Sentinel
Social and Environmental Trade-Offs in African Agriculture

Policy Brief
October 2022

www.sentinel-gcrf.org

Serious gaming to inform local scale scenarios of land cover change to 2050 in North–Western province, Zambia

Summary

Scenario analysis allows policymakers to explore and map plausible futures in a systematic manner; yet there are few examples of applying this tool at local scales, thereby missing the detail needed for a better understanding of local processes. In collaboration with local farmers, serious gaming is used to map the impacts of future land cover change on biodiversity and ecosystems in Zambia.

Background

As global populations grow and demand for agricultural land increases, conflicts between competing land uses need to be minimised. Tools are being developed to aid decision makers, such as a land change modelling (LCM) technique described in this brief, to project land cover change at the local scale in in Zambia to 2050, based on a set of scenarios that emerged from an exercise in serious gaming with local farmers.

As pressure on agricultural land increases, there is an urgent need to develop easy-to-use tools, that are applicable at a wide range of geographic scales, to improve our understanding of the trade-offs between food production and the protection of ecosystems.

Cereal production in Zambia tripled over the period 1994–2014 and food demand in Africa is projected to again triple over the period 2010–2050.[1] Recent work has demonstrated the potential utility of modelling and mapping future land cover change at national scales (in Zambia, Ghana and Ethiopia) as part of the Social and Environmental Trade-Offs in African Agriculture (Sentinel) project.[2] This provided useful insights into how **national policy** can influence the critical trade-offs between agricultural expansion and the protection of biodiversity and other ecosystem services, but failed to provide the level of detail that is essential for land-use planning at sub-national scales (district and below).[3] The national-scale scenarios were developed by national-level experts drawn from government, civil society, academia and NGOs during a series of workshops,[4] but without representation from farmers who make day-to-day decisions about future land use. Furthermore, it was inevitable that at the national scale, the physical (soils, topography, and climate) and cultural (farming system, land tenure, etc) conditions were assumed to be uniform and that national policies could be applied equally across all regions. This made a strong case to undertake land change modelling LCM at sub-national scales, either within separate ecoregions[5] or at the provincial/district level, to account for the diversity of physical and cultural landscapes across the country.

Scenario analysis allows policymakers to explore and map plausible futures in a systematic manner.[6] A novel technique – serious gaming – was used to explore farmers' decision-making processes when determining whether or not to expand into previously uncultivated forest land.[7] Survey data and community consultation were used to inform the game design. Farmers were assigned into teams of two, coded by colour (red farm, blue farm, etc). The starting conditions (amount of land, soil fertility, wealth, access to labour) were different for each team, representing a variety of wealth categories. This technique proved useful for identifying and evaluating the consequences of alternative actions and was an effective approach in uncovering the key factors that motivated expansion

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

Funded by:
GCRF Global Challenges Research Fund; UK Research and Innovation

into forest and other native vegetation. The results were used to develop four contrasting scenarios which were subsequently modelled using LCM and visualised as maps of projected land cover change to 2050.

Scenarios

The serious gaming exercise was played with six farms in different wealth categories (better off, 25%; intermediate, 23%; poor, 52%). Unlike at national level where the scenarios that emerged from the stakeholder workshop were based on climate change and governance, at the local scale differences in soil fertility and crop prices were the most important factors influencing future land use decisions by farmers (Table 1).

Table 1: The significant drivers of land cover change for four scenarios at the local scale, Chitokoloki, North-Western province, Zambia

		Driver one: *Impact of soil fertility*	
		Low	High
Driver two: *Crop prices*	High	*Scenario 1:*	*Scenario 2:*
	Low	*Scenario 4:*	*Scenario 3:*

The gaming exercise was followed with a debrief in which participants discussed the factors that motivated them to expand into surrounding forests, some of which are quoted below:

> Black farm (male): *"Yes, we will expand into the forest because high prices mean more profits for us".*
>
> Blue farm (female): *"Expanding into the forest will be the order of the day because our soils are poor here in Chitokoloki. Therefore, in order to increase crop yield given the increase in price farmers will be motivated to expand into the forest where soils are more fertile".*
>
> Red farm (female): *"Our crops are very poor in Chotokoloki. This is what causes us to go into the forest where soils are more fertile. So, if provision of inputs is enhanced then farmers can stay on their fields and not clear the forest because the inputs can improve crop yield".*
>
> Green farm (male): *"Encouraging crop rotation can also help because it can help to improve our soils".*
>
> Red farm (male): *"Introducing crops that help to improve soil fertility can also help to encourage farmers to stay on their fields. Farmers expand into the forest in search of fertile soils. Some crop like soya beans should be introduced in this community".*

Based on the outcome of the serious gaming, the following general assumptions were made in guiding the interpretation of areas for land demand:

- Soil fertility drives decisions about agricultural production, specifically whether to expand into forest, intensify, or diversity
- Crop price intersects with soil fertility and the availability of inputs (for example, farmer input support programme (FISP) designed to pay for improved crop varieties, fertilise etc) to determine whether a farmer expands into forest, intensifies or diversifies.

