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Projected Land Use Change in an Oil-rich Landscape in Uganda: A Participatory Modelling Approach

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Highlights

- Prospective oil shapes trajectories of change in the Northern Albertine Rift Landscape
- Land conflicts arise within the nexus between agriculture, conservation and extraction
- Area under sugarcane is predicted to expand under status quo and oil scenarios
- Combined methods elucidate human decision-making mechanisms

Key words: agriculture, land grabbing, oil imaginaries, conservation, Northern Albertine Rift Landscape, Uganda

Abstract

The discovery of oil in the North Albertine Rift Landscape of Uganda has increased pressure on land and heightened the potential for resource use conflict. In this article, we focus on changing land use dynamics as oil extraction unfolds in a new resource frontier. We ask how the development of the nascent oil industry will affect land use dynamics, including land use conflicts. This leads us to identify the land use change already arising and to use this as the basis for participatory modelling of projected change. Given they are dominant forms of land use, agriculture and forestry are central to our analysis. Design of the methodology combined remote sensing with innovative modelling incorporating participatory development methods. This facilitated insight into projected land use patterns, and specifically relationships between small-scale food production, commercial sugarcane production, and forestry conservation adjacent to settlement areas. Our data show that ill–defined land boundaries and an aggressive sugarcane out-grower scheme are avenues for so-called land grabbing. Modelling scenarios under both the status quo and under oil extraction suggest the land area covered by sugarcane production will increase at the expense of food crop farming. Given a context where forestry conservation is an important form of land use, we also consider the implications of local agricultural change on land reserved for conservation. Overall, our modelling indicates that in accounting for land use change within the resource frontier associated with oil extraction, there needs to be insight into the intricate interconnections between different forms of rural land use as future change unfolds. Understanding how oil extraction effects rural land use patterns holds relevance for planning in contexts of the Global South where new oil industries are emerging. Innovative methodologies for teasing out these complex land use dynamics can aid planning that seeks to anticipate and reduce land use conflict and support agricultural livelihoods.

Keywords: oil extraction; resource frontier; land-use change; participatory modelling; remote sensing; North Albertine Rift Landscape; Uganda

1. Introduction

The extraction of oil within African resource frontiers stimulates new territorial and spatial dynamics. Writing on the Niger Delta, a context deeply entwined with oil since its discovery in the 1950s, Watts (2004) explores how 'petro-capitalism' produces governable and ungovernable spaces, which he argues becomes associated with specific forms of conflict and violence. Presenting a view of unconstrained global corporations and reduced states, Ferguson (2006) takes issue with this perspective, instead proposing an 'Angolan model' of mineral (oil) extraction, based on a mercantile enclave largely separated from local economy and society. In recent work, Watts (2021) counters Ferguson's notion of the mineral enclave by focusing on the multi-scalar spaces of oil and gas extraction and examining how scalar dynamics are (re)-produced through the circulation of oil

capital and state territorial power. This debate - and a wealth of literature on oil in Africa (e.g., Heilbrunn, 2021) - draws attention to the question of how local economies and societies become reconfigured by oil extraction. In rural Africa, where people are dependent on agricultural production for livelihoods, the relationship between oil industry development and land use change is an important issue.

Unlike Nigeria, Angola, and other African countries where oil has been extracted for decades, in Uganda the discovery of oil is more recent. Indeed, in the North Albertine Rift where oil has been identified, production is still only anticipated for the future because oil has yet to be extracted on an industrial scale (in 2022), despite small amounts of crude oil being sold on international markets. Even so, national aspirations have ridden high on the potential oil holds to transform the Uganda economy. Who will benefit and how is a divisive issue. In this line, writing on the African Atlantic island state of São Tomé and Príncipe (STP), Weszkalnys (2014) explores how the anticipation of oil becomes entwined with the "affective fabric" of contemporary life, emerging in people's aspirations – whether of wealth and prosperity or anxieties over future outcomes. Likewise, as Uganda lays down the infrastructure for industrial oil extraction, reconfiguring territorial claims and commercial development around the promise of oil in the Northern Albertine Rift, it becomes relevant to understand how the dynamics of this new frontier unfold within the local economy and society. This includes in relation to agriculture and forestry, which are dominant forms of land use in the region.

In African resource frontiers, the discovery and extraction of oil is documented as contributing to significant land use and vegetation cover changes, impacting livelihoods, biodiversity and local economies (Butt et al., 2013; Goklany, 2020; Muñoa Capron-Manieux, 2021). Moreover, oil extraction fuels conflict where pressure on limited resources and competing demands on land are reinforced by the ill–definition of land tenure rights, especially in rural areas undergoing rapid

64 change (Rockmore, 2020; Sabir & Torre, 2020). These circumstances are apparent in the North
65 Albertine Rift Landscape (NARL) in western Uganda, a region known for its abundant natural
66 resources, which range from forests and wild animals to fertile soils and oil rich wells (Mclennan &
67 Plumptre, 2012; Ogwang et al., 2019; Owiunji & Plumptre, 1998). In this vein, the region is an
68 important biodiversity hotspot, with endemic plant and animal species (Plumptre et al., 2007) that
69 are also a valuable source of livelihood for local people (Mwavu & Witkowski, 2008). Against this
70 background, growing pressure on land emerges from a nexus between commercial sugarcane
71 production, the protection of species under forestry laws, and a nascent oil industry.
72
73 We refer to the NARL as an 'oil rich' landscape because there are oil reserves present in the region,
74 notably beneath Lake Albert. This prospect of oil has started to influence the local economy and
75 society. This includes with respect to land transactions, a situation made complicated by legal
76 ambiguity and the sheer complexity of tenure rights. All of these factors have the potential to
77 stimulate and reinforce conflict in local communities, as apparent in oil rich landscapes elsewhere
78 in Africa (Agade, 2017; Matemilola, et al., 2017).
79
80 Factors contributing to changing land use dynamics in the NARL are manifold, generating tensions
81 that are readily apparent between competing land use demands within the agriculture-conservation-
82 extractives nexus, as our data will demonstrate. These factors include, but are not limited to, the
83 displacement of people from their original settlements due to oil industry development, coupled
84 with an in-flux of migrants working in this industry whose households seek to access land.
85 Likewise, expanding sugarcane cultivation increases occurrences of richer landowners "grabbing
86 land" from poorer ones, linked also to changing household gender relations (Byakagaba et al., 2019;
87 Mawejje, 2019; Ogwang & Vanclay, 2019). This mix includes land issues associated with forestry
88 conservation, played out through everyday conflicts between farmers and wildlife, through forestry

guard-community relations, and through people's need to access forests for livelihood activities (this study).

Our study builds on Twongyirwe and colleagues' previous research in the region, which established deforestation, forest degradation and land use change baselines, and detailed livelihood characterisations (Twongyirwe, 2015; Twongyirwe et al., 2017). This research demonstrated that deforestation is driven by agricultural practices, with expanding sugarcane plantations being the leading cause of forest erosion in the locality (Twongyirwe et al., 2017, 2018). However, whereas the dynamics of land use change in the context of oil extraction, the decision-making mechanisms underpinning associated land utilisation remain less understood. To explore these dynamics, we use participatory modelling tools to interrogate local perceptions of the relationship between sugarcane production and small-scale agriculture under the status quo, and under oil extraction scenarios. The purpose of doing so is to understand how associated resource use conflicts arise, including through a resource affect from the prospect of oil. Forestry conservation is not built into the participatory modelling because of the current "fortress" protection (no new dynamics are envisaged between the status quo and oil scenarios). By engaging with these objectives, we aim to contribute to debates on the complex dynamics of land use change at the nexus between agricultural development, forest conservation, and extractive industries (petroleum) development.

To gain insight into contemporary debates on the subject of investigation, we provide a thematic framing in Section 2. We then turn in Section 3 to explain our methodological approach, including elaboration on how natural resource mapping and Role Play Games (RPG) are employed to understand local farming dynamics, power and gender relations, and conflict under the status quo and under the oil scenarios. We present the key findings in Section 4 and discuss the results in Section 5. We then reflect on the key outputs, and the conclusions in Section 6.

2. The Dynamics of Land Use Change

Here we draw on literature from Uganda and elsewhere in Africa to explore how the promise of oil stimulates change in ways that complicate established land use dynamics, which historically have been shaped by the twin forces of agricultural development and forestry conservation. We then connect this to the evolution of oil discovery in Uganda and the local political setting within which prospective oil evolves.

Before proceeding, a brief explanation of the different land tenure systems in Uganda is necessary because it has a bearing on our data in subsequent sections. The 1995 Constitution of Uganda and the 1998 Land Act stipulate four land tenure regimes: freehold, leasehold, mailo, and customary – each with different outcomes for agricultural investment and productivity (Okuku, 2006; Place & Otsuka, 2002). First, *freehold* is legally documented private land ownership, with registered land owned in perpetuity, which can be sold or passed on. Second, *leasehold* is a contractual agreement between a property owner granting exclusive use, and a tenant renting for a defined period (usually 49 or 99 years), when it can be used and the tenant can obtain profits from use. Third, *Mailo* was legally the result of an agreement between the Buganda Kingdom[1] and the British colonial authorities in 1900 (Batungi & Rüther, 2008).[2] Today, this system includes land owned by former chiefs and elders who may exercise jurisdiction as 'absentee landlords' (Okuku, 2006). Because of the complications created by *Mailo*, political actors use it to patronise people for votes, if the latter wish to avoid eviction by "powerful" landowners (Médard & Golaz, 2013). Fourth, *customary* tenure is the largest land tenure regime in Uganda. Customary tenants are entitled to official certificates of tenure that could indeed permit transfer rights of sale, lease or mortgage, and such certificates of customary ownership could be converted to freehold tenure following a survey of the land (Hunt,

[1] Buganda is a traditional kingdom, the largest in present-day Uganda, covering the Central Region of the country.

[2] *Mailo* has had a difficult evolution, including abolition and reinstatement, creating uncertainties about security of tenancy. It differs from *freehold* in that simultaneous ownership by the landowner and a lawful occupant, or 'squatter', who has lived uncontested on the land for 12 or more years, is permitted but an annual rent is required with the amounts regulated by the government. The complexity of the *Mailo* land tenure system has attracted large development-partner funded projects in an attempt to find lasting solutions (Musinguzi et al., 2020: 1).

2004). In addition to these four types of tenure, is gazetted land under forestry legislation (i.e., 'public land') owned by the Government of Uganda, which takes a form of a quasi-*freehold* tenure regime.

2.1 Land grabbing and sugarcane production

It is against the background of the complexity of land tenure regimes in Uganda that some of the land massification, also referred to as "land grabbing", occurs. Land grabbing for large-scale agricultural and infrastructural projects is widespread in Sub-Saharan Africa (White et al., 2012: 619). In rural areas, this land grabbing can have critical implications for agriculture-based livelihoods, and impacts on wealth distribution and socio-economic inequality.

Through land grabbing, corporate entities (private or public) can gain access and user rights to large areas of land, often capitalising on complex loop holes in legal and institutional frameworks (White et al., 2012). This can stimulate displacement that may be violent following compulsory acquisition, and compensation (or lack of) (Ogwang & Vanclay, 2019). Land grabbing may also involve more subtle, non-violent incursions that elicit agreements with local landowners while exploiting inequalities of knowledge, power and wealth.

