POLICY Brief

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Towards Resilient Futures
Can fibre-rich plants grown on degraded mine land fuel a multi-product value chain?

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Summary

To stimulate economic growth, post-mining economies could target downstream product diversity based on sustainable and renewable agricultural raw materials such as fibre producing plants. However, without an understanding of the plants that are both best suited to providing the valuable raw material for these products and also for cultivation in the regions of interest for economic development, this cannot be attained. To this end, this brief sets out to identify the fibrous plant species best suited for the recovery of value, including an assessment of the potential of the bast fibre hemp and kenaf plants, and the grass fibre, bamboo. We focus on the conceivable application(s) of these plants as raw materials for post-mining economic activity to counter the impact of mine closure, focussing on the opportunities for these selected plants to thrive in mining regions in South Africa. Finally, the impact of metal contamination on plant production is addressed. This was done through a comprehensive review of the published literature and interviews with relevant experts in South Africa. Based on this research, policy recommendations are then put forward to support the development of a fibre-based micro-industry.

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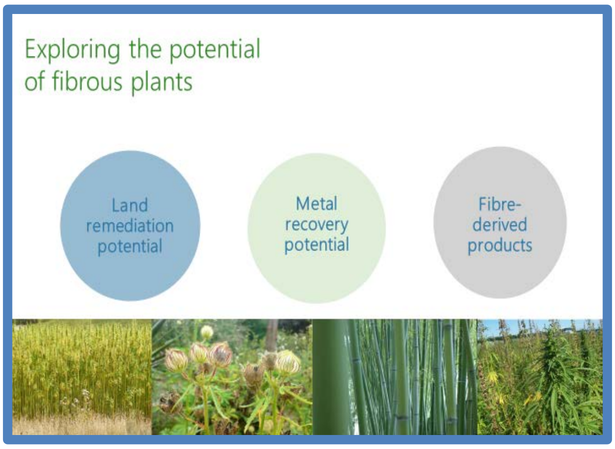
Introduction

The drive to produce bio-based, renewable materials and products requires a sustained source of plant-derived materials. One class of feedstock with potential to yield a diverse grouping of products is fibre crops. These are used in products ranging from wood-like products through to biocomposites and functional materials. Non-fibre components of the plant can be converted into sugars for production of platform chemicals or bioenergy. Further specialty products present in the plant can be extracted. This diverse range of potential products and uses forms the backbone of the concept of using crop fibre production as the raw material for a variety of processing approaches to manufacture a diverse product range as a route to a post-mine economy that is sustainable and has potential to provide economic complexity for both robustness and enhanced quality of life.

On introducing fibre crops as the replacement renewable feedstock for the new fibre economy, awareness of the need to remediate or reclaim the degraded mine land is essential. Further recovery of metals forms a secondary income source for the post-mine community. To achieve this, the role of the fibre crops in phytoextraction needs to be ascertained, along with their growth in (and tolerance of) poor quality soil.

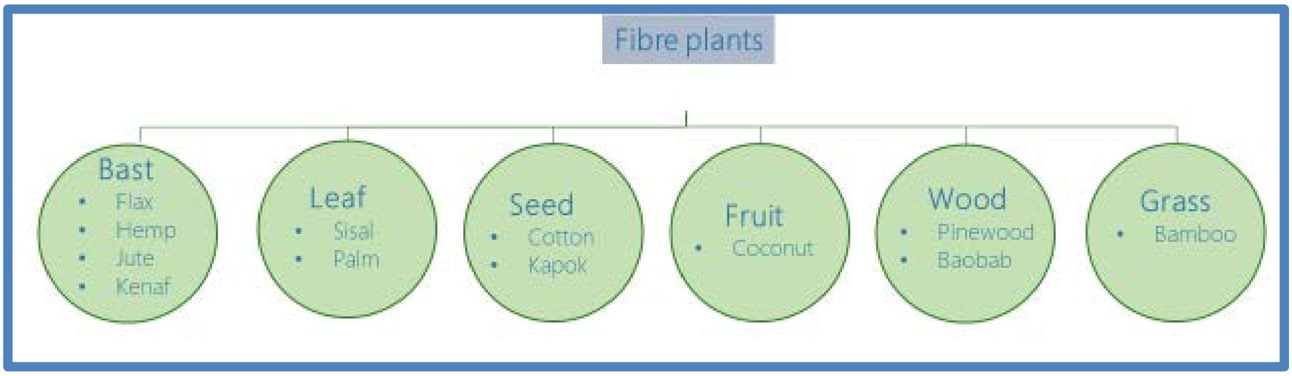


This policy brief considers the potential for production of fibre-based plant crops on degraded mine land. This fibre resource will serve as a renewable raw material and feedstock on which to develop the fibre-based economy as an example of delivering post-mining economic complexity. We identify suitable fibre crops for the environments of the mining regions of interest. We explore the ability to combine remediation and reclamation of this degraded land as an alternative to a two-stage development of remediation and reclamation, followed by agriculture.

Fibre Crops and Their Properties

The fibre crops are classified on the location of their fibres into bast or stem fibres, seed fibres, stalk fibres, grass or reed fibres and wood fibres. These plants produce fibres suited for differing product applications. The fibres are renewable, cheap and biodegradable, fulfilling the requirements for renewable, bio-based raw materials. Common fibre plants are shown in Figure 1.

Figure 1: Classifying Fibre Plants Grown in South Africa



Fibre plants show potential for manufacture into a broad range of products. Products are formed from the fibres themselves. These vary, depending on fibre characteristics (particularly the length of fibre). Products include paper products, textiles, cordage, biocomposites, nanofibers and regenerated cellulose, to name a few. Further products are formed from the woody tissue, leaves and stalks, and other biomass fractions. These include chemical products, composite products and energy products, as shown in Figure 2.

