Miombo network

Land use planning: a tool to minimize the environmental and social impacts of agricultural expansion in southern Africa

POLICY BRIEF 3

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The Miombo Network with contributions from

Archibald S[1], Syampungani, S[2], Kamoto, J[3], Ryan, C[4], and Ribeiro N[5]

1 Centre for African Ecology, School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg 2050, South Africa, sally.archibald@wits.ac.za
2 Copperbelt University, Box 21692 Kitwe
3 University of Agriculture and Natural Resources, Box 219, Lilongwe, Malawi
4 School of GeoSciences, University of Edinburgh, Edinburgh EH9 3FF, UK
5 Eduardo Mondlane University, Faculty of Agronomy and Engineering, Box 257, Mozambique

Key Policy Pointers

Agricultural production is expected to increase across the miombo region of southern Africa, but it is possible to plan this in a way that minimizes impacts on rural livelihoods and the environment.

There are tools available that can quantify the costs and benefits of different development pathways to the environment and to human wellbeing. This “full cost accounting” is necessary for planning where and how to promote agriculture in Miombo.

This analysis indicates that support for small-holder agriculture, combined with clear guidelines about how to farm in an ecologically sensitive way, can increase agricultural productivity in Africa with the least environmental cost.

The Miombo Network: Science in action

Miombo woodlands are the dominant land cover in southern Africa. These mixed tree-grass ecosystems stretch across seven countries and have been termed "social woodlands" as they support upwards of 150 million people and contribute about US$ 9 billion to rural livelihoods[1]. The miombo is also largely untransformed by cultivation or urbanisation and is one of the few remaining expanses of natural vegetation in the globe, providing important climate regulation and biodiversity services. These woodlands therefore represent a valuable economic and environmental resource.

The Miombo Network (*http://miombonetwork.org/*) is composed of scientists and policy makers from across the southern African region. It aims to provide science-based information on management policy and practice in the region through the use of field-studies, remote sensing and other geospatial information technology.

Agricultural development in the Miombo ecoregion

The Food and Agriculture Organisation (FAO) predicts that sub-saharan Africa needs to add more than 100 million hectares (ha) of cropland by 2050 and has the potential to add over 400 million ha[2]. Thus, there is pressure for both intensification and expansion of agricultural activities in Africa. This is driven by increased local demand from growing populations whose diets are changing, as well as need to increase Gross Domestic Product (GDP) through exports. Food production is a priority, but it can negatively impact biodiversity and the vital ecosystem services on which so many people depend. For example, commercial cropland expansion in South America has resulted in loss of natural resources to local people, and large CO_2 emissions through land use change[3].

Governments in southern Africa are therefore faced with some important decisions – how to ensure food security to a growing population and encourage economic investment and growth, without taking away life-lines for the poorest of the poor or damaging the environment. Research has the potential to influence these development pathways by providing policy-relevant information about the environmental and socio-ecological costs and benefits of different development options.

What type of agriculture?

Traditional agriculture in the Miombo ecoregion is shifting cultivation, where people cut down Miombo trees, burn them, and grow crops in the resulting high-nutrient ash soils for a few years, before moving onto a new patch of woodland. As minimal ploughing is involved the vegetation recovers

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[1] Ryan, C. M., Pritchard, R., McNicol, I., Lehmann, C. & Fisher, J. 2016 Ecosystem services from Southern African woodlands and their future under global change. Philos. Trans. R. Soc. Lond. B. Biol. Sci. (doi:10.1098/rstb.2015.0312)

[2] Alexandratos, N. & Bruinsma, J. 2012 World agriculture towards 2030 / 2050 The 2012 Revision.

