CENTRE FOR BIOPROCESS ENGINEERING RESEARCH
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Can fibre-rich plants serve the joint role of remediation of degraded mine land and fuelling of a multi-product value chain?

Towards Resilient Futures Community of Practice Project

Project team

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Background to study

- Over 5900 abandoned mines in SA
- Over 300 000 mine job loses since 1987 in SA
- 27,5% unemployment rate in SA
- Loss of biodiversity

Creating a new economy..

- Land remediation
- Beneficial use of metals
- Generating new economic outputs

Phyto-mining and multi-product fibrous economy

Phytoremediation

Phytodegradation

Pollutants are degraded or mineralised by specific enzyme activity

Phytostabilisation

Pollutants are immobilised by the soil

Phytoextraction

Pollutants are accumulated in harvestable parts of the plant

Phytovolatisation

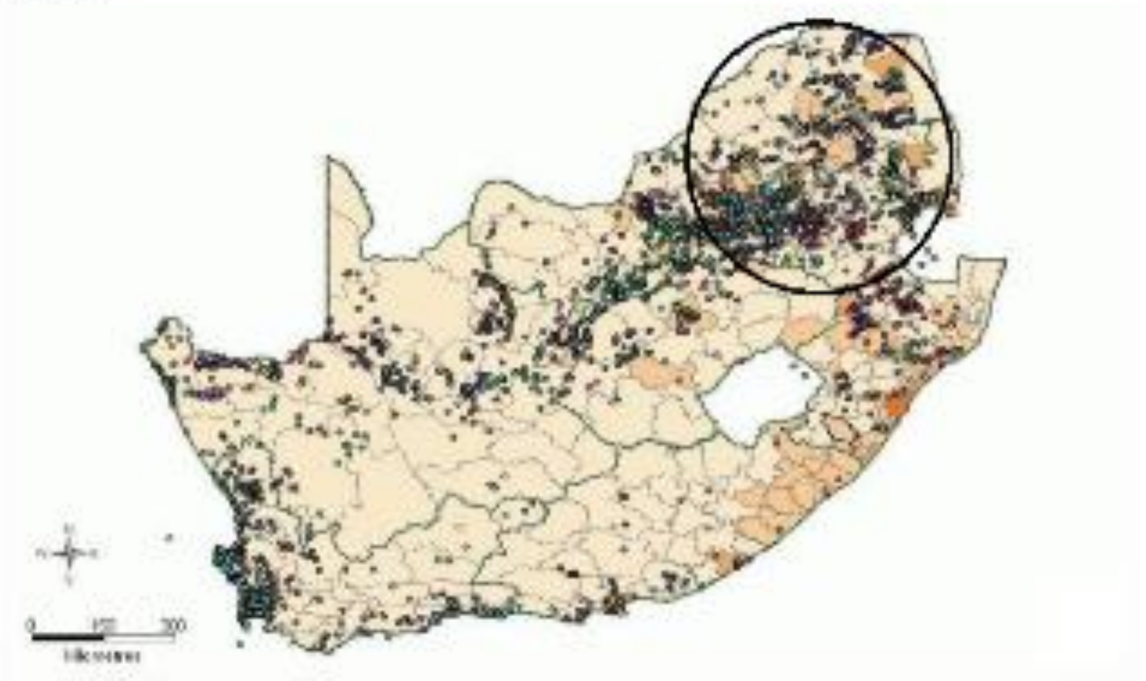
Pollutants are released into volatile form through plant

Metal ions

Developing a fibrous economy

Example sites for case studies

Illustration 1: Correlation between abandoned mines in South Africa and population density



- Degraded mine land
- Surrounding areas are densely populated
- Water pollution and scarcity
- Potential arable land in terms of pH, rainfall and climatic conditions

Example sites - Characteristics

Potential Sites	Metals Found	Soil Texture	Soil pH	Rain (mm pa)	Temp (°C)
Carletonville, Gauteng	Au – Pb, As, Ni, Cd, Cu, Zn, Hg, Co & U	Shallow - rocky	5.6 – 6.4	100 – 200	7 – 33
Witbank, Mpumalanga	Coal - Al, Ba, Ca, Cl, Cu, Fe, K, Mg, Si, S, N	Sandy-clay loams	5.5 – 7.2	100 - 300	7 - 31
Rustenburg	Pt – Pd, Rh, Ni, Au, Ir, Cu	Loamy topsoil on rocks	5.5 – 6.4	100 - 200	10 – 30
Amandelbult	Pt – Pd, Rh, Ni, Au, Ir, Cu	Clay-rich	6.8 – 6.9	100 - 300	7 - 32