Land grabbing is a topical discourse in Uganda and politicised. President Museveni instituted a commission of inquiry into land disputes headed by Lady Justice Catherine Bamugemereire, and between 2017 and 2019, a total of 8528 cases (from 123 districts out of 135) were presented to the Commission (New Vision, 2020)[3]. The Commission established that "well-to-do persons" had obtained land through illegal means, "bribing their way through all systems of land administration and registration" (*ibid*). Despite such examples, the appropriation of land continues to occur and is

[3] Bamugemereire hands over land probe report to Museveni, available at https://www.newvision.co.ug/news/1523640/bamugemereire-hands-land-probe-report-museveni (accessed 30.9.2020)

frequently masked by development narratives whilst nonetheless dispossessing the poor and vulnerable from the basis of their livelihood (e.g., Murphy et al., 2017: 1). In this context, traditional conflict resolution capacities are very stretched and seen to proceed at a "snail pace"; they also are sometimes considered unjust due to influences from local council committees and clan leaders (Kansiime & Harris, 2020).

Although there are many forms of land dispute, we limit our discussion to land grabbing for sugarcane production. This draws on our previous work in the NARL that showed that a sugarcane outgrower scheme was responsible for erosion of food crop land and patches of natural forest (Twongyirwe et al., 2018). Sugar factories demand sustainable supplies of cane for profitable business. The companies may own an estate, but if they wish to expand production, they need to extend their land area. This is done through purchase, rent, or franchise-based arrangements that can be set up with landowners through contracts, also referred to as "outgrower schemes". Typically, participants in an outgrower scheme are small landholders who wish to engage in small-scale sugarcane production. Governments and corporate agri-businesses view the sugarcane commodity as a vehicle through which small-scale farmers can be integrated within commercial agricultural chains that stimulate rural development and reduce rural poverty (Martiniello, 2020; Martiniello & Azambuja, 2019). Win-win scenarios are promoted: agribusiness companies obtain regular and standardized quantities of produce while small-scale farmers reciprocally secure access to the market (Martiniello & Azambuja, 2019). Nevertheless, deeply entrenched inequalities in the local political economy and social fabric can be reproduced, as played out within rural livelihood opportunities and constraints.

Middle men, and wealthier landowners (not necessarily farmers) take the larger share of the sugarcane business proceeds, with the expansion of the sugar frontier at cheap costs (Martiniello, 2020). In this respect, wealthy entrepreneurs and processing plants maximise value extraction from

188 farmers in ways that are exploitative whilst dramatically affecting existing livelihoods and
189 landscapes (*ibid*). Current outgrower schemes reinforce land-based inequalities, with widespread
190 transformation of existing forms of land use from small-scale food crop production to commercial
191 sugarcane farming. This skews the benefits of commercial farming towards a capitalist agenda at
192 the expense of the livelihoods and welfare of the local population (Martiniello, 2020; Mwanika et al.,
193 2020).
194
195 Evidence from Eastern Uganda shows that sugarcane outgrower schemes perpetuate household
196 poverty, or in Martiniello's (2020:1) words "bitter sugarification". In these schemes, subtle land
197 grabbing is described: landowners are not necessarily displaced, but by signing binding contracts
198 they are convinced about elusive "inclusive development" through their integration within global
199 agro-industrial production complexes (*ibid*). Large-scale farmers are best placed to participate in
200 sugarcane outgrower schemes, as they can afford space for cane and food, or are wealthier and can
201 cope with market fluctuations. Small-scale farmers on the other hand are prone to land
202 dispossession as their land is "locked up" in binding agreements (Martiniello & Azambuja, 2019).
203 Given the already constrained livelihood options in rural areas, this reinforces food insecurity and
204 inability to generate sufficient income.
205
206 It is against this background of the expansion of sugarcane production that we turn to a second
207 factor within the resource frontier of the NARL, with an important bearing on land use in the
208 region, namely forestry conservation.
209
210 **2.2 Forestry conservation and forest-based livelihoods**
211 The NARL is a biodiversity hotspot, with numerous animal and plant species endemic to this region
212 (Plumptre et al., 2006). Natural forests and savanna grasslands are predominant in the region, the
213 majority of which are under fortress protection as conservation areas, taking the form of game

reserves, national parks and forest reserves, attract national and international tourism. The largest forests in the landscape include Budongo and Bugoma, which are home to chimpanzees (Mclennan & Hill, 2012). In the last few decades, the natural forest corridors that connected these large forests were cleared for food crop and sugarcane farming (Twongyirwe, 2015), disrupting feeding rages of the apes, heightening crop-raiding and human-wildlife conflict (Mclennan & Hill, 2012; Mclennan & Plumptre, 2012). The strict protection is enforced by two public institutions whose areas of jurisdiction are overlapping: 1) the National Forest Authority (NFA) – in charge of the trees – and 2) the Uganda Wildlife Authority mandated to take care of wildlife. But a lack of coordination between these bodies has created loopholes for deforestation (Twongyirwe et al., 2015).

To reduce human-wildlife conflict, Collaborative Forest Management (CFM) was implemented as an innovative structured partnership between key stakeholders (e.g. government departments such as NFA and local communities in this case) through which forest-based communities can gain access to, while taking responsible management of forestry resources (Egunyu & Reed, 2015; Turyahabwe et al., 2013). Such projects typically involve creating income–generating projects for local communities adjacent to the forests (e.g., beekeeping, goat rearing) in "exchange of" conservation benefits such as increased live stems of timber, pole tree species, trees with harvestable logs, and lowered incidences of human disturbances (Turyahabwe et al., 2013: 36).

Moreover, forests remain a key source of forest-based livelihoods for the local communities. Key to this are the Non-Timber Forest Products (NTFPs). Even with fortress protection, harvesting NTFPs is permitted, although under restrictions, and evidence suggests that whilst important, restrictions limit amount of NTFPs accessed, hence remain of negligible value for improving livelihoods (Bitariho et al., 2016). But they can be of critical value in maintaining them and acting as a safety net, particularly for the very poor and for poor female-headed households.

We now turn to the third factor driving land use change within the resource frontier, namely extraction and the prospect of oil wealth.

2.3 The prospect of oil

Uganda's oil trajectory has been well documented (e.g., Alstine et al., 2014; Ogwang, 2020; Vokes, 2012). Although oil was first discovered in the region in the 1870s, commercially viable oil reserves were only confirmed in 2006; planning for commercial production has been underway ever since (Mackenzie et al., 2017). It is argued that the amount of oil discovered in the Albertine graben could potentially transform Uganda's agriculture-based economy (Vokes, 2012). The discovery has stimulated scholarship on oil as a resource curse (e.g. Gillies, 2020; Mosbacher, 2013; Ogwang, 2020), and attempts have been made to compare Uganda with "resource cursed" or "resource blessed" African countries. This has prompted extensive national debate over whether Uganda will be able to use its oil resources to promote growth and development (Mbabazi, 2013); although this maybe "misplaced and premature" because oil is not yet out of the ground and the required socio-technical infrastructure is still underdeveloped (Hickey & Izama, 2016, 2019)

Given that oil extraction remains a future scenario, Wezskalyns (2016) work on how the prospect of oil influences the affective fabric of contemporary economic life is pertinent, as highlighted in our introduction. Oil imaginaries create images of prosperous states, where better roads can be constructed, people can earn higher salaries, electricity can be widespread, and sewer systems developed among others (Weszkalnys, 2016: 138). In tracing the "resource affect" of prospective oil and how future scenarios shape land use and livelihood trajectories in the present within the NARL, it is helpful to give an insight into the way the national political context frames extractives development, as with commercial agricultural development and forestry conservation.

Uganda has had a difficult political history marked by economic recession, ethnic rivalry, brutality, and *coup d'état,* especially during Idi Amin's and Milton Obote's regimes between 1960 and 1985 (Nyombi & Kaddu, 2015). President Museveni's coming to power in 1986 was received with new hope and enthusiasm, but after about 36 years, the majority of his contemporaries have either died or joined opposition parties, and the nation is now dominated by youth who are disconnected from the liberation arguments that were popular during Museveni's earlier years in power (Reuss & Titeca, 2017). To remain relevant, Museveni's discourse has shifted towards oil, highlighting how he will protect "his oil" to spur economic development, an issue that continues to bother opposition politicians, civil society organisations, and actors in the private sector (Alstine et al., 2014: 51). Visions of a modern Uganda under the oil scenario are pervasive in Museveni's discourses on resource nationalism, as too on mineral extraction (Fisher et al., 2020). He has promised strict control of the resource to benefit Ugandans and, indeed, if well managed, it is predicted that the oil resource could drive Uganda out of poverty, and propel it into middle income status as per its planning 'Vision 2040' (World Bank, 2016; Ogwang, 2020). However, fears exist over bribery scandals amongst institutions that are mandated to administer the resource (Vokes, 2012: 303).

Reflecting the lie of the land within Uganda's wider political landscape, the NARL has been heavily militarised: the largest military installation in Uganda has been established in Kyangwali, Hoima and the oil fields are guarded by the Special Forces Group (formerly commanded by Museveni's son Gen. Muhoozi Kainerugaba), and a private security company (owned by his brother Salim Saleh) (Vokes, 2012). Museveni's long stay in power following oil discovery was predicted (Barkan, 2011 in Alstine et al., 2014: 51). No wonder the constitution was amended in 2017 to lift the presidential age limit, paving the way for Museveni to contest again in 2021. He won the election amidst compelling questions about the transparency of the elections and curtailing the rights of opposition politicians to reach the populace. Museveni will have been in power for 40 years by the end of the new term. It therefore becomes unsurprising that part of the "resource affect" of

prospective oil draws in notions of the oil curse or blessing within contemporary debate on oil in Uganda.

Such is the national context to prospective oil in the NARL and how, in line with Weszkalyns (2016), it brings an "uncertain future into the present" with the time-lag between exploration and extraction raising the potential for "cruel optimism", with people's lives indefinitely trapped between exploration and extraction (Weszkalnys, 2016: 138). Kinyera & Doevenspeck (2019: 11), for instance, blame overfishing on labour mobilities into Lake Albert region. Because promised oil work was not forthcoming, the majority turned to fishing livelihoods, increasing pressure on the fisheries resources. There are wider geographies of conflict within this "resource affect" framed around local narratives on the mobility of pastoralists, labour, and fishers, coupled with tensions between elephant conservation and local communities in the Albertine rift landscape (Kinyera & Doevenspeck, 2019). In the process ethnic tensions between the native *'Banyoro'* and immigrant cattle keepers '*Baraaro*' have been exacerbated, as people become more aware of the past and present, hoping to secure their futures through clarifying their "share" of the land and oil resources, as the basis of their livelihoods. Other futures are also invoked as biodiversity and elephant mobility are placed in the spotlight. Such conflicts reveal how "excesses" of anticipation can build unrealistic expectations of prosperity, yielding negative consequences that "redirect anticipation against itself" (Weszkalnys, 2014: 211).

With the prospect of oil, the older twin dynamics of small-scale agriculture and forestry conservation have been drawn into a trajectory of future oil prospects, framing contemporary political and economic life. This plays out both within narratives on resource nationalism, in which an elderly president clinging to power recognises the significance of resource nationalism for a contemporary citizenry, and plays out too within local livelihood conflicts. In the following sections, we seek to better understand these trajectories of resource affect at a local scale, using

sugarcane production as an entry point to wider land use conflict within the agriculture-conservation-extractives nexus.

