Gold phytoextraction in developing countries:

using the value of gold to pay for the clean up of degraded land

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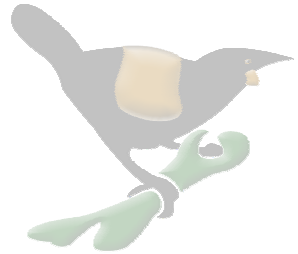
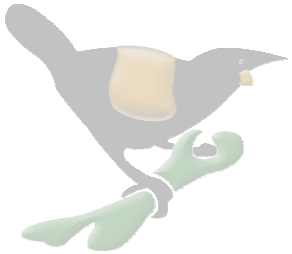
outline…….



- context: phytoremediation
- quick review and background
- modelling tools
- basic economics
- scenario for developing countries
- where and what next?

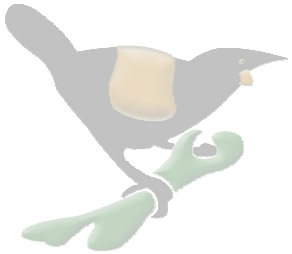
Phytoremediation: what is hindering implementation?



- Lack of environmental regulation
- Perceived security of conventional technology
- Client hesitation, plants take time to grow
- Cost

- There is no money to be made in clean up, so why do it?

Phytoremediation: how can we overcome the problem?



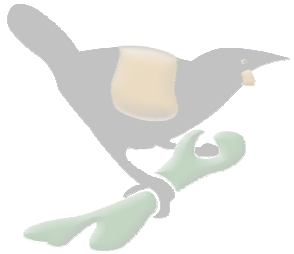
- Revenue; make remediation pay for itself

Gold

- I will admit that gold is not a contaminant
- But it does occur with contaminants
- Let’s get them both out at the same time and make money
- Gold revenue pays for phytoremediation

background to gold phytoextraction

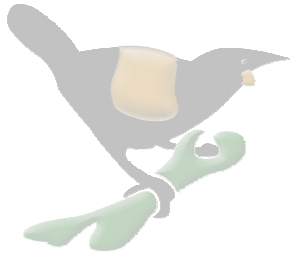
review: 1997 - 2004



- 1997: discovery at Massey University, plants could be induced to accumulate Au
- 1998: concept of Au phytomining published (Anderson *et al*., 1998, Nature)
- 1998-2004: ongoing laboratory and greenhouse research in NZ
- 2002: US discovery of Au nanoparticles inside plants (Gardea Torresdey *et al*., 2002, Nano Letters)
- 2003: NZ field research culminated in Brazil (Anderson *et al*., 2005, Min. Engin.)
- 2003: nanoparticle research commenced in NZ

