Exploring trajectories of shifting-cultivation landscapes through games: the case of Assam (India)

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Abstract

1. Understanding landscape change starts with understanding what motivates farmers to transition away from one system, shifting cultivation, into another, like plantation crops, given that they often have limited labour and money available. In this study we explored the resource allocation strategies of the farmers of the Karbi tribe in Northeast India, who practise a traditional shifting cultivation system called jhum.
2. Through Companion Modelling, a participatory modelling framework, we developed a model of the local farming system in the form of a role playing game. Within this environment local jhum farmers participated in a simulation that covered 18 years of farming, while also allowing us to analyse the impacts of their decisions together.
3. In the game, farmers allocated labour and cash to meet household needs, while also investing in new opportunities like bamboo, rubber and tea, or the chance to improve their living standards. When given new opportunities, the farmers were eager to embrace those options where investment costs, especially monetary investments, are low.
4. Returns on these investments were not automatically re-invested in further long-term, more expensive and promising opportunities. Instead, most of the money is spend on improving the household living standards, and especially on the education of the next generation.
5. The landscape changed profoundly as a result of the farmer strategies. Natural ecological succession was replaced by an improved fallow of marketable bamboo species. Plantations of tea and rubber became more prevalent as time progressed. However, old practises that ensure food security are not yet given up.

Introduction

Shifting cultivation is still widespread throughout the tropics, constituting the main agricultural production system for the rural poor living predominantly in tropical forest margins. Landscapes shaped by shifting cultivation currently cover roughly 280 million hectares worldwide (Heinimann et al. 2017), with an estimated 30 and 40 million people directly depending on shifting cultivation in Southeast Asia alone (Brady 1996*,* Mertz et al. 2009a). Trends in shifting cultivation differ worldwide, with regions showing a rise in its occurrence, and others a decrease (van Vliet et al. 2012). It appears that farmers are still both maintaining and departing from shifting cultivation (Fox and Vogler 2005, Robiglio and Sinclair 2011, van Vliet et al. 2012, Adams et al. 2013).

The drivers affecting the practice of shifting cultivation are strongly linked to changes in local demographics, such as population growth and migration, but also to economic development, road network development, market access, agricultural policies, and changes in public attitudes (van Vliet et al. 2012, Hurni et al. 2013, Cairns 2015, Cochard et al. 2016). Both public policies and an increased access to economic structures (such as credit and cooperative) can push towards a reduction in the area used for shifting cultivation (Fox et al. 2009, Mertz el al. 2009b). Though shifting cultivation often blamed as a main cause of both forest degradation and deforestation, it is the discontinuation of shifting cultivation, and its replacement by intensified land uses, that results in far larger negative environmental impacts (Heinimann et al 2017), including the loss of biodiversity and reduced carbon stocks (Bruun et al. 2009; Rerkasem et al. 2009). The patchy landscape, with vegetation of different ages regenerating and maintaining a high conservation value, both for flora and fauna, ends up becoming dominated by annual crops and/or permanent plantations grown in monocultures. The transition away from shifting cultivation is often also associated with higher incomes and new livelihood strategies (Cramb et al. 2009, Feintrenie et al. 2010). However, to date it remains unclear how this transition affects local food security, health, education, social and cultural shifts, and long-term economic development of the rural communities involved (van Vliet et al. 2012). In Southeast Asia, the transition away from slash-and-burn agriculture towards intensified cropping systems resulted in more households having an increased income, but also in a significant decline in livelihood security. This was expressed by an overall reduction of customary practises, socio-economic wellbeing, available livelihood options and stable yields, coupled with a decrease of soil organic carbon content and aboveground carbon storage (Dressler et al. 2017).

The Karbi Anglong hills—Assam, northeast India—are predominately used for a shifting cultivation system, locally known as jhum, and have not yet undergone significant changes (e.g., Neog 1997, Teron and Borthakur 2009, Darlong 2017), despite efforts by the Indian Government to replace the perceived ecologically harmful practices in the region with more economic beneficial cash crop systems (Krishna 2012, Darlong 2017). However, the area is not immune to socio-economic change. The national highway separating Kaziranga National Park and the Karbi Anglong hills is being developed to become India's main overland transport link to both China and Myanmar. Rubber, bamboo and tea are emerging as alternatives to jhum (Krishna 2012) for small-scale farmers; their decisions have the potential to shape both their livelihoods and the landscape.

To investigate drivers of landscape and livelihood changes in this jhum system, we adopted a constructivist approach based on participatory modelling (Basco-Carrera et al. 2017, Redpath et al 2018). We co-developed together with local jhum farmers a simulation of their landscape in the form of a role-playing game and invited them to play out their strategies. Specifically, we examined (i) resource allocation: how jhum farmers allocated their resources (i.e., labour tokens and money) when having the opportunity to plant rubber and tea and sell bamboo, and (ii) sources of income: how their allocation strategies impacted their income in the game. From this we identified their (iii) livelihood strategies: what their resource allocation revealed about their priorities and values concerning their livelihood (sensu Scoones 1998), and recorded (iv) landscape cover change: what was the impact of the farmer's decisions on the game board mimicking their landscape.

Methodology

The case study was conducted in Assam (North Eastern Region of India), in the district of Karbi Anglong. The region is home to over 220 different ethnic groups, many of them still practising their traditional shifting cultivation (Amarjeet Singh 2008, Darlong 2017). The northern Karbi Anglong hills overlook the Brahmaputra flood plains, bordering the Kaziranga National Park, a UNESCO world heritage site, renowned for its biodiversity (Heinen and Shrivastava 2009) (Fig. 1). The hills also provide an important wildlife refuge during monsoon floods. Local jhum farmers clear the forest to grow upland rice, vegetables and cash crops such as ginger, chillies and sesame. After one or two growing seasons, the field is abandoned, and weeds and bamboos are allowed to initiate ecological succession, until secondary forest is re-established (Grogan et al. 2012, and references therein). Villages are located in the valleys, which also allow some farmers to grow paddy rice.

