Sentinel
Social and Environmental Trade-Offs in African Agriculture

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Future trade-offs to 2050: land cover change, biodiversity and agriculture in Zambia

In Zambia, demand for cereal to feed a growing population is predicted to double by 2050.[1] As pressure on agricultural land increases, there is an urgent need to develop tools to minimise conflicts between competing land uses.

Introduction

The effective management of natural resources requires tools to explore the trade-offs between competing land use demands, including agricultural production, biodiversity and other ecosystem services. Biodiversity and other ecosystem services are critical for agricultural production; however land use change can result in their loss.[8]

To date, most research exploring conflicts over land use has been conducted at global scales,[9] using data and models that do not necessarily reflect direct and indirect drivers of change at national and sub-national scales. To overcome some of these limitations, methods were developed to translate nation-specific scenarios into maps of projected land cover change. This briefing describes the process to translate the 'storylines' that emerged from a national stakeholder scenarios development workshop in Zambia in 2018,[3] and presents the results as national maps of projected land cover change to 2050.

The workshop involved a structured process to identify key drivers of change, in particular climate change, and the quality of governance. The critical innovation has been to translate the qualitative scenarios of future change into quantitative estimates of land demand and to map possible trajectories of future land cover across the whole of Zambia.

Scenarios

The four scenarios that emerged from the workshop are summarised in Figure 1. The 28 workshop participants were drawn from central government (eg the Ministry of Lands and Natural Resources), NGOs (eg WWF, Green Living Movement Zambia), national research institutes and universities, and the Sentinel project team. The scenario development process included the identification of:

1. Focal issues: Future of agricultural development; specifically, the expansion of agriculture into forests driven by increasing food demand due to population increase, food security concerns and improvement in global markets for agricultural commodities, among other factors.
2. Main drivers of change: governance issues, primarily the frequency of policy change, and impacts of climate change on the social and economic development of Zambia now and by 2040.

Summary

Scenario analysis is a powerful tool that allows policymakers to explore plausible futures in a systematic manner.[2] This technical briefing describes the process to translate the 'storylines' that emerged from a stakeholder workshop in Zambia in 2018,[3] into maps of projected land cover change to 2050.

Background

As global populations grow and the demand for agricultural land increases,[4,5] there is an urgent need to develop tools to aid decision makers in minimising conflicts between competing land uses,[6,7] at both national and sub-national scales. This brief describes a land change modelling (LCM) technique to project land cover change in Zambia to 2050, based on a set of scenarios that emerged from a national stakeholder workshop.[3]

Partners:
Copperbelt University; Policy Studies Institute (PSI); University of Ghana; University of Greenwich, NRI Natural Resources Institute; Imperial College London; iied; eci University of Oxford; University of Reading; RUFORUM; UCL

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A total of four scenarios were identified, related to two axes: governance and adaptation to climate change (Figure 1).

Figure 1. The four scenarios

		Driver one: *Impact of climate change*	
		Low	**High**
Driver two: *Frequency of policy change*	**High**	*Scenario 1*	*Scenario 2*
	Low	*Scenario 4*	*Scenario 3*

Scenario 1: This scenario is characterised by a high frequency of policy change and a high level of adaptation to climate change. Governmental policies are driven by the short-term political aspirations of politicians, rather than effective evidence-based decision making.

Scenario 2: This scenario is characterised by frequent policy change and high impacts of climate change due to low adaptation capacity. High government borrowing and low agricultural production result in environmental degradation.

Scenario 3: A scenario where the quality of governance improves leading to a more stable policy environment with policies grounded in scientific evidence and more effectively implemented (although measures to adapt to climate change that also enable the agricultural sector to continue to prosper may not be effective).

Scenario 4: This scenario is characterised by a high, stable policy environment with evidence-based polices that take a long-term perspective, and a high ability to adapt, where agricultural investments lead to increasing prosperity, and clear recognition and management of trade-offs levels of climate change impacts.

Method: transforming qualitative storylines into quantitative change in land cover

The process of translating the qualitative storylines into land 'demand' (ie the area of land for each land cover category under each of the four scenarios), relies on careful interpretation of the type and magnitude of change described by each scenario. Note that the 'baseline' business-as-usual (BaU) scenario is a simple linear extrapolation to 2050 of observed land cover trends between 2000 and 2016, consisting of the latest good quality land cover data available from satellite imagery.[10] This scenario projects land cover change under the assumption that prevailing conditions remain stable into the foreseeable future, with, for example, no change in government policy and negligible impacts of climate change or socio-economic conditions.