[3] Martinelli, L. A., Naylor, R., Vitousek, P. M. & Moutinho, P. 2010 Agriculture in Brazil: impacts, costs, and opportunities for a sustainable future. Curr. Opin. Environ. Sustain. 2, 431–438.

quickly (within ~35 years), and it is therefore not incompatible with conservation goals or provision of other ecosystem services. However, with increasing populations the miombo patches receive less rest between agricultural periods, lowering productivity, decreasing sustainability, and taking up more and more land[4]. Some countries in the region have successfully promoted a more intensive form of small-holder agriculture, where inputs of industrial fertilizer and improved seedstock can compensate for reduced soil conditions. This form of agriculture can result in higher return and as most of these farms do not use mechanical ploughs and do not spread into riverine areas the environmental impacts are still contained. In contrast, large-scale, high input commercial agriculture is spreading in many regions. High capital inputs – often from foreign investors - are required and commodity crops such as maize and soybeans are grown using improved germplasm and high fertilizer inputs[5]. Commercial agriculture can achieve similar yield per unit area under cultivation as smallholder agriculture[6]. However, as these crops are often intended for export this pattern of production may reduce local food security by depriving people of smallholder opportunities and wild food resources[7].

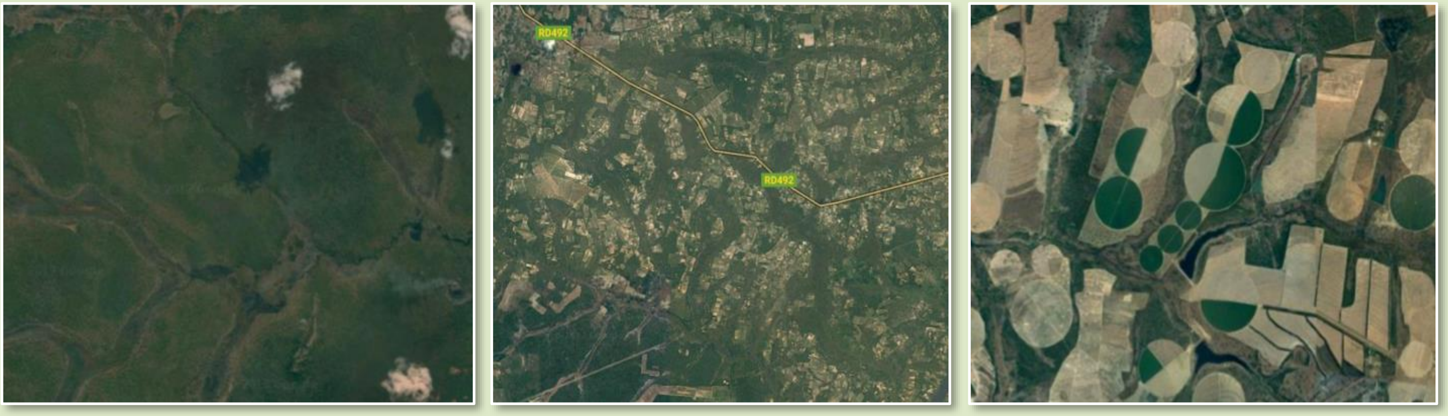

Figure 1: Demonstrating how Miombo landscapes change with different levels of land use intensity. On the left, intact landscapes utilized for shifting cultivation, in the middle, an example of small-holder intensification, but with some landscape features retained. On the right, commercial intensification and mechanization.

Several key issues need to be considered to assess the consequences of different agricultural development options for Africa.

1. Agricultural yield: this increases with intensification (fertilizer additions, better seed, land preparation) but large-scale agriculture is not necessary to maximise yield. Studies in Africa and elsewhere show that small-holder farms are at least as productive and efficient as large ones[6].
2. Non-crop products: woodland products are used for fuel, food and medicine[1]. These provide household incomes of 100-500 US$ per year, totaling 9 billion US$ across the region. Mixed, or inter-cropping systems can still provide some of these products, but wholescale transformation to commercial agriculture eradicates these resources, depriving local communities of income.
3. Carbon emissions and radiative forcing: ploughing is a major source of greenhouse gas emissions as it reduces soil carbon. Traditional agriculture in Miombo uses hoes, not ploughs,

