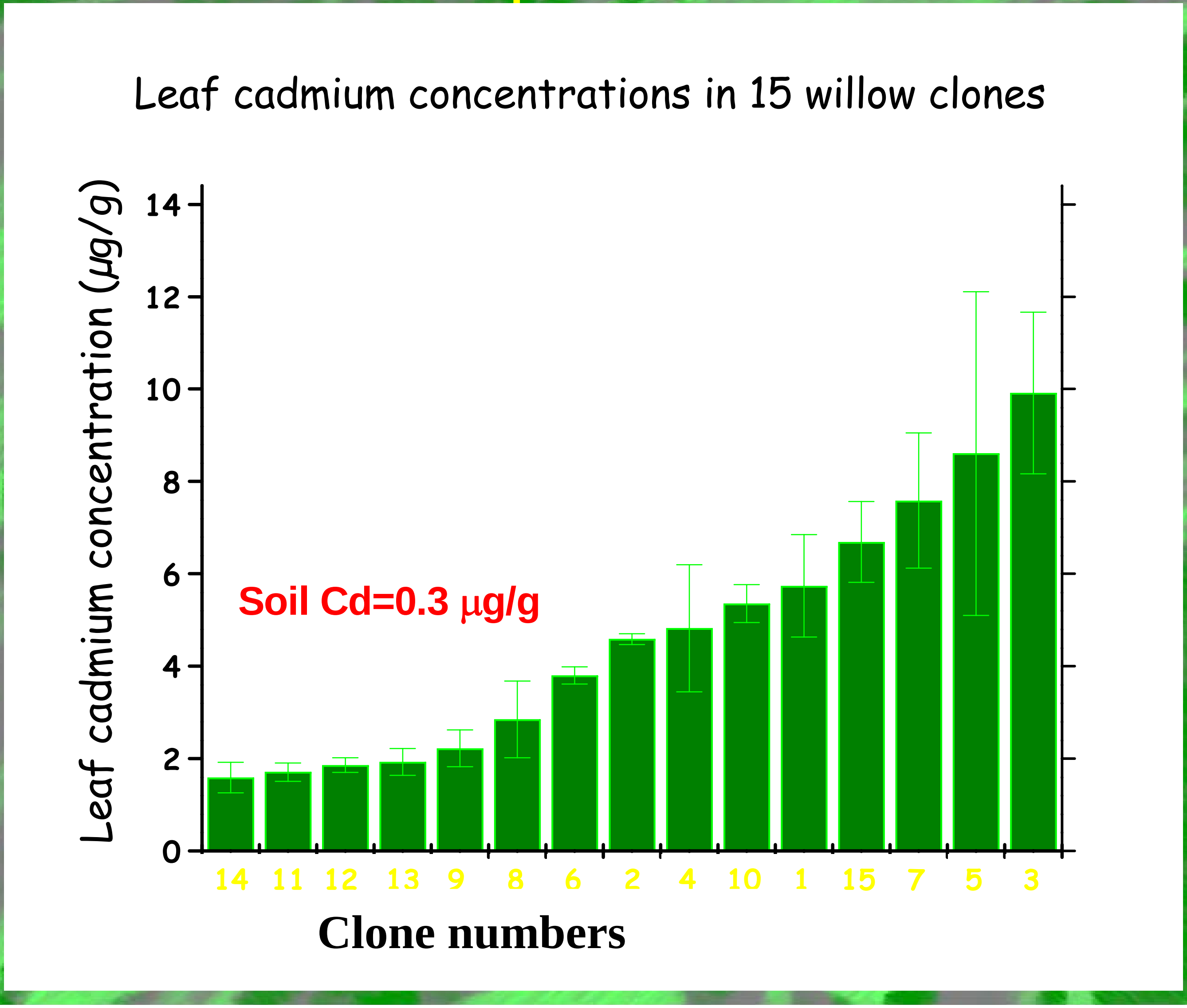
Future challenges: determining nutrients and metal contents of plant used for wastewater disposal