gold-soaking plants

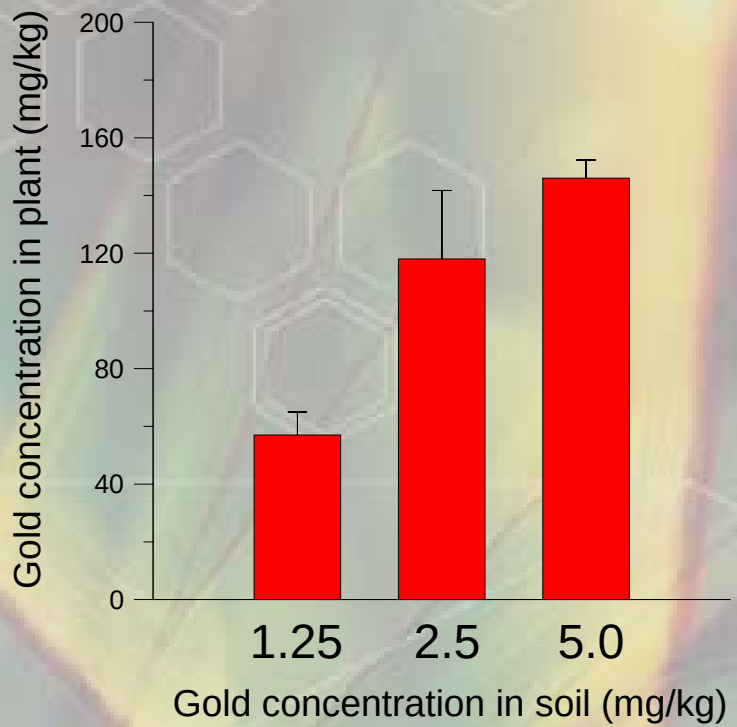
induced hyperaccumulation



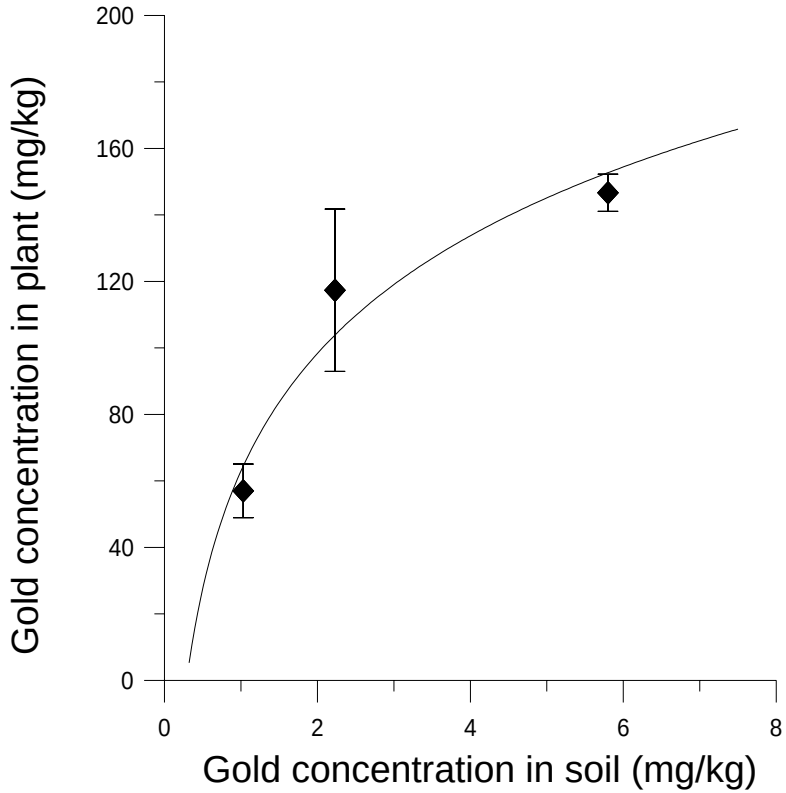
- If Au is soluble plants will take it up
- The mining industry has solubility expertise
- Plant concentration is limited by the ‘soil’ concentration and by suitable ligands
- This is a natural process…. environmentally occurring chemicals will cause plants to accumulate Au
- This is also a known process ….biogeochemical exploration

