A PHYTOEXTRACTION DECISION SUPPORT SYSTEM AND ITS USE IN THE COMMERCIAL ENVIRONMENT

Phyto-DSS

HortResearch

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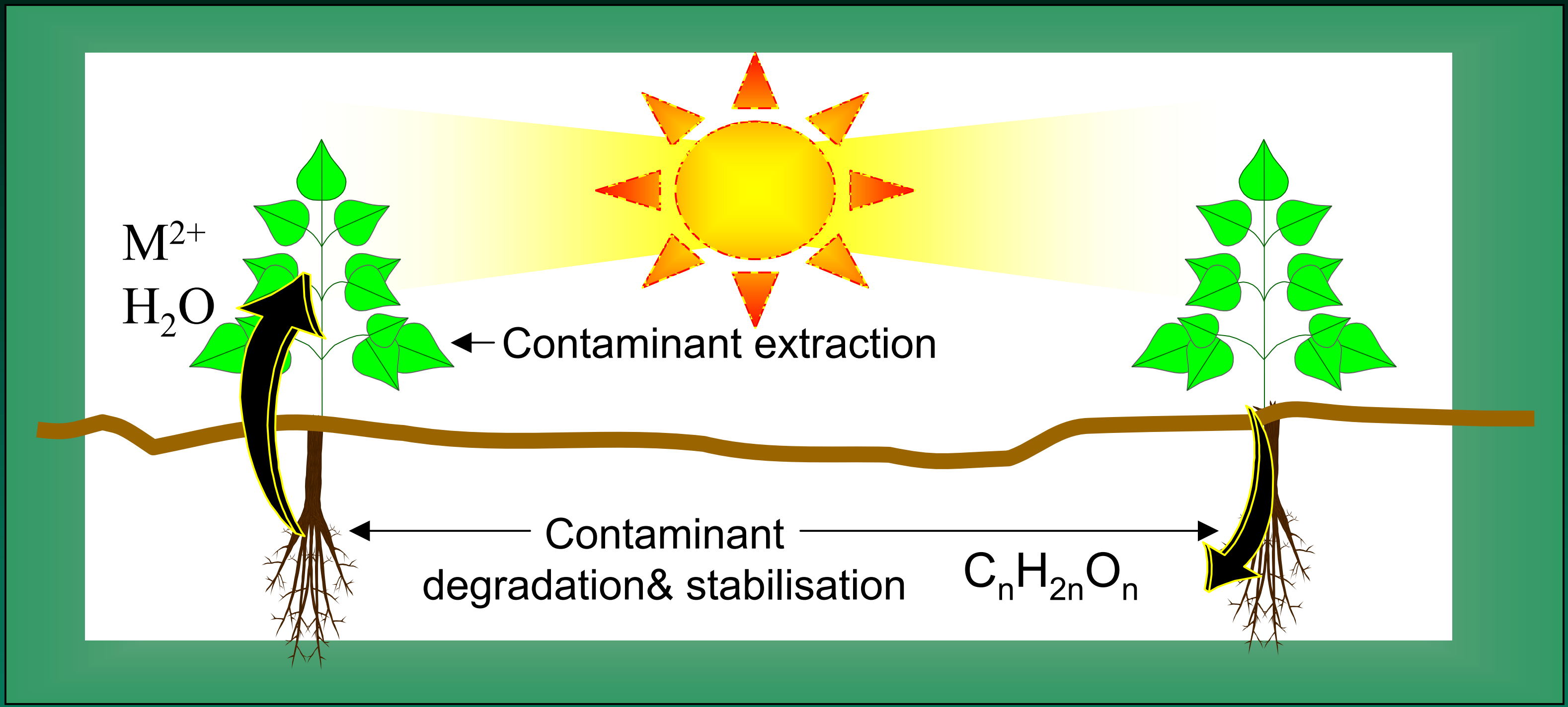
Phytoextraction: using the sun's energy to extract water and contaminants



- Stabilise polluted sites and prevent leaching
- Break-down some toxic chemicals in the soil
- Remove heavy-metals

Generic pros and cons of phytoextraction

- Low cost
- High public appeal
- Permanent
- Leaves site fertile
- Can involve local communities
- May generate a profit off contaminated land

- Limited to areas that support plant-growth
- Long time-frame
- Most effective on surface contamination
- Unsuitable for rapid cleansing

When should phytoextraction be used?

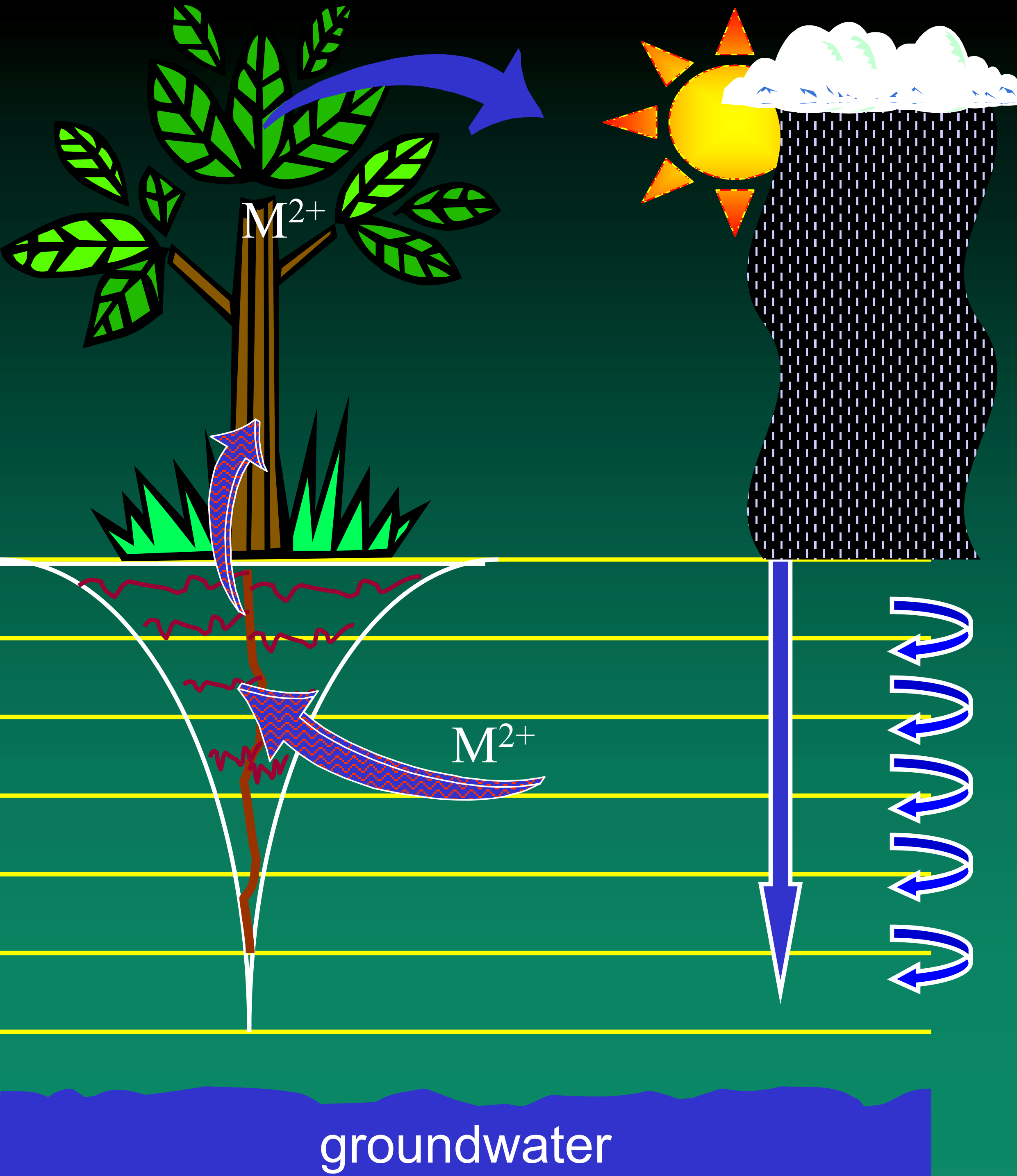
- Most cost-effective long term strategy
- Satisfies environmental legislation