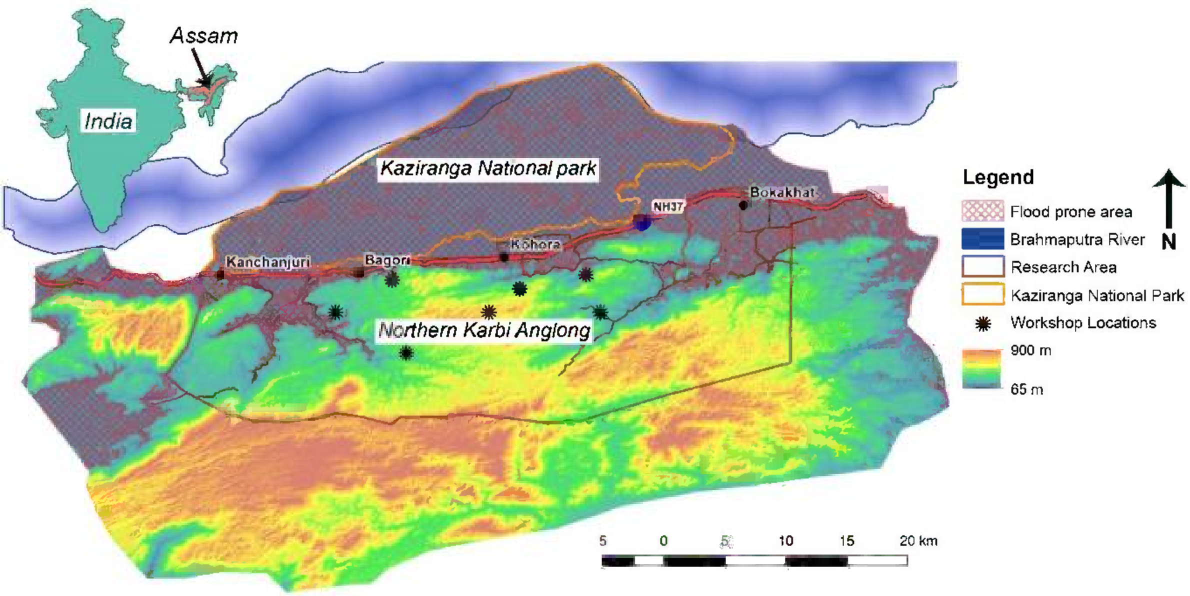

Fig. 1: The northern hills of the Karbi Anglong district, located in Assam, India (Adapted from Schmid 2016).

Participatory approach

We use a Companion Modelling (ComMod) approach (Campo et al. 2010, Etienne et al. 2011, Etienne 2014) to co-construct with local farmers a shared representation of their landscape in a form of a role-playing game. The foundation of ComMod is the willingness to incorporate on equal footing the multiple and often conflicting viewpoints of the stakeholders into a single model, validated by all stakeholders involved in the process (Bousquet et al. 1999, Bousquet et al. 2005, Dumrongrojwatthana and Trébuil 2011). Through workshops facilitated by the research team, stakeholders collectively decide and organise the knowledge they consider relevant for the problem at stake (e.g., Reibelt et al. 2017, Garcia et al. 2018).

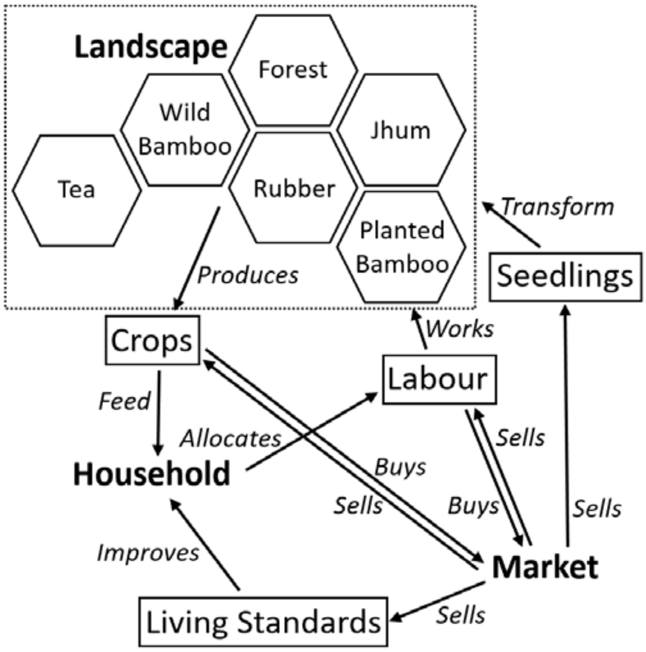

Fig. 2. The model used in the game. The three main game components are shown bold. The landscape is where production takes place, labour is invested and seedlings for establishing rubber and tea plantations are planted. The player's household supplies family labour, requires food for home consumption and can be improved by buying living standard tokens from the market. The market can be used to provide additional labour and food, as well as allowing for investments in rubber and tea seedlings and improvements to the players living standards. Game money is not shown as a separate resource, as it is used to facilitate all the other transactions in the model.

Model development

The conceptual model was built through an iterative process of community participation and engagement. We started the model development with a diagnostic phase using focus group discussions and semi-structured interviews. We explored jhum farmers' preferences in regard to four agricultural development opportunities that are currently available in the area, within the Jhum system: (1) increase the production of cash crops, (2) plant bamboo in the fallows, (3) establish a tea plantation or (4) plant rubber. In three villages a total of 36 individual and group interviews were conducted, complementing the 16 game development workshops to parameterize, calibrate and verify the model. The model was then turned into a role-playing game. Alongside the first three villages, another four different villages were selected for running a simulation with local jhum farmers, while also validating the model (Fig. 1).

Role-playing game description

The game explores how jhum farmers secure their livelihood and shape the landscape. Players embody the role of jhum farmers and can invest and allocate labour tokens and game money into different activities to produce crops for sale or home consumption, or to improve their standard of living (Fig. 2). Their actions in turn affect the composition of the landscape. The game has three distinct components; the board that represents the Landscape, the players' Households that represent the standard of living of the farmers and the Market that represent all the transactions with the outside world (Fig. 2).