laboratory and greenhouse trials

Experimental data illustrating the plant-soil correlation



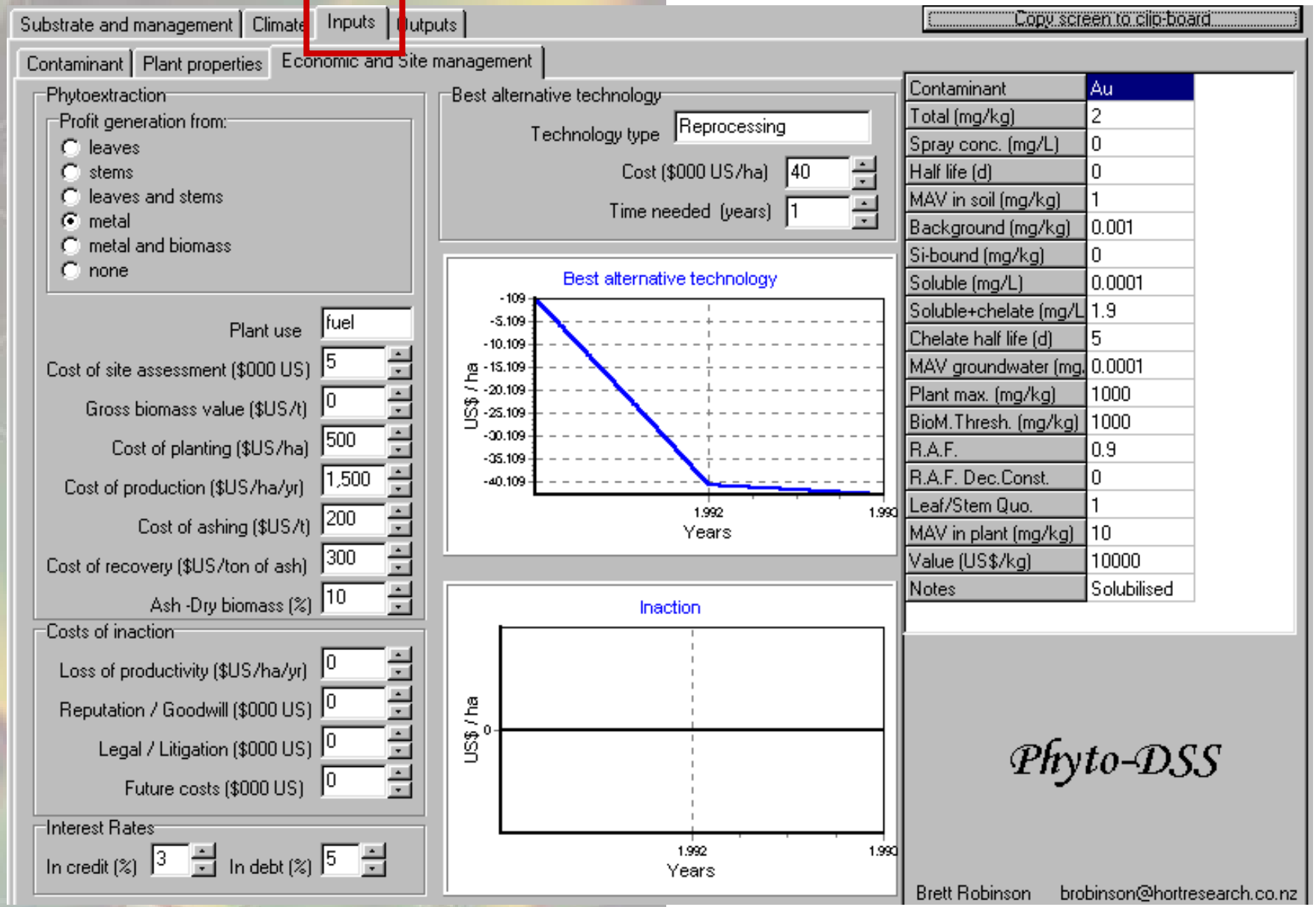
Gold uptake by *Brassica juncea*
Anderson *et al.* 2003, www.gold.org