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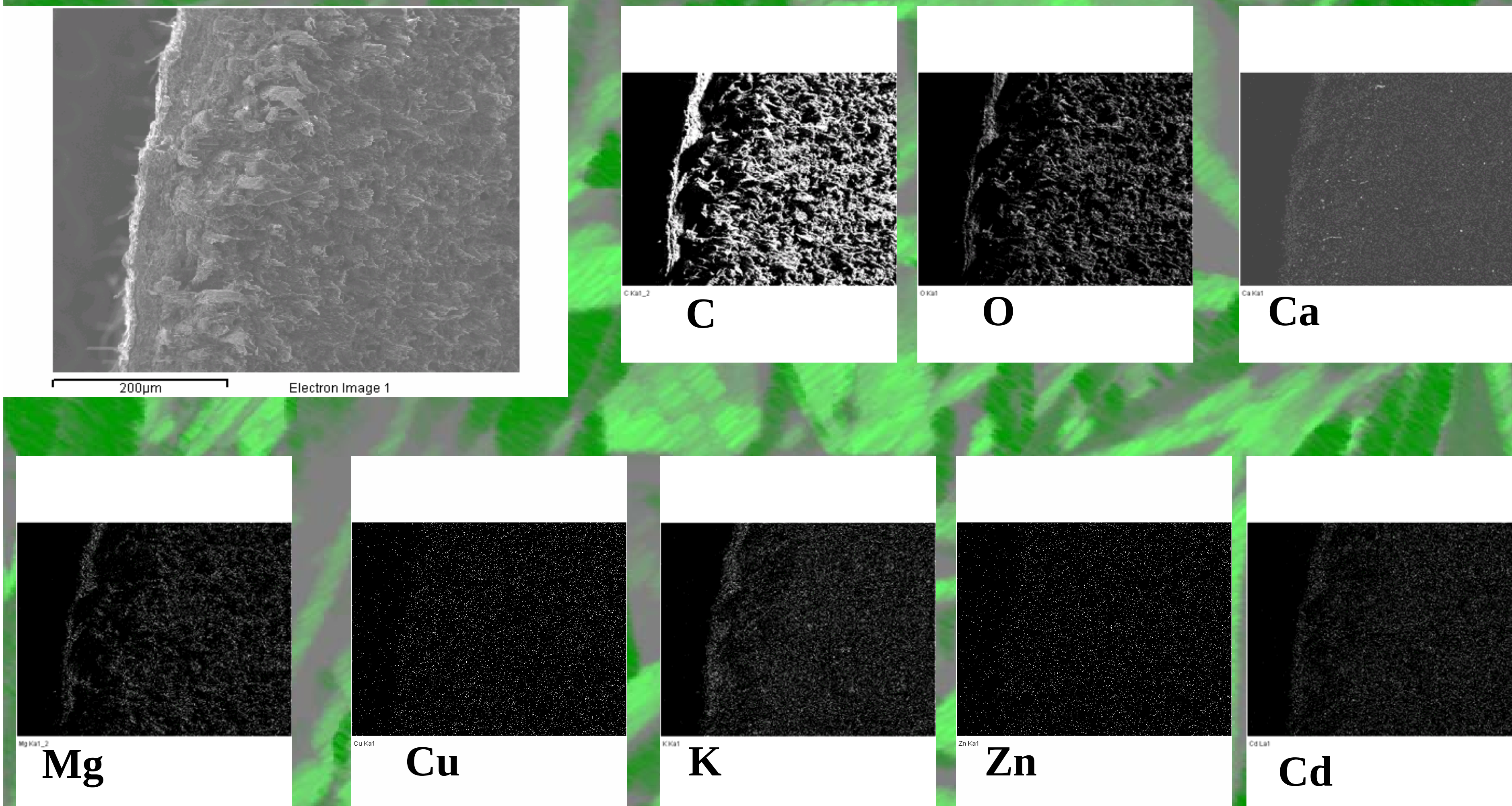
Preliminary SEM/EDX screening of sections from willow branches



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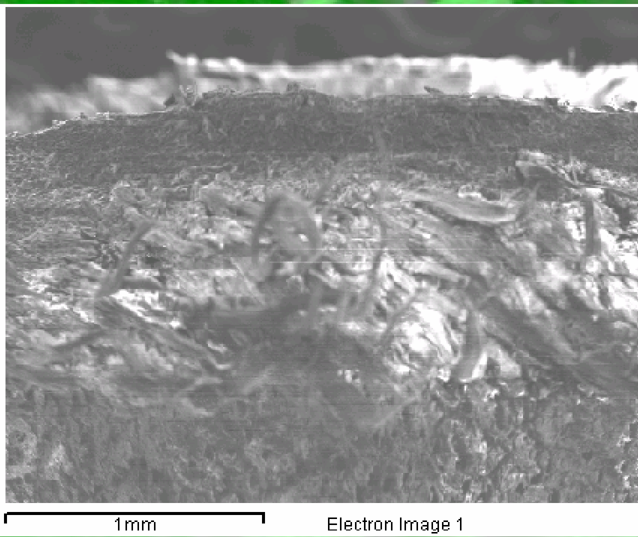


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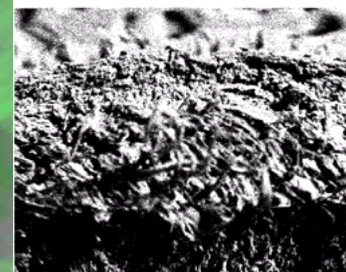
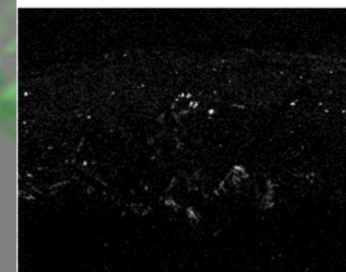
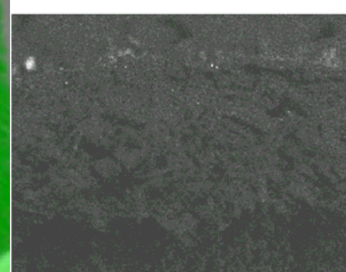

O


Mg


Ca


Cu


K


Zn


Cd

Take home message

- Dairy farms are getting larger and the problem of disposing of wastewaters is becoming urgent
- Green-house lysimeters experiment with willow stands can simulate leaching and plant growth under dairy shed effuent irrigation
- Data from green-house experiment are instrumental to shape a suitable DSS to help farmers to follow an environmental sound and cost effective disposal of wastewaters

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