Based on the serious gaming exercise, the following scenarios were developed and described:

Scenario 1: High crop prices and maintenance of good soil fertility result in good profits and spare cash to expand, leading to a significant loss of closed/open woodland and other native vegetation, including grass/shrub.

Scenario 2: High crop prices and declining soil fertility result in strong motive to **intensify**, using extra cash from crop sales to purchase inputs.

Scenario 3: Low crop prices combined with declining soil fertility result in rapid **expansion** into areas of closed open forest and other native vegetation.

Scenario 4: Maintenance of soil fertility but low crop prices provide the motivation to diversify, planting different crops to minimise the risk of poor harvests resulting from poor fertility. This scenario is nearly equivalent, therefore, to B-a-U.

Business-as-Usual (B-a-U): Business-as-Usual is a simple linear extrapolation of past trends in land cover change (2000–2021) derived from the most recent good quality land cover data available from satellite imagery. It assumes that the factors affecting land cover change remain stable and strictly, is not a scenario.

Method: transforming qualitative storylines into quantitative change in land cover

The process of translating the description of each scenario into a table of land 'demand' relies on a qualitative assessment of the area of land required to satisfy the conditions of each of the four scenarios for each land cover category at an arbitrary year in the future, in this case 2050.

The direction and magnitude of change for each scenario were used to estimate the 'land demand' for each land cover type under B-a-U and the four scenarios (Table 2). For example, there is a strong contrast between Scenario 2 (S2) and Scenario 3 (S3). For S2, despite declining soil fertility, high crop prices are driving intensification with the use of inputs (fertiliser, improved crop varieties etc), resulting overall in relatively stable land use. By contrast, for S3, low soil fertility is not offset by high crop prices resulting in a strong motivation to expand into forest areas, leading to rapid land use change.

Terrset Land Change Modeller (LCM) software was used to project future land cover change to 2050.[8] The technique relies on 'explaining' the observed change in land cover mapped from two sets of classified satellite images[9,10] with reference to a set of statistically significant physical (soils, topography) and socio-economic (population, proximity to roads/settlements) variables. These significant variables are subsequently used to generate maps of land cover to 2050 based on the land demand for each land cover category generated for each of the four scenarios. Table 2 illustrates the considerable increase in cropland (5.5%) and the decline of closed woodland (more than 13%) between 2000 and 2021, and how the trajectories of projected change to 2050 for the four land cover types vary between scenarios.

Results

The results are mapped as land cover transitions, showing the type and location of land cover change to 2050 for B-a-U and the four scenarios, although only selected examples are shown here. Figure 1, for example, shows the difference in the projected expansion of cropland between 2021 and 2050 for S2 and S3. Whilst some of this expansion is along water courses, roads and close to existing settlements, the expansion is generally widespread across the study area and appears to be at the expense of closed woodland. This is confirmed in Figure 2, which shows how the projected loss of closed woodland between 2021 to 2050 corresponds closely to the distribution of cropland expansion in Figure 1.

Table 2: Land cover demand (low, medium, high) under the four scenarios and Business-as-Usual

			% change 2021–2050				
	Land cover: 2000	Land cover: 2021	B-a-U	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Cropland	6.65	12.2					
Closed woodland	32.83	19.4					
Open woodland	12.53	20.0					
Other (riparian, grass/shrub)	47.98	49.8					

Positive	Negative
Low 1–20	Low 1–20
Medium 20–40	Medium 20 –40
High > 40	High > 40

The colours are designed to show positive (green shades) and negative (red shades) as low, medium and high change between the 2021 baseline and 2050

Figure 1: The difference between Scenarios 2 and 3, showing the projected expansion of cropland to 2050