3. Study Area, Materials, and Methods

3.1 Study Area

The study area lies in the NARL within a location renowned for its abundant natural resources. The study was conducted in four villages that lie south of a forest named Budongo. Location and village selection was based on, firstly, satisfying the conditions for studying the agriculture-conservation-extractives nexus, and secondly, the ability to capitalise on our previous research in the region, with an existing rich dataset to build on. The villages are: Nyabyeya I, Nyabyeya II, Kibwona and Nyakafunjo, whose sizes are approximately 323.4 km^2, 106.18 km^2, 635.2 km^2, and 128.9 km^2 respectively. The villages are located approximately between 1°38′–1°42′N and 31°27′–31°40′E (Figure 1). The rainfall received is bimodal in nature, with peaks from March to May and September to November, and a mean annual range between 1150-1500 mm. The minimum annual temperature is 17-20 °C, while the maximum is 28-29 °C. It occupies slopes gently rolling towards the escarpment of the rift valley with an altitude range of 914 m and 1097 m asl. (Turyahabwe et al., 2013).

Until recent years, small scale–farming has been the predominant land use by people with long-established ties to the area, but in-migration driven by business prospects from the expanding sugarcane outgrower scheme and the promise of oil's prosperity are changing land use patterns (Twongyirwe et al., 2018). The region south of Budongo forest, is characterised by the expansion of sugarcane farming that started around 1995, eroding forests on privately owned land and reducing space for food production (Twongyirwe et al., 2015).

Oil industry development has included violent land dispossession with subsequent conflict for communities living outside the study area (Byakagaba et al., 2019; Ogwang & Vanclay, 2019; Ogwang et al., 2019). This has heightened pressure on land in the region – including in the study area - and on the natural forest, pressure that is further reinforced by insecure land tenure regimes, coupled with factors such as demand for timber and timber products, and the impact of crop raiding by wildlife. As our data shall demonstrate, these pressures have increased both community-level conflicts, and conflicts between local communities and the protected forest estate authorities.

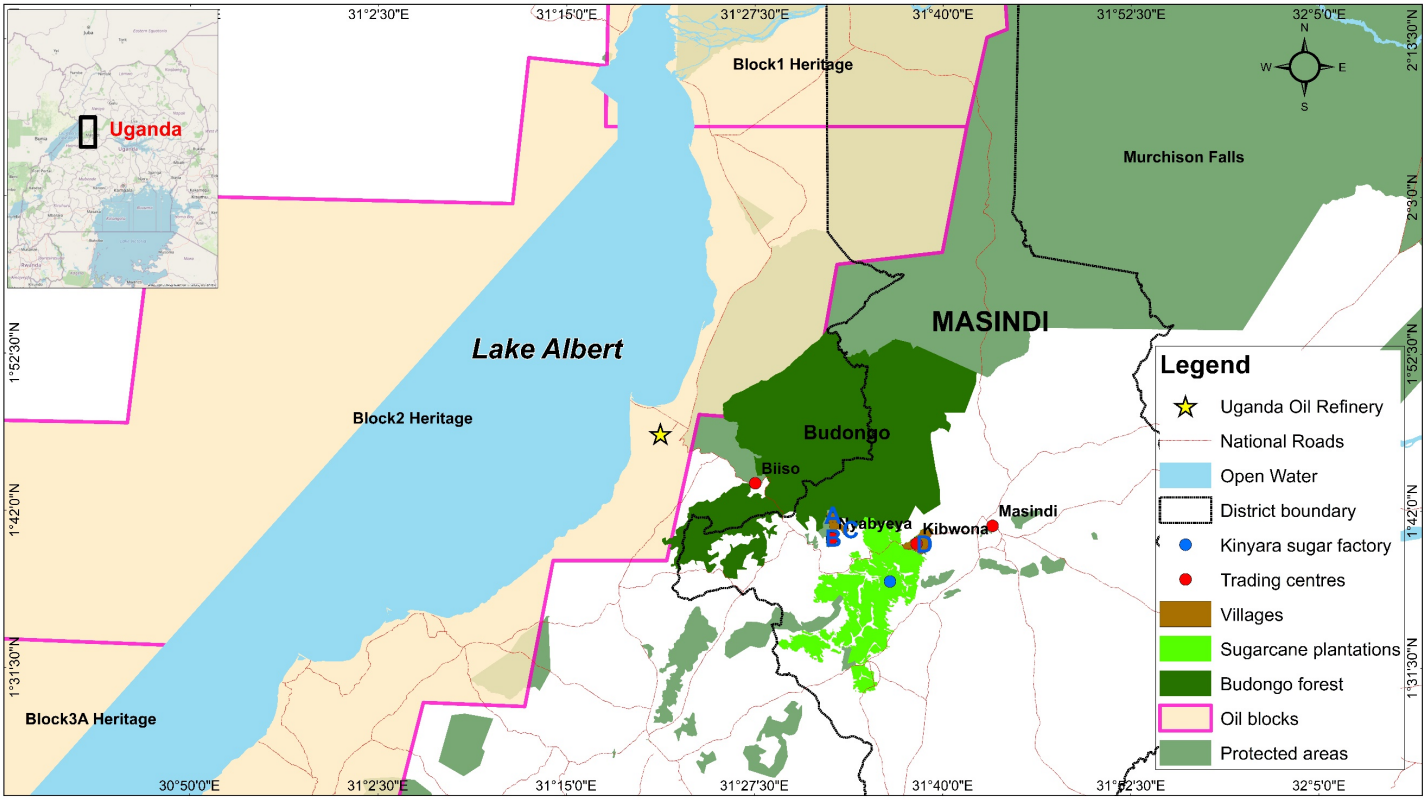


Figure 1. A map indicating villages south of Budongo forest where the study was conducted: A–Nyakafunjo, B–Nyabyeya I, C–Nyabyeya II, D–Kibwona (source: authors).

All the villages are located in 'close' proximity to sugarcane plantations, natural forest, and oil blocks, enabling investigations into the agriculture-conservation-extractives nexus.

3.2 Community–based Natural Resource Mapping

Across the four study villages, we conducted eight (8) Focus Group Discussions (FGDs) in late 2018 and an additional four (4) FGDs in early 2020. We took a gendered lens in our approach: we aimed for an equal number of male and female participants in each group in each village. All groups

were comprised of 10 people (5 men; 5 women), except for Nyabyeya I that had 12 participants in both groups. The FGDs were arranged in such a way that the data collected in 2018, and its subsequent analysis, formed the basis of the design of the RPG conducted in 2020. The emphasis was on understanding utilisation of community resources, especially the interactions between the expanding outgrower sugarcane scheme, strict forest protection, and emerging oil extraction. The selection of participants and group composition was carefully considered. We expound more on these as follows, under Supplementary Information (SI.1) participant selection and community-based natural resource mapping are described.

We used the community-based natural resource management tool to generate community-level maps. The rationale was to gain an understanding of what natural resources are present in the community, linked to issues of ownership and access, including how conflicts could arise from competing land use demands. The mapping process helped identify the "fault-lines" of community-based conflict or cooperation related to land and natural resources, taking into account social and power relations (including gender), as well as changing dynamics of resource use and ownership. Before the map was drawn, FGD participants conducted a transect walk through the village for a period of 30-45 minutes. While the type of map generated sought to reflect a representation of the locality, we emphasised that it was not necessary to develop an accurate map, instead the main goal was to obtain useful information about local perceptions of resources. In any case, the generated maps formed the basis for initialisation of the board for the Role Play Game (RPG). We qualitatively compared the output of this mapping exercise with remote sensing data nonetheless. This session concluded by asking participants what they learnt and what they could do to change the situation in their community, based on their analysis.

3.3 Participatory Modelling based on Role Play Games (RPGs)

382 Modelling land use and land cover change is one of the leading topics in the burgeoning Land Use
383 Science literature: but model parameterisation is fraught with difficulty, not least because they do
384 not effectively represent human decision–making given its irrational nature (Celio, Ntsiva,
385 Andriatsitohaina, & Zaehringer, 2019). Participatory modelling (based on Role Play Games) is an
386 established methodology whose use is re-emerging as being of value in improving our
387 understanding of human decision–making in complex socio-ecological systems (SES) (Mariano &
388 Alves, 2020; Merlet et al., 2018). A RPG is a game in which players/participants take on the roles
389 of characters in a fictional setting – but are required to make decisions following a structured set of
390 the rules – often overseen by a game master who assures adherence (Biggs et al., 2015). Each player
391 takes turns, and has to respond to particular constraints, but unlike in conventional games, RPGs do
392 not have a winner, although the game can provide some entertainment to the participants (Merlet et
393 al., 2018). Used in various disciplines, examples include RPG to understand natural resource
394 management in Vietnam (Boissau et al., 2004); watershed management in Thailand (Promburom,
395 2004); shrimp production systems in Vietnam (Joffre et al., 2015); and, farming practices in France
396 (Moreau et al., 2019). The RPG in this study is comprised of two scenarios: 1) the baseline/status quo
397 scenario that depicts the current state of land use in the villages, and 2) the oil scenario that provides
398 a hypothetical case in which oil is extracted from the ground. The details of the RPG
399 operationalisation (inputs, process, outputs) for this study are elaborated in SI.2.
400
401 **3.4 Mapping Land Use and Land Cover in the Studied Villages using Remote Sensing data**
402 We have previously undertaken extensive remote sensing analyses over this region where we
403 showed selection of training sites, separability of the classes based on spectral signatures, and
404 accuracy assessments (Twongyirwe et al., 2015). For purposes of this study however, using the
405 same conventional techniques [ibid], we analysed a Landsat 8 image (30m resolution) acquired in
406 January 2020 to obtain land use and land cover classes in each village where fieldwork was
407 conducted. Our interest was in triangulating remote sensing data with community-based mapping.

This enabled us to further inform, for instance, data generated from the NARL RPG based on indications of quantities of land uses that are of interest.

Image pre-processing, processing (classification) and post-processing was undertaken using Erdas Imagine software (version 2016) following procedures we have previously employed to characterise land use and land cover in the region (Twongyirwe, 2015; Twongyirwe et al., 2015). The definition of land use and land cover classes also follows our definition in (Twongyirwe et al., 2015). In brief, the raw image was downloaded from the USGS website (at earthexplorer.usgs.gov) and bands were stacked to create false colour composites, followed by image subset extract each of the villages we studied. The village layers were obtained from Uganda Bureau of Statistics. Training sites were then selected over various land uses and land cover, based on our previous visits and knowledge of the area. These were used in extracting an average spectral signature for the classification. The Maximum Likelihood Classifier (MLC) was chosen to classify the image: it puts pixels in a corresponding class with the maximum likelihood of belonging to it based on a pool of spectral signatures (Nangendo et al., 2007). We selected five classes: natural forest, woodlots (including timber grown on small-scale farms), settlements, small-scale agriculture (representing food crop farming) and sugarcane plantations (including both Kinyara sugar estate, and the small-scale sugarcane plots in the outgrower scheme). We have good knowledge of the villages following our longstanding experience in the region. Based on this, we can confirm that the classification was reasonably accurate.