Figure 2: Processing the Fibre Crop into Products Yields a Diverse Product Range

Fibre Crops for Phytoremediation and Phytoextraction

Phytoremediation describes the use of plants to remove metals and other contaminants from the soil, whereas phytomining describes the active concentration of a specific metal into a specific region of the plant e.g. seed or shoot. Both processes can proceed by phytoextraction.

Fibre crops have potential for phytoextraction. For example, bamboo concentrates lead and zinc into shoots and roots at a concentration of 36 mg/kg and 43 mg/kg biomass respectively. Kenaf concentrates nickel and cadmium at a concentration of some 150 mg/kg leaves and copper at 1500 mg/kg leaves, while sisal concentrates cadmium and copper into leaves at some 1500 mg/kg. This metal can be recovered during processing. Where the metals are accumulated into different zones of the plant to the fibre zone, concomitant production of fibre and recovery of metal can be achieved.

Where metal loadings in the soil are very high or rapid remediation of the soil is required, hyperaccumulators may be grown in early years. These plants accumulate specific metals preferably and achieve much higher internal concentrations. For example, the hyperaccumulator *Berkheya coddii* accumulates nickel to levels 100- to 1000-fold that of hemp – however, its biomass is less valuable.

Selecting Fibre Plants for the Post-Mine Economy in South Africa

To select fibre plants for the post-mine economy, the first hurdle is to match the plant requirements (of which a sub-selection are specified in Figure 3) with the growing conditions in the mining regions, while addressing all criteria listed in the pull-out box.

Criteria for plant selection for example sites:
- Non-invasive and/or indigenous
- Preferred soil type
- Temperature tolerance
- pH tolerance
- Multi-product possibility

The climatic and soil conditions in the mining regions of Gauteng, Mpumalanga and Limpopo include soil pHs in the range pH 5.5 to pH 7.2, average rainfalls between 300-500 mm and 600-800 mm with summer rain, and average minimum and maximum temperatures ranging from 5-30 °C to 10-30 °C. The soils are shallow rocky, sandy-clay loams, and loamy topsoil on rocks. Metal contamination is significant and varied. The plants of interest as fibre crops for the South African post-mine fibre economy are: bamboo (*Bambusa balcooa*), flax, hemp, kenaf and sisal.

Figure 3: Plant Growth Requirements and Characteristics of Lead Fibre Crops in South Africa

	Bambusa balcooa	Flax	Hemp	Kenaf	Sisal
	400 – 5400 mm	450 – 750 mm	500 – 700 mm	240 – 490 mm	500 – 1500 mm
	9 – 35 ° C	5 - 30 ° C	6 - 32 ° C	10 - 35° C	10 – 32 ° C
	12 – 18 tons/ha	~ 2 tons/ha	2.2 – 8 tons/ha	5 – 7 tons/ha	1 – 4 tons/ha
	5 – 6 years	80 - 100 days	90 -170 days	100 – 240 days	2 – 4 years
M	Pb, Zn, Cr, Fe	Pb, Zn, Cd	Cd, Zn, Fe, Cu, Ni, Pb	Cd, Zn, As, Fe, Pb, Cr	Zn, Cd, Cu

Key Policy Implications and Recommendations

The available mine land associated with abandoned and end-of-life mines as well as mines planning for end-of-life in South Africa provides a valuable base resource for the post-mine economy. Owing to the need for robust post-mine economies with potential for sustained wealth generation, agriculturally-based renewable raw materials require potential for value addition and development of economic complexity. Fibre crops deliver this opportunity.

Fibre-rich plants can be supported by the soil types and climatic conditions in South Africa's mining regions, and offer the potential to create multi-product value chains and a diverse manufacturing sector. Further, they offer potential for simultaneous land reclamation through phytoextraction of metals with potential value recovery.

Meaningful selection of fibre-producing plants requires consideration of soil quality, climate, productivity, potential product range, and phytoextraction potential, with inter-related selection criteria. Promising fibre plants include the bamboo *Bambusa balcooa*, flax, hemp, kenaf and sisal.

The clear interaction between the degree of contamination of the lands, plant performance, climate, fibre quality and metal location in the plant needs to be assessed by specific case studies. With extreme metal contamination, prior reclamation of the lands using hyperaccumulators should precede fibre crop production.

Conclusion

Robust post-mining economies require both reclamation of the mining region to achieve a functioning and stable ecosystem, and the generation of a new economy to sustain livelihood and augment quality of life. The establishment of a fibre-based economy in which fibre crops are cultivated on degraded mine land to produce a sustained, bio-based feedstock for a diverse product range from subsequent processing and manufacture shows potential. Fibre crop cultivation can achieve four goals, potentially simultaneously: land remediation, metal recovery and sustained production of a bio-based feedstock, while also providing livelihoods.

A review of the climatic and soil environment in three mining areas selected based on the presence of mines which have been abandoned and where closures are planned has highlighted the potential for fibre crop plants such as the bamboo *Bambusa balcooa*, hemp, flax, kenaf and sisal. The final selection must be mapped to a specific site, owing to changing conditions. While these plants have phytoextraction potential, it is necessary to establish whether initial phytomining with a hyperaccumulator will be needed for rapid extraction. Similarly, the final selection depends on the product range selected. Based on the potential shown through the desktop study, it is now necessary to explore particular sites and proceed to field trials.

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*Disclaimer:

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