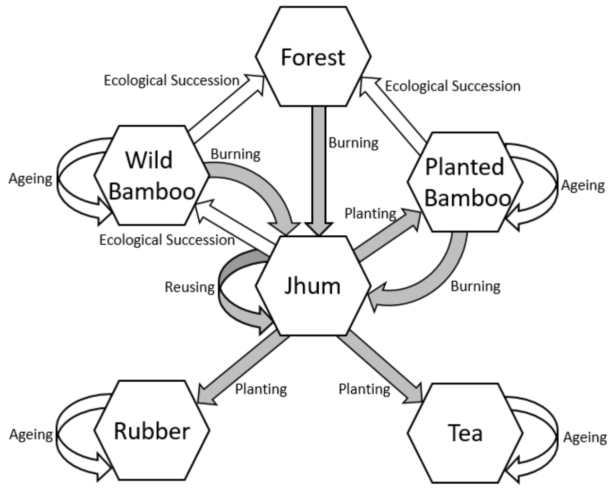

Fig. 3: The model's landscape dynamics as the result of ecological succession and player management. The white pathways are natural processes transforming a landscape tile from one state into the next, while the grey pathways indicate transformations that are the result of interventions made by the players.

The Landscape (game board) is where the players choose to clear forest and plant their crops, allocate their labour and plant bamboo, tea or rubber plantations, or allow forest to naturally regenerate. The initial landscape composition is based on the analysis of Landsat 5, 7 and 8 satellite images of the research area, spanning the period between 1988 and 2015. This was done to ensure that the landscape at the start of the simulation is representative of the general situation on the ground, though not an exact copy of any specific location or village, thus representing an implicit reality. The game board is made of tiles. Each tile has a specific land cover type (either forest, jhum, wild bamboo, planted bamboo, rubber or tea), and the transitions between different land cover types are based on the decisions of the players and on a set of rules mimicking the ecological succession of the fallows and forests (Toky and Ramakrishnan 1983) (Fig. 3). The game is played in rounds, each round representing the passing of time, loosely covering one growing season. Between rounds the landscape becomes two years older, with the second round representing the state of the system three years after the start of the first round. This is done to allow for incorporating long term processes, without the need for playing too many rounds. The age of a tile since the last burn event is a proxy for its seral stage and allows for vegetation growth and soil fertility regeneration to be represented in the model. The soil fertility of the tile determines the yield of a crop. Colour codes on the landscape tiles indicated the degree of fertility if converted into a Jhum field.

Players allocate labour to their fields. Labour allocation was measured in labour tokens, each representing six weeks of work for an adult jhum farmer. Players could allocate labour to harvest bamboo, maintain and harvest rubber and tea plantations (the two plantation crops), and to grow rice, vegetables or cash crops (the three jhum crops).

The Household is where players can choose to improve their standard of living, store their harvest and save their money. When improving the standard of living, the players can choose to buy tokens and allocate these to reflect investments on five different parameters: healthcare, housing, education, religious activities and 'family', which covers life improvements such as weddings, buying meat for dinner more often, new clothes, traveling, etc. The standard of living tokens have a fixed price, independently of where they are allocated.

The market in the game is where extra labour can be hired or excess labour can be sold, rice and vegetables can be sold or bought to meet family food needs, bamboo and cash crops can be sold by the farmers and materials for establishing plantations of tea and rubber be bought. The market is managed by the research team. We used game money, Karbi Tanka (KT), as game currency. Yields and crop value were derived from interviews and model development workshops. Tea and rubber plantations require additional labour and monetary investments for two rounds before they reach maturity and generate a profit. All the other activities yield returns in the same round.

Session organization

The game was played with a total of 48 jhum farmers during 12 separate workshops, spread over seven different villages in the Northern Karbi Anglong, from September to December 2016 (Fig. 1). Participants were compensated twice the locally going daily wages. This would allow players to hire someone to do the farm work that would need to be done during the busy harvest season, while also compensating the players for their own time. The payment was independent of the player's performance in the game. No player participated twice in the final version of the game.

Each session had the same starting conditions, with the initial landscape (game board) reflecting a mosaic of secondary forest and fallows. The workshops were held in the local language Karbi, and the introduction to the workshop and the game were done following a written script, to ensure all games were introduced through the same procedure. The players were given the objective to acquire enough rice to feed their family. No other game objectives were given, allowing the players to develop their own strategies, and define their own objectives as the game unfolded.

The game is played for six rounds, with each round consisting of nine consequential steps (Table 1). One game session represents 18 years of landscape change. The first round was used to familiarize the players with the game and its rules. Most players did not have problems playing after round one.

The session ends with a debriefing, which allows players to reflect on their experience during the game, compare strategies, and discuss links with the real system. Players develop narratives to explain the decisions they took in the game, and we discussed differences and similarities between what happened in the game and what happens in real life. The debriefing is thus also used to validate the model and its outputs (Garcia et al. 2016).

Table 1. Game round structure. The tasks of the players and research team during each step of a game round.

Step	Player	Research team
1	Select jhum land, convert tiles to jhum, claim land ownership	Note tile types chosen for conversion to jhum
2	Hiring and allocating labour	Note labour purchases and allocation
3	Planting jhum crops	Note # of each crop type planted, take photograph of landscape
4	Harvesting crops and bamboo	
5	Selling harvests at the market & buying rice (if needed), standard of living tokens and plantations	Note # tokens sold/bought/kept and plantation seedlings bought Update landscape age and resources, except jhum fields, for next round
6	Allocate standard of living tokens	Note token allocation, take photograph of household sheet
7	Pay plantation management costs	Track player seedling/plantation ownership and payments
8	Meet family food requirements	Collect rice and vegetable tokens.
9	Replace old jhum with planted/wild bamboo or plantations	Count money left in each player household, update landscape. Take photograph of landscape.
	Next round	

Data collection

The data was gathered via note taking, photographs and audio recordings (cf. Table 1). Prior agreed consent was asked for and received on data been used anonymously and confidentially based on the KFPE (Swiss Commission for Research Partnerships with Developing Countries) principles (Stoeckli et al. 2014). During the game sessions and for each round, we recorded players' decisions and the associated reward, which included (1) players' labour allocation to different crops, (2) player's money allocation to different categories of living standards, and (3) players' income from different sources. Players could allocate money to hire labour, buy rice and vegetable tokens, buy and plant two plantations crops (tea, rubber), and invest into the five standard of living parameters (education, health, house, religion, and family). We assumed that the money allocation to the different investment opportunities, as well as the standard of living categories, is reflective of the player's strategic priorities. Their income could come from the three jhum crops, planted bamboo, the two plantation crops rubber and tea, and from selling family labour. We further recorded the number of landscape tiles of each cover type among forest, jhum, planted bamboo, wild bamboo and the two plantations crops for each round.