3.5 Data Analysis

Remote sensing data were only used to augment mapping outputs from the FGDs, so our data were mostly qualitative. We extracted themes from the FGDs in line with the study objectives. NARL RPG data were summarised using plots – to show patterns in decision–making. Three variables

were plotted: small-scale agriculture (representing food plots), sugarcane parcels, income (cash in hand). We define the main parameters of our graphical exploratory analysis as follows:

(i) Rounds: We interpret this as a replacement of time (season). Each round represents six months, per the seasonal calendar from previous fieldwork.

(ii) Gender: We have two: Male and Female gender. In our graphics, Male gender is denoted by solid curves, and dashed curve for the Females, for ease of comparison.

(iii) ID: For ethical reasons, we do not display the names of participants, but rather Identity (ID) numbers given to each participant, ranging from 1 to 9. These participants' IDs are indicated on the graphs.

(iv) Net income: We also perform basic econometrics by tracking the running incomes of each participant at every timestep following the basic formula:

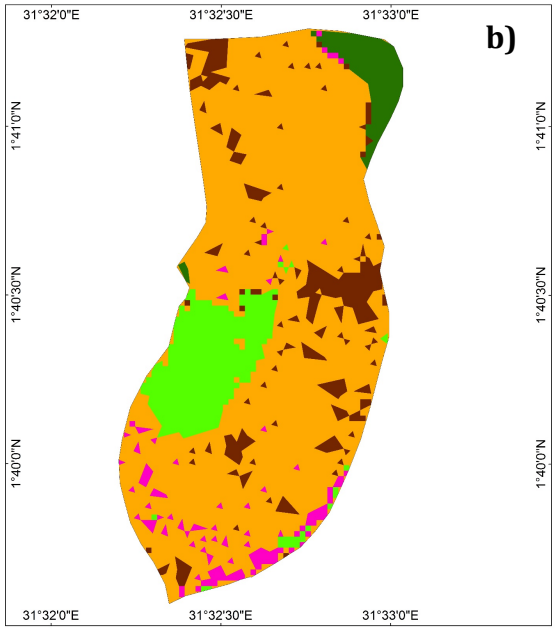
Net Income = Total Incomes – Total Expenditures.

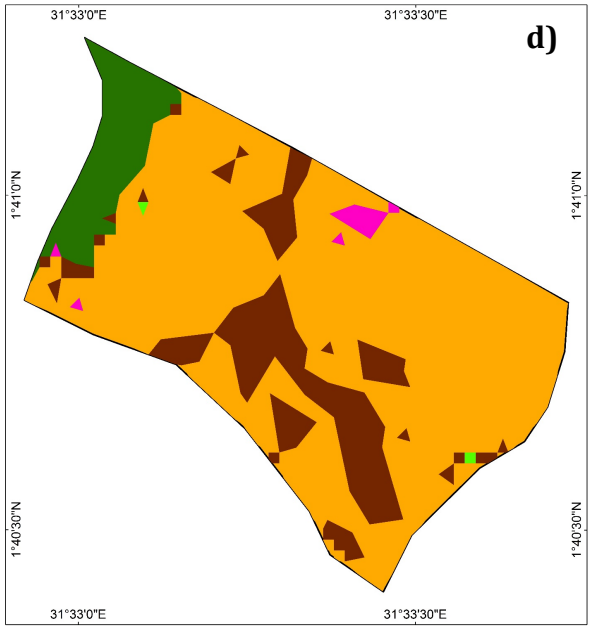
The main source of the income in the RPG are: income from selling/renting land (food or sugarcane plots; income from labour service to oil industry; and, income from selling sugarcane harvest to the factory. While the main expenditure in the game is related to buying/renting land parcels. The various income/expenditure is updated every timestep, summed and then used to calculate the Net Income at every timestep.

We present graphs from our exploratory analysis, presenting time series of land cover ratio change for all the participants in the villages (Nyabeya I, Nyabeya II and Kibwona) under both status quo and oil scenarios, followed by an exploration of income dynamics under both scenarios for each village. Presenting spatial patterns of land uses in the status quo and oil scenarios from the participatory modelling based on a hypothetically set up board by study participants would be challenging.

4. Findings

458 We examine the dynamics of land use and land tenure regimes, linked to participatory profiles of
459 wealth differentiation and economic activities in the study villages.
460
461 **4.1 Land Use for Agriculture and Forestry**
462 FGD participants indicated relative abundance and spatial extents of each land use (Figures 3 and
463 4). A visual assessment indicates some agreement with maps generated from classifying Landsat
464 imagery. FGD participants highlighted that small-scale farming (food production) covers the largest
465 percentage of land use in every village. This is clear from the 2020 remote sensing classification,
466 with small-scale agriculture accounting for 72.9%, 74.4%, and 65.6% of land use in Nyabyeya I,
467 Nyabyeya II, and Kibwona respectively. The acreage under settlement is second to small-scale
468 agriculture, followed by natural forest in Nyabyeya I, Nyabyeya II, Kibwona (Table 1). There is
469 also a reasonable agreement with the amount of sugarcane and forest cover indicated on the maps
470 (e.g., Figures 4a and 4b, and Figures 4c and 4d, and southwestern parts of Figures 3a and b),
471 although spatial extents varied. For instance, there is more sugarcane mapped in Figure 3c than that
472 detected in 3d, especially “strips” indicated in the south and west in the former. As identified in the
473 FGD mapping too, area under sugarcane in Nyabyeya I and Nyabyeya II from remote sensing
474 imagery is relatively small, accounting for 3% and 1% respectively. Kibwona has a significantly
475 higher acreage under sugarcane accounting for 13.8%. Nyakafunjo is peculiar: the majority of the
476 village space – some 39.1% – is under forest, and has no sugarcane compared to the other villages.
477 Woodlots were identified in all villages, although their acreage is much smaller than the other land
478 uses/cover (Table 1).





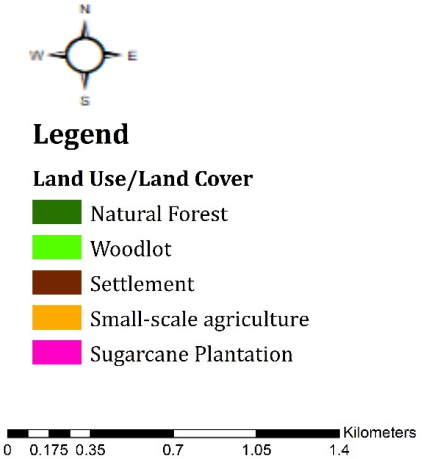
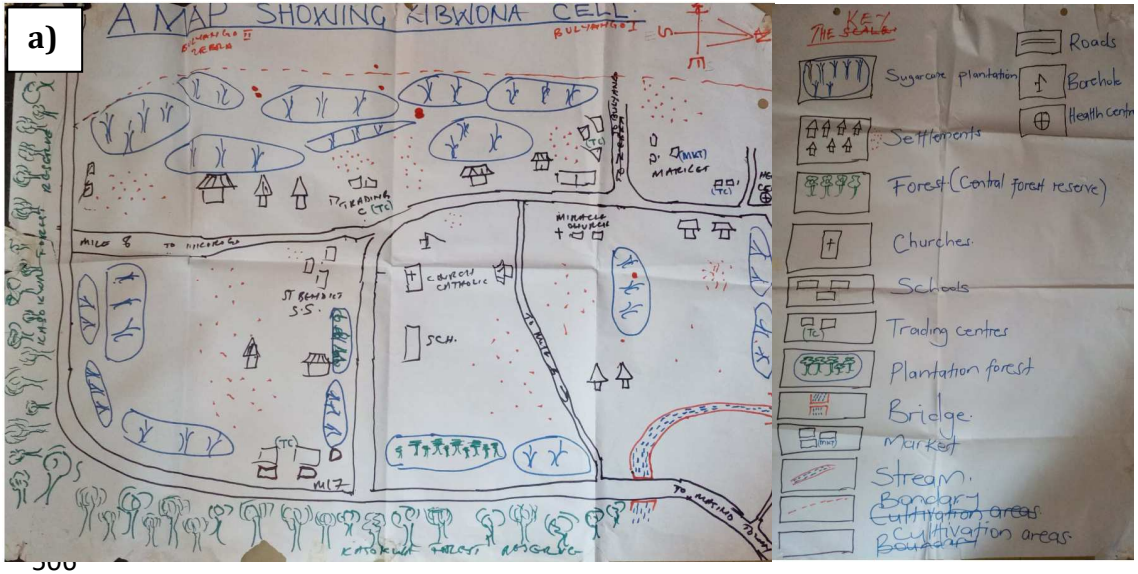
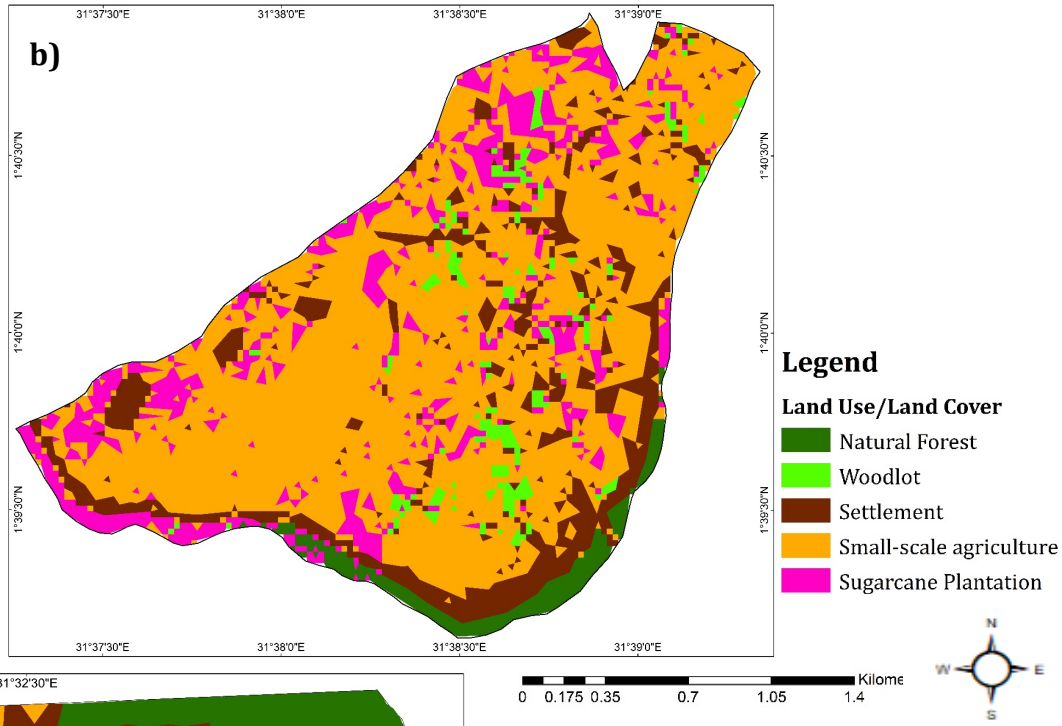
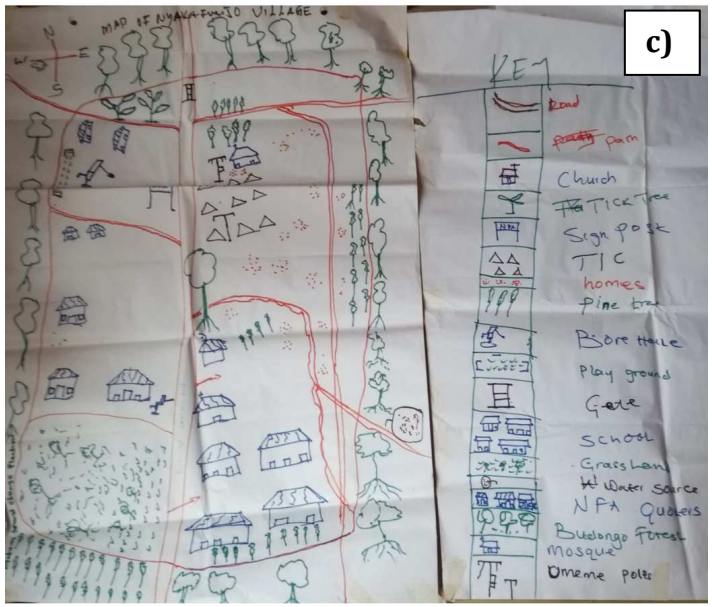