Fibrous plants grown in SA

Fibre plants

Bast
- Flax
- Hemp
- Jute
- Kenaf

Leaf
- Sisal
- Palm

Seed
- Cotton
- Kapok

Fruit
- Coconut

Wood
- Pinewood
- Baobab

Grass
- Bamboo




Fibrous plants selection

Name	Preferred soil type	Preferred annual rainfall (mm/yr)	Temp. tolerance	pH tolerance	Annual/perennial
Bambusa balcooa	Clay, loamy	400 - 4500	9 – 35 °C	4.5 – 7.5	Perennial
Baobab	Clay, sandy	< 1500	Cannot tolerate cold climate	7	Perennial
Coconut	Coarse sand, clay	1500 - 2500	13 – 35 °C	5.5 - 7	Perennial
Cotton	Sandy loam	500 - 1250	21 – 37 °C	5.5 – 7.5	Annual
Flax	Loamy	450 - 750	10 – 27 °C	5 - 7	Annual
Hemp	Clay, silt loam	500 -700	19 – 28°C	6 – 6.5	Annual
Jute	Silt, sandy loamy, clay	1000 - 2500	24 - 37 °C	4.8 – 5.8	Annual
Kapok	Loamy soil	750 - 3000	17 - 38 °C	5 – 6.5	Perennial
Kenaf	All soil types	240 - 490	15 - 27 °C	4.3 – 8.2	Annual
Pinewood	Sandy soil	850 – 950	> 13	5 - 6	Perennial
Sisal	All except clay	500 - 1500	10 – 32 °C	4 - 6	Perennial

Fibrous plants selection

Name	Dry biomass (tons/ha)	Harvest time	Fibre yield (tons/ha)	Preferred annual rainfall (mm/yr)	Potential products
Bambusa balcooa	20 – 40	5- 6 years	12 - 18	400 - 4500	Paper products, furniture, bioenergy etc..
Flax	3 – 5	100 days	1 - 2	450 - 750	Pulp, chemical products from oilseeds, composite products, energy products
Hemp	10 - 20	120 days	2.2 – 8.1	500 -700	
Kenaf	14.8 – 24.7	90 – 125 days	5 - 7	240 - 490	
Sisal	13 - 17	2 – 4 years	1 - 4	500 - 1500	

Fibrous plants selection

Name	Preferred bioaccumulation site	Metal selectivity	Metal uptake/absorption/concentration
Bambusa balcoola	Roots, shoots	Pb, Zn, Cr, Fe	Pb: 36; Zn: 43 (mg/kg of biomass)
Flax	Roots, capsule	Pb, Cd, Zn	Pb: 311; Cd: 13.1; Zn: 490 (mg/kg soil)
Hemp	Roots, shoots, leaves, stems	Ni, Pb, Cd, Zn, Cu	Ni: 123; Cd: 151; Cu: 1530 (mg/kg leaves)
Kenaf	Roots, shoots, leaves and seed capsule	Pb, Cd, Zn	Pb: 42.2 (mg/kg soil)
Sisal	Leaves	Cd, Zn, Cu	Cd: 1850 ; Cu: 1340 (mg/kg sisal fibre)

Role of hyper-accumulators

Plant	Rainfall (mm/year)	pH preference	Temp preference (°C)	Harvest time	Metals selected	Major metals location	Dry biomass (tons/ha)	Metal uptake (mg/kg dry weight) in leaves
Berkheya coddii	35 -250	4.2 -7.4	4.3 – 21.7	4 months	Ni, Cd, Cu, Fe, Pb, Zn, Au*, Pd, Pt, etc	Leaves	22	Ni: 13979; Cu: 33; Fe: 3771;
Senecio coronatus	35 - 250	4.2 – 7.2	9 - 32	5 months	Ni plus Ca, Cu, Fe, K, Mg, Mn, P and Zn	Leaves, roots	10	Ni: 12000; Ca: 26000; K: 8700; Mg: 15000;
Cynodon dactylon (grass)	50 -500	2.0 – 8.5	6 - 28	5 – 6 months	Mn, Zn, Cu, Pb, Cd and Co	Leaves, roots and stems	5 - 15	Mn: 232; Zn: 40; Cu: 48;