Major drawback of phytoextraction in the commercial environment

- Unlike other land-treatment technologies, the cost and performance of phytoextraction on a given site can be difficult to predict.
- Phytoextraction is very sensitive to
  - climate
  - chemical, physical and biological properties of the substrate.
  - local ecosystem

AIM:

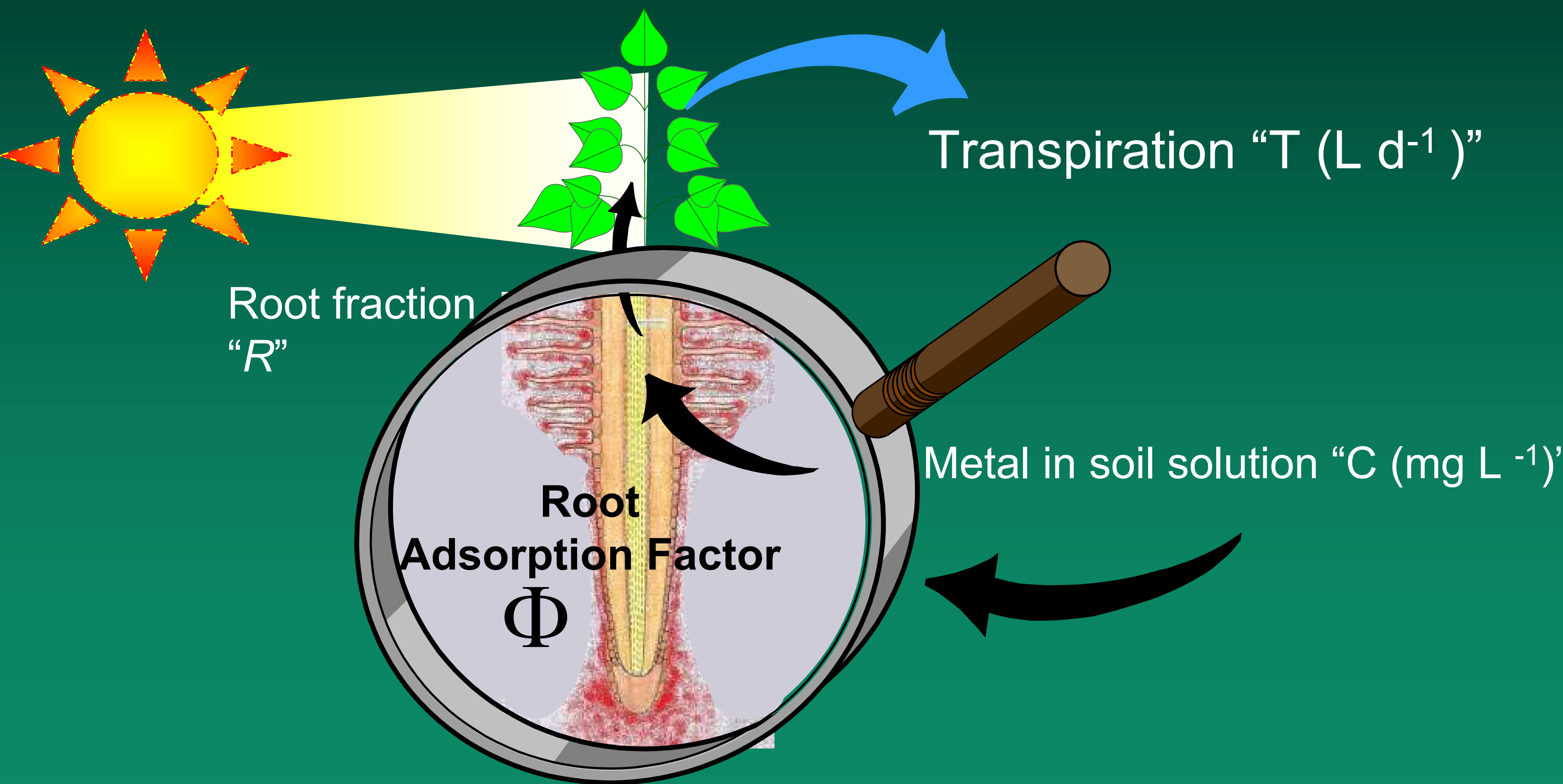
To create a Phytoextraction Decision Support System (Phyto-DSS) that predicts performance and cost of phytoextraction.



- Climate
- Plant water-use and growth parameters
- Plant contaminant-uptake parameters
- Substrate properties affecting water movement and contaminant solubility
- Cost over time of phytoextraction compared to other technologies or inaction