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[4] Campbell, B. D. 1996 The Miombo in Transition: Woodlands and Welfare in Africa. CIFOR.
[5] McIntire, J. M. 2014 Transforming African Agriculture. Glob. J. Emerg. Mark. Econ. 6, 145–179.
[6] Smart, T & Hanlon, J. 2014. Galinhas e cerveja: uma receita para o cresimento. Maputo: Kapikua.
[7] Wily, L. A. & Mbaya, S. 2001 Land, People and Forests in Eastern and Southern Africa at the Beginning of the 21st Century: The Impact of Land Relations on the Role of Communities in Forest Future.

which have minimal impact on soil carbon[8]. Intensifying production inevitably increases emissions, but most of the soil carbon is in the dambo's, or wetlands, and when these are drained and transformed by large-scale agricultural operations carbon emissions skyrocket (from 20 000 to 140 000 tons CO_2 per km^2 per year)[9].

4. Pollution from fertilizer use: increased production requires fertiliser addition, which can result in air and water pollution.
5. Biodiversity: African woodlands are naturally dynamic ecosystems, and the biodiversity of Miombo is resistant to certain levels of land transformation. Corridors and patches of indigenous vegetation within the farmland are key to maintaining high bird, insect and mammal numbers[10]. Many forms of smaller-scale intensive agriculture maintain these corridors and keep landscapes 'intact'.
6. Resilience/speed of recovery: Miombo woodlands are highly resilient to biomass removal, but very sensitive to ploughing and soil disturbance. This is because the dominant tree species grow clonally from root buds, but do not easily germinate and recruit once their roots have been disturbed. i.e. the vegetation can recover from heavy utilization within 10 to 30 years, but not from ploughing associated with some smallholder and all commercial agriculture.