Enhancing remediation and product formation

- Combining the use of hyper-accumulators and fibrous plants → offer more possibilities over long term
- Fibrous plants grown on heavily contaminated soils show a reduction in growth, performance and yield
- Remediation can be done quicker and more efficiently using hyperaccumulators
- Offers flexibility in choosing products (fibre vs seed products vs metals)
- Processing will be easier

Scenario Analysis

- Using *Berkheya coddii* and hemp on 10 ha of land of contaminated land to extract Nickel and produce fibres and/or hemp seeds

1) Value of Ni extracted from *Berkheya coddii* vs Hemp

Dry biomass of *Berkheya coddii* for 10 ha (tonnes)	220
Amount of Ni extracted for 10 ha (1 % w: w) (kg)	2200
Price of Ni (R/kg)	184
Potential revenue from Ni (R)	404 800

Amount of Ni extracted from Hemp (kg/ha)	0.285 - 2.03*
Amount of Ni extracted for 10 ha (kg)	2.85 - 20
Price of Ni (R/kg)	184
Potential revenue from Ni (R)	524 - 3680

* Considering the shoot harvest only or the entire plant harvest respectively

Scenario Analysis

2) Value from Hemp fibre price ($ 260/ton) and Seed price ($ 1.38/kg)

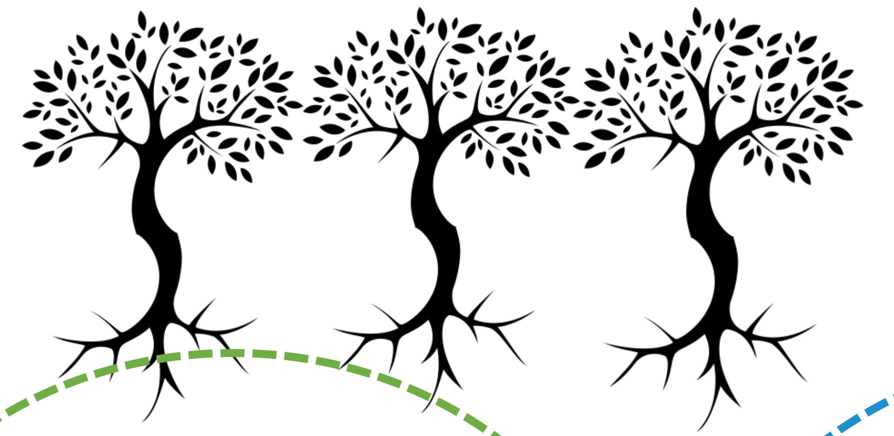
Hemp system only

Production system	Low productivity		Medium low productivity	
	Fibre yield (ton/ha)	Seed yield (kg/ha)	Fibre yield (ton/ha)	Seed yield (kg/ha)
Fibre only	4.6		5.8	
Dual system	2.2	236	2.8	295
Seed only		272		340

Production system	Medium high productivity		High productivity	
	Fibre yield (ton/ha)	Seed yield (kg/ha)	Fibre yield (ton/ha)	Seed yield (kg/ha)
Fibre only	6.9		8.1	
Dual system	3.3	353	3.9	413
Seed only		408		476

Berkheya coddii and Hemp system

Scenario Analysis



Production system	Low productivity	Medium low productivity	Medium high productivity	High productivity
Fibre only	R 171 028	R 215 644	R 256 542	R 301 158
Dual system	R 128 368	R 162 319	R 192 355	R 226 503
Seed only	R 53 676	R 67 095	R 80 515	R 93 933

Hemp system only

Berkheya coddii and Hemp system

Future work – Experimental

Randomly collect metal contaminated soil from potential sites

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Soil Inductively Coupled Plasma (ICP) treatment to determine metal concentrations in soils