The process of phytoextraction

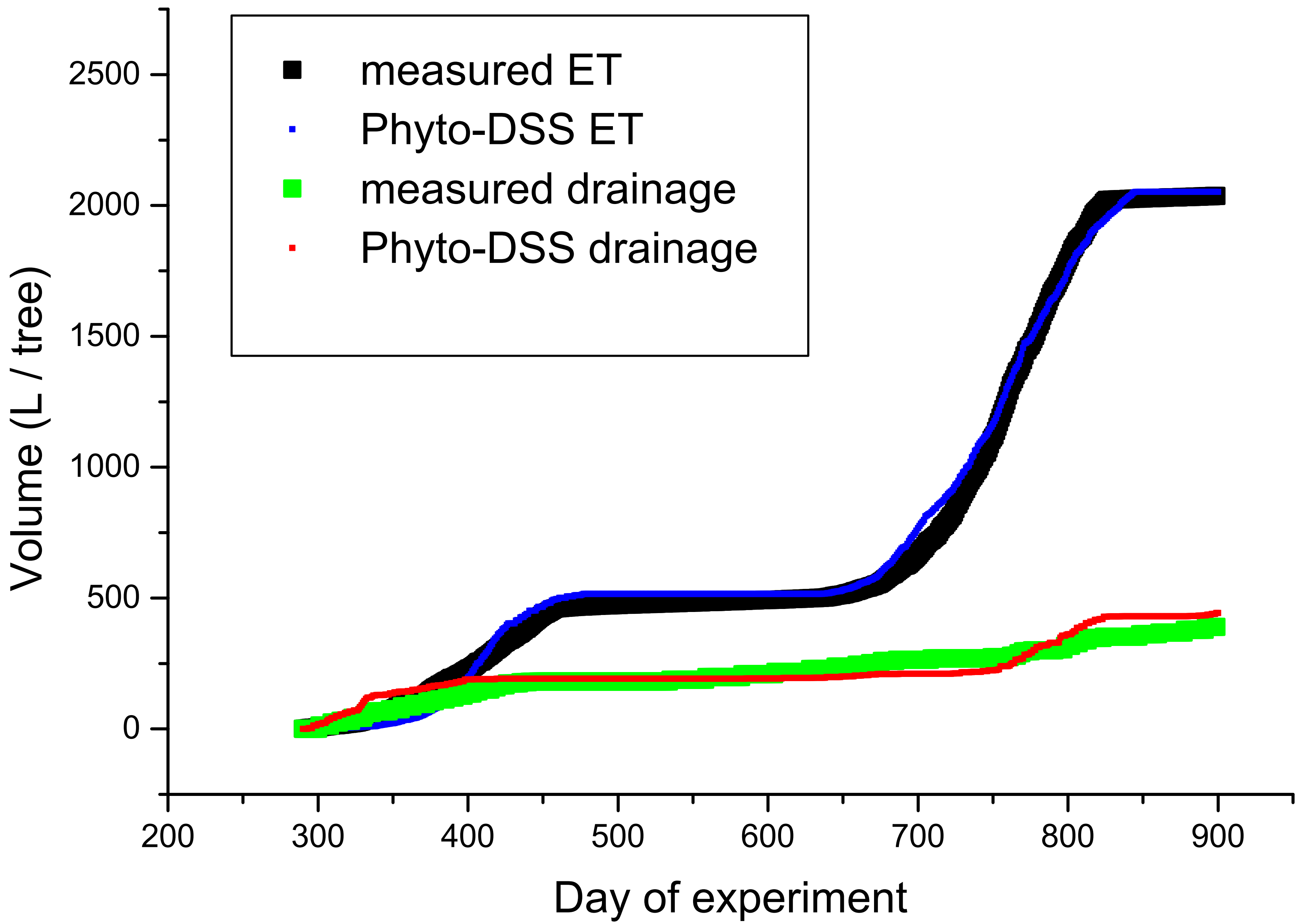
$$M(t) = \int_0^{z_R} \int_0^{t} R(t`, z)\, T(t`)\, C(t`z)\, \phi\big(C(t`z)\big) \;\; dt \;\; dz$$