Anderson, Moreno and Meech, 2004,
Minerals Engineering

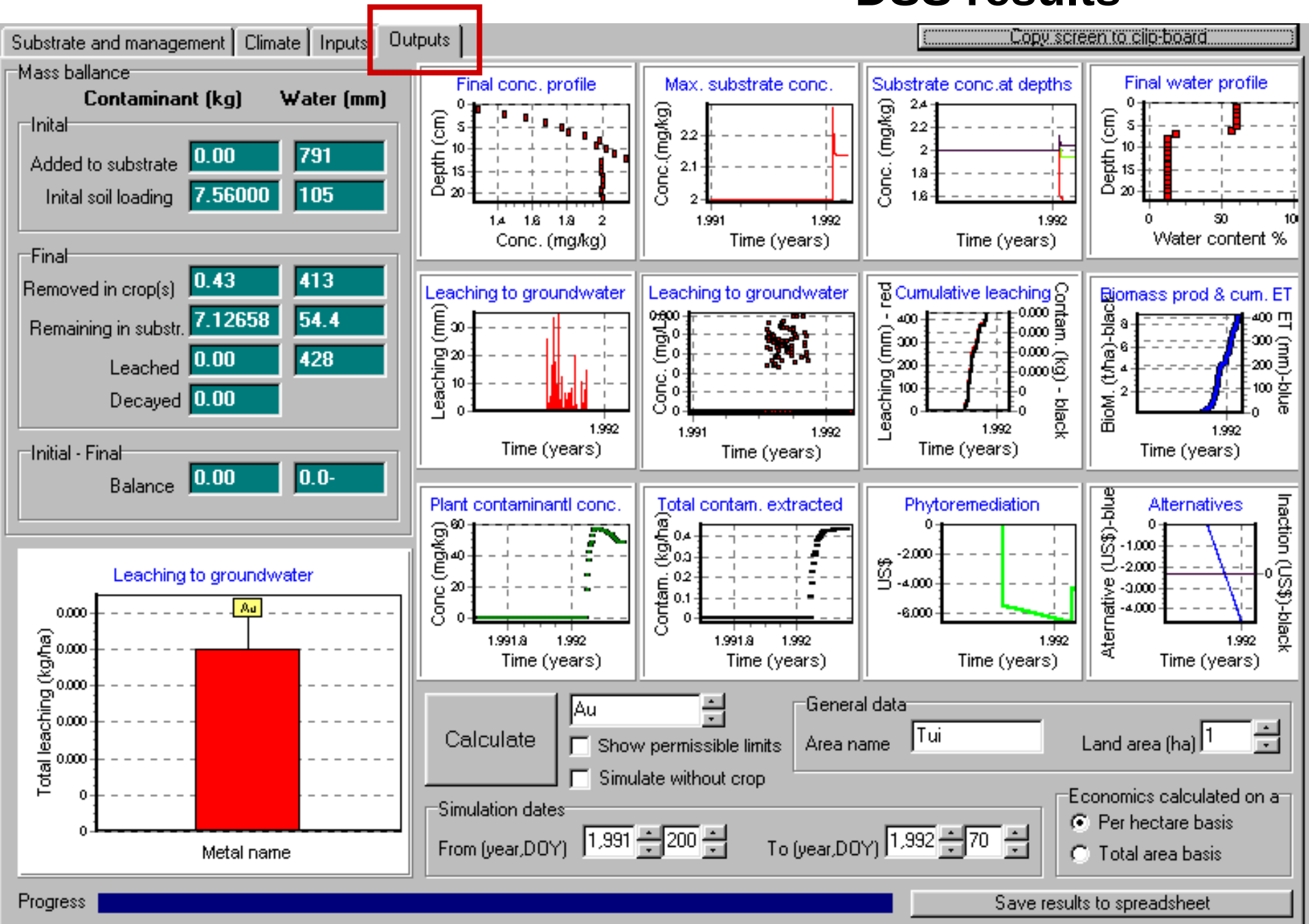
modelling tools

- Modelling is used to design chemical irrigation
- Ensures limited potential for leachate
- Ensures best possible recovery of gold



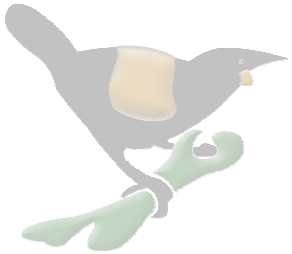
Modelling gold uptake, a DSS

DSS results


Substrate and management
Climate
Inputs
Outputs
Copy screen to clip-board
Mass ballance
Contaminant (kg)
Water (mm)
Inital
Added to substrate
0.00
791
Inital soil loading
7.56000
105
Final
Removed in crop(s)
0.43
413
Remaining in substr.
7.12658
54.4
Leached
0.00
428
Decayed
0.00
Initial - Final
Balance
0.00
0.0-
Final conc. profile
Depth (cm)
Conc. (mg/kg)
Max. substrate conc.
Conc.(mg/kg)
Time (years)
Substrate conc.at depths
Conc. (mg/kg)
Time (years)
Final water profile
Depth (cm)
Water content %
Leaching to groundwater
Leaching (mm)
Time (years)
Leaching to groundwater
Conc. (mg/L)
Time (years)
Cumulative leaching
Leaching (mm) - red
Contam. (kg) - black
Time (years)
Biomass prod & cum. ET
BioM. (t/ha)-black
ET (mm)-blue
Time (years)
Plant contaminantl conc.
Conc (mg/kg)
Time (years)
Total contam. extracted
Contam. (kg/ha)
Time (years)
Phytoremediation
US$
Time (years)
Alternatives
Aternative (US$)-blue
Inaction (US$)-black
Time (years)
Leaching to groundwater
Au
Total leaching (kg/ha)
Metal name
Calculate
Au
Show permissible limits
Simulate without crop
General data
Area name
Tui
Land area (ha)
1
Simulation dates
From (year,DOY)
1,991
200
To (year,DOY)
1,992
70
Economics calculated on a
Per hectare basis
Total area basis
Progress
Save results to spreadsheet