Data analysis

All decisions made by the players, such as labour token placement, the number of plantations bought, standard of living investments made, crops produced and bamboo harvested, were recorded during the workshops by members of the research team. Photographs were taken of the landscape and the player household sheets to allow for double-checking the data recorded (table 1). The debriefing sessions were recorded on voice recorders and video, for subsequent transcriptions and translations. These discussions allowed us to better understand the reasoning behind observed decisions made by the players during the simulation. As the debriefing sessions with the players themselves were discussions of the results observed during the workshops, we add their discussion inputs into our discussion section.

In a first step, we examined players' decisions and their associated reward over round. We then investigated the cumulative monetary return for the cumulative labour investment and for the cumulative monetary investment at the end of the game. Finally, we analysed landscape cover changes over rounds. All data analyses were performed in R (R Development Core Team 2008).

Labour allocation: We investigated trends in number of labour tokens dedicated to the different crop types over *round* by fitting a generalised additive mixed effect model (GAMM) with a Poisson distribution from the package MGCV (version 1.8-6, Wood 2011) to account for nonlinearity. We used a full tensor product smooths for the fixed continuous effect *round*. The same procedure was applied for the other GAMMs performed in this study, except when stated otherwise. We fitted one model for each crop type plus one for the cover type jhum, regrouping the three jhum crop types (rice, vegetables and cash crops). In all models, we accounted for the random effects of the *player ID* and the *village ID*.

Money allocation: Similarly to labour allocation, we fitted a GAMM to examine the trend over *round* of the monetary expenditures (non-cumulative) of the players for each money allocation category except for the standard of living improvement which were grouped together into one category. In a second step, we analysed the cumulative monetary expenditure of the different standard of living separately over round with a generalised linear mixed effect model (GLME) from the LME4 package (version 1.1-17, Bates et al. 2015) with a Gaussian distribution, again treating *player ID* and *village ID* as random effects. The response variable, cumulative monetary expenditure, was square root transformed to fulfil criterion of the Gaussian distribution.

Player income: To evaluate the monetary gain of labour allocation strategies and of money allocation strategies, we investigated the relationships between the cumulative income at the end of the game per cumulative number of labour token allocated to each category and per cumulative amount of money allocated to each category. In both cases, we fitted a GLME with a Poisson distribution and a square root link function and included *player ID* and *village ID* as random effect. The first model included the two fixed effects, *round* and crop type. Crop type included jhum (regrouping the three jhum crop types), rubber, and tea. Even though players could also allocate labour to bamboo, this category was excluded from the model because one labour token allocated to bamboo always generates 270 KT each round, as determined by the game mechanism. There is thus no variability in this relationship. The second model included *round* and investment category. The investment categories included jhum (regrouping the three jhum crop types), rubber, tea and hired labour. The income generated by labour hired from the market was calculated using the average income generated by one labour token for each player for each round. Bamboo and standard of living improvements were excluded from the model. The former because it requires no monetary investment and the second because it does not generate revenue. It should be noted that the cumulative income generated by labour allocation to jhum varies depending on the combination of jhum crops planted. The cumulative income generated by labour and money allocated to rubber and tea likewise varies as it depends on the age of plantation at the end of the game. A young plantation will not have had time to generate income, in contrast to a 6-round old plantation.

Landscape cover changes: For each cover type, we fitted a GAMM with *round* as a fixed effect, and *workshop ID* as a random effect. The changes in the landscape over round as the result of a 'no human intervention'-scenario were included as a baseline.

Results

Labour allocation

Over the course of the game, players allocated most of their labour token to jhum (mean=5.66 tokens per round, SD=1.12 tokens per round) which also remained their main source of income throughout the game (mean=562.74 KT per round, SD=218.11 KT per round), closely followed by harvesting planted bamboo (mean=515.16 KT per round, SD=386.24 KT per round). Most of their wealth was invested into improving living standard (mean=760.41 KT per round, SD=368.76 KT per round), in particular education, with important variation amongst the players (mean=232.29 KT per round, SD=160.68 KT per round). In each session, few players planted tea and/or rubber (mean=3.25 players owned a tea plantation per session, SD=1.05, mean=1.08 players owned a rubber plantations per session, SD=0.90), and plantations never represented more than 16.27% of the landscape (mean=9.1%, SD=4.40%).

Labour allocated to jhum followed a slow downwards trend over the rounds, while labour allocated to harvesting bamboo, cultivating tea and rubber increased over the rounds (Fig. 4a). Models for the number of labour tokens allocated to different land cover described 9.6%, 46.8%, 87.4% and 70.9% of the deviance for jhum, planted bamboo, rubber and tea, respectively. In all cases, the smoothing term for *round* differed from zero ($p<0.001$). In all cases, the variation in the number of labour tokens allocated increased over rounds (GLME model: intercept (reference Jhum) = -0.052, SE = 0.113, additional effect for Tea = -0.053, SE = 0.151, additional effect for rubber = -0.145, SE = 0.151, *round effect* = 0.199, additional effect for bamboo = -0.078, SE = 0.151, *round effect* = 0.199, SE = 0.027, additional *round* effect for Tea = -0.107, SE = 0.039, additional *round* effect for rubber= -0.056, SE = 0.039, additional *round* effect for bamboo = 0.070, SE = 0.039, with workshop as a random effect). The labour requirements of rubber plantations are three times as high as those of tea, however, more labour was allocated to tea. The total number of labourer hired increased over rounds from 0 in round 1 (SD=0) to 2.208 (SD=2.018) in round 6.