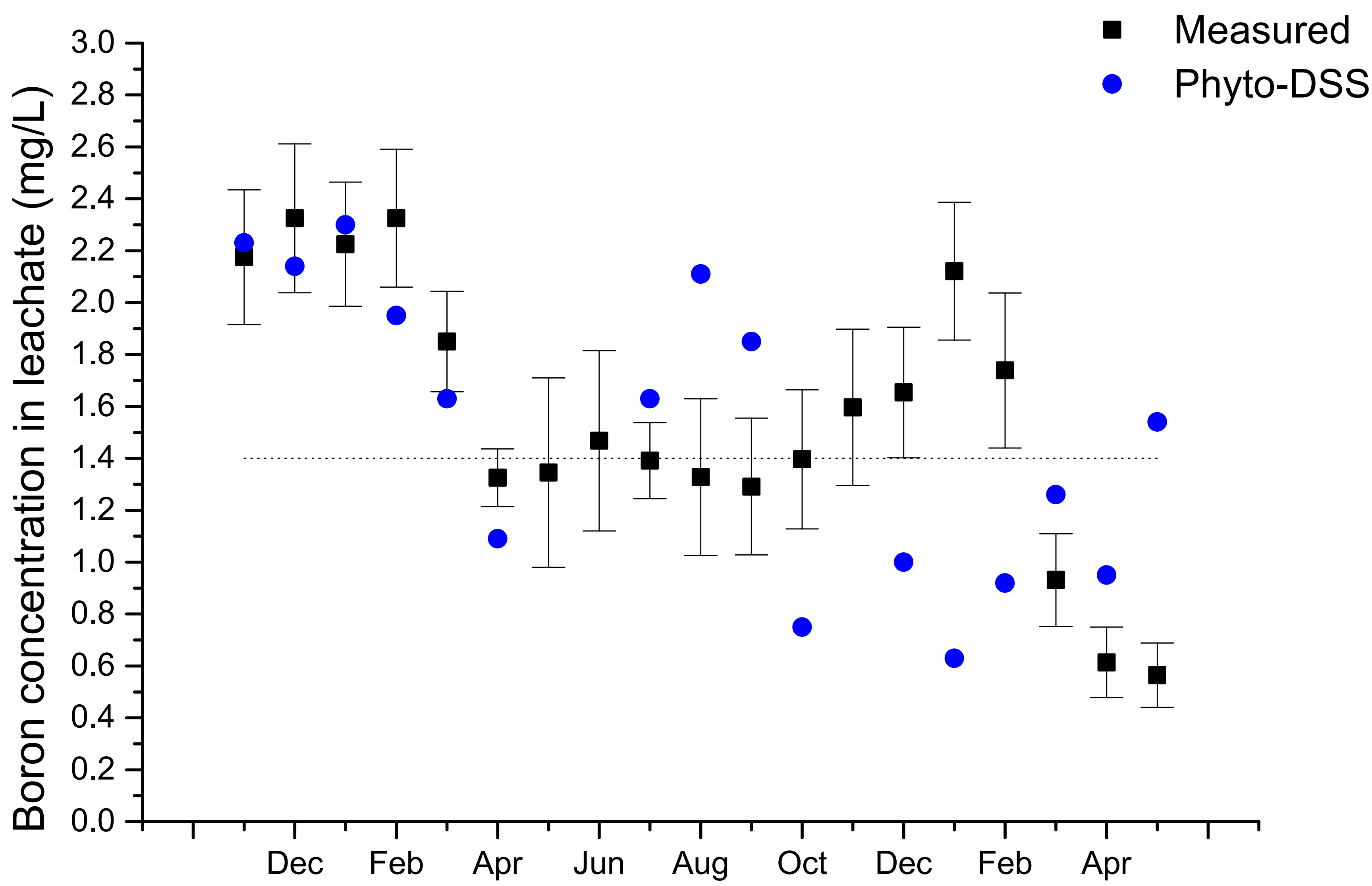


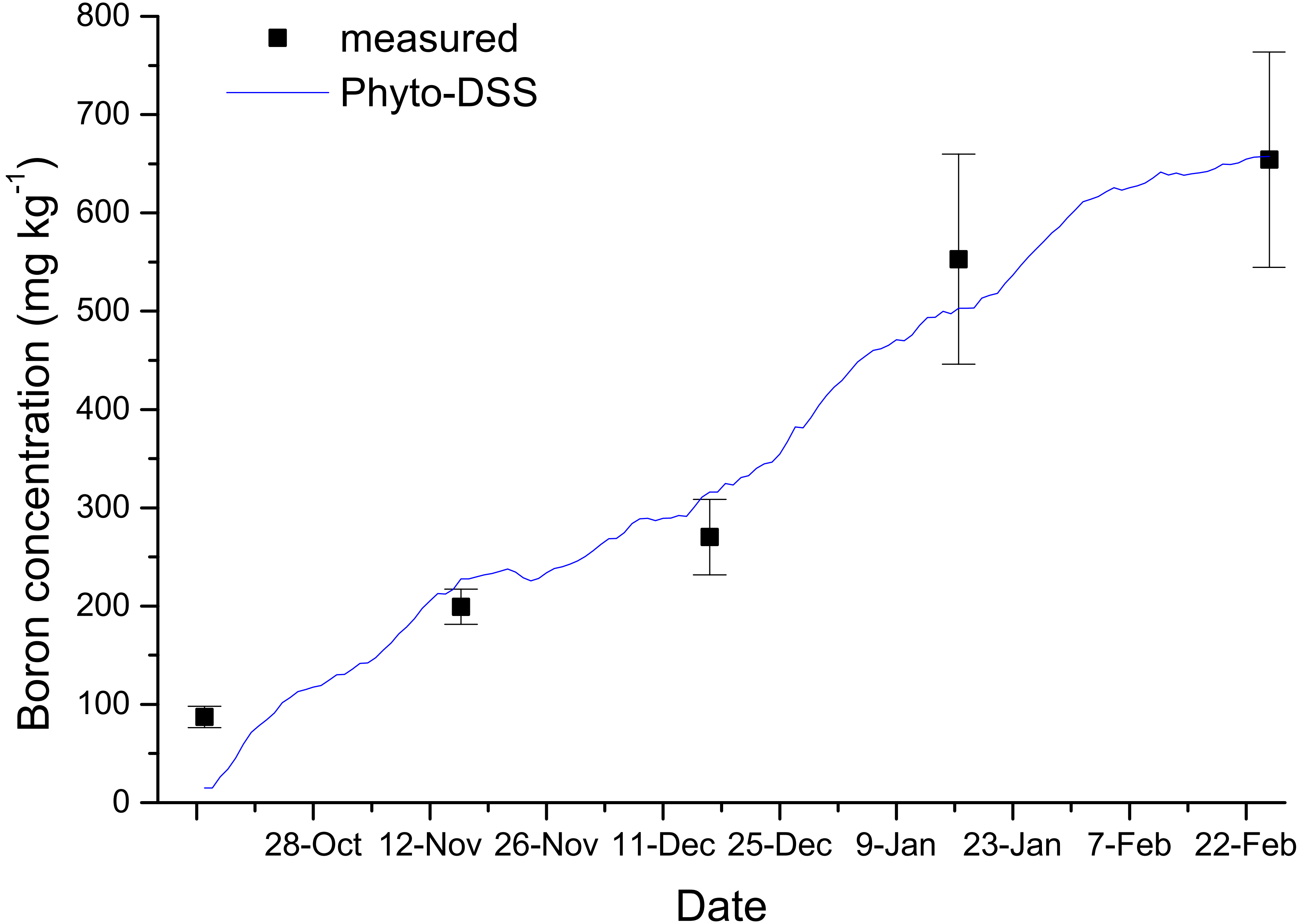
Phytoextraction in action: contaminated sawdust

- A 5ha, 15m deep pile of sawdust leaching unacceptable amounts of boron into local waterways

- The Regulatory Authority demanded a US$ 700,000 capping of this site


measured ET
Phyto-DSS ET
measured drainage
Phyto-DSS drainage
Volume (L / tree)
2500
2000
1500
1000
500
0
200
300
400
500
600
700
800
900
Day of experiment


Measured
Phyto-DSS
Boron concentration in leachate (mg/L)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr