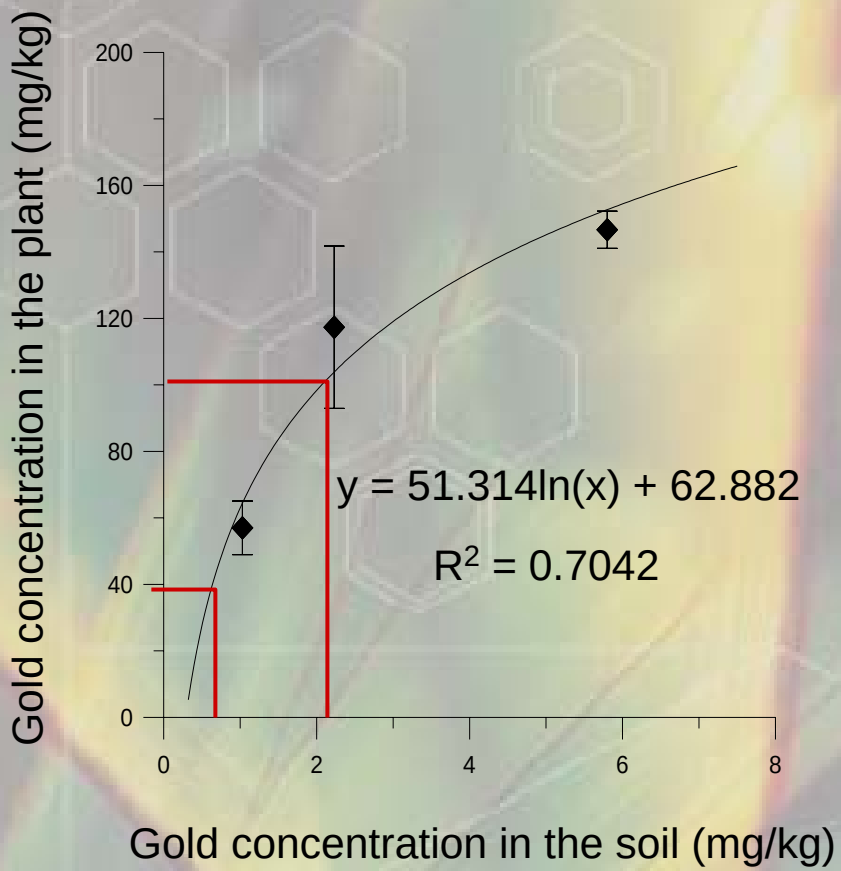
economics of gold phytomining

real life application



- Our *economic* aim is to achieve a gold concentration of 100 ppm in a crop with a harvested biomass of 10 t/ha
- Yield 1 kg of gold per hectare from 1 t of ash
- Gold is not the only metal removed in the plants
- Other, valuable metals can be recovered (Ag, Pt)
- Other, less or non-valuable but toxic metals can also be recovered (Hg, Cu)

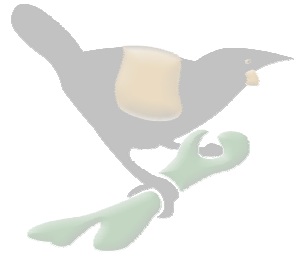
progress towards our target



- 2003 Brazil work generated biomass with a max. average Au concentration of 40 mg/kg
- The ‘soil’ contained 0.6 mg/kg
- Uptake was well modelled by controlled studies
- Conservative modelling shows that we need > 2 mg/kg Au in the soil to reach our target of 100 mg/kg in the plants
- Biomass of 10 t/ha is realistic