Based on the outcome of the stakeholder workshop and informed by evidence from further consultation and literature, the following general assumptions were made in guiding the interpretation of areas for land demand:

- Climate change is likely to have a direct impact on cropland production and productivity. For example, at the current emissions trajectory, it is estimated that 30% of maize production will be lost in Southern Africa.[11] However, the actual impact will vary according to the effectiveness of adaptation, which will be closely related to the effectiveness of governance.
- The impacts of climate change on typical miombo forests are predicted to be highly variable. However, whilst it is difficult to generalise (as different species will respond differently), it seems likely that there will be substantial time lags and periods of re-organisation, rather than wholescale shifts in vegetation formations.[12]
- Governance will affect the future of agricultural development. Under conditions of policy stability, higher inputs for improved yields (although in practice this may not be the case given the recent relative failure of the Farmer Input Support Programme (FISP))[15] and other innovations (eg mechanisation as part of the farm blocks scheme) may motivate farmers to intensify rather than expand the area of land under cultivation. By contrast, under conditions of policy instability, there will be both winners (farmers who expand) and losers (the community which loses access to the direct/indirect benefits of proximity to communally used natural ecosystems).[13]
- Governance is likely to be critically important for the future of Zambian forests. Where the protection of existing forest is strongly enforced and the selection of new areas for forest protection is evidence based,[14] forest loss will be reduced.

These assumptions, in combination with the storylines that emerged from the scenario workshop, were used to estimate the 'land demand' for each land cover type under the BaU and four other scenarios (Table 1). Thus, for Scenario 2, it is estimated that, given poor adaptation to climate change and continuing poor governance, crop expansion into areas of primary forest is high. By contrast, under Scenario 4, crop expansion is minimised, helping to protect remaining areas of primary forest and other natural vegetation. Further work is needed to develop and refine the assumptions that support the scenarios, given the complexity of the drivers of change. For example, a complicating factor will be the balance between the production of staple food versus domestic production of food. The scenarios assume that this will remain stable (ie current conditions), but this is unlikely to be the case in the medium to long term.

Terrset Land Change Modeller (LCM) software was used[15] to project future land cover change to 2050. The technique relies on 'explaining' the observed change in land cover mapped from two sets of classified satellite images[10] with reference to a set of statistically significant physical (soils, topography) and socio-economic (population, proximity to roads/settlements) variables. These selected variables are subsequently used to generate maps of land cover to 2050 based on the land demand under each of the four scenarios.

Table 1. Translation of stakeholder 'storylines' into percentage change in land cover for each scenario

Scenarios: Percentage change against 2016 baseline to 2050

	Business-as-Usual	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	% change	% change	Comments	% change	Comments	% change	Comments	% change	Comments
Cropland	Low increase	Low increase	Agriculture continues to expand, but at a rate only slightly higher than BaU	Medium increase	Rapid expansion of agriculture to combat low yields resulting from limited adaptation to climate change and ineffective governance	Low increase	Rate of increase remains stable, even declining slightly in some areas as improved investment from outside combined with strong extension services and strong climate adaptation improves yields	Low increase	Continued decrease in rate of agricultural expansion
Grassland	Low increase	Low increase	Small increase, possibly as a result of land degradation following loss of forest cover	Negligible change	Large areas of grassland converted to agriculture	Negligible change	No change in grassland area, partly as national policy recognises its importance for biodiversity	Negligible change	Slight increase in grassland area in recognition of its importance for biodiversity combined with lower pressure for agricultural expansion
Irrigated crops	Medium increase	27	Low investment/ extension services result in similar decline to BaU	Negligible	As above	Medium increase	Rapid increase, with high yields contributing strongly towards national food security	Medium increase	Rapid increase, with high yields contributing strongly towards national food security
Plantation forest	High decrease	High decrease	Losses continue due to low investment and agricultural expansion	High decrease	Rapid losses due to low investment in planting/forest management and poor enforcement of regulations	Medium decrease	Rate of loss declines sharply compared to BaU	Low increase	Possible increase in plantation forest in recognition of its potential economic importance with improved management
Primary forest	Low decrease	Low decrease	Continuing loss due to unstable policy environment, encouraging agricultural expansion	Low decrease		Low decrease	Slowing rate of loss due to national policies recognising importance of primary forest for biodiversity/ carbon	Low decrease	Continued slowing of rate of decline due to strong focus on national policies for protection
Secondary forest	Negligible	Negligible decrease	As above, agricultural expansion begins to encroach rapidly into secondary forest	Low decrease	Rate of encroachment increases because of rapid agricultural expansion from limited adaptation to climate change and declining yields	Low increase	Slow increase in area as some marginal areas of agriculture are abandoned as yields improve	Negligible	Continuing increase as the importance of secondary forest for carbon/ biodiversity is recognised and large areas of agriculturally marginal land area abandoned
Settlement	Low increase	Low increase	Similar to BaU	Low increase	Rapid rate of urbanisation due to rural-urban migration	Low increase	Improved agriculture slows rate of rural-urban migration, reducing pressure on city expansion	Negligible	