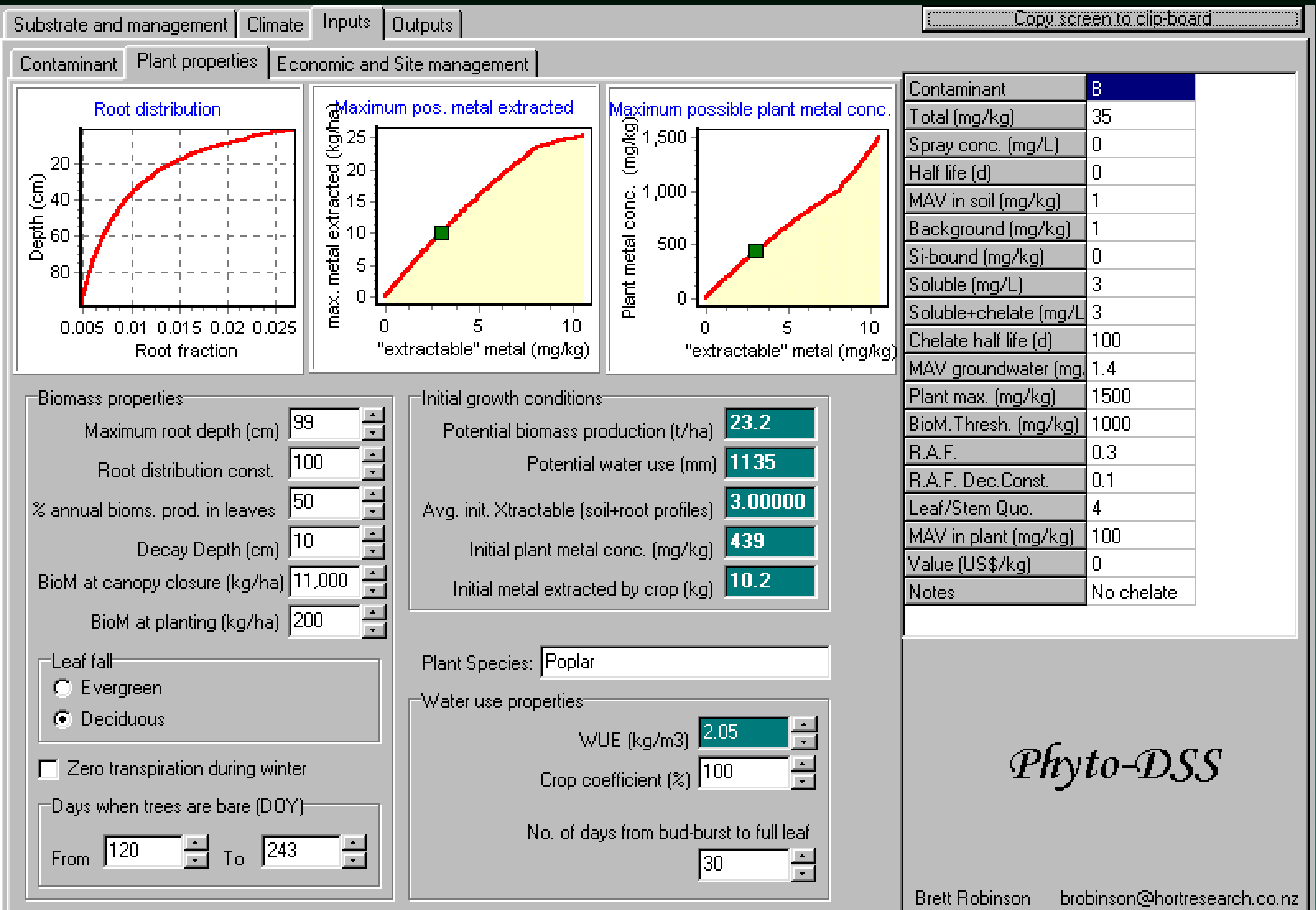


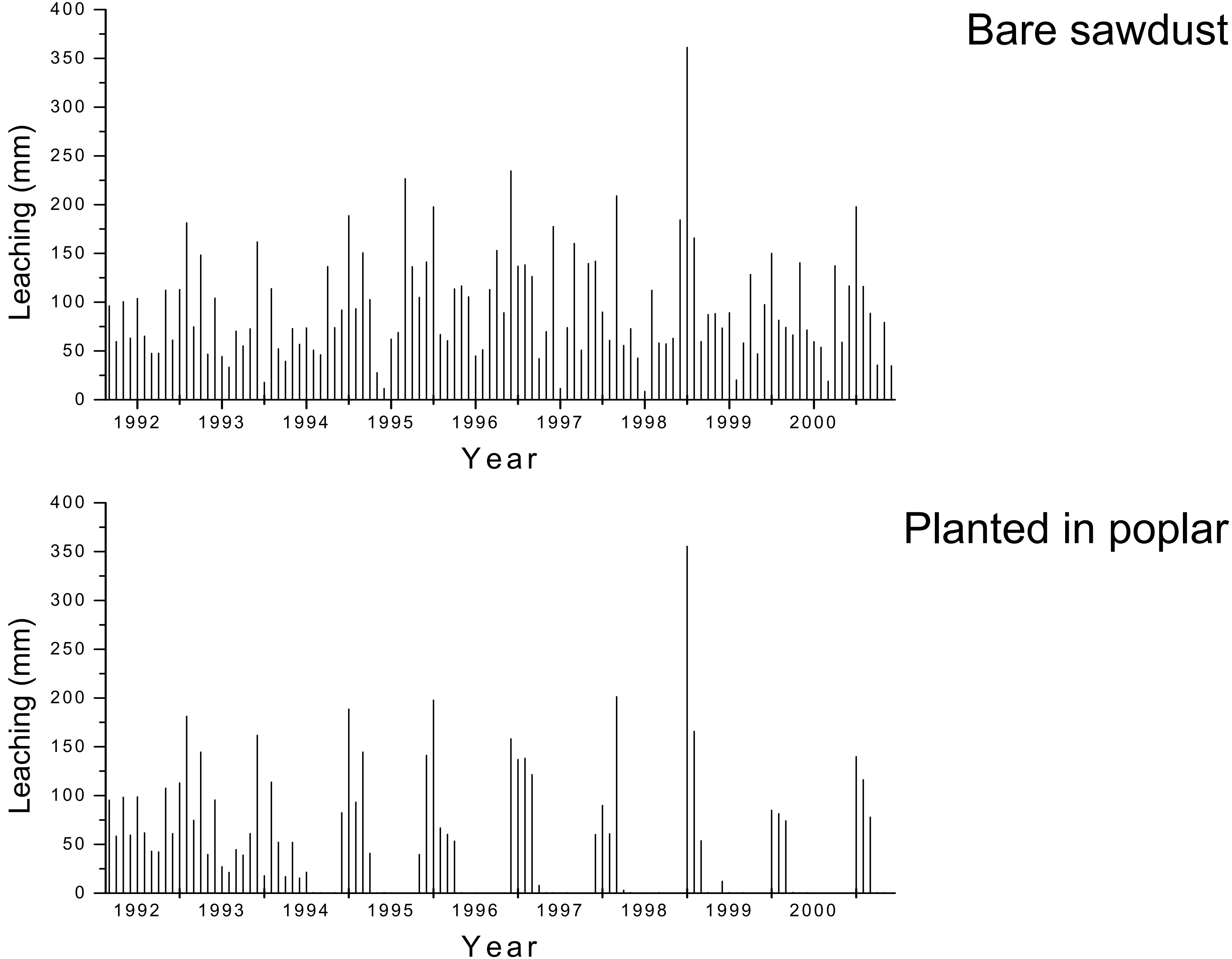
measured
Phyto-DSS
Boron concentration (mg kg-1)
800
700
600
500
400
300
200
100
0
28-Oct
12-Nov
26-Nov
11-Dec
25-Dec
9-Jan
23-Jan
7-Feb
22-Feb
Date

Using the correct varieties and soil amendments is essential….

Phyto-DSS plant properties

Phyto-DSS





Bare sawdust
Planted in poplar
Leaching (mm)
Year
0
50
100
150
200
250
300
350
400
1992
1993
1994
1995
1996
1997
1998
1999
2000


2000


2002

Phyto-DSS economic variables

Phyto-DSS

Substrate and management | Climate | Inputs | Outputs

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Contaminant | Plant properties | Economic and Site management

Phytoextraction

Profit generation from:

- ( ) leaves
- ( ) stems
- ( ) leaves and stems
- ( ) metal
- ( ) metal and biomass
- (•) none

Plant use	none
Cost of site assessment ($000 US)	20
Gross biomass value ($US/t)	
Cost of planting ($US/ha)	9,000
Cost of production ($US/ha/yr)	1000
Cost of ashing ($US/t)	
Cost of recovery ($US/ton of ash)	
Ash -Dry biomass (%)	

Costs of inaction

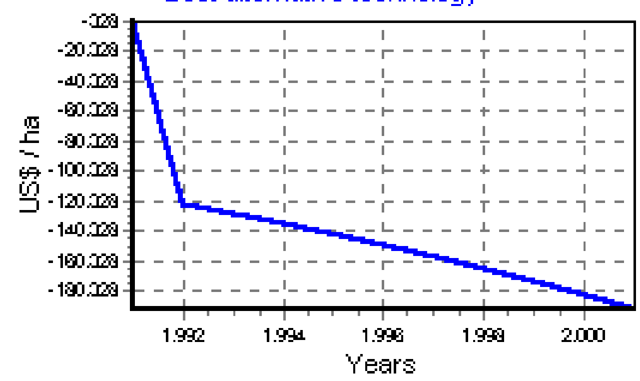
Loss of productivity ($US/ha/yr)	0
Reputation / Goodwill ($000 US)	50
Legal / Litigation ($000 US)	600
Future costs ($000 US)	0

