Learning landscape sustainability and development links

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SUMMARY

Landscape is a complex of interacting ecosystems and humans. Conflicting interests among various actors with different values and rationalities occurs. A board game, the Landscape Game, was developed based on game theory to help understand the dynamics of land competition, policy measures and sustainability of a landscape. This game introduces landscape conservation, development, environmental services risks and investment alternatives. The game challenges rational players to maximize their revenues, while at the same time sustaining the landscape. Through this game, various policy instruments, e.g. rules, taxes, land use incentives and disincentives were tested. The game play results show the easiness in harmonising sustainability and development when productivity is low. If productivity increases then landscape sustainability can either increase or reduce, affected by government policies and players' actions. Lessons learned from the game can trigger changes in players' mental model. The digital version of the game provides opportunities for its wider use.

Keywords: landscape approach, conservation, agricultural development, deforestation, mental model

Apprendre les liens entre la durabilite et le developpement des paysages

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Le paysage est un complexe des interactions des écosystèmes et les humains. Des intérêts conflictuels existent parmi les acteurs qui ont des valeurs et rationnelles qui se distinguent. Un jeu, Le Jeu du Paysage, a été développé en se basent sue la théorie de jeu pour mieux comprendre les dynamiques de la concurrence de la terre, les politiques de gestion des paysages et la durabilité d'un paysage. Ce jeu introduise la conservation des paysages, le développement, les risques pour les services environnementaux et les alternatifs pour des investissements. Le jeu demande aux joueurs rationnels de maximiser leurs revenues, pendant ils gardent l'objectif de la durabilité du paysage. A travers ce jeu, quelques instruments politiques p. ex. la règlementation, les impôts, les incitations de l'utilisation des terres et les contre-incitations ont été teste. Les résultats des jeux ont montré la facilite d'harmoniser la durabilité et le développement pendant que la productivité reste basse. Si, au contraire, la productivité augmente puis la durabilité du paysage peut accroitre ou réduire, en fonction des politiques gouvernementales et les actions des joueurs. Les leçons tires du jeu puisse provoquer des changements dans le model mental des joueurs. La version digitale du jeu va donner des opportunités pour une utilisation plus large.

Aprendizaje sobre la sostenibilidad del paisaje y los vínculos con el desarrollo

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El paisaje es una mezcla compleja de ecosistemas y seres humanos que interactúan entre sí. En él aparecen conflictos de intereses entre diversos actores con diferentes valores y puntos de vista. Con el fin de ayudar a entender la dinámica entre la competencia por la tierra, las medidas políticas y la sostenibilidad de un paisaje, se ha desarrollado el Juego del Paisaje, un juego de mesa basado en la teoría del juego. Este juego incorpora la conservación del paisaje, el desarrollo, los riesgos sobre los servicios ambientales y las alternativas de inversión. El juego desafía a los jugadores más racionales a maximizar sus ingresos, a la vez que mantienen la sostenibilidad del paisaje. A través de este juego se han probado diversos instrumentos políticos, como reglas, impuestos, incentivos al uso de la tierra y desincentivos. Los resultados del juego muestran la facilidad de armonizar la sostenibilidad y el desarrollo cuando la productividad es baja. Si la productividad aumenta, entonces la sostenibilidad del paisaje puede aumentar o disminuir, en función de las políticas gubernamentales y las acciones de los jugadores. Las lecciones aprendidas de este juego pueden provocar cambios en los esquemas mentales de los jugadores. La versión digital del juego ofrece oportunidades para un uso más amplio.

INTRODUCTION

Landscape degradation is continuing to occur globally. There were 7.6 million hectares of natural forests in the world are deforested annually (FAO 2016). Land conversion and appropriation of land are widespread. Landscape is not empty (Purnomo *et al*. 2012a). Managing natural resources means managing an ecosystem with various stakeholders who have interests in that ecosystem. Stakeholders can act and behave with diverse and sometimes conflicting interests. Synergy among stakeholders is likely, but trade-offs can occur. Resource users frequently behave individually to maximize their interests and may change their strategies and actions to respond to other users. Policy makers need to find policy options and measures to sustain the ecosystem. If we cannot sustain landscapes and, at the same time, make them productive for human beings then we may face dire consequences. Thus, how can a landscape be managed when stakeholders have conflicting interests? Is it possible to create synergies instead of trade-offs between sustainability and development?

Landscape users often fail to recognize the complexity of a landscape. Stakeholders may be interested in growing palm oil or acacia plantations, logging timber, teak agroforestry or ecotourism. Trade-offs occur due to different conflicting interests, for example, in terms of income, carbon stock reduction or biodiversity losses at the landscape scale. For example, investment in palm oil plantations by replacing natural forest will increase income but reduce biodiversity.

This paper describes the development of the Landscape Game http://www.cifor.org/LPF/landscapegame/ and uses it to investigate policies to: (a) Enhance productivity and sustainability through better landscape management; (b) improve policies and institutions to enhance landscape sustainability; (c) understand the processes and impacts of forest-related trade and investment. The game has been used worldwide including in Indonesia, Thailand, Somalia, the Netherlands, Finland and Brazil.

The Landscape Game challenges its players to maximize their revenues, while at the same time sustaining ecological and social conditions, using various indicators. The ecological indicators include landscape diversity, while the social and economic indicators include value-added during the game play. This game provides a model where stakeholders can learn rapidly how human strategies impact a landscape mosaic where competing land uses exists. This learning process can change players' mental model (Cárdenasa and Ostrom 2004).

THEORY AND METHOD

Theory

The research questions addressed in landscape management are frequently questions of collective decision making. Multiple actors have to coordinate a common landscape and manage the externalities generated by individual decisions. Game theory modeling has been developed since the end of the 1950s to understand strategic interactions between actors (Bousquet *et al.* 2001). Understanding the linkages between sustainability and productivity of a landscape provides the best prospects for reconciling the often-conflicting goals of poverty alleviation and forest conservation (CIFOR 2011). A landscape is a mosaic of different land cover and land-use patches, which work as an ecosystem. It includes everything you can see when you look across a large area of land (Hornby and Wehmeier 2000). The overall goal of landscape management is the sustainability of its ecological, social and economic functions. Discussion of landscape management commonly includes scale, ecological integrity, monitoring, cooperation, humans as an ecosystem component and human values, as well as ecological resilience (Holling 1986, 1996, Carpenter *et al.* 2001).

Meinzen-Dick *et al*. (2004) provided an overview of studies that present applications of qualitative, quantitative, experimental and action research methods, including experimental games, for studying collective action. Game theory is an influential framework that can be used to develop a coordinated strategy among different actors, particulary when some actors oppose or counteract and limit the action of others who share the common resources. Such a strategy may also lead to the development of new institutions and revitalize existing ones (Purnomo 2014). Meadows *et al.* (1993) developed the Fishbanks game to inform people about using natural resources effectively and prudently. The game participants play the role of fisher folk and seek to maximize their net worth as they compete against other players and deal with variations in fish stocks and their catch. Participants buy, sell, and build ships; decide where to fish; and negotiate with one another. Policy options available include auctions of new boats, permits, and quotas.