Figure 3 Map of studied villages drawn by local participants versus maps generated from analysing Landsat imagery acquired in 2020: a) community map of Nyabyeya I, b) Classification of Nyabyeya I, c) community map of Nyabyeya II, d) classification of Nyabyeya II







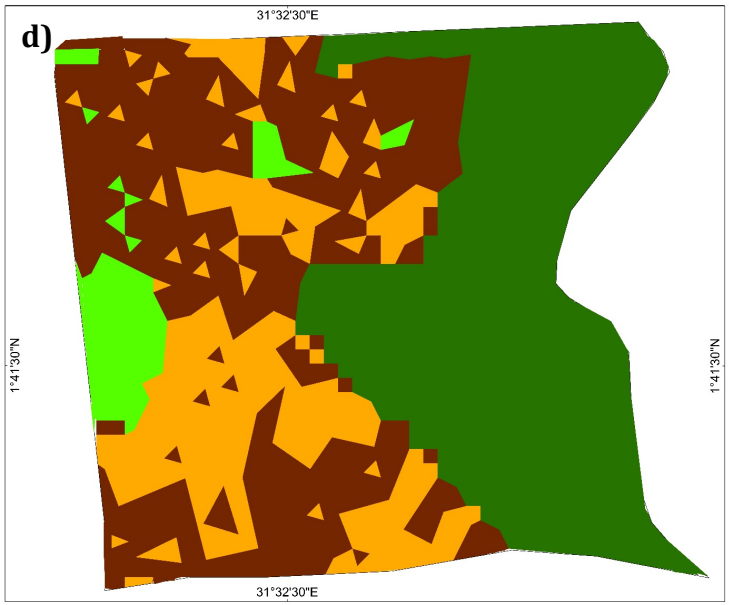


Figure 4. Map of studied villages drawn by local participants versus maps generated from analysing Landsat imagery acquired in 2020: a) community map of Kibwona, b) Classification of Kibwona, c) community map of Nyakafunjo, d) Classification of Nyakafunjo

Table 1 Size of land uses/cover (ha) classes in the studies villages from the Jan 2020 Landsat image classification

Land use/cover	Nyabyeya I	Nyabyeya II	Kibwona	Nyakafunjo
Natural forest	13.42	8.88	20.85	50.36
Woodlot	13.90	0.15	20.61	6.57
Settlement	27.86	17.14	88.24	45.42
Small-scale agriculture (for food)	235.59	78.98	417.83	26.58
Sugarcane plantations (on small-scale)	9.64	1.03	87.89	0.00
Total acreage (in ha)	**323.41**	**106.18**	**635.42**	**128.93**

4.1.1 Livelihood and wealth differentiation

Across all study villages, the dominant mode of livelihood is based on agriculture for food crops and for sugarcane. There was minimal variation in rural livelihood opportunities between villages (Table 2), with the exception of Nyakafunjo, where due to the protection of chimpanzees through forestry laws, sugarcane cannot be grown.

Ownership of land is a key wealth indicator, closely linked to land area under sugarcane production, with a "richer" category of people owning 2–5 ha of land devoted to sugarcane. Other wealth indicators include housing structure (e.g., permanent – made of bricks and iron sheets), ownership of cars and motorcycles, and schooling for children linked to affordability of more expensive private schools, pursuing education post-primary. The majority of residents across all villages were perceived to belong to "middle" income status based on their perceived wealth ranking (Table 2), consistent with national statistics that poverty levels are relatively low in this region of Uganda (UBOS 2016). The households keep barely any livestock, and the majority of food crops grown are for home consumption with some surplus for sale in local markets. The dominant crops are maize, beans, cassava, groundnuts, and bananas. Coffee was mentioned in Nyabyeya I –but participants categorically added that this is in very small quantities, so it is not a significant cash crop like it is elsewhere in the region. Due to land fragmentation, barely any livestock could be kept.

Local employment opportunities exist within the sugarcane outgrower scheme – especially during the peak season of harvesting and at Kinyara sugar factory, but the majority of people work on own farms. Other limited opportunities exist within local schools, conservation organisations, trading in merchandise, and the construction industry.

Table 2 Perceived socio-economic differentiation at village level

Characteristics/Village	Nyabyeya 1	Nyabyeya II	Kibwona	Nyakafunjo
Wealth indicators for the "Richer"	- Own sugarcane 3-5 ha, - Formal employment (colleges, NGOS, LGs)	- "Nice house" – made of bricks, and with iron sheets, - Total land size > 3 ha, - Own sugarcane plantations >2 ha	- Own sugarcane, 2-5 ha - "Enough" food, - Schooling children, - Owns a car or motorcycle, - Permanent house	- Permanent house - Own a motorcycle - Absentee landlords (or own properties outside the village)
Wealth indicators for the "Middle"	- Own sugarcane 0–3 ha	- Own sugarcane 0–2 ha	- Owns sugarcane 0–2 ha	- Middling
Wealth indicators for the "Poor"	- Have no sugarcane plantations	- Live in grass thatched huts - Owns no sugarcane	- Cannot afford growing sugarcane	(not identified)
Proportion of wealth categories in terms of numbers in the village	Poor > Middle > Rich	Middle > Poor > Rich	Poor > Middle > Rich	Poor > Middle > Rich
Crops grown	Maize, beans, cassava, groundnuts, rice, "*matooke*" and coffee (very small scale), jackfruit	Maize, beans, sweet-potato, millet, sorghum, groundnuts, cassava	Maize, beans, *matooke*, cassava, groundnuts, sweet potatoes	Maize, beans
Ethnicity/dominant tribes reported in the village			*Banyoro, Acholi, Alur, Iteso, Batoro, Banyankole, Lugbar*	*Alur, Lugbar, Banyoro* and *Lendu* (from Congo)
Employment opportunities in the village (most of the residents work locally)	In schools – teaching and cooking, night guarding, NGOs	Protecting sugarcane against vermin, weeding	Casual labour in sugarcane plantations & Kinyara sugar factory, bars as waitresses, shop attendants, teaching	Digging in the gardens, brick laying
Livestock kept	Small ruminants kept rarely: 1 or 2 goats per HH in spite of wealth status	None reported	None reported	None reported
Land tenure	Predominantly customary, with some freehold ("*people come in to buy land*")	Predominantly customary, with some buying and renting	Mainly customary, with freehold system increasing	Predominantly customary with some freehold
Commercial sugarcane growing	Franchise-based, owned by a few members	Franchise-based, owned by a few members	Owned by outgrowers found in village	Not permitted

NGOs – Non-governmental organisations

4.1 Perspectives on the expanding sugarcane outgrower scheme and oil prospects

Sugarcane has a history in the villages – which is perceived locally as having often resulted in land dispossession, and in marginalisation of poorer land-owners:

"The project for sugarcane growing was started by Kinyara sugar works over 20 years ago. They provide seeds to people – a few people own the land where the sugarcane is grown… Kinyara sugar limited comes in if you have registered enough land, they come and survey, plough on a loan until the cane is grown. They come and harvest, and recover their upfront costs. At times, you remain with little money or nothing. But it gives you a starting point to grow sugarcane because the next time you grow it, Kinyara will not come to own it again. What they do is to help people start growing even without money especially during the first harvest" (male FGD participants in Nyabyeya I, 2018).

"*People who have money come from other places and rent land to grow sugarcane. They count seasons – normally one and half year – and pay the land owner according to those seasons*" (male FGD participant in Nyabyeya I, 2018). This remark was reiterated by respondents in other villages.

"*Sugarcane is owned by a few members in the village. However, some people from Kinyara (and far away) to hire land from the residents to grow sugarcane...it is not always better to hire land to outsiders… You may not have enough capital to start up the sugarcane business, so you don't have an option apart from hiring your land to someone else"* (male FGD participant in Nyabyeya II, 2018).

In Nyakafunjo village where sugarcane growing is prohibited due to human-wildlife conflict is viewed as unfair and a way to take away a livelihood from the locals.

"*We used to grow sugarcane in the past but chimpanzees would come from the forest and destroy them. And as a result, some people would kill them which led NFA*

575 [National Forest Authority] *to intervene and stop sugarcane growing*" (male FGD
576 participant in Nyakafunjo, 2018).
577
578 "*It is bad that we cannot grow sugarcane and yet others are growing it. So, our*
579 *development and income levels are down. As you can see, our children do not even*
580 *go to school"* (male FGD participant in Nyakafunjo, 2018).
581
582 However, growing wood for fuel and building poles (i.e., woodlots) practiced on privately owned
583 land (rather than sugarcane growing) is perceived as more viable than food crops grown on small–
584 scale because of the vermin problem.
585 "*Pine is grown next to the natural forest due to monetary benefits from owning*
586 *trees…also wild animals are more likely to raid crops if grown next to the forest,*
587 *therefore pine growing is a better option*" (FGD participant in Nyakafunjo, 2018).
588
589 The expansion of sugarcane in for instance Kibwona is creating land shortage as poorer people are
590 renting out their land to wealthier people both from the village and from outside, creating food
591 insecurity for less well-off people who are also turning part of their land over to sugarcane growing.
592 It was mentioned that men have to provide labour in sugarcane plantations at a time that coincides
593 with labour demands for food crop production. However unconventional employment opportunities
594 in the village have also emerged [e.g., "*sex workers within the trading centre have increased these*
595 *days*" (female FGD participant in Kibwona, 2018)]. Furthermore, the sugar boom has also had some
596 unintended consequences such as increased (petty) theft and heightened the risk of food insecurity.
597 Food insecurity was viewed as a likely control to the rapid sugarcane expansion.
598 "*Land is scarce but even those with small pieces of land work tirelessly to grow*
599 *sugarcanes as well. However, the challenge is that it results into hunger since they*
600 *tend to neglect growing other food crops*" (male FGD participant in Kibwona, 2018).

601

602 "*All the land cannot be allocated to sugarcane growing. We must spare some land for*
603 *growing food crops*" (female FGD participant in Nyabyeya II, 2018).

604

605 "*We plan for the land according to how the family will survive. I cannot plant*
606 *sugarcane and yet my family is starving because a good sugarcane takes 18 months*
607 *for you to harvest so by the time you get money out of it your children will have died,*
608 *instead you opt for maize, beans*" (female FGD participant in Nyabyeya I, 2018).