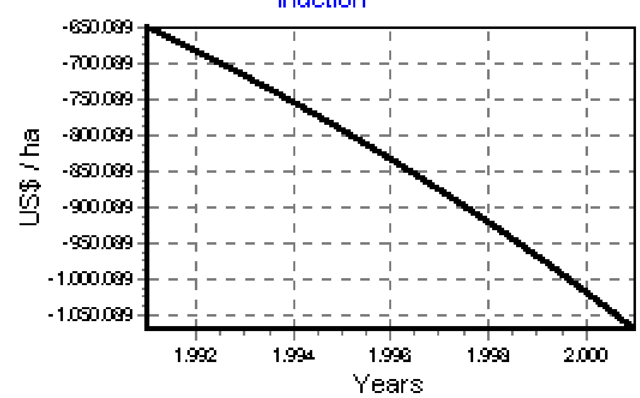
Interest Rates

In credit (%) 3 In debt (%) 5

Best alternative technology

Technology type	Capping
Cost ($000 US/ha)	120
Time needed (years)	1





Contaminant	B
Total (mg/kg)	35
Spray conc. (mg/L)	0
Half life (d)	0
MAV in soil (mg/kg)	1
Background (mg/kg)	1
Si-bound (mg/kg)	0
Soluble (mg/L)	3
Soluble+chelate (mg/L	3
Chelate half life (d)	100
MAV groundwater (mg.	1.4
Plant max. (mg/kg)	1500
BioM.Thresh. (mg/kg)	1000
R.A.F.	0.3
R.A.F. Dec.Const.	0.1
Leaf/Stem Quo.	7
MAV in plant (mg/kg)	100
Value (US$/kg)	0
Notes	No chelate

Phyto-DSS

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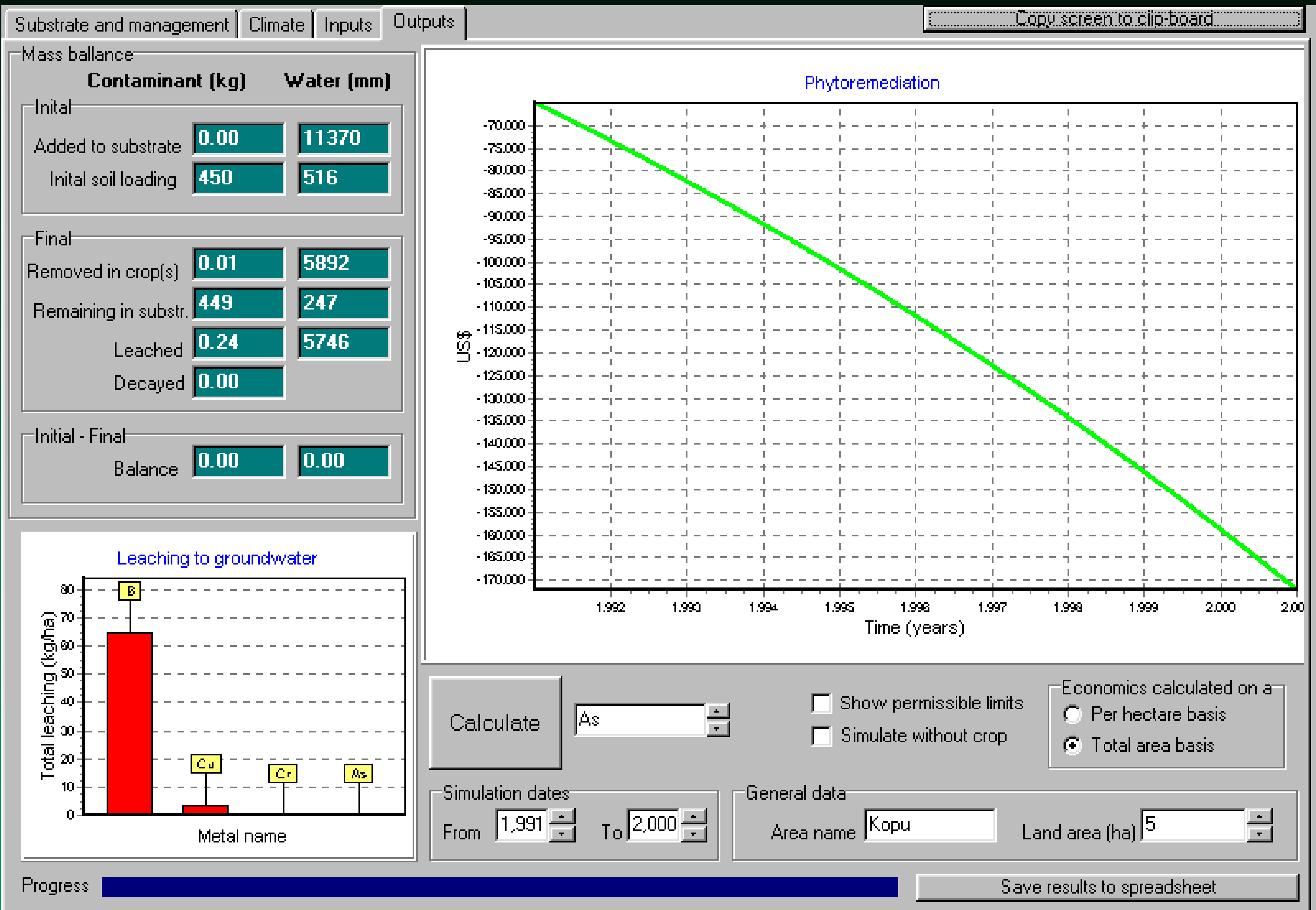
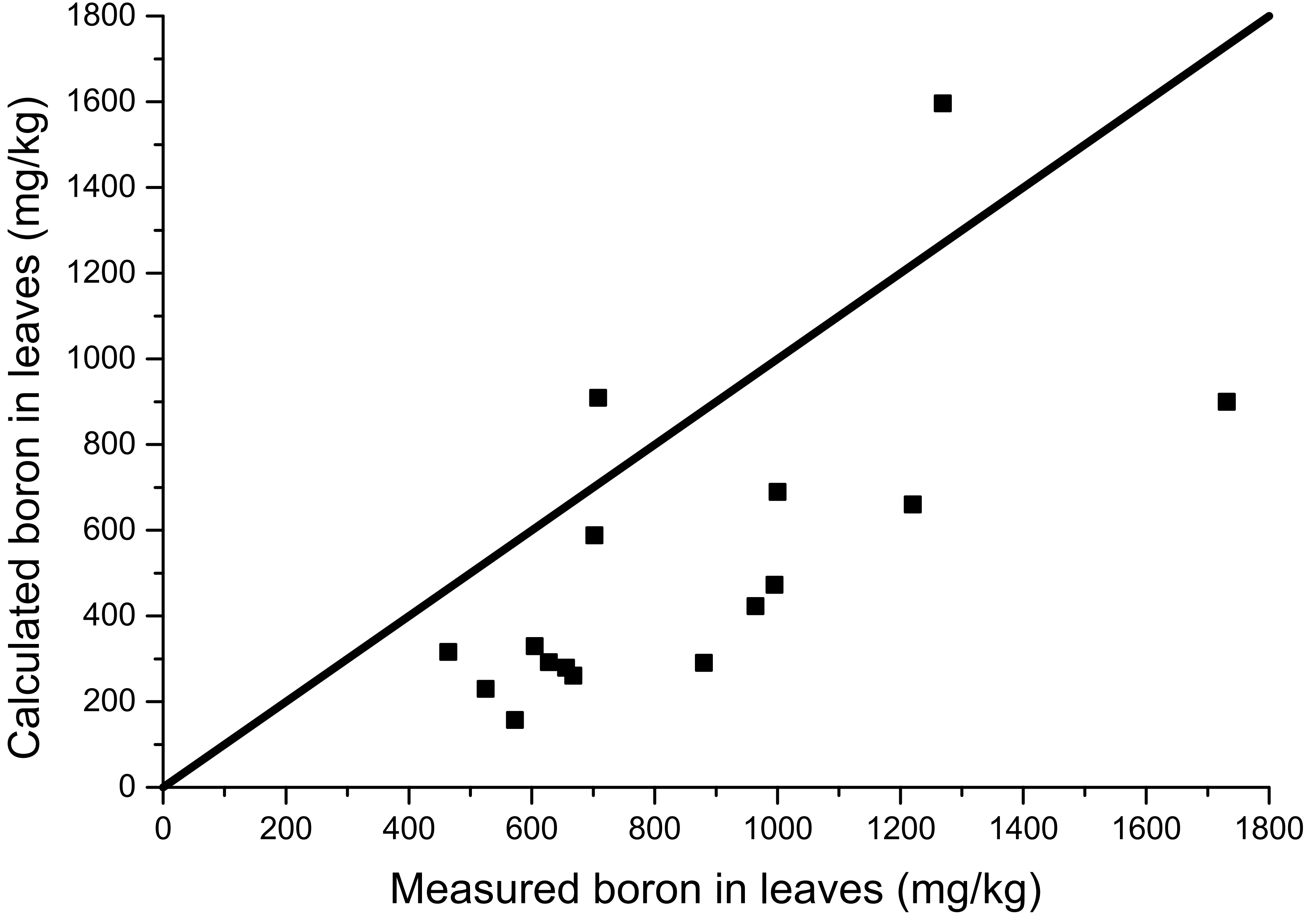
Phyto-DSS economic variables