Vanclay *et al.* (2006a) developed a 'beer-bottle top' game to make forest planning and management concepts easier to grasp. The game provides an effective way to demonstrate different concepts and facilitate deeper understanding of approaches and practices to sustainable forest management. The game focuses on the principles underlying area and volume control of timber harvesting, and provides a basis for discussion of inventory and monitoring needs. García-Barrios *et al*. (2015) presented the design, experimental design, and analysis of results of a four-player, land-use board game with stark resource and livelihood limits and coordination/cooperation challenges. The game illustrated that the lives of poor landowners in tropical mountains depend upon their collective capacity to create and coordinate social preferences.

A game is an action that triggers a reaction, which then triggers further actions and more reactions. A game is characterized as: (a) a free activity; (b) having imaginative components; (c) bounded by space and time; (d) that triggers group discussion; and (e) mimics normal behavior The game's realism may take one of several forms: *Explicit reality,* where the game presents the actors' real situation and their resources; *implicit reality,* where the game represents a simplified version of actors and their resources; *virtual world,* where the game is based on an issue that is not necessary related to a specific actor or resource (COMMOD 2004).

Behind a game is a body of knowledge called 'game theory', which spells out how rational individuals make decisions when they are interdependent. In game theory, individualism, rationality and interdependency are the basic theoretical constructs that predict the behavior and mind state of the players (Romp 1997). Game theory provides a methodological framework to analyze strategic interactions between rational agents' behavior. Each agent, aware of these interactions, must choose an action from a set of feasible actions and perform it. The strategic interactions correspond to choices that explicitly and directly take into account the behavior of others agents. A well-known example of game theory modeling of environmental issues is the "Tragedy of the Commons" by Garett Hardin (Hardin 1968, Heckathorn 1996). This uses the prisoner's dilemma game. The game describes how increasing the exploitation of shared resources can be a rational choice for an individual and a dominant strategy for all players but can lead to a disastrous collective outcome. Game theory was used by Elinor Ostrom in common pool resource problems for analyzing action situations and to draw precise and logical conclusions (Ostrom *et al.* 1994).

A normal game will have players, available strategy for each player and payoffs. A set of strategies reach a Nash equilibrium if no player can do better by unilaterally changing his or her strategy. Each strategy in a Nash equilibrium is a best response to all other strategies (Romp 1997). The Nash equilibrium may sometimes appear non-rational or not Pareto optimal. Pareto optimality or efficiency is a state of economic allocation of resources in which it is impossible to make any one individual better off without making at least one individual worse off. If a Nash equilibrium is not Pareto optimal, this implies that the players' payoffs can all be increased. However, in the absence of perfect information or complete markets, game outcomes will generally be Pareto inefficient (Greenwald and Stiglitz 1987).

Method

There are four key phases in the development of a model as stated by Grant *et al*. (1997). These phases were used to develop the game i.e.

(a) Forming the game concept to state the overall game's construct and structure and bound the system of interest.
(b) Specifying the game to elaborate the constructs, relations and estimate the parameters and to represent it.
(c) Evaluating the game to reassess the logic underpinning it and get feedbacks from its users.
(d) Using the game to get insights for governing landscape.

The game uses describes three trials of the game played in Bogor and Bangkok. The first trial was played by four students from the Faculty of Forestry, Bogor Agricultural University. The second was played during the Regional Community Forestry Training Center for Asia and the Pacific (RECOFTC)–University of Wageningen training on 'Landscape and Governance' in October 2010. The participants came from many institutions and various backgrounds. The third was played by forest stakeholders in Bogor. In addition, we analyzed the 12 Landscape Game trial results of Pradana (2012) and Prabowo (2012). At the end, the paper illustrates the recently-developed online version of the board game.

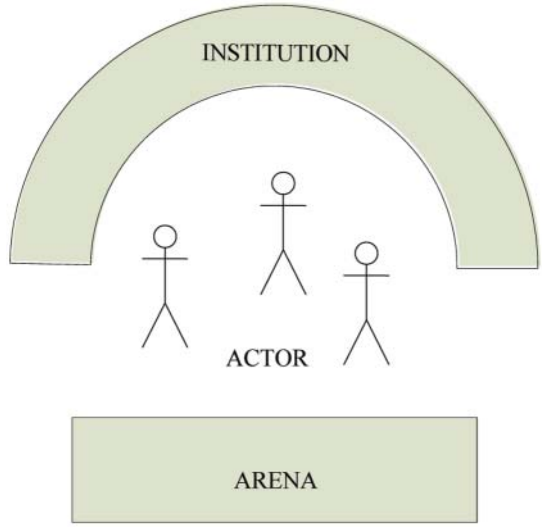
RESULTS

Forming the game concept

The Landscape Game concept adopted the Arena–Actor–Institution approach, as shown in Figure 1 (Purnomo *et al.* 2009). Arena is the landscape, actor is the game player and institution is the game's set of rules. In this approach the arena, actor and institution interact dynamically. Sato (2005) applied the Structure–Institution–Actors (SIA) approach in analyzing economic change and its impacts. *S* is defined as a playing field, i.e. a field or arena in which actors play; *I* as formal and informal rules and their enforcement; and *A* as an entity of action. We adopted the SIA approach but replaced 'structure' with 'arena' to better illustrate the playing field.

Ostrom *et al*. (1994) used the term 'action arena' in their framework for institutional analysis to illustrate the playing field where actors meet and negotiate. Costanza *et al.* (2001) proposed an ecosystem–human interaction framework that is similar to the arena and actor -arena approach for understanding the change of nature. Sterman (2000) provides useful lessons on feedback and causal loops among various components in a system. The Landscape Game comprises players as landscape actors, a set of possible strategies and policies as institutions and a forested landscape as the arena or playing field.

FIGURE 1 *Arena–Actor–Institution approach*



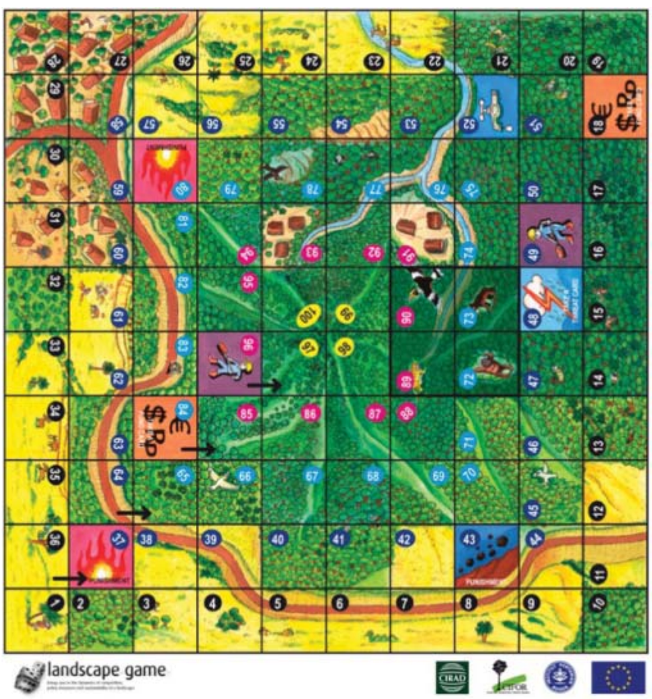
The game constructs and specification

A landscape is a mosaic of different land-cover and land-use patches, which work as an ecosystem. For the landscape, we used three zone types, as proposed by Chomitz (2007): forest core, forest edge and mosaic-lands. The Landscape Game combines the power of investing and trading of property of Monopoly®, cellular automata of SimCity™, investments of American Farmer and rules dynamics of the genetic algorithm (Purnomo and Guizol 2006).