609

610 ***The prospect of oil***

611 Uncertainty about land ownership given the oil prospects worried the residents and created mistrust.
612 This did not reduce their scepticism about researchers in the area too (in spite of clearly explaining
613 what our study was about):

614 "*You guys are here writing, writing* [all laughing…] *but in future you will be leading*
615 *the government in evicting us "mbu"* [that] *there is oil discovered here. You start*
616 *telling us to leave our land and go to settle elsewhere, and yet we are poor… The*
617 *government just tells you to go away because they want to construct a road, yet the*
618 *money given to you as a compensation cannot even buy a plot of land somewhere*
619 *else, we are so confused of what to do. So, even seeing you here makes me worried*
620 *and I am telling you the truth*" (male FGD participant in Kibwona, 2018).

621

622 Furthermore, FGD participants anticipate that oil will bring big changes in the studied villages, with
623 mixed consequences for land (dis)possession:

624 "*Some people will gain from it and others will be affected for example, now that there*
625 *is oil, roads will be constructed but remember there are people who have plots of*
626 *land/ plantations along the road. Part of their land will be lost in the process of road*

construction, so, when you are left with a small piece of land, will you be able to cultivate or construct anything on it? More so, some people constructed their houses [permanent structures] *and settled along the road, so, what will happen during expansion is eviction. Will they be compensated or not? And more to that if they are compensated, where will they go? Land is scarce and very expensive nowadays; do you understand me? However, on the positive side, some people will get employment opportunities as a result of oil discovery. For example, working as guides during the road construction, cooking food for the workers among others. This will be a source of income. Our transport and communication will be improved as well thus creating market for our agricultural products. Basically, the effects of oil discovery will be both positive and negative*" (male FGD participant in Kibwona, 2018).

"*All things have a good and bad effect. Sugarcane growing will* [likely] *increase, as well as theft due to having nothing to eat. Someone will not sleep hungry when they are seeing a garden of sugarcanes, cassava, sweet potatoes among others. So, development comes with both good and bad things*" (female FGD participant in Kibwona, 2018).

There is also a view that the oil resource will be useful for future generations:

"*Actually, we are educating children such that they can work in oil industries in future*" (male FGD participant in Nyabyeya I, 2018).

4.2 Participatory Modelling (RPG) Outcomes

At village level, the RPGs indicate that, on average, sugarcane is projected to increase ($p<0.05$) at the expense of small-scale agriculture in both the baseline (status quo) and oil scenarios (Figure 5). Sugarcane expansion is more marked in the status quo and oil scenarios in Nyabyeya I village, consistent in both groups (Figures 5 a and b, and, c and d). In Kibwona, a gentle increase in

generally projected, albeit group one had less sugarcane parcels on average (Figures 5 e and f) compared to the other (Figures 5 g and h). In Nyabyeya II sugarcane increase is only marginal overall, and small-scale agriculture declines only slightly in subsequent game rounds in the status quo (Figure 5 i). However, under the oil scenario, sugarcane increase is less marked, but area under small-scale agriculture increases with subsequent game rounds (Figure 5 j).

Individual gaming sessions however reveal mixed non-linear patterns of ratios of sugarcane to small-scale agriculture, including both increase and decrease in both the status quo and oil scenarios (Figure 6). Some players show consistency in decision–making. They for instance consistently increase number of sugarcane plots they own at the expense of small-scale agriculture under both the status quo and oil scenarios: For instance, player 6 in Nyabyeya I (Figures 6 and b); players 2, 4 and 8 in Nyabyeya I (Figures 6 c and d); player 3 in Kibwona (Figures 6 e and f); and player 4 in Nyabyeya II (Figures 6 i and j). Some patterns are more erratic and inconsistent however – sharp changes (spikes) are visible in either scenarios: for instance, player 1 in Nyabyeya 1 (Figures 6 a and b) makes decisions to increase sugarcane under the status quo but then initially increases sugarcane in the first three rounds of the game before a sharp decline under the oil scenario; player 6 in Nyabyeya I (Figures 6 c and d) initially increases number of parcels under sugarcane before reducing in subsequent rounds of play – and this is consistent in both the status quo and oil scenarios while player 1 in the same group decreases sugarcane in status quo but increases it under the oil scenario (Figures 6 c and d). A few players made decisions to reduce on the sugarcane plots they owned under both scenarios: For instance, player 7 in Kibwona (Figures 6 g and h); and player 6 in Nyabyeya II (Figures 6 i and j).

Generally speaking, there isn't a significant difference ($p>0.05$) between the incomes earned under the status quo and oil scenarios on average (Figure 7). In both scenarios however, incomes progressively increase in general, but income under the oil scenario are on average marginally

679 higher than the status quo scenario except in one group in Kibwona (Figure 7 c). In some instances,
680 income variability is large (Figures 7 c, d and e). This variability becomes clearer when individual
681 player patterns are observed under both scenarios (Figure 8). The patterns are erratic and non-linear
682 in all scenarios.
683
684 There is statistically no gender differentiation ($p>0.05$) between patterns in land use and decisions
685 made by both men and women under both scenarios: mixed patterns in sugarcane to small-scale
686 agriculture ratios are visible amongst both male and female participants (Figure 6). Although lost in
687 the overall statistics and patterns, during the gaming sessions, some women mentioned that they
688 preferred more food gardens to sugarcane plantations.
689
690

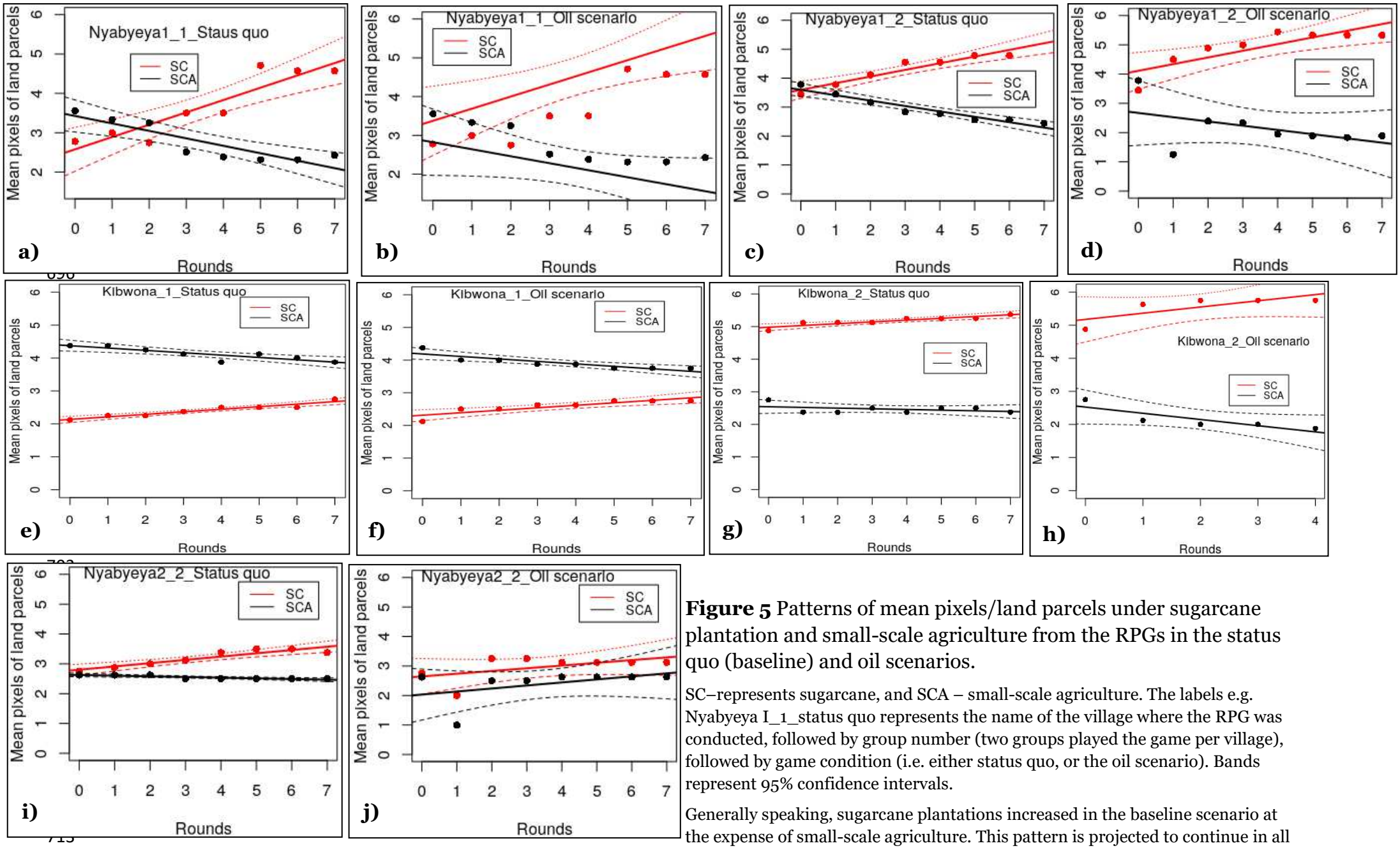


Figure 5 Patterns of mean pixels/land parcels under sugarcane plantation and small-scale agriculture from the RPGs in the status quo (baseline) and oil scenarios.

SC–represents sugarcane, and SCA – small-scale agriculture. The labels e.g. Nyabyeya I_1_status quo represents the name of the village where the RPG was conducted, followed by group number (two groups played the game per village), followed by game condition (i.e. either status quo, or the oil scenario). Bands represent 95% confidence intervals.

Generally speaking, sugarcane plantations increased in the baseline scenario at the expense of small-scale agriculture. This pattern is projected to continue in all villages even under the oil scenario.