Phyto-DSS





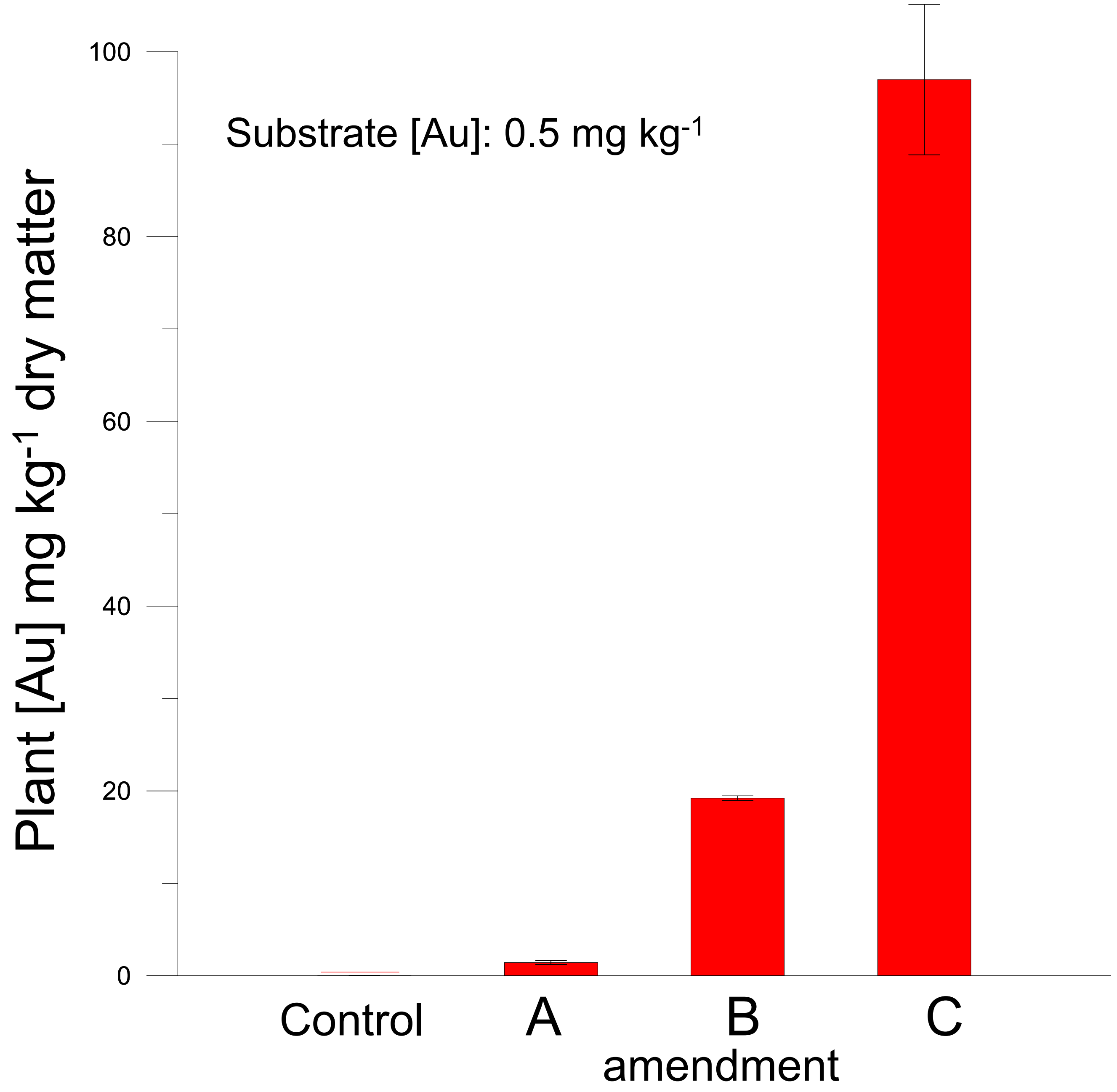
1800
1600
1400
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
1400
1600
1800
Calculated boron in leaves (mg/kg)
Measured boron in leaves (mg/kg)

Assessment of phytoextraction at Kopu

- Phytoextraction satisfies environmental legislation on this site
- The total cost of phytoextraction over a ten-year period will be US$ 170,000 compared to capping at US$ 950,000
- Selective coppicing will allow B to be removed from the site
- Harvested material could be used as an organic B-rich mulch on nearby avocado orchards that are deficient in B