Arena setting
The Landscape Game provides a spatial arena concept that includes land competition, forest cover, community settlements, a river and road (Figure 2). A cell, plot or patch can represent 1000 ha, so the game grid altogether represents 100,000 ha of land. Land competition means the land is limited. If a player has already used the land plot then the other player cannot use it. Players acquire land by buying it from the land appropriator. Players can negotiate buying an investment if they are located in or adjacent to that investment. Neighboring matters. Forest cover type (core, edge, mosaic land) characterizes each plot. A road divides the landscape. Investing in plots close to the road tends to be cheaper than investing in plots far from the road. Social costs may emerge if investments are created adjacent to community settlements. Some cells are labelled with coal mining, HCVF (High Conservation Value Forest) and local community settlements areas.

The investment types will depend on the area types where a player is located. 'Investment time' is a time period during which an investment return can be obtained. One cycle is the time taken for a player to get back to the patch where s/he previously invested. For instance, a player investing in patch number 15 needs to move from 15 to 100 and then from 1 to 15 in order to complete one cycle.

FIGURE 2 *Landscape Game*



A patch or pixel changing during the game play determines the sustainability score. A change from mosaic land to forest due to planting will add it by 1 or '+1'. If it is conserved, from forest to forest, the sustaibility score is unchanged. If forest is converted into mining area then the score is reduced by 1 or '-1'. In the game play you would notice that forest logging would change the sustainability score '-1'. The game play assumed that logging was done unsustainably. You might assume it otherwise.

Investment strategy, payoffs and policies
Total economic value (TEV) comprises *use value* and *non-use value*. *Use value* is the sum of *direct use value* (DUV; food, recreation, etc.), *indirect use value* (IUV; ecological function, flood control, etc.) and *option value* (OV; biodiversity, etc.). *Non-use value* comprises *existence value* (EV; spiritual beliefs) and *bequest value* (BV; future use for successors). So we say that TEV = DUV + IUV + OV + EV + BV. This game is able to present direct use value only as in the following descriptions.

Holmesa *et al.* (2002) studied conventional and reduced impact logging (RIL) in the eastern Amazon. They concluded that for conventional logging, the total cost per cubic meter is $15.66, and the total gross return is $25.50. While for RIL, the total cost is $13.84 and the gross return is $25.50. A study in Borneo (Dwiprabowo 2002) estimated the total cost per cubic meter as Rp 26,035 (or $2.89) for conventional logging and Rp 22,875 (or $2.54) for RIL. Since the Borneo costs do not include road construction and log transport, the figure from the Amazon study is used for the game. We assume the players use conventional logging and for each hectare produce 80 m^3. Therefore the total cost is $1,253 and the gross return is $2,040 for 1 ha.

Ecotourism revenues are heavily dependent on the area's popularity, uniqueness, accessibility and distance from tourist markets. Accordingly, revenues received from entrance fees vary significantly. Gössling (1999) summarizes from other authors: Costa Rica earned approximately $0.25/ha of protected area. In the Volcanoes National Park in Rwanda, entrance fees and indirect revenues provided $466.7–666.7/ha per year of protected area. Studies of less popular parks indicate lower values. The recreational value of the Mantadia National Park in Madagascar was estimated at $9.0–25.0/ha per year and tourism revenue from admission, lodging, transportation, food and other services in the Khao Yai Park in Thailand brought in $17.8–35.5/ha per year. Since the benefit of ecotourism varies, we take the median ($9.0–25.0/ha per year and $17.8–35.5/ha) for this game. The game landscape distinguishes between general forest and HCVF. Therefore, for the general forest, we take $17/ha/year and for HCVF we take $27/ha/year. HCVF is a forest area that contains concentrations of biodiversity values, rare ecosystems or with cultural identify as defined by theForest Stewardship Council (FSC) in 2009.

Benítez-Ponce (2005) illustrated the carbon stock in secondary forest and *Cordia alliodora* (laurel) plantations in Ecuador. The secondary forest accumulated 420 t CO_2/ha in 30 years, so that the sequestration rates are about 14 tCO_2/ha/year. The general transaction cost for carbon trade is $2 per tonne of CO_2. If we assume the price for CO_2 is $2 per tonne and the rate of sequestration is constant, then the gross return of secondary forest every year is $28/ha (=14 t × $2/t). We used secondary forest as an approach for avoiding deforestation cost and benefit. The cost of maintaining forest is estimated to be approximately $200/ha for 30 years (or $6.7/ha/year). The benefit from carbon trade for avoiding deforestation is estimated as $840 for 30 years. This number comes from 14 t × 30 years × $2.

Based on our study of an *Acacia mangium* plantation in South Sumatra, we estimated that for 1 m^3 acacia the total cost is $15 and the gross return is $27. We assumed that 1 ha of acacia produces 150 m^3 after 7 years, so that the total cost per hectare is $2,250 and the gross return per hectare is $4,050. Siregar *et al*. (2007) provided a benefit and cost ratio (BCR) for sengon (*Paraserianthes falcataria*) in East Java after 8 years. The cost per hectare is $1,562, with BCR of 4.45, so the net present value (NPV) return is $5,396. High quality teak plantation investment is estimated at $6,000 and the return is $15,000 for each cycle which is longer than the sengon cycle.

The gross revenue per hectare for oil palm plantation is $5,865 and the total cost is or $2,120. We assumed that the return is obtained after 5 years and continues for 20 years. The investment in jatropha per hectare in India is estimated at $552, while the gross return per hectare is $828 (GFU and GTZ 2004).

The game uses points (Þ) instead of $, with Þ1 equal to $100. In addition to investment payoff, the Landscape Game has features to increase the fun of the game; these are the 'sustainability fund' and 'risk' cards. 'Sustainability fund' cards are arranged randomly. A player located here takes a card, follows the instruction and puts it back. The banker will pay this chosen fund to the player. We used 'Þ' as an abstract currency for this game. The stack comprises ten cards of: (a) payments for environmental services Þ 15 (three cards); (b) poverty network fund Þ 30 (two cards); (c) premium sustainability award Þ 50 (one card); and (d) corporate social responsibility card Þ25 (four cards). In contrast to 'sustainability fund' cards, the 'risk' cards take money from the player. The 'risk' cards comprise twelve cards of: (a) disease for fast wood plantations Þ20 (per patch of fast wood plantation; two cards); (b) typhoon Þ30 (three cards); (c) thunderstorm Þ40 (three cards); (d) flooding Þ50 (two cards) and (e) fires Þ60 (two cards).