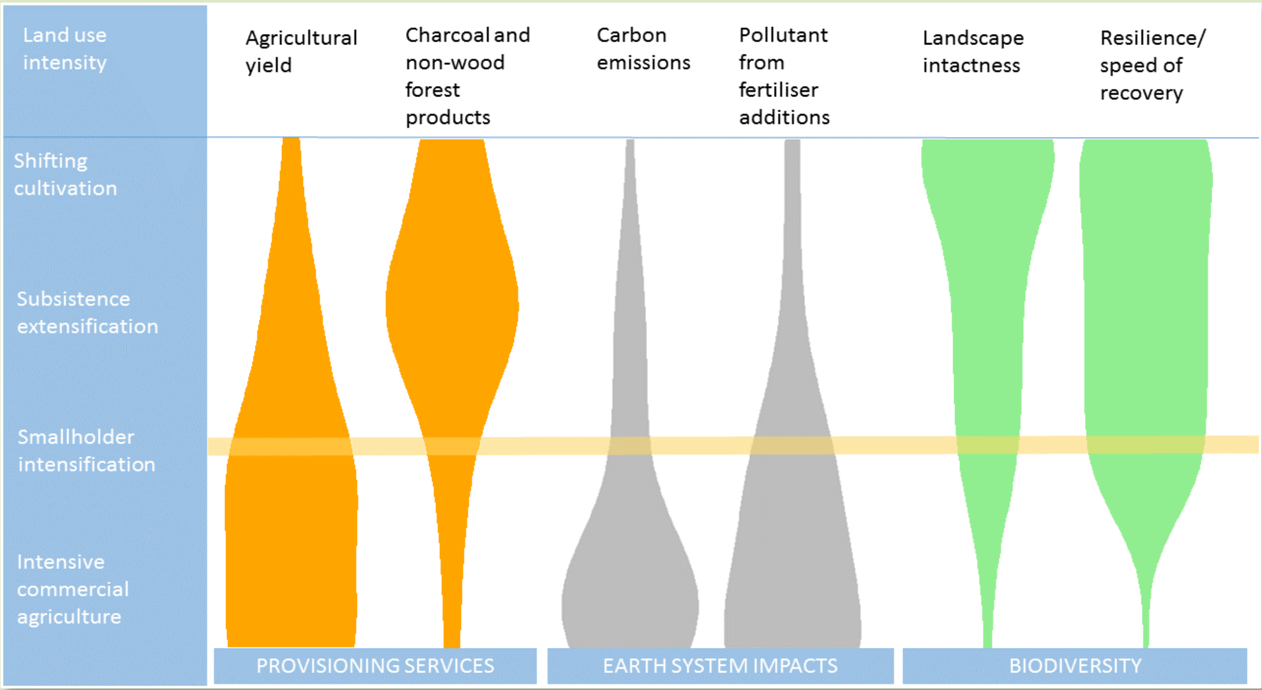

Figure 2: Quantifying all the impacts/benefits of different land use intensities in the Miombo allows for informed decisions about the most appropriate development options for the region. For example, smallholder intensification avoids some of the more extreme costs of intensive commercial agriculture, while still producing high yields. Data on yield, carbon emissions and fertiliser use from[11]. Data on charcoal and other forest products from[1], data on landscape intactness from[10], data on resilience from[8].

As illustrated in *Figure 2*, the information now exists to quantify the socio-economic, conservation, and environmental impacts of different agricultural development options. This indicates that

[8] McNicol, I. M., Ryan, C. M. & Williams, M. 2015 How resilient are African woodlands to disturbance from shifting cultivation? Ecol. Appl. 25, 2320–2336.
[9] Wilson, S and RJ Scholes (2018). In prep: The climate regulation service provided by miombo landscapes. MScc Dissertation, University of the Witwatersrand
[10] Tripathi, H.G., 2017. Biodiversity of the African savanna woodlands : How does it change with land use ? PhD thesis, University of Edinburgh.
[11] Wilson, S and RJ Scholes (2018). In prep: The climate regulation service provided by miombo landscapes.

smallholder intensification can avoid some of the more extreme costs of intensive commercial agriculture due to the different ways the landscapes are utilised. Importantly, the small scale of the farming parcels, and the limited soil disturbance mean that many biodiversity corridors remain intact, and the carbon losses are much lower. This, combined with the similar, or higher production obtained from small to medium-sized farms, provides a strong case for shifting national development strategies towards smaller-scale commercial farmers[12].

Where to locate the agriculture?

The environmental costs of intensive agriculture vary spatially. It is therefore possible to plan future agricultural expansion in a way that minimizes the costs to biodiversity and climate regulation services. Spatial information on soil properties, carbon stocks, and biodiversity indicators are being developed across the region which allow for informed spatial planning. Decision-making tools such as Marxan[13] can be used to quantify the impacts of different development scenarios and interact about the acceptable trade-offs and land use preferences.

A case study from Zambia[14] (*Box 1*) quantifies potential food production of different spatial configurations of commercial agriculture against other environmental impacts. They show that adjusting the location of commercial agriculture to reduce the CO_2 costs of transport and biodiversity costs of transforming pristine land has only a small reduction in food production. i.e. a small reduction in productivity can result in a massive savings for biodiversity, carbon stocks, and transport costs. Optimizing productivity against other ecosystem services results in very different spatial development patterns that will be less costly to the environment.

Agricultural expansion vs renewable energy production

In South America commercial agricultural expansion has resulted in economic growth[15], and the same is probably true for African countries. However, as detailed in *Figure 2* above, it will also deprive local people of food, energy, and economic opportunities[3,16]. These trade-offs need to be quantified and planned for. In particular, a reduction in charcoal production due to land conversion to agriculture will require that alternative energy sources be found (*Figure 5*). Some countries can potentially replace this energy source with renewable sources like hydro-electric power, but if coal replaces charcoal then the carbon costs of intensive agriculture will be much higher.

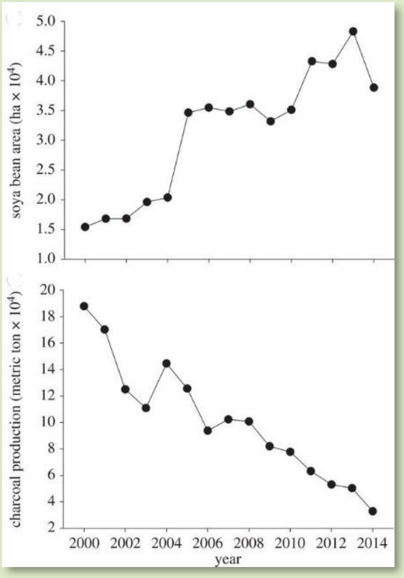

Figure 3: indicating the reduction in charcoal production associated with increased agricultural activity[11]. Currently charcoal is a renewable energy source: the trees regrow after harvesting. The costs of finding alternative energy sources need to be considered with agricultural expansion.