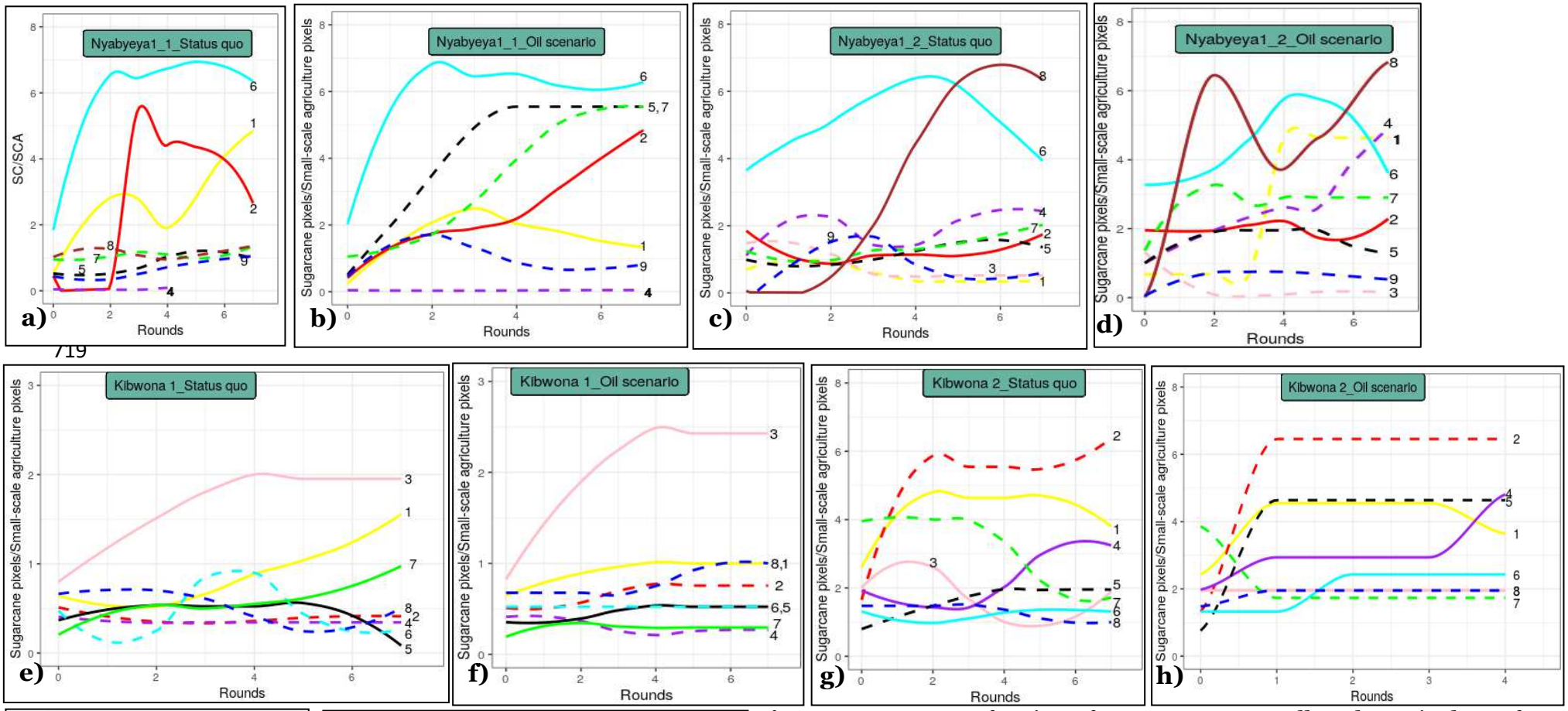


Figure 6 Patterns of ratios of sugarcane to small-scale agriculture from the RPGs in the status quo (baseline) and oil scenarios.

SC–represents sugarcane, and SCA – small-scale agriculture. The labels e.g. Nyabyeya I_1_status quo represents the name of the village where the RPG was conducted, followed by group number (two groups played the game per village), followed by game condition (i.e. either status quo, or the oil scenario). Male gender is denoted by solid curves: Female gender by dashed curves.

Gender: a) & b) 1–M, 2–M, 3–M, 4–F, 5–F, 6–M, 7–F, 8–F, 9–F; c) & d) 1–F, 2–M, 3–F, 4–F, 5–F, 6–M, 7–F, 8–M; e) & f) 1–M, 2–F, 3–M, 4–F, 5–M, 6–F, 7–M, 8–F; g) & h) 1–M, 2–F, 3–M, 4–F, 5–M, 6–F, 7–M, 8–F; i) & j) 1–M, 2–F, 3–M, 4–F, 5–M, 6–F, 7–M, 8–F (M–Male, F–Female).

The amount of sugarcane increases in all the games while that of small-scale agriculture decreases. The decision–making patterns are non-linear though with some spikes, sometimes indicating irrational choices.

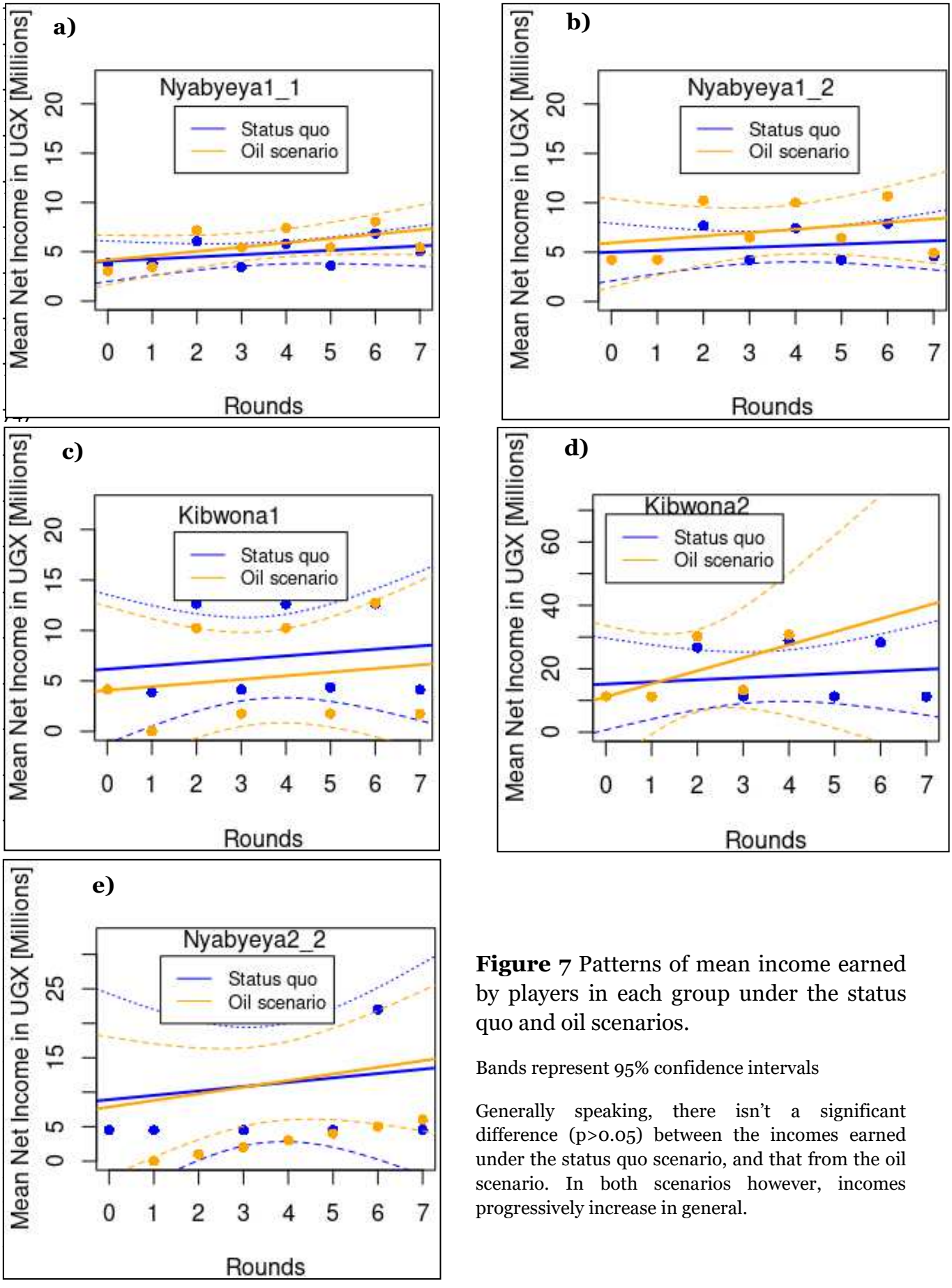


Figure 7 Patterns of mean income earned by players in each group under the status quo and oil scenarios.

Bands represent 95% confidence intervals

Generally speaking, there isn't a significant difference ($p>0.05$) between the incomes earned under the status quo scenario, and that from the oil scenario. In both scenarios however, incomes progressively increase in general.

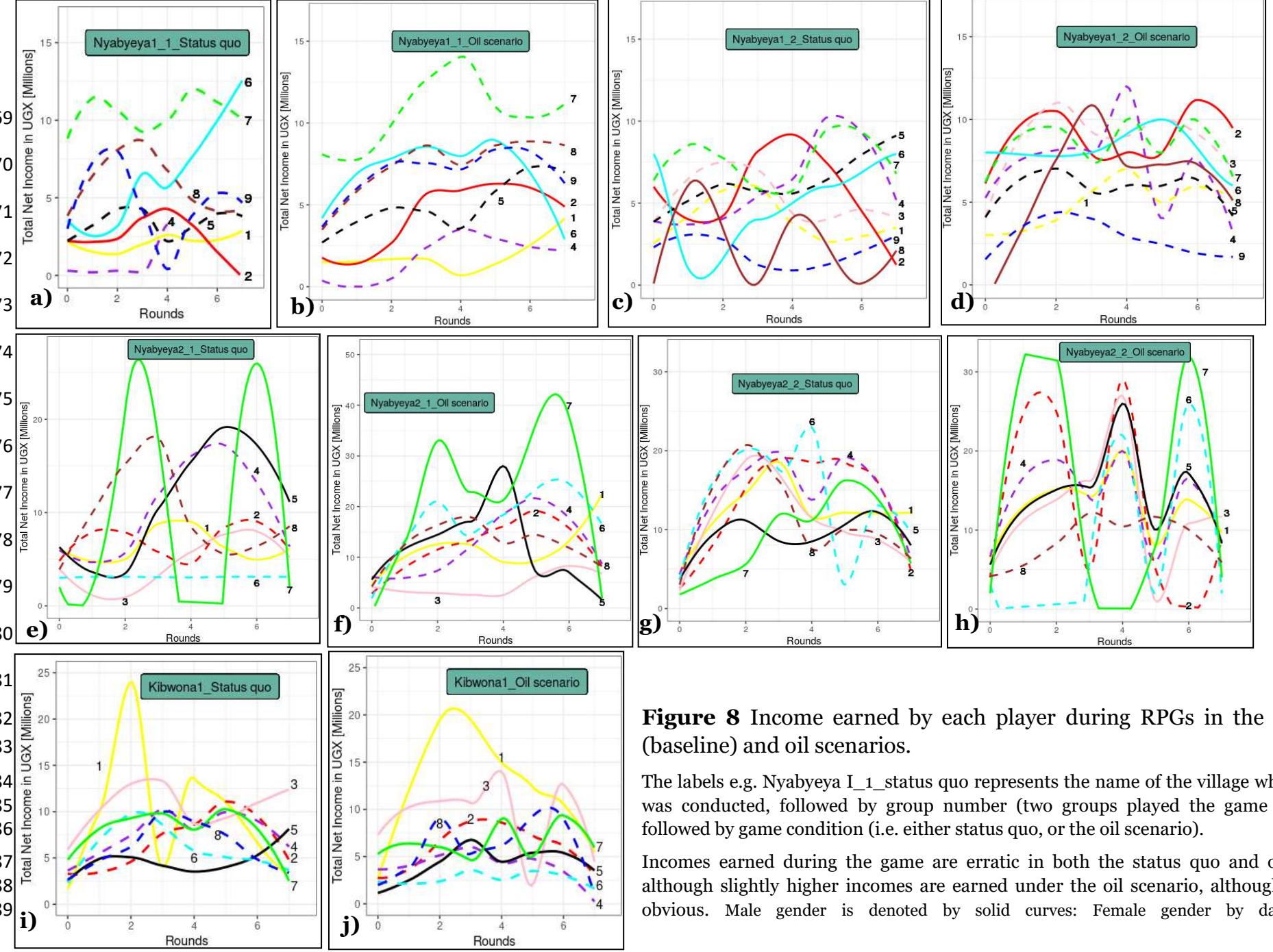


Figure 8 Income earned by each player during RPGs in the status quo (baseline) and oil scenarios.