The game investment strategy, payoff, sustainability change and conditions are detailed in **Annex 1**. Planting trees will improve the sustainability, while timber logging will reduce it. Conservation activities will maintain the sustainability level. The goverment, in order to maintain or improve sustainability in terms of economic, ecological and social aspects, can modify the game rules after the game has been played for half a period. For instance, if the game is played for 1–2 hours, the government can modify the rules after 30 minutes. The rule modification is limited to give incentives or disincentives for certain investments and to forbid certain types of investment.

Players

The Landscape Game is ideally played by six people: four players, one banker and one policy maker, who can also act as an arbiteror government. A minimum of three people are needed: two players and one banker, who also acts as the government. The players actually compete in the game. Their moves are controlled by two or three dice, depending on the level of game speed the players want. The players think, make investments, get investment returns and experience with unexpected events such as floods and fire, negotiate to buy and sell their property, etc. They are challenged to maximize their prosperity, including assets and rewards due to sustainability behavior, by the end of the game. The winner of the game is he most prosperous player. All players are assumed to be mostly rational, so they want to win the game.

The banker distributes money at the beginning to all players. The banker takes care of all transactions including receiving investments, paying investment returns, giving loans, receiving property deeds etc. The Landscape Game challenges the banker not to lose money, though this is not the main aim of the game, so that when the banker makes a loan to the players, an appropriate interest rate is set.

The government or policy maker assesses the overall landscape during and after the game. The assessment is based on the following indicators: (a) land-use change; (b) value added; and (c) environmental risk through revenue paid to government. If the landscape is getting better in terms these indicators, then the government may reward the best player. The government may distribute rewards or punishments among several players. In order to make the judgment transparent, the indicators for assessment must be announced at the beginning.

Annex 2 provides a short manual of how the Landscape Game is played. Please read this manual to better understand how the game works.

Evaluation of the game

The game was evaluated by different stakeholders including students, non-governmental organizations (NGOs), commercial sectors and academics. We confirmed that the game was able to represent the complexity of the landscape use and management. The stakeholders stated by playing the game they understood better the inter-dependency among the different landscape components i.e. forest core, forest margin and agricultural mosaic lands. They could learn how their strategies, either playing as players or government, were responded to, counter-acted and given feed backed by other players. They also needed to act appropriately to respond to other players' reactions to new policies introduced by the government. This feed back loop between landcape, actors, government provide complexity and non-linearity to the landscape management.

The game was also interesting and a useful way to learn about landscape management. About 1,000 copies of the game board have been distributed and sold. The high demand for the game led us to develop a digital version, available at http://www.landscapegame.org/.

The game uses

The first trial took place on 3 October 2010 at CIFOR headquarters, Bogor, Indonesia. The players were students from the Faculty of Forestry, Bogor Agricultural University. There were three players in the trial, plus one observer. The game facilitator acted as the bank and government/policy maker. The results are shown in Table 1. As written on the game manual, at the beginning all players obtained Þ100 that would constitute the gross productivity.

The players followed the rules in the game manual. There were also incentives with payments paid by one player to another who had common properties, such as water. The game was won by Player C with the total points amounting to Þ140, followed by Player A with Þ39 and Player B with Þ29. The total player points were obtained from the asset value, added to cash the player had, with revenue paid to government and Þ100, by subtracting the initial points that each of the players were given. In this game, the policy maker encouraged green investments in the landscape. The players competed to win by applying various strategies. Player A made investments in teak because it gave a high return after two cycles. Player A also invested in oil palm, acacia plantations and forest logging because of a high return value after one cycle. In order to maintain landscape sustainability, Player A made investments in ecotourism and carbon two times as indicated by number in bracket. Player B invested in forest logging and oil palm to get a high return. Similar to Player A, Player B invested in ecotourism and carbon to maintain the landscape. But these two players received a penalty from the government because they invested in forest logging. They had to pay for their logging investment amounting to Þ10. Player C became the richest player. Player C invested in teak and acacia plantations to get a high return, but received the biggest amount of cash because of his investment in water. Investments in water and penalty revenue for logging for the others were key to Player C's victory.

The net productivity of the landscape after playing was Þ228, which comprised Þ208 from the all players, Player A Þ39, Player B Þ29 and Player C Þ140, and Þ20 coming from the government income, which are revenues paid by the players. Player A got sustainability increased +3 through planted teak, acacia and CDM, but decreased -1 by conducting timber logging, therefore the total score is +2. Player B obtained a score of 0, because of planting sengon +1 and logging -1. Player C got +3 because of planting biofuel trees, acacia and teak. The total sustainability level of the landscape increased by 5. This meant that the government made a good effort to add value to the landscape and maintain value added. The government policy interventions encouraged green investment options, although timber logging still occurred.

The second game was played on 28 March 2012 in Ciawi Subdistrict, Bogor, by players who came from various backgrounds. Player A represented the forest village community, Player B was an academic, Player C represented an environmental NGO and Player D was an officer from a state-owned forest company, Perhutani. The player who acted as government was from the Forestry Agency. Again, the policy was to encourage players to make green investments. The government in this game set revenue payable by each

TABLE 1 *The first game trial results with green investment encouraged*

Landscape	Player A		Player B		Player C	
	Property	**Value**	**Property**	**Value**	**Property**	**Value**
Asset (number of cells)	Teak	50	Ecotourism (2)[1]	14	Carbon/REDD+ (2)	10
	Oil palm	16	Logging (2)	14	Biofuel	5
	Carbon/REDD+	5	Sengon or Sengon	25	Acacia	17
	Logging	7	Oil palm	16	Teak	50
	Ecotourism	7	Carbon/REDD+(2)	10	Water	40
	Acacia	17				
	Carbon/CDM	5				
Cash		42		60		118
Logging revenue paid to government		-10		-10		0
Total asset and cash		139		129		240
Net productivity		**39**		**29**		**140**
Sustainability		+2		0		+3

[1]Number of investments

TABLE 2 *The second game trial result with green investment encouraged*

Landscape	Player A		Player B		Player C		Player D	
	Property	Value	Property	Value	Property	Value	Property	Value
Asset (number of cells)	Carbon/REDD+ (2)	10	Teak	50	Carbon/REDD+ (3)	15	Ecotourism	21
	Ecotourism (3)	21	Ecotourism	7	Ecotourism	7	Acacia (5)	85
	Ecotourism HCVF	15	Sengon	25	Ecotourism HCVF	15		
	Sengon	25	Logging	14	Sengon (2)	50		
	Biofuel	5	Coal Mining	30	Biofuel	5		
	Acacia	17						
Cash		136		75		28		172
Revenue paid to government		-6		-44		-6		-8
Total asset and cash		223		157		114		270
Net productivity		123		57		14		170
Sustainability		+3		0		+3		+5

player. For plantation investments, revenue was 10% of the assets value, logging was Þ20 and mining was Þ15. Every player who passed through a carbon investment such as REDD+ owned by another player had to pay Þ1 to the owner.