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[12] Bank, W. 2009. Awakening Africa's Sleeping Giant.

[13] Watts, M. E., Ball, I. R., Stewart, R. S., Klein, C. J., Wilson, K., Steinback, C., Lourival, R., Kircher, L. & Possingham, H. P. 2009 Marxan with Zones: software for optimal conservation based land-and sea-use zoning. Environ. Model. Softw. 24, 1513–1521.

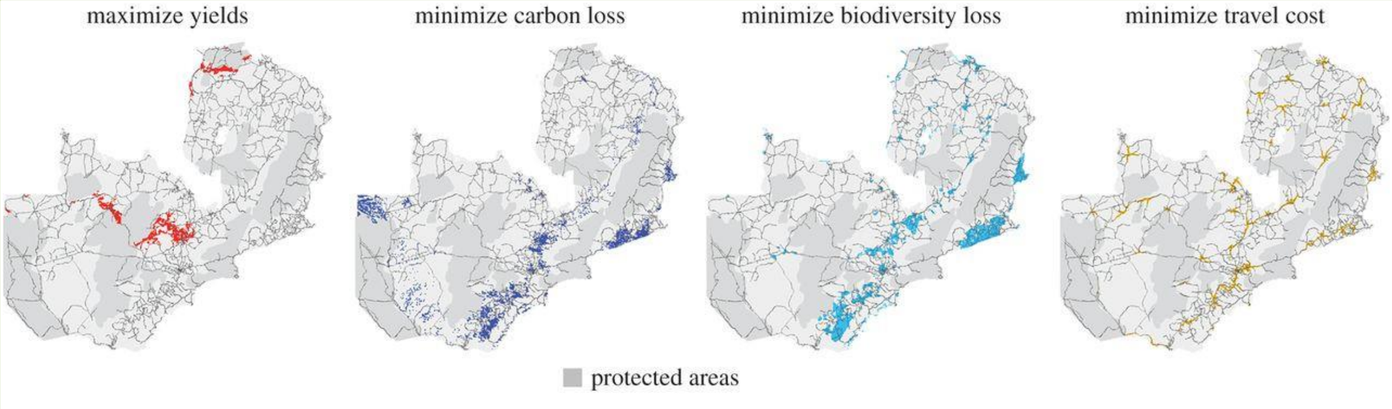
[14] Estes, L. D. et al. 2016 Reconciling agriculture, carbon and biodiversity in a savannah transformation frontier. Philos. Trans. R. Soc. London B Biol. Sci. 371. (doi:10.1098/rstb.2015.0316)

[15] Espírito-Santo, M. M., Leite, M. E., Silva, J. O., Barbosa, R. S., Rocha, A. M., Anaya, F. C. & Dupin, M. G. V. 2016 Understanding patterns of land-cover change in the Brazilian Cerrado from 2000 to 2015. Philos. Trans. R. Soc. London B Biol. Sci. 371. (doi:10.1098/rstb.2015.0435)

[16] Chomitz. 2007 At loggerheads?: agricultural expansion, poverty reduction, and environment in the tropical forests. World Bank Publications.

Box 1: Where to locate agriculture? A case study from Zambia

Zambian population is set to triple by 2050, requiring an additional ~2500km^2 of land to be converted to crop production even if yields can be increased to FAO standards. Estes[14] investigated exactly how much land needs to be converted, and where it should be placed using a decision-making tool that enabled trade-offs between yield, carbon, transport costs, and biodiversity to be quantified and visualized (*Figure 3*). They demonstrated that a very small compromise in total yield can result in large reduction in the other factors considered, and that an "optimized" spatial plan could be found which avoided 27-47% of the carbon, transport and biodiversity costs while only increasing total crop area by 2.7%.