The players invested most of their labour in jhum (as shown in Fig. 4a), with rice being given a higher priority than cash crops and vegetables (Fig. 4b). However, the distribution of these crops varied amongst the players. Though growing cash crops on jhum land is the most profitable activity in the game, there is no indication that the farmers increased their production. The model estimated an overall decrease over time without obvious differences in slopes between the crop types. (GLMER model: intercept (reference rice) = 1.822, SE = 0.056, additional effect for vegetables = -0.644, SE = 0.099, additional effect for cash crops= -0.570, SE = 0.092, *round effect* = -0.036, SE = 0.015, additional *round* effect for vegetables = -0.040, SE = 0.024, additional *round* effect for cash crops = 0.026, SE = 0.024). Selling family labour was not a strategy employed by the players in the game.

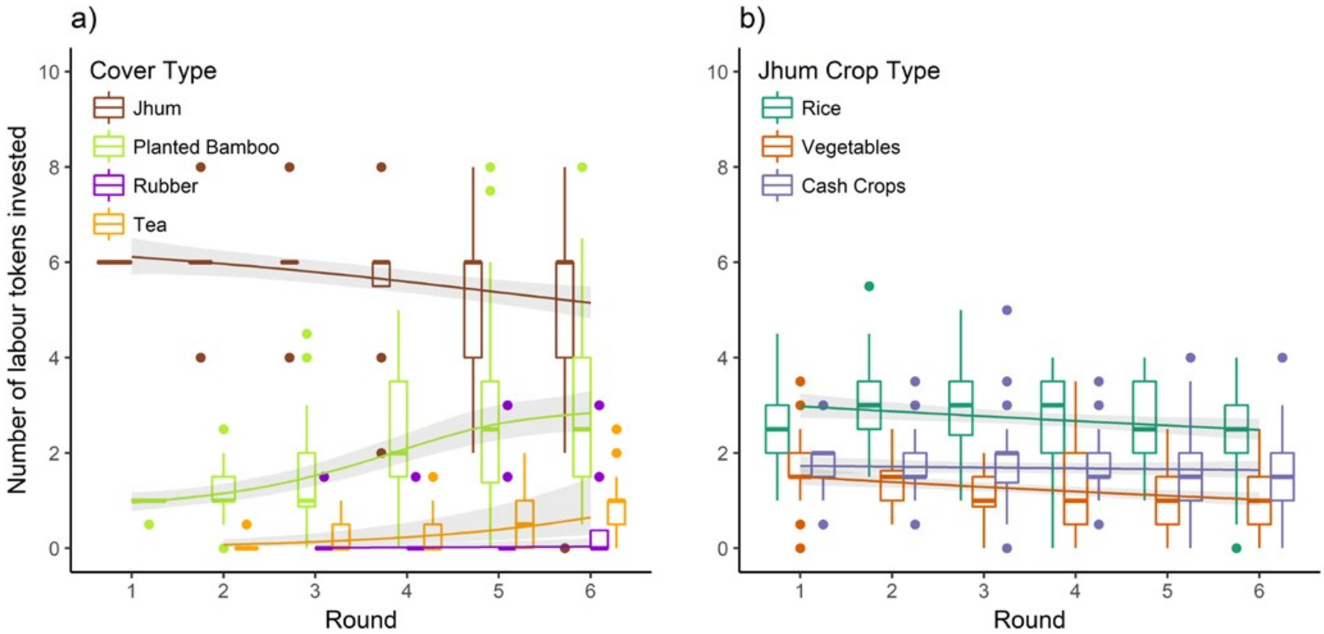

Fig. 4. Labour allocated to the different land cover types (a) and crop types (b), per round. The boxplots and the dots represent the dispersion of the observed data. The lines are the predictions from generalised additive models accounting for the nested random effects of the players with village ID. The grey area represents the 95% confidence intervals.

Money allocation

Every round, players consistently allocated most of their money to improving their standards of living (Fig. 5a). Spending on the other categories was considerably less. The players moderately increased their spending on hired labour, buying rice and planting tea as the rounds progressed (Fig. 5a). The models for the money allocated to different categories described 37.1%, 57.2%, 44.7%, 31.3% and 57.2% of the deviance for living standards, hired labour, rice bought, tea, rubber, respectively. In all cases, the smoothing term for round differed from zero ($p<0.001$). Most players, 39 out of the 48 participants, invested money in tea before the end of the game, while 17 of the players chose to invest in rubber. However, the total investment, compared to the other spending categories was small.

The workshop participants allocated money to one of five categories amongst education, health, house religion and family to improve their standard of living. The cumulative investments in education were higher than in any of the other categories, and remained so as the game progressed (Fig. 5b). The model describing cumulative investment over round per standard of living investment category estimated a higher initial investment into education than into the other categories, with the lowest initial investment allocated to family (GLME model performed on the squared root of the response variable: intercept (reference education) = 10.688, SE = 0.935, additional effect for health = -5.986, SE = 1.219, additional effect for house = -8.455, SE = 1.219, additional effect for religion = -9.483, SE = 1.219, additional effect for family = -12.194, SE = 1.219). There were no differences in the rate at which cumulative investment increased over round between education, house and religion, whereas cumulative investment in health increased at a slower pace and family at a faster pace compared to education (round effect = 4.459, SE =0.221, additional round effect for health = -0.817, SE = 0.313, additional round effect for house = 0.051, SE = 0.313, additional round effect for religion = 0.042, SE = 0.313, additional round effect for family = 0.685, SE = 0.313).