Negligible: 0 – 5; Low: 5 – 25; Medium: 25 – 50: High: 50 – 100.
The percentages are derived from the estimated land demand (ha) for each land cover type under each of the four scenarios.

Summary

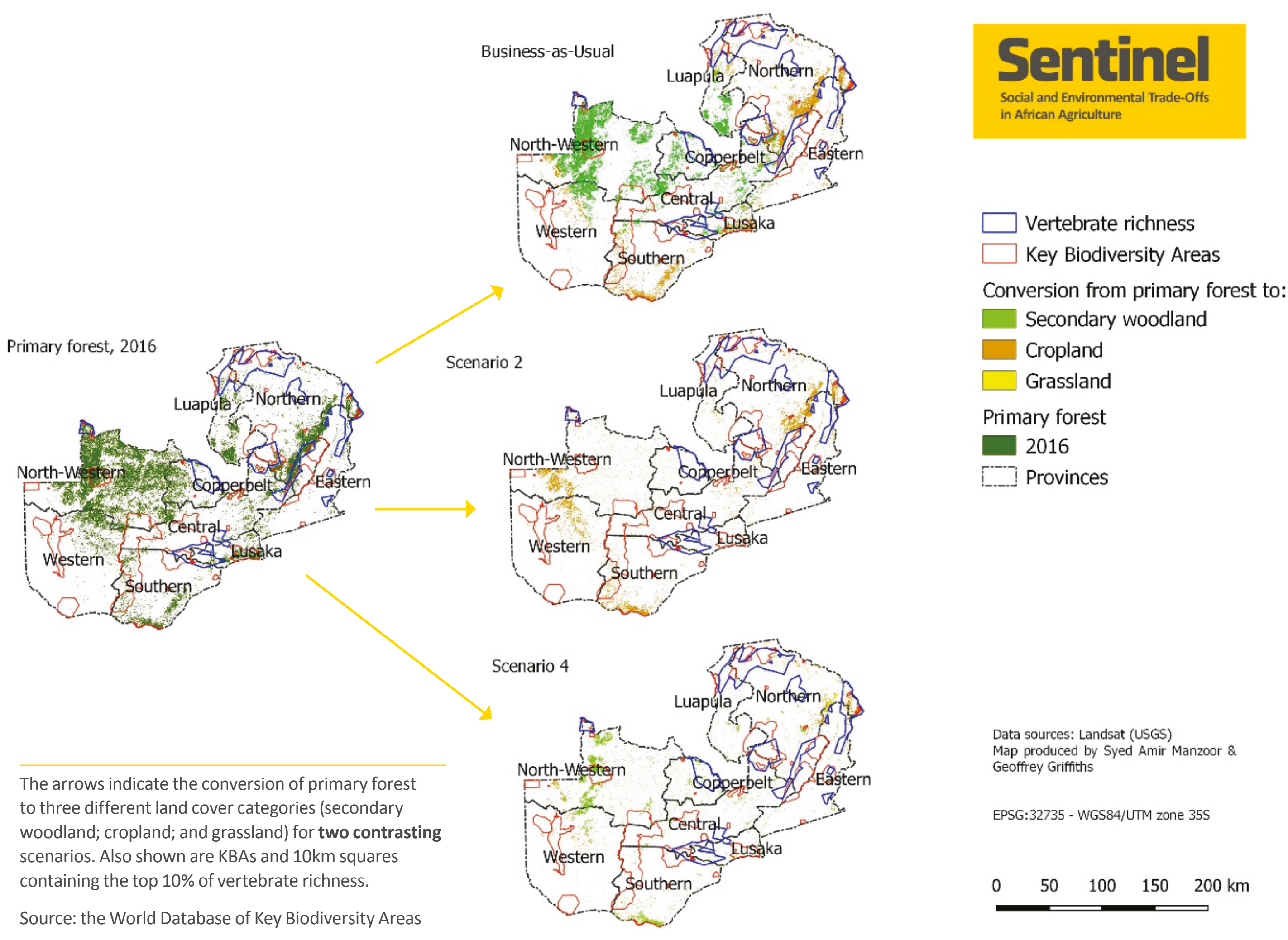
Figure 2 provides an example of the type of land cover change projected under two contrasting scenarios. It shows significant differences between the areas of primary forest loss compared to the 2016 baseline (mapped from Landsat imagery):