The labels e.g. Nyabyeya I_1_status quo represents the name of the village where the RPG was conducted, followed by group number (two groups played the game per village), followed by game condition (i.e. either status quo, or the oil scenario).

Incomes earned during the game are erratic in both the status quo and oil scenarios, although slightly higher incomes are earned under the oil scenario, although not always obvious. Male gender is denoted by solid curves: Female gender by dashed curves.

From the RPGs – no major conflicts were experienced, except for a few members who attempted to take advantage of others to "grab" their parcels. In the debriefing session, the following are some of the voices about the game outcomes: "*Land grabbing is very common in day-to-day life. The difference with this game is that the plots are well labelled and it is easy to know when someone wants to take a parcel that doesn't belong to them. In our village, we lack clear boundaries, and the land is not titled*" (male RPG participant in Kibwona, 2020).

> "*This game teaches tolerance. We learn how to live with each other even if we do not agree on decisions your neighbour is making on land use*" (female RPG participant in Nyabyeya I, 2020)

5. Discussion

In this article, we have sought to examine how the prospect of oil shapes trajectories of change or a 'resource affect' in the NARL. We have built on our existing research, which reveals how spatial patterns of land cover change in the Albertine Rift region reflect people's decision making over land and crops, linked to change in the dynamics of population mobility, capital investment and market opportunities (Twongyirwe et al., 2015, 2017, 2018). Pre-existing knowledge of the context based on GIS analysis, led us to deploy a methodology focused on participatory modelling of land use decisions within the current status quo and an oil extraction scenario. Here we reflect on our findings, turning first to unpack local land use and change taking place to land tenure regimes. We then consider the implications of sugarcane expansion under both the status quo and oil extraction scenarios, taking into account too the issue of forest conservation and forest-based livelihoods. This leads to a discussion on the trajectory of prospective oil, as it shapes the "affective fabric" of economic life within the locality. Finally, we discuss how participatory modelling – in particular the RPGs employed – can illuminate community values and decision-making in specific landscapes.

816 **5.1 The changing dynamics of land use for agricultural production**

817 Our primary data revealed that the dominant form of land use in the studied villages is agriculture,
818 which divides into food crop production and sugarcane farming. Natural (and plantation) forest
819 cover is mostly beyond village boundaries; some small patches can be detected within these
820 boundaries but over the last few decades natural forest patches outside the protected forest estate
821 have been eroded, partly for food crop production, but more for sugarcane growing.

822

823 Changes to land tenure and demand for land are clearly being driven by the sugarcane outgrower
824 system. As recorded in the FGDs, ownership of a sugarcane plot/garden is an indicator of wealth,
825 except in Nyakafunjo where sugarcane growing was not permitted. This points to how sugarcane
826 growing maybe entrenching inequality in three of the study villages, particularly with wealthy
827 outsiders contributing to demand for land for sugarcane production. Kinyara sugar factory was
828 closed in the 1970s due to political turbulence, but reopened in 1995, however the sugarcane boom
829 is visible from the satellite imagery after 2002, linked to the expansion of the outgrower scheme
830 (Twongyirwe et al., 2015). The FGD reveal how today people shift cultivation from food crops to
831 sugarcane and moreover, unlike other crops, sugarcane growing precludes any form of
832 intercropping. It is also the case that land rental decreases acreage devoted to food production,
833 coupled with the use of male agricultural labour also detracting from food crop cultivation and
834 placing a greater burden on women's agricultural labour for own-farming.

835

836 A trade-off between sugarcane and food production is therefore inevitable, as are threats to food
837 security. Nonetheless, part of the pressure on agricultural land relates to the fact that sugarcane
838 production is one of the main forms of income generation in the area, being of value to people as an
839 income source to pay for children's education, caring for the sick, and purchasing household
840 essentials (e.g., salt, soap, sugar, etc). Some respondents were unwilling to spend proceeds from
841 sugarcane growing on food purchases and suggested there could be a threshold beyond which

households maybe unwilling to give up more land for sugarcane given the need to fend for their families. Nevertheless, overall, sugarcane production is predicted to increase in the landscape at the expense of food crop production. Such findings are not dissimilar from other sugarcane dominated landscapes in Uganda (Mwanika et al., 2020; Mwavu et al., 2018).

The reasons for the expansion of sugarcane into the future in the studied villages in the status quo and oil scenarios are speculative. From the FGDs however, sugarcane is viewed as a secure source of income by local people. Employment in oil production, they suggest, will provide an additional stream of income, which could offset deficits created by reduced food availability following conversion of food plots into sugarcane. On the other hand, the FGDs also indicated that some growers were in the habit of renting out their sugarcane fields to businessmen and opting for other businesses, casting doubt over the sustainability of the enterprise in the future under the oil scenario.

Whilst no major conflicts were experienced during the participatory modelling, except for a few members who attempted to take advantage of others to "grab" their parcels (as conflict was not incorporated into the gaming rules but was hoped to arise organically), FGDs revealed some recent land conflicts, and those that are predicted for the future, under the oil scenario. Accounts of rich businessmen from Kampala conniving with locals in the case study villages to buy land very cheaply, taking advantage of the lack of land titles were highlighted, and are predicted to continue, taking advantage of 'grey zones' of land governance (Kjær, 2017). Respondents felt that this would create an in-migration flux that could escalate land conflicts in the region.

Moreover, land conflicts occur at various scales (e.g., household, community and regional levels). Elsewhere in the Albertine Rift region, multinational corporations, have compulsorily acquired land, with government approval, while domestically-owned companies have engaged in various

forms of land grabbing, with reportedly compensation either delayed or denied (Kansiime & Harris, 2020). At household level, power and gender dimensions have fuelled land conflicts, with the customary tenure regime creating more confusion. Typically, women have less land rights, although access is often guaranteed through marital relationships, but proceeds are inequitably shared. Land dispossession and displacement even with monetary compensation is not an idea that several FGD participants (especially women) agreed with, and any eviction/relocation suggestions would be vehemently resisted.

5.2 Forestry conservation and forest-based livelihoods

Conflicts over forested land also arise in the study areas but are more subtle than those related to sugarcane production – partially due to strict enforcement by forestry authorities. Nevertheless, there are local contradictions, for example, one key informant working with the NFA based in Masindi asked why people would not be stopped from harvesting bananas, millet and other things grown, but are stopped from harvesting trees planted on their own land, or why they would have to get a license before harvesting own eucalyptus, or transport the trees.

As is clear from the preceding data, livelihoods around Budongo forest are agriculture-based, for food crops and sugarcane, but people also rely on access to forest products. Here, we give attention to forest-based livelihoods, in especially Nyakafunjo village that has received less attention so far. Our FGD data informs us that access to fuelwood and building materials from Budongo forest is strictly controlled to limit forest degradation. Moreover, only women and children are permitted to gather firewood from the forest, and occasionally medicinal plants; men are able to access light building materials for constructing huts (temporary housing structures). Our previous work shows that this access gives opportunity for illicit activities including illegal logging and poaching (Twongyirwe et al., 2015), although reportedly very risky. For people living in Nyakafunjo, crop raiding by especially primates and bushpigs sparks off human–wildlife conflict, undermining local

894 support for conservation efforts, as is reported elsewhere (Hsaio et al., 2020; Tweheyo et al., 2005).
895 Compensation for loss has not always been forthcoming and it is unsurprising that the FGD
896 highlighted demand for more access to the forest for NTFPs (this study). Moreover, residents of
897 Nyakafunjo felt that they were unjustly prohibited from growing sugarcane, without having
898 equivalent cash crop substitutes. Our data indicate that people are fully aware that such a decision
899 was made by the forest authorities to reduce on human-wildlife conflict.
900
901 Although livelihoods initiatives linked to Collaborative Forest Management have been introduced,
902 as discussed in Section 2, residents of Nyakafunjo felt that this approach has not done enough to
903 improve their livelihoods as there is often limited community engagement in decision–making,
904 inequality in benefit sharing, also corroborated by an earlier investigation (Turyahabwe et al., 2013).
905
906 **5.3 The prospect of oil and conflicts over land**
907 Generally speaking, the FGD revealed how people perceive oil as a resource for a few people in
908 comparison to sugarcane that is grown by any household that may wish to participate, provided they
909 have land. Considering debates on resource nationalism, and taking into account how the prospect of
910 future oil shapes the affective fabric of people's lives in terms of their hopes and aspirations, clearly
911 an important issue will be what is done with oil revenues and whether there will be equitable
912 distribution and tangible local benefits. From the case study villages however, our modelling
913 exercise revealed no indication that sugarcane enterprises will be abandoned even if the prospect of
914 future oil is positive. Instead, there is a projected increase in sugarcane at the expense of food crop
915 farming within small-scale agriculture. Other oil imaginaries, such as expectations on productive
916 and innovative sectors, government mismanagement, weak institutions, etc., are likely to operate at
917 different scales from those that have local relevance, although their consequences maybe felt at the
918 village level. In the current state however, the data that we gathered suggests no direct linkage.
919 While not explicit, our analysis indicates that a mixture of no/(mis)information, mistrust,

uncertainty, unpreparedness by institutions, and optimism about success and prosperity, epitomise visions of the future of the case study villages.

6. Conclusion

In this study, we analysed the interaction between land use, livelihoods, and natural resource conflict in the Northern Albertine Rift Landscape. Using four case study villages, we examined land utilisation (for small-scale food crop and commercial sugarcane growing) and related decision-making through participatory modelling, under both the current/status quo and the oil scenarios.

Our data show that land use and related decision–making are complex, shaped by intricate land tenure regimes and livelihood choices – with small-scale agriculture dominant and a main source of food for households, but with sugarcane expansion replacing food plots, for cash. Conflicts over land use have different sources and are perceived from different perspectives. These range from household level land conflicts, fuelled by unclear boundaries, and land tenure systems – to land grabbing by wealthier actors coming into the landscape due to oil prospects. Crop raiding was a marked problem amongst communities adjacent to a forestry conservation area and their exclusion from sugarcane agriculture for conservation reasons was viewed in the community as a time-bomb for future conflict.

While we lack data on the impact of sugarcane production on livelihoods, its expansion at the expense of food crops is arguably an emerging form of land grabbing, similar to what has been documented in Eastern Uganda, one that has already heightened the threat of food insecurity and could fuel conflict over food and petty theft amongst communities. The expansion of sugarcane is foreseen in both the status quo and oil scenarios per the RPGs across all villages. Methodologically, we show that qualitative social science approaches can illuminate decision making at household level to a certain extent. But the modelling approach employed (i.e., RPGs) is based on a few

parameters for purposes of easy implementation. Land (use) conflicts are already numerous in the Albertine Rift landscape, and our data show that these are projected to increase under the oil scenario as extraction stimulates local economic and social change.

Considering future oil, conservation and development policies need to demonstrate cognizance of the intricate interactions that exist between different forms of rural land use and associated land use dynamics, as local economies are reconfigured by new oil frontiers. These dynamics shape whom will benefit and whom will lose out from the societal change associated with oil extraction, and how these balances of gains and losses are played out within local economies and amongst the population. Innovative interdisciplinary methodologies that facilitate understanding of the nuances of land use change and its implications hold value for decision-making, as policy makers and planners try to enhance societal benefits from oil development while mitigating the high potential for negative and highly unequal consequences.

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