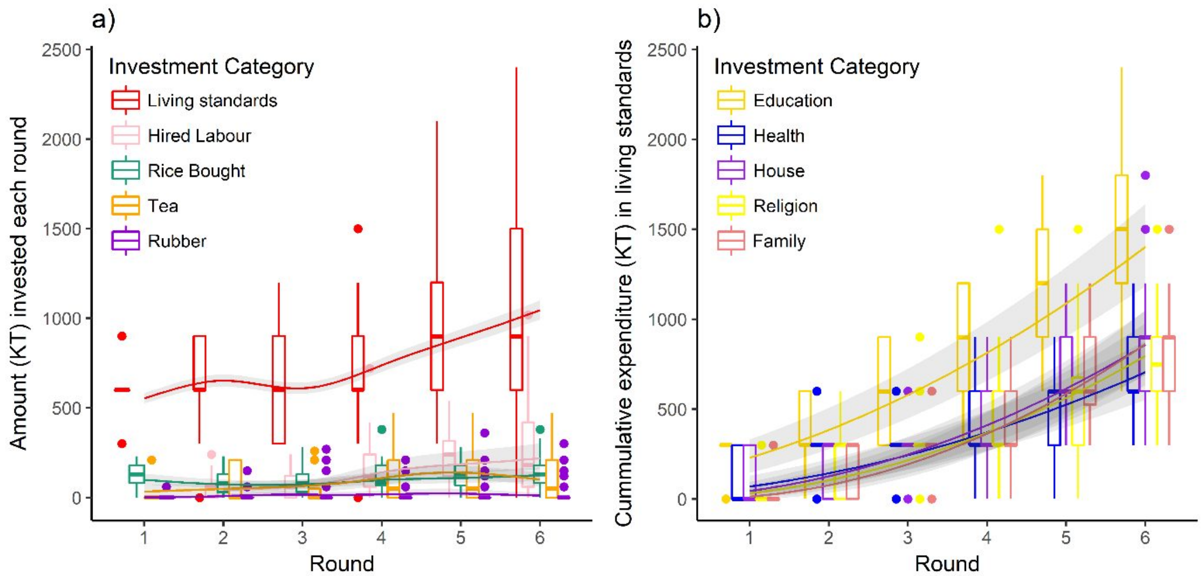

Fig. 5. Monetary investments. Investment in the different categories per round (a) and cumulatively for the different standard of living categories (b). The boxplots and the dots represent the dispersion of the observed data. The trends are the predictions from the models, the grey area the corresponding 95% confidence interval, including the variation from the random effects. Jhum and bamboo are not shown since they require no monetary investment.

Players’ income

Players could receive an income for their investment in labour and/or money into different activities, as determined by the game mechanisms. Jhum was the main source of income for most players and harvesting bamboo second (Fig. 6). Yet one labour token allocated to bamboo generated a cumulative higher income compared to a labour token allocated to jhum (Fig. 6a). As jhum and bamboo only requires labour allocation and no financial investments, these activities generated income for a cumulative financial investment of zero (Fig. 6b).

Many players failed to generate income from allocating labour and money to tea and rubber (18 out of 39 and 11 out of 17 respectively, Fig. 6). Players investing into plantations chose to invest mostly in tea rather than in rubber (39 vs 17 players respectively), yet the players who invested in rubber derived on average higher income from each labour token and each monetary unit allocated to this plantation type compared to those investing in tea (for *labour token allocation*: Fig. 6a, glmer model on the squared root of the response variable: effect of jhum at the intercept = 46.930, SE = 0.989, effect of rubber at the intercept= 95.465, SE = 0.881, effect of tea at the intercept = 74.409, SE = 0.953, effect of cumulative labour for jhum = 17.115, SE =0.482, effect of cumulative labour for rubber = 120.613, SE = 0.713, effect of cumulative labour for tea = 94.158, SE = 0.940, for *financial investment*: Fig. 6b, glmer model on the squared root of the response variable: effect of rubber at the intercept= 39.656, SE = 3.066, effect of tea at the intercept = 13.75, SE = 1.640, effect of labour at the intercept = 29.782, SE = 1.548, effect of cumulative amount of KT for rubber = 28.266, SE = 3.617, effect of cumulative amount of KT for tea = 8.269, SE = 1.693, effect of cumulative amount of KT for labour = 9.282, SE = 1.183*)*.

Even though allocating money to improving standard of living is not an income generating activity in the game, this is the category to which players allocated the most money (Fig. 6b).

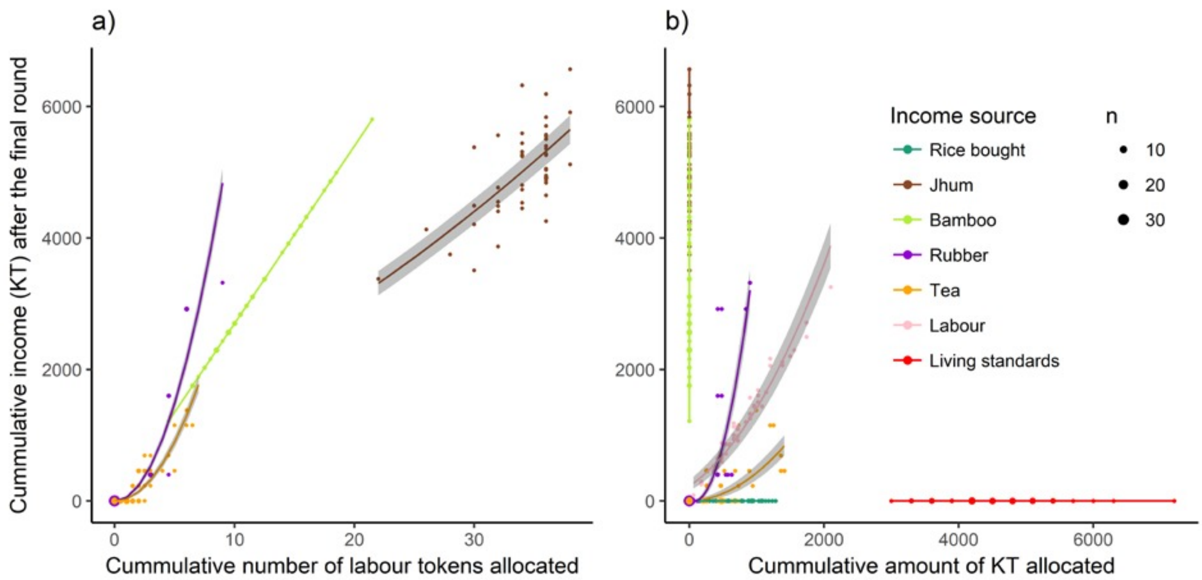

Fig. 6. Total cumulative income generated at the end of the game by the cumulative number of labour tokens allocated to (a) and financial investment in (b) the different categories, over the course of the game. The dots represent the observed data, the size of the dot reflects the number of observation at each location. The trends are the predictions from the models, the grey area the corresponding 95% confidence interval, including the variation from the random effects.