Field trial for gold phytomining

Induced gold uptake in *Brassica juncea* - greenhouse experiment

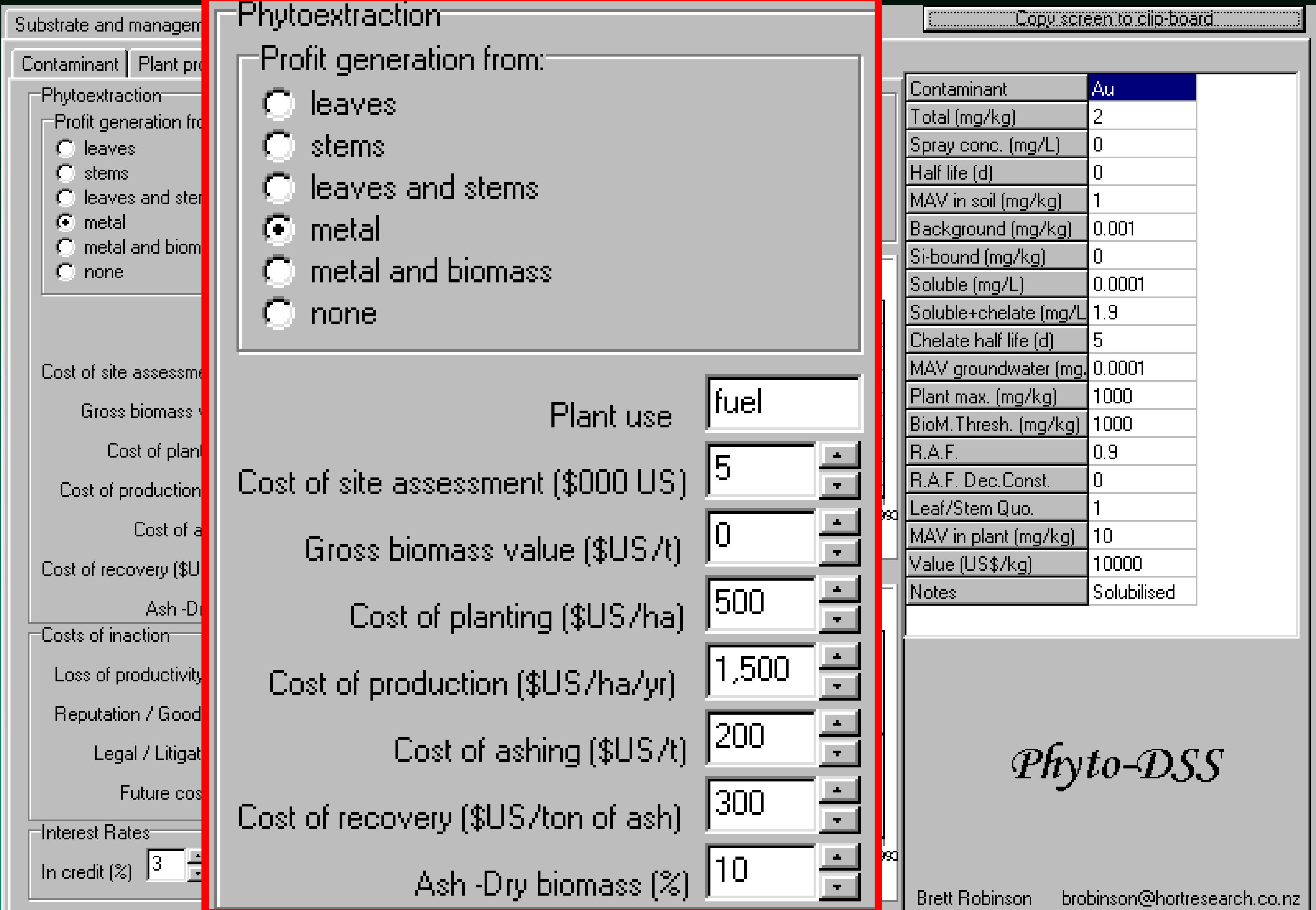


Gold extracted by *Brassica juncea*

Phyto-DSS

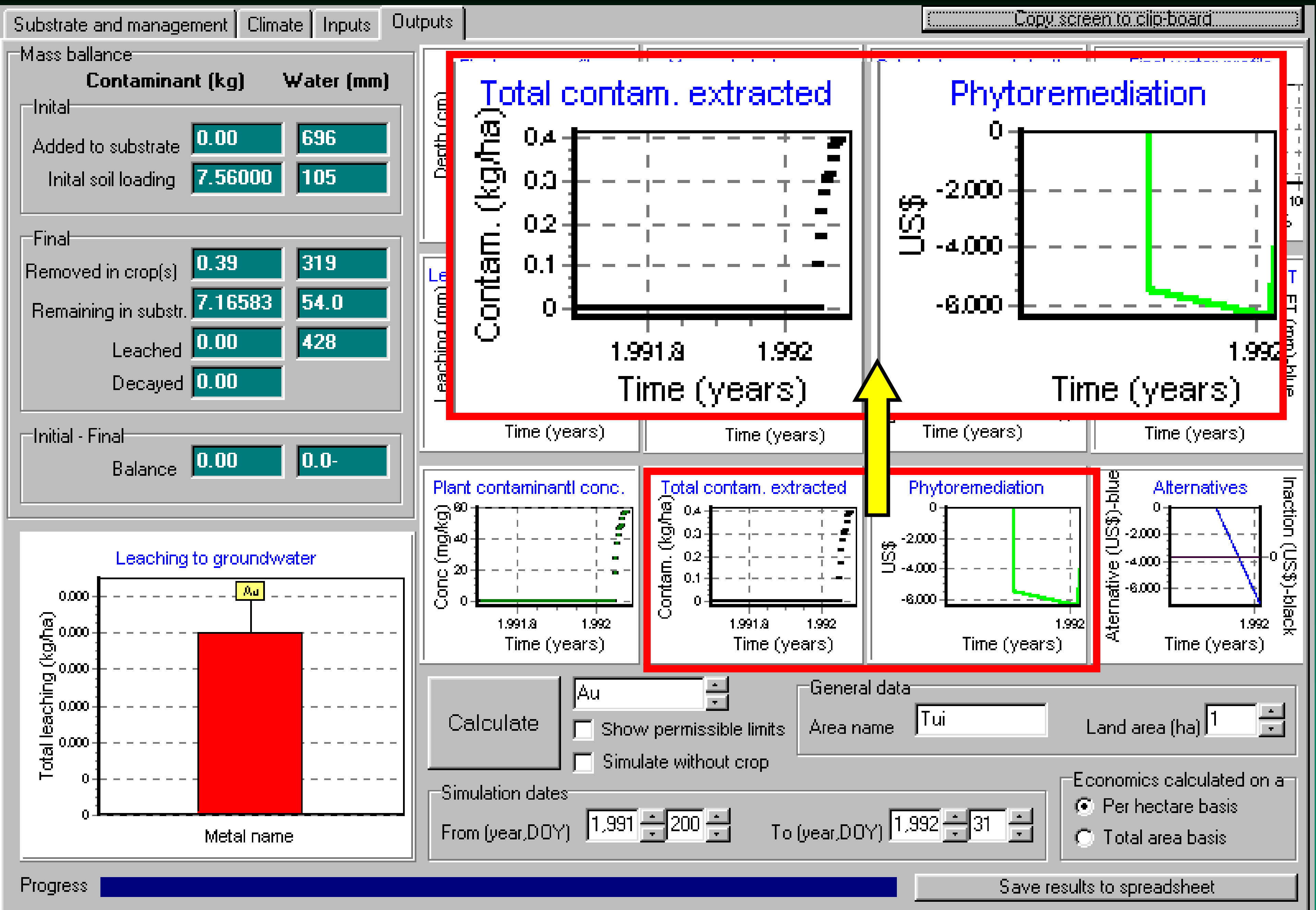
Phyto-DSS economic inputs

Phyto-DSS



Phyto-DSS induced gold uptake

Phyto-DSS



Assessment of gold phytomining

- Most effective on small ‘orphan sites’ where conventional extraction is uneconomic
- Can be effectively combined with the rehabilitation of the site
- Timing of amendment addition is critical
- Highly sensitive to the price of gold

Conclusions

- Modelling can be used to predict the appropriateness of phytoextraction
- Accurate site assessment is essential
- Science costs are part of phytoextraction
  - Correct species / variety
  - Substrate amendments
  - Irrigation regime