Anderson, Moreno and Meech, 2005, *Minerals Engineering*

can this really make money?



nominal-case scenario, 10 t of biomass incinerated then solvent extraction of 1 t of ash. Gold @ US$400 / oz

Item		cost	revenue
Agricultural and labour costs		$ 1,327	
Irrigation and chemical costs		$ 1,975	
Processing costs		$ 2,657	
Sub total		$ 5,959	
Gold recovered	1 kg @ US$400 / oz		$12,862
Gross margin			**$ 6,903**

Fosterville gold mine, Australia

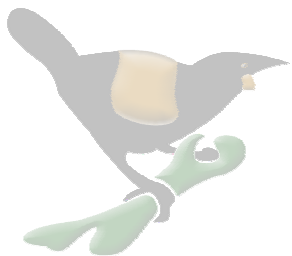
US$7k / ha for clean up here

Igarape Bahia mine, Amazon

or maybe
US$7k / ha for
clean up here

scenario for the developing world……

phytoextraction and artisanal gold mining

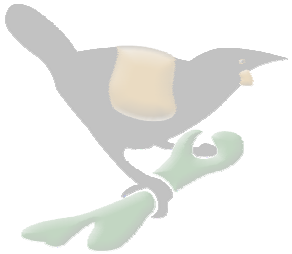


The Serra Pelada artisanal gold mine, Brazilian Amazon, 1980

vision for artisanal communities

- A ‘farming’ system for mercury and gold
- Value of the gold pays for clean-up and education
- Subsidise the development of sustainable agriculture
- We’re looking to recover 1 kg of gold per hectare and to remove 0.5 kg of mercury
- This is the same vision as Brooks in the 90’s and Baker *et al.* today for Ni

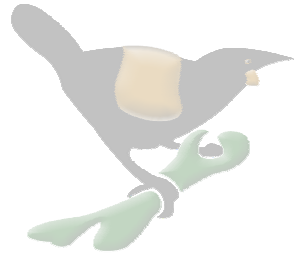
what does this achieve?



- Gold for sale
- Employment, training and education for local communities
- A cleaner environment

- The value of gold pays for these benefits
- Once the gold is exhausted, the land can be farmed by trained workers
- The lure of gold will make farming an attractive livelihood

where do we hope to work?

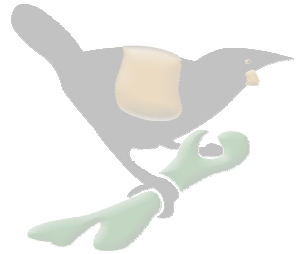


- Carajas region in Brazil; the Serra Pelada mine

- Project team:
  - Tiaki International Ltd
  - Tiaki Brazil Ltd
  - CVRD

Aim: sustainable development and poverty reduction

where do we hope to work?



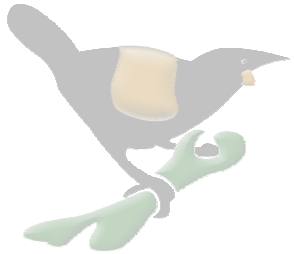
- Tongguan County, Shaanxi Province, China

- Project team:
  - Tiaki International Ltd, NZL
  - Scitrax UK Ltd
  - State Key Laboratory for Environmental Geochemistry, Guiyang, CN
  - Massey University, NZL

Aim: sustainable development and poverty reduction

what and where next?