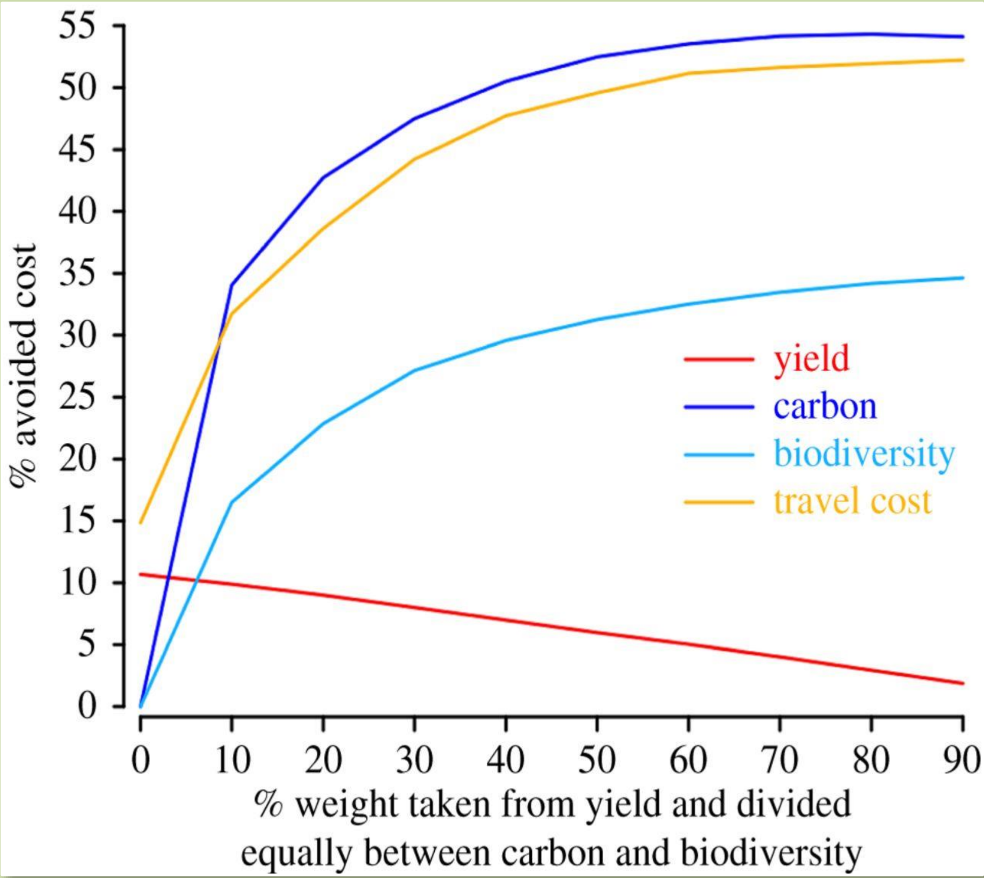


Figure 4 (top): A case study for Zambia contrasting the spatial patterns of agricultural expansion when different aspects (maximising yield, minimizing carbon costs, minimizing transport costs, minimizing biodiversity loss) are given 100% weight. Areas with the highest productivity also have high transport, carbon, and biodiversity costs.

Figure 5 (left): However, a spatial development plan that compromises only 5% on yield becomes much more aligned with other objectives and can avoid much of the costs.

Conclusions

Policy decisions made now about how to develop the Miombo region of Africa will have far-reaching consequences for the people living in this region and for the globe. This represents an opportunity for Africa, which is expanding and intensifying its agricultural production with far more information on the long-term consequences of this for the environment and the economy. There are currently conflicting viewpoints about the best way to ensure development goals and human livelihoods in the region, while also fulfilling conservation ideals and sequestering carbon. The information to quantify these trade-offs is becoming more available. These, and spatial decision-making tools must be leveraged to help make agricultural development more effective in southern Africa.

Acknowledgments

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