Business-as-usual. The majority of this change is the conversion of primary forest to secondary woodland, a degraded habitat that often lacks the structural and species diversity of intact primary forest. Much of this conversion is concentrated in the northwestern province, for example Manyinga district, with other foci in, for example, Malenge district, Luapula province. Some of this loss of primary forest, either to cropland or secondary woodland, also intersects with Key Biodiversity Areas (KBAs).[16] For example, the West Lunga National Park KBA in the northwestern province and the Middle Zambezi Valley KBA in Lusaka province. Similarly, hotspots of vertebrate richness are also impacted, notably north of Kitwe in Copperbelt province, and in the Kasanka National Park, Serenje district, Central province.

Scenario 2. This scenario represents the worst-case scenario in relation to the other scenarios: poor adaptation to climate change and the deteriorating effectiveness of governance with rapid policy shifts based on poor or absent evidence. Unsurprisingly, the projection to 2050 shows a steep decline in the area of primary forest. In this scenario however, in contrast to BaU, the conversion is confined mostly to cropland (Table 2). There are three foci: (i) a clear spreading front westwards in the northwestern province (Zambezi district) and Western province (Kaoma district); (ii) Southern province (Zimba district); and (iii) the largest area of loss, Northern province (eg Isoka district).

Scenario 4. This scenario represents the best case, with high levels of adaptation to climate change and long-term, evidence-based policy. Cropland expansion is relatively low and the loss of primary forest is also correspondingly low (Table 1). The distribution of the conversion of primary forest to cropland is similar as for Scenario 2, but the spatial extent is more limited.

Figure 2: Conversion of primary forest to other land cover types.



The arrows indicate the conversion of primary forest to three different land cover categories (secondary woodland; cropland; and grassland) for **two contrasting** scenarios. Also shown are KBAs and 10km squares containing the top 10% of vertebrate richness.

Source: the World Database of Key Biodiversity Areas

Discussion and conclusions

This example of land change modelling from Zambia demonstrates the potential for exploring possible scenarios of land cover change and its impact on protected areas and biodiversity. The negative impact of forest loss on carbon storage and biodiversity, and the possibility to reduce this impact by developing and enforcing land use planning to focus inevitable deforestation on areas with less carbon and lower biodiversity, suggest that effective land use planning will play an important role in minimising the conflict between competing land use. The scenarios illustrated strengthen the case for developing this type of modelling to assist decision makers at all levels in government involved in land use planning.

While the scenarios show a range of potential outcomes, they can be adapted to reflect multiple direct and indirect drivers of change and varying assumptions about, for example, global food commodity prices, the balance between traded and domestic crop production and national food consumption, population trends, and the level of protection for important biodiversity areas. We have only presented here a contrast between two scenarios: the worst (Scenario 2) and the best (Scenario 4) for a single land cover category – the conversion of primary forest to three land cover types: cropland; secondary woodland; and grassland.

Projections of future land use in Zambia indicate that the amount and nature of miombo forest loss varies depending on the scenario. Further work will be needed to intersect projected land cover change with KBAs[16] and biodiversity hotspots[8,9] to evaluate the impact of different scenarios of change on these landscapes. Whilst LCM can be used to explore trade-offs between the different drivers and impacts of land cover change, if this is to be an effective decision-making tool, a more user-friendly version will need to be developed.

The projections were developed at the national-level workshop, based on the views and experience of a relatively limited cross-section of stakeholders. Zambia is a large country, characterised by contrasting ecoregions, and it is likely that the drivers of change and assumptions that support each scenario will be markedly different between ecoregions and farming systems. Other recent work in Zambia by Sentinel[17,18] indicates that national-scale drivers of change may not translate to the local level. Indeed, according to recent data from household surveys, in general and irrespective of national policy, many farmers prefer to expand rather than directly combat soil degradation and loss of soil fertility. This is often due to the high cost of inputs and the easy availability of virgin land. Thus, the development of local-scale scenarios and projections of land cover change based on different sets of drivers and assumptions supported by local-level household data could yield new and interesting insights. This would especially be the case where improved data on biodiversity and ecosystem services are available, enabling the trade-offs and impacts between farmer's individual decisions and local/national policy to be explored in detail.

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