the future for gold phytoextraction

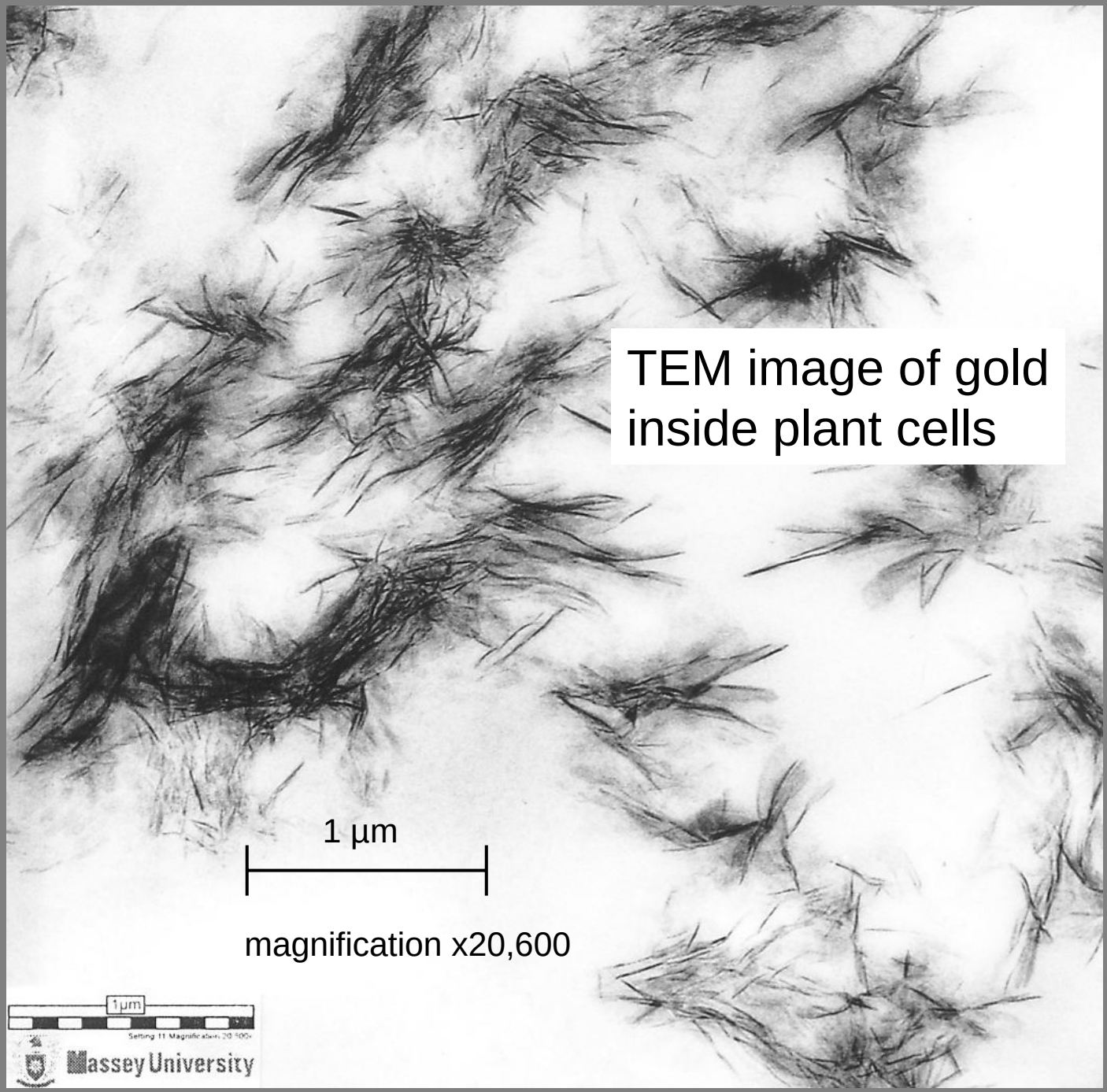


- Concept is proven. Commercialisation operation undergoing due diligence

- Niche market technology to farm small deposits (< 10,000 t) of gold-rich soil, mine waste and tailings
- We need to implement applications

- Potential high value applications for the gold

nanotechnology

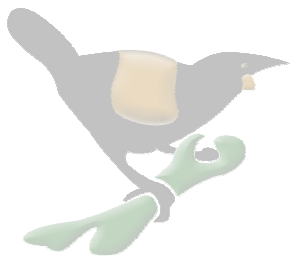


US Airforce funded research

- Nanoparticles could have use as industrial catalysts
- Gold nanoparticles also find application in gold-colloid paints, electronics and medicine

- Develop a more cost-effective gold recovery system based on nanotechnology

- New generation lixiviants to make gold soluble



future

to conclude……

we find

or this

this

we then

no

we farm gold

do this