Landscape cover

The Landscape (gameboard) evolved from a wild bamboo and forest dominated landscape to a planted bamboo dominated landscape (Fig. 7a). The same initial landscape left unexploited would have evolved towards a forest dominated landscape (Fig. 7b). The decrease of wild bamboo happened in both settings reflecting ecological succession, as after six rounds, wild bamboo turns into secondary forest. The same applies to planted bamboo; left unmanaged, planted bamboo turns into forest after six rounds. The area dedicated to jhum decreases gradually over game round while plantations of both rubber and tea are slowly appearing into the landscape (Fig. 7a). The models for forest, jhum, planted bamboo, wild bamboo and plantation cover over round described 78.7%, 29%, 97.1%, 95.1% and 85.0% of the deviance, respectively. In all cases, round was found to have a smoothing term different from zero ($p<0.001$).

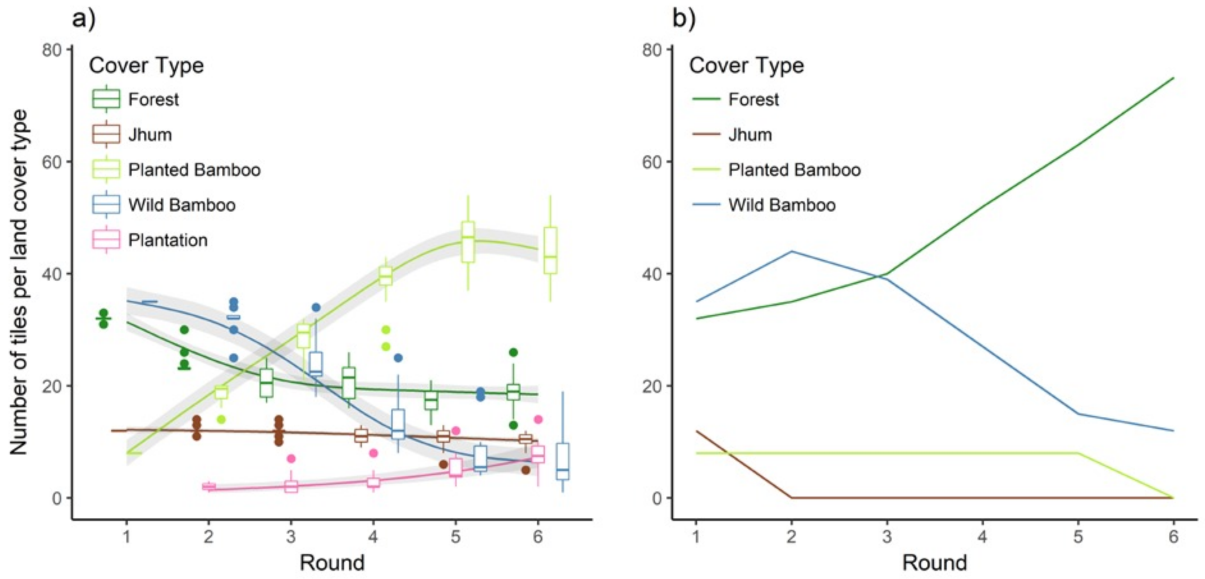

Fig. 7. Trajectory of landscape composition as exploited in the game (a) versus baseline landscape with natural succession only from round 2 onwards (b). The boxplots and the dots represent the dispersion of the observed data, and the lines are the predictions from generalised additive models accounting for the nested random effects of the players with villages; the grey area represents the 95% confidence interval and the variation from the random effects (a).

Discussion

In this study, we examined the behavior of small-scale farmers from the Karbi Anglong hills in India immersed in a role-playing game representing their socio-ecosystem. In addition to planting jhum, farmers had the possibility to harvest and sell bamboo and plant and sell rubber and tea, representing economic alternatives that have recently become available in the area (Shrivastava and Heinen 2005, 2007, Krishna 2012). We found that despite the presence of these alternatives, labour is mainly allocated to jhum, even after six game rounds, representing 18 years of farming. Jhum also remained the main source of income despite not being the most efficient income generating activity per unit of labour allocated. Agricultural practices were nevertheless changing over the course of the game as increasingly more labour was allocated to harvesting bamboo. Selling bamboo was even the second main source of income by the end of the game. On the other hand, establishment of tea and rubber plantations was slow, even though rubber was the most financially profitable allocation of both labour and money. Money was primarily allocated to improving standard of living, in particular into education. This suggests that even though there is some diversification in agricultural practices—mostly with the appearance of bamboo harvesting—players hold on to traditional farming practices. This strategy in the game is adopted despite the possibility to plant rubber and tea, two emerging plantation systems in the region, which are economically more interesting alternatives to jhum (Krishna 2012).

Even though farmers allocated increasingly less labour to jhum, this remained the main labour investment category throughout the game. Instead of planting exclusively cash crops, the most financially rewarding jhum crop, farmers opted for planting a mixture of rice, vegetables and cash crops. Allocating labour to jhum cultivation of mixed crops is suboptimal in terms of income per labour unit. The best return is obtained by allocating labour to rubber early in the game. However, very few resources were allocated to growing rubber. In contrast to jhum cultivation, investing in rubber has a financial cost; it generates income only after a few rounds of exploitation. The initial financial investment and the income lag may have put off players to adopt rubber early in the game. Yet, this alone does not explain the predominance of jhum as the next best alternative—from an economic perspective—is harvesting and selling bamboo. Like jhum cultivation, bamboo requires no financial investment. Harvesting bamboo generates a higher income per units of labour than jhum with mixed crops and, unlike rubber, has an immediate return. Accordingly, we found that over the course of the game increasingly more labour was allocated to harvesting planted bamboo.