In the second trial, Player D was the winner. As we can see in Table 2, Player D had just two types of investment (ecotourism and acacia plantation). Player D got a high return from acacia plantation and received cash from other players produced by the ecotourism investment. This player was playing safe and made an environmentally friendly investment. The total net productivity was Þ364 and sustainability increased by 11. Both were higher than the first result.

The third trial was played on 27 October 2010 in Bangkok during the RECOFTC–University of Wageningen training on Governance and Landscape. The participants came from various backgrounds and expertise. They came from Indonesia, Guatemala, Costa Rica, Colombia, Cambodia, Bangladesh, Kenya, Burkina Faso, Mongolia, Namibia and Nepal. The game was played by four players, with one person acting as the government and one person as a banker. Other participants were also involved in the game as advisors to the players. The policy was again to encourage green investment. The players actively wanted to win the game, while the government wanted to keep the landscape green. The government provided policy with high taxes on logging and mining to preserve the environment.

The results of the third trial are shown in Table 3. The game was won by Player A with Þ198, followed by B, D and C. The total productivity was Þ241 and the level of sustainability increased by +4. The winner was the player who possessed the water investment. This game was more interactive and debated. The government changed the regultation during the game play to encourage green investment. However, the players thought the government was unfair. Regulations such as revenue or penalties were applied after one player received benefit from a certain investment; the others who applied the same investment did not want to follow the new rule.

DISCUSSION

During the game, all players imagined and connected the spatial landscape, social actors and rules of the game to reality. Each player had different experiences. Some had more experience of natural forests and others were more experienced with plantations, community forests, carbon trading and advocacy policy work. Each landscape they had experienced differed in detail from the game landscape. However, they accepted that the Landscape Game represented a generalized landscape. The game landscape pattern, which followed the idea of Chomitz (2007), was an implicit reality and the representativeness of the game was accepted by the players.

In the real word, the initial rules, incentives and disincentives in landscape management vary from place to place. In some places, the government practices timber logging as a main source of income from landscape. In other places, the government has shifted to ecosystem services as the main focus of landscape management. Modest incentives through REDD+ (Reducing Emissions from Deforestation and Forest Degradation Plus), for instance, are now available. Incentives are also given to boost community forestry activities. The good governance indicators, e.g. transparency, participation and government effectiveness, and corruption level also vary widely. The Landscape Game provides a general system of landscape management, where players can execute strategy, scrutinize responses from other players and policy makers, and examine the impacts of different strategies on a landscape.

TABLE 3 *The third trial result with green investment encouraged*

Landscape	Player A		Player B		Player C		Player D	
	Property	Value	Property	Value	Property	Value	Property	Value
Asset (number of cells)	Sengon	25	Sengon	25	Biofuel (2)	10	Teak (2)	100
	Water	40	Logging	14	Carbon/REDD+ (5)	25	Ecotourism (4)	28
	Ecotourism HCVF	15	Carbon/REDD+	10	Ecotourism (2)	14	Coal mining	30
	Carbon/REDD+	5	Biofuel	10	Logging	7		
			Ecotourism	21				
Cash		133		223		129		237
Revenue paid to government		0		-110		-110		-220
Total asset and cash		198		193		75		175
Net productivity		98		93		-25		75
Sustainability		+1		+1		+1		+1

All players enjoyed playing the game. They laughed at the way the dice fell to give rewards or penalties and they enjoyed seeing how good strategies worked or did not work at all. For instance, the players that invested in teak plantations discovered that they needed years to produce timber, but the game was over before the teak provided benefit. The game was fun due to the uncertainty of dice rolls and unpredictable responses from other players. The game also encouraged the players to devise strategies to win, predict and anticipate how other players would act and how policy makers would develop, implement and change rules. The game encouraged policy makers to develop policy to maintain landscape sustainability in harmony with its productivity. The policy maker encouraged people to invest their money through planting in a mosaic landscape, carbon trading, ecotourism, etc. to make the landscape more productive.

The statement, "If we were all better people the world would be a better place" (Levine 2009) could be applied in this game. In order to create a better landscape and to make the landscape more productive, all players should become 'better' people. But it is not necessarily better people that will win the game if the others act as free riders or rent seekers. These people take benefits from activities without contributing to the costs. For instance, maintaining ecological integrity needs to balance timber logging and forest conservation. While conserving forest gives benefits to all stakeholders, irresponsible forest logging only benefits logging companies.

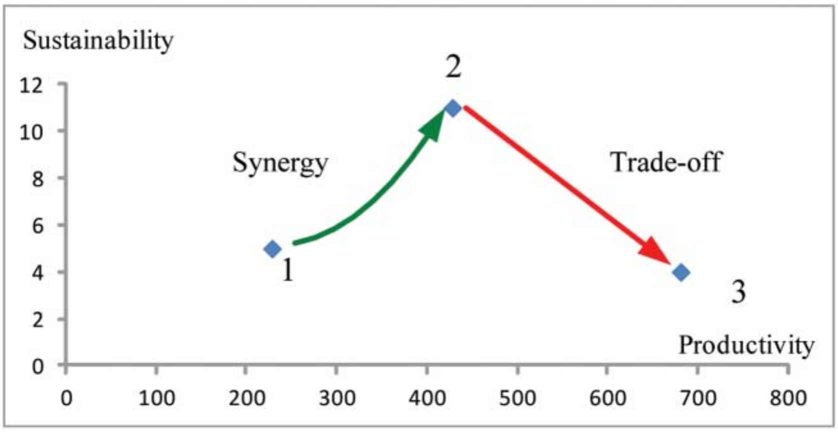
The policy maker ensured a Nash equilibrium was approached during the game by informing all possible strategic payoffs and revenues were paid to the government. Therefore, each player tried to devise the best strategy by taking into account the other players' strategies. When each player has chosen a strategy and no player can benefit by changing their strategy, then the current set of strategic choices and the corresponding payoffs constitute a Nash equilibrium. Likewise, a group of players are in a Nash equilibrium if each one is making the best decision that he or she can, taking into account the decisions of the others.

The results show that the first trial gave the lowest productivity and moderately improved sustainability (Table 4). The second trial game provided better productivity and sustainability. This was due to the low revenue demanded by the government and quick and high return investments, such as acacia, chosen by the players. Many investments were located on bare mosaic land and as a result improved the landscape sustainability. A combination of investing in fast-growing species on bare land and investing in green environmental strategies, such as ecotourism and REDD+, meant the second trial provided better productivity and sustainability, even though players also invested in timber logging and mining.