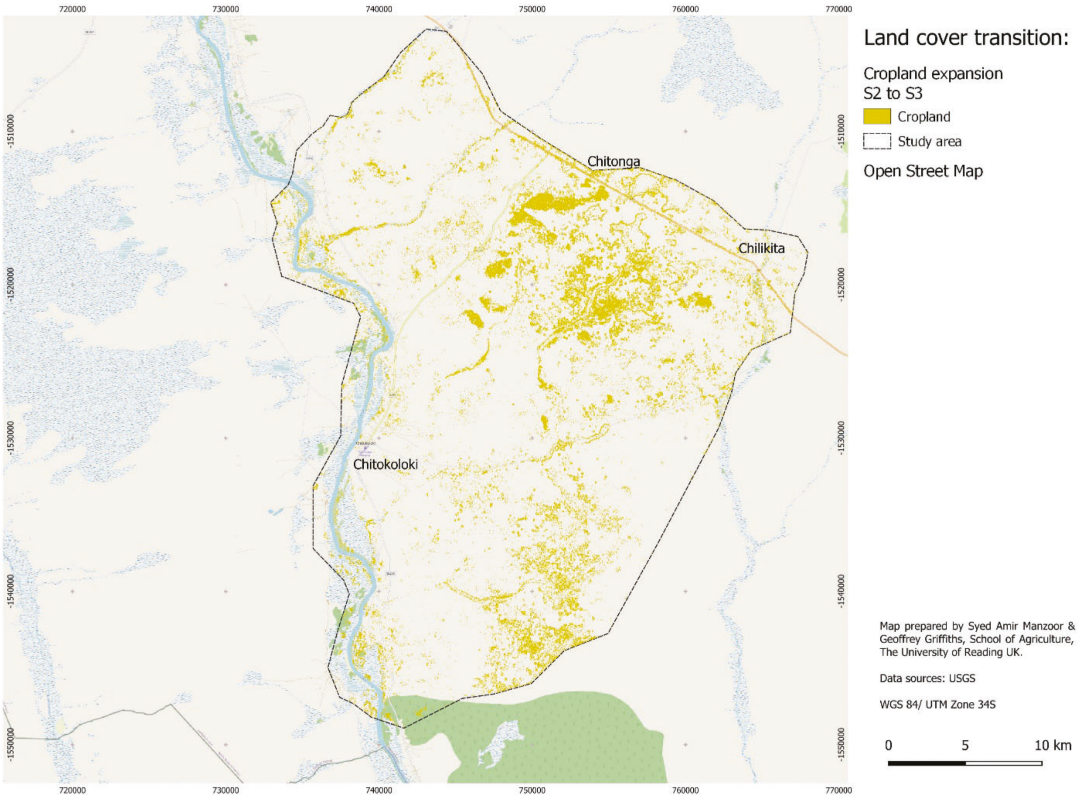
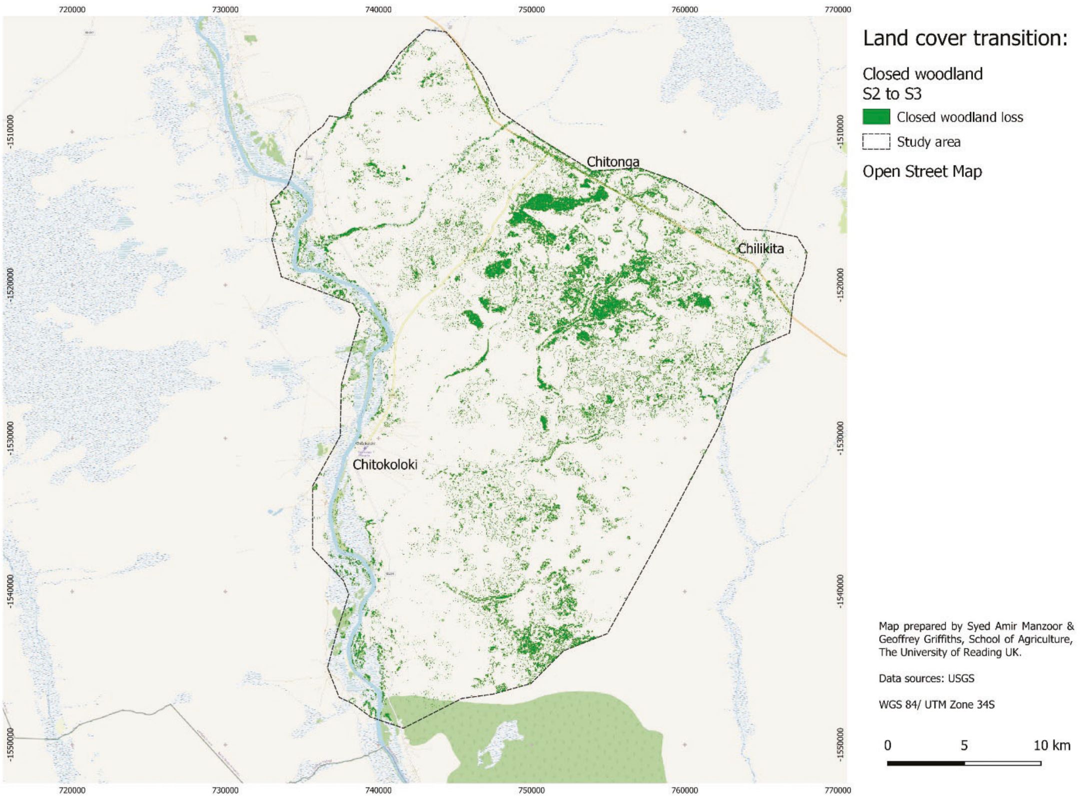