The maintenance of jhum cultivation alongside the increase in bamboo harvesting suggests that farmers are not aiming at maximizing their income per unit of labour. One of the reasons brought forward by the players during the game sessions was that jhum rice is considered to be tastier than food from the market, and they attributed higher health benefits to rice and vegetables intercropped and grown on their jhum. Wangpan and Tangjang (2015) pointed out similar findings for the Arunachal

Pradesh region of India, where jhumming plays an important role harbouring precious germplasms of different indigenous plant species, which are also selected for taste preferences and nutritional benefits. Dietary diversity has found to be higher under a jhum regime in comparison to other cash cropping systems (Behera et al. 2016). Mixed- or multi-cropping systems are more resilient to disturbances (Trenbath 1999); however, mixing more species requires more work and knowledge, especially about timing. Jhum is hard work (e.g., seeding, weeding, planting, guarding crops from wildlife, harvesting). Reducing workload was often cited by participants of the game as one of the main reasons to develop alternative income strategies, echoing the position expressed by other farmers from similar systems (Feintrenie et al. 2010). However, the reluctance of abandoning shifting agriculture, even when other options are available is not unique to this case study (Hansen and Mertz, 2006, Bodonirina et al. 2018).

Fewer resources were invested into rubber and tea compared to any other investment alternative in the game despite both being perceived by the participants as good investment. The lowlands in Assam have been used for growing tea since colonial times (Das 2016). Based on game workshop participants' statements, owning a tea garden is a status symbol, and perceived to be a path to wealth. Planting tea is also recognized as a low risk investment, mainly because crop-raiding wildlife such as elephants tends to avoid tea gardens; tea seems not to be palatable to elephants (Mackenzie and Ahabyona 2012). However, depending on tea for household income has its drawback, as harvested tea needs to be cured the same day, and this can locally only be done at the large tea estates. These estates are in full control of the prices offered to outside producers, and the better prices are associated with high quality requirements that are hard for small-scale farmers to meet (Awashti 1975). The tea estates also have irregular demand for freshly plucked tea and can only accommodate tea from outside producers when their own fresh tea production does not meet production capacity (Awashti 1975). It may be because of these constraints—known to famers but not incorporated in the game mechanism—that establishing tea plantations was not one of the prevailing strategies in the game.

India is one of the world-leading rubber producers with over 88% of its production being placed in the smallholder sector (Fox and Castello 2013). Rubber represents potentially an interesting crop for small-holders due to its qualities of intercropping. It can be intercropped for both, short rotation and long-term agroforestry systems (Levang et al. 2007). In the game, more labour and money was invested in establishing tea plantations than for planting rubber, even though the long-term rewards of rubber are much larger and the work was also perceived as easy and light comparatively. The participants to the game workshops, however, have no real life experience in growing and harvesting rubber themselves. Human-wildlife conflicts are prevailing in Assam, especially elephants as the main crop-raiders (Talukdar and Choudhury 2017). The vicinity of Kaziranga National Park is perceived by the players as extra risk to investing in rubber plantations with fencing investments being prohibitive for the small-scale farmers. According to the participants of the game workshops, only a few young rubber plantations have been established in the area so far, and the facilities for processing harvested latex are still out of reach for most farmers. An embrace of rubber as the main crop, as observed elsewhere in Southeast Asia (Ziegler et al. 2009, Fox and Castella 2013), has not become apparent in our case study.

Most of the money spent by players was allocated to improving their standard of living before allocating it to any income-generating activity. This likely reflects the high importance the workshop participants attributed to their quality of life. During the game, players would compare how much others had invested into standard of living parameters such as education, housing, or family, and would spend considerable time deciding in which category to invest. Amongst the different standard of living categories available in the game, players invested the most into education. Though free, the local schools were considered by the participants to be of very low quality, with children going to school just to receive the free state-funded lunch, instead of education. To the parents it is paramount that their children need to be well educated to have a chance of escaping poverty. One concern issued by the game workshop participants is that sending children off to boarding schools bears the complication that children and teenagers would no longer be doing farm chores, resulting in a loss of skills and the motivation to continue the hard-labour jhum farming. The difficulty to enter and succeed in the school system, and the job market afterwards, as voiced by the Karbi participants, is reflective of India's primary and higher education system, which still suffers from high inequalities based on cast and ethnicity (Desai and Kulkarni 2008).

The choices and decisions of the farmers in the game impacted the landscape which transitioned from a forest and wild bamboo dominated landscape towards a planted bamboo dominated landscape with few rubber and tea plantations. The traditional jhum system has only recently seen the introduction of bamboo gardens as an improved fallow (Das and Das 2005, Shrivastava and Heinen 2005, Nath and Das 2008). As time progressed in the game, these fallows took over, while the first plantations slowly appeared in the game landscape. The planted bamboo was described by some of the players to be a stepping stone that allows for investments in tea and rubber at a later stage. Once local processing infrastructure gets developed and highway access to international markets, especially China and Myanmar, two important rubber producers (Fox and Castella 2013) is improved, farmers might be able to reap the benefits.

Though jhum is perceived as hard and intense work and carrying a high risk of loss to wildlife, farmers prioritized jhum cultivation over the more economically lucrative tea and rubber plantations. Abandoning shifting agriculture for other land uses and practices obviously is not just an economic affair; where livelihoods are at risk, or, where vulnerabilities to change and risks of failure are difficult to grasp, people favour the current system. Farmers are however willing to explore new opportunities, and most of the players established at least one small plantation. When asked how the farmers viewed the changes in the landscape that occurred during the game sessions, the response was that the changes were good, providing them more income. Throughout the simulations is was evident that the

Farmers were actively trying to secure a better livelihood for their children, and both the investment in education, as well as the plantations were seen as a means for the next generation to escape poverty.

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