TABLE 4 *Summary of results*

Trial no.	Number of players	Productivity of all players (Þ)	Government revenue (Þ)	Overall productivity (Þ)	Sustainability level change (+/-)
1	3	208	20	228	+5
2	4	364	64	428	+11
3	4	241	440	681	+4

FIGURE 3 *The relation between productivity and sustainability*



The government did not employ high taxes for these investments, but encouraged green investment to compensate.

The third trial gave medium productivity and the lowest sustainability level, but the government collected the highest revenue. The revenue for natural resource use gave a medium amount of value added to all players. The players concentrated on working in the forest core and forest edge rather than on mosaic land. Productivity resulted from investment return on logging, mining, ecotourism, forest plantations and taxes paid by players due to these investments. Since there was not much green investment, the sustainability improvement was relatively low. In the first trial, players were more willing to invest in mosaic land that provided better sustainability than the third trial.

Figure 3 shows a two-dimensional diagram of productivity and sustainability, in which the three game trials are located. Shifting from trial 1 to trial 2 gives synergy, while shifting from 2 to 3 is a trade-off between sustainability and productivity.

Table 5 summarizes the results of this study (numbered 1–3) and gives results from two other studies. Pradana (2012) describes six game trials (numbered 4–9) in Table 5, and Prabowo (2012) describes another six game trials (numbered 10–15). Productivity is negative in trial 14, indicating a loss rather than a profit during the game.

A link between productivity and sustainability is shown in Figure 4. This figure describes the trade-off, but is insignificant with R-squared of 0.007, between sustainability and productivity links. The figure shows the phenomena that when we enforce productivity to the landscape then its sustainability will have greater variance. So it seems that it is easy to get sustainability with minimal production, but that production/productivity is a double–edged sword that can enhance or reduce sustainability.

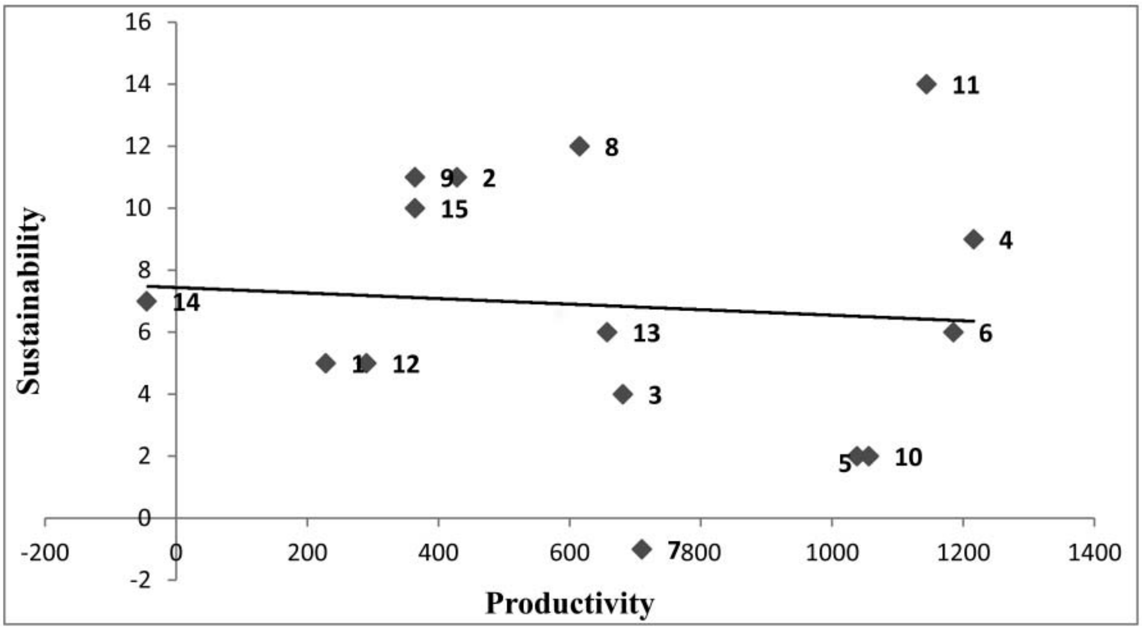
These game trials provide insights on how sustainability and productivity are linked. Commonly there is a trade-off between them (Feiock and Stream 2001). Rees (2003) argues on both theoretical and empirical grounds that, there is an unavoidable conflict between economic development (generally taken to mean 'material economic growth') and environmental protection. To grow and develop, the economy necessarily 'feeds' on sources of high-quality energy/matter first produced by nature. This tends to disorder and homogenize the ecosphere. The ascendance of humankind has consistently been accompanied by an accelerating rate of ecological degradation. Millner *et al*. (2001), however, conclude with a discussion of emerging planning and policy models that may facilitate a convergence of values in the new conservation debate on a common policy of eco-social sustainability. Sayer *et al*. (2016) underline the importance of the landcape approach and its metrics to reconcile forest conservation and agriculture development.

Synergy and trade-off links between productivity and sustainability exist within the landscape. The trade-off is in line

TABLE 5 *Game trials made by Pradana (2012) and Prabowo (2012)*

Trial no.	Productivity (Þ)	Sustainability change
1	228	5
2	428	11
3	681	4
4	1216	9
5	1038	2
6	1185	6
7	710	-1
8	615	12
9	364	11
10	1056	2
11	1144	14
12	290	5
13	657	6
14	-45	7
15	364	10

FIGURE 4 *The landscape productivity and sustainability links, with y = -0.0009x + 7.4674 (R^2 = 0.0071)*



with the concept of Grand Utility Frontier (GUF), as shown in Figure 5 (Bator 1957). We argue that a GUF can exist under different intervention policies. Given that for various intervention policies there is a relation between productivity and sustainability. Pareto optimum cannot be determined from this game, however, non-Pareto optimum can be identified. Trial 11, for example, has better utilities than every trial but 4 and 6, in terms of productivity. Therefore, all trials except trials 11, 4 and 6 are not Pareto optimal. Communication and collaboration among players is another layer of a game (Purnomo *et al*. 2012b). If all players communicate and collaborate with each other to improve landscape productivity and sustainability, the landscape might get better (Purnomo *et al*. 2013). In other words, Pareto optimum can be better pursued with better communication.