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Plant germinated seeds in pots

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Monitoring plant growth; control soil comparison

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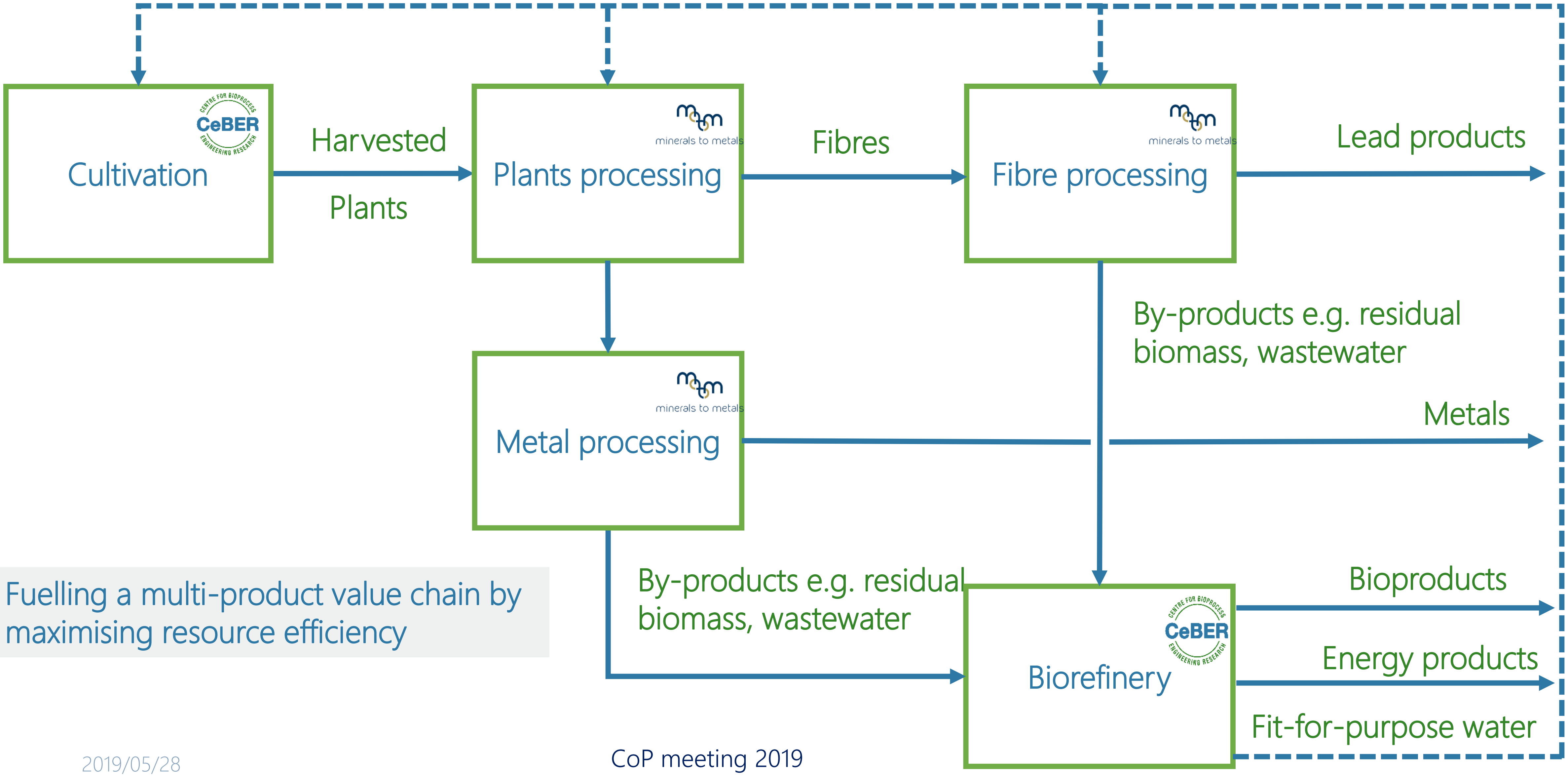
Analysis of concentrations of metals in soils and plants after harvest

Future work - Biorefinery concept



Fuelling a multi-product value chain by maximising resource efficiency

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