Figure 2: The difference between Scenarios 2 and 3, showing the projected loss of closed woodland to 2050, mostly to cropland expansion (Figure 1)



Conclusion

Serious gaming is a participatory tool that can be used to identify the key factors that motivate farmers' land use decision making. However, challenges arise in ensuring that the game is calibrated to local conditions, and that decisions in the game are as accurate as possible in reflecting real-world conditions (ie the trade-off between simplifying for the game to work, while not actually losing too much of the analytical power of the game). This local scale 'on the ground' analysis is invaluable for developing scenarios of change that can be visualised as maps under different sets of assumptions to aid understanding of the trade-offs between agricultural production and the protection of ecosystem services. An important next step will be to demonstrate how the integration of serious gaming, scenario development, and land cover change modelling can be used for land use planning.

References

1 IFPRI, Foresight modeling with IFPRI'S Impact Model. www.ifpri.org/program/impact-model

2 Griffiths, G, Adolph, B, Chapman, A, Davies, J, Devenish, A, Jellason, N, Kanja, K, Kwenye, J, Manzoor, A, Mwitwa, J, Newbold, T, Phiri, D, Robinson, E and Zurek, M (2022) Future trade-offs to 2050: land cover change, biodiversity and agriculture in Zambia. IIED, London. Sentinel, London. https://pubs.iied.org/20896g

3 Franks, P (2019) Conservation versus food production in Africa: better managing trade-offs. IIED, London. https://pubs.iied.org/17738IIED

4 Kwenye, J, Mwitwa, J, Zurek, M, Adolph, B, Devenish, A, Franks, P, and Hebinch, A (2022) Scenarios of agricultural development in Zambia - Produced during the Sentinel participatory scenario development workshop 2018, Sentinel / IIED, London. https://www.sentinel-gcrf.org/scenarios-agricultural-development-zambia-produced-during-sentinel-participatory-scenario

5 WWF (1 August 2012) Terrestrial Ecoregions of the World. www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

6 Zurek, MB and Henrichs, T (2007) Linking scenarios across geographical scales in international environmental assessments. *Technological Forecasting and Social Change* 74, 1282–1295. https://doi.org/10.1016/j.techfore.2006.11.005

7 Den Haan, R-J and Van der Voort, MC (2018) On Evaluating Social Learning Outcomes of Serious Games to Collaboratively Address Sustainability Problems: A Literature Review. *Sustainability* 10. https://doi.org/10.3390/su10124529

8 Clark Labs, Land Change Modeler in TerrSet. https://clarklabs.org/terrset/land-change-modeler

9 Landsat (2000) USGS, Landsat Missions. www.usgs.gov/landsat-missions

10 Landsat (2021) USGS, Landsat Missions. www.usgs.gov/landsat-missions

Sentinel

Social and Environmental Trade-Offs in African Agriculture

Sentinel is an interdisciplinary research project seeking to address the challenge of achieving 'zero hunger' in sub-Saharan Africa, while at the same time reducing inequalities and conserving ecosystems.

Download this report at www.sentinel-gcrf.org/publications

www.sentinel-gcrf.org

Authors
Geoffrey Griffiths, School of Agriculture, Policy and Development, University of Reading, UK
Syed Amir Manzoor, University of Multan, Pakistan
Barbara Adolph, Principal Researcher, International Institute for Environment and Development, London
Jo Davies, School of Agriculture, Policy and Development, University of Reading, UK
Adam Devenish, Imperial Collage, London
Philip Franks, Principal Researcher, International Institute for Environment and Development, London
Nugun P Jellason, School of Agriculture, Policy and Development, University of Reading, UK
Jane M Kwenye, School of Natural Resources, The Copperbelt University
Elizabeth Robinson, London School of Economics, UK
Monika Zurek, Environmental Change Institute, The University of Oxford, UK

Corresponding author:
Geoffrey Griffiths, g.h.griffiths@reading.ac.uk

Acknowledgements
We kindly acknowledge the QGIS project for open-source GIS tools; the farmers of a community in North-Western province who participated in the serious gaming exercise; and members of the field team.

Image credits:
Front cover: Barbara Adolph/Sentinel

Publisher:
Sentinel / International Institute for Environment and Development
Third Floor, 235 High Holborn, London, WC1V 7DN, UK

Tel: +44 (0)20 3463 7399
Email: info@iied.org
www.iied.org

Funding: Sentinel is funded by UK Research & Innovation (UKRI) through the Global Challenges Research Fund (GCRF) programme for 'Growing research capability to meet the challenges faced by developing countries' ('GROW'). Grant Ref: ES/P011306/1. However, the contents of this document are the sole responsibility of the authors and do not necessarily reflect the position of our funders.