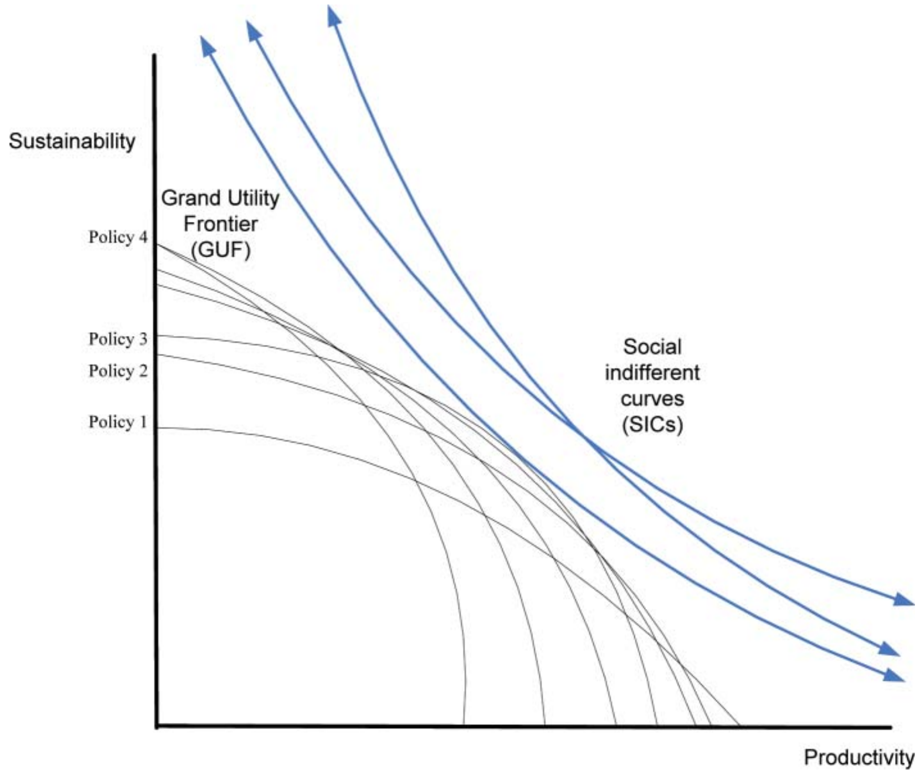
It is very important for policy makers to be fair to all players to make the game run smoothly. The policy maker can implement principles of good governance, such as participation, accountability, transparency and effectiveness to sustain the landscape. During the first trial, players tended to experiment with many different possibilities. They started by playing safely, then tried to play at extremes, e.g. by maximizing profit. In the second trial, practitioners tended to represent their daily activities in the game. So, if they were from forest concessionaires, they tended to invest in timber logging activities, if they were conservationists, they tended to invest in ecotourism or carbon trading activities.

While GUF is in a convex form, the landscape stakeholders commonly perceive the utility satisfaction in a concave form. It means that different stakeholders cannot be 100% satisfied with only one utility. Bringing all stakeholders to environmental sustainability utility only is almost impossible. Likewise, bringing them to only development utility by neglecting environmental conservation is also undoable. Social indifferent curves (SICs) represent this situation (Samuelson 1955) as shown in Figure 5. There is, however, hypothetically an intersection point where the GUF and the SICs meet. This point satisfies both utility trade-offs and stakeholders preferences.

The game play results (Figure 4) show not only trade-off but also synergies between sustainability and development. When development takes place, deforestation commonly begins to happen. After a period of time, when development has produced better prosperity for the people, the environment or forests begin to recover. An Environmental Kuznets Curve (EKC) describes this situation. The curve is a hypothesized relationship between environmental quality and economic development. Environmental degradation tends to get worse as economic growth occurs until average income reaches a certain point over the course of development. EKC was formulated based on the work of Simon Kuznets in the 1950s and ‘60s and was used for deforestation analysis in Indonesia (Waluyo and Terawaki 2016). The game play results fit EKC and suggest that environmental sustainability with low income is easy to achieve but is more challenging with high incomes. High incomes can be in synergy or result in trade-offs with environmental sustainability.

The game play results provide three modes of landscape development i.e. unsustained but growing, EKC-like development, and sustained and growing. The first mode will not be sustainable and can lead to difficulties and collapse. The second one is commonly what happens in countries that are now called developed countries. The third mode is what the world is pursuing in terms of harmony between conservation and development, and achieving the Sustainable Development Goals (SDGs). These three modes are in line with how Burns (1986) describes three modes of forest development i.e. treadmill deforestation, runway deforestation and forest-rich

FIGURE 5 *GUF and SICs between productivity and sustainability*



development. The treadmill deforestation is deforestation due to timber harvesting that provide capital for investment but fails to achieve value-addition for sustainable development. In contrary, runway deforestation enables economic and social reforms leading to sustainable development. Forest-rich development is an ideal format, in which economic development is in synergy with environmental sustainability (Figure 6).

Kastens *et al*. (2017) provide an example of how the soy moratorium in Brazil can lead to reducing deforestation and intensification of agriculture. Nurrochmat *et al*. (2010) used the example of Papua Province as the new frontier of sustainability of Indonesia in which forest conservation and agricultural development need to go together. However, currently Papua is experiencing the early stages of deforestation. With productivity as absis and sustainability as ordinat, possible combination between productivity and sustainability can be explored. Good landscape governance aims to harness such combinations to meet its goal e.g. forest rich development.

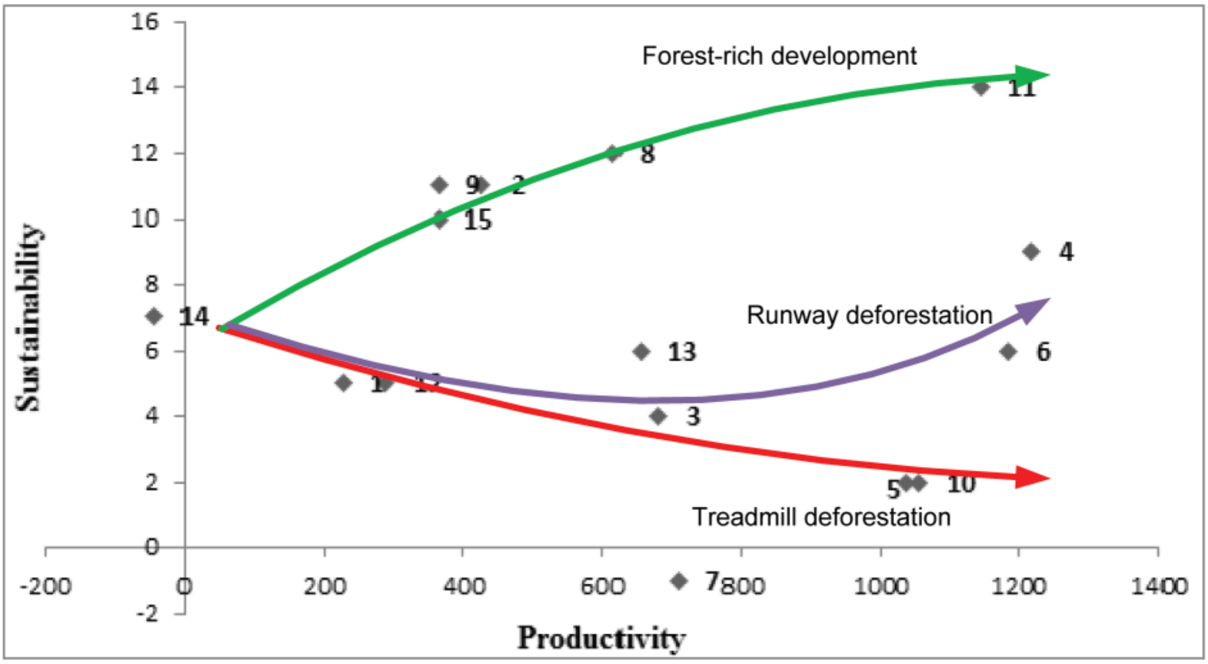
The major obstacles to better forest management are not silvicultural, but are social, political and economic (Vanclay 1991). The landscape game can be a tool to help learn how synergies among social, ecological and economic aspects can be investigated. At the end of the Landscape Game play, step 10 (Annex 2), all players, government and banker discussed and explained what lessons can be learned. For example, one of the game plays documented lessons on how to win the game i.e. getting lucky, investing in eco-tourism and carbon, and developing oil palm plantations. This strategy conducted conservation and development simultaneously. While lessons for sustaining the landscape were notably by providing incentives for green investments, encouraging green investments in mosaic or non-forested land, and disincentivizing timber logging in the forest core. Another game play provided lessons that governments need to be consistent with chosen policies, so that players can optimize more easily their strategies to win the game.

Changing policies and strategies by players will be responded to, and adjusted by other players. The government also obtained lessons that every policy they delivered would be responded by the players by changing their strategies to win. The game play provides lessons to all players including those who play the role of government and banker. These lessons can be tested when they play the game again.

The fundamental question of a game was whether it can change the mental model and behaviors of the players (Atrana *et al.* 2005). We believe by playing the Landscape Game, players better understand landscape management and governance. The following are the results of playing the Landscape Game: Having more knowledge on strategies to win; Understanding reciprocal strategies of opponents; Understanding the benefit of integrating development and conservation activities; Anticipating new policies as a result of their activities; and Learning to develop new policies to sustain the landscape

These insights can be inputs for triggering the players' mental model change. We observed they have more understanding and confidence on the possible links between conservation and development. This understanding can be

FIGURE 6 *The game play results and modes of forest development*



applied to a real landscape where the players work, institutionalizing the policies and rules that are good for landscape productivity and sustainability. The Landscape Game players were able to communicate and articulate their mental model in game play and received responses from other players and government. They could observe the effects of their mental model changes to landscape sustainability. At least this kind of tool, as stated by Vanclay *et al.* (2006b), has become a platform for bringing people's mental models of their world to the surface and allowing them to be reconciled with each other. Participatory modelling, called ZimFLORES, has proved an effective way to consolidate a diverse body of knowledge and make it accessible and able to produce insights into the issues under consideration (Prabhu *et al.* 2003). Pre- and post-tests conducted during the ' Felling Safety Game' trial showed the respondents' knowledge of occupational safety and health protection significantly increased, indicating its effective application as a learning tool (Yovi and Yamada 2015, Yovi *et al.* 2016). The learning from this model and game can be a 'stepping stone' in developing the confidence needed for communities to take action (Vanclay 2010, Purnomo *et al*. 2011).

The board game of Landscape Game has attracted interest from all over the world. The major newspaper in Malaysia 'The Star' on 22 August 2014 featured it at http://www.thestar.com.my/lifestyle/features/2014/08/22/rules-of-engagement/. Asubsequent challenge was to meet demand as the production and stock of the board game was limited. At the same time, the digital age, indicated by penetration of Internet and social media, has provided new means of delivery of the game to wider audiences. Therefore, a project was initiated to develop a digital version of the Landscape Game so that it can be played globally.

The game http://www.landscapegame.org is now available as a beta version and was officially launched during the Global Landscape Forum (GLF) in Lima, Peru in December 2014. (GLF 2014, Velde 2014). The game has received many citations and positive reviews (AAA 2014, Luleva 2014, MAHB 2014, ForestInfo.org 2015). Figure 7 shows the interface of the digital version of the Landscape Game. Its video manual is available at http://www.cifor.org/landscapegame/ that shows how it works.

For the digital version we added some more features including different landscapes that can be used in the game e.g. Java, Borneo, Amazon, Congo, Peatland, Mangrove and randomized landscape. The digital game can also measure the different elements of sustainability such as carbon emissions, biodiversity etc. The game can be played by human players as well as a human player against a computer agent or avatar. The computer avatar can become more intelligent during the game play, if the player so chooses as we applied artificial intelligence techniques to it as a learning agent.

CONCLUSIONS

The Landscape Game is an implicit reality, where players can gain experience in development and conservation of landscapes. Policy makers can experiment with policy interventions to improve the sustainability and productivity of a specific landscape. The game is fun and stimulates thinking about landscape management and governance. Although each landscape and its rules are different from place to place, the Landscape Game is able to represent a generalized landscape and its governance. The policy trials provide lessons showing that there are various relationships between conservation and

FIGURE 7 *The interface of the digital version of Landscape Game*

development. Low landscape productivity can provide sustainability easily. With greater productivity, the greater the variance of sustainability.

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Annex 1. Investment payoffs and conditions[1]

Type of area	Possible investment	Cost[2] (Þ)	Return (Þ)	Hypothec (Þ)	Asset value (Þ)	Time period to get return	Sustain-ability change	Conditions
Forest core/ Forest edge	Ecotourism	10	2	5	7	Whenever another player lands on the patch	Un-changed	
	Ecotourism in High Conservation Value Forests (HCVF)	20	3	10	15	Whenever another player lands on the patch	Un-changed	HCVF areas
	Logging concession	13	50	6	7	One cycle	-1	Non-HCVF areas; needs re-investment after each cycle
	Carbon for avoiding deforestation (REDD+[3])	2	8	5	5	One cycle	Un-changed	
Mosaic land	Acacia plantation	22	40	11	17	One cycle	+1	Needs re-investment after each cycle
	Oil palm plantation	21	59	10	16	One cycle	Un-changed	Needs re-investment after each cycle
	Jatropha curcas plantation for bio-energy	6	8	3	5	One cycle	+1	
	Community based agro-forestry (*Parasianthes falcataria* or sengon)	30	74	15	25	One cycle	+1	Needs re-investment after each cycle
	Teak plantation	60	150	30	50	Two cycles	+1	Needs re-investment after every two cycles
	Carbon for afforestation and reforestation (CDM[4])	6	6	3	5	One cycle	+1	
Specific areas	Sustainability fund	—	Take a card			—	—	Fund card displays how many points you receive
	Fire	25	—			—	-1	If there are five patches of fast wood plantation (acacia, sengon) and oil palm (together)
	Landslide	15	—			—	-1	If there are five patches of logging concession and coal mining (together)
	Risk	—	Take a card			—	—	Risk card indicates what risk/ threat you face
	Coal mining	50	75	20	30	One cycle	-1	Reinvest after every two cycles
	Drinking Water	50	5	30	40	—	Un-changed	Get Þ5 for every other player's investment

[1]Investment costs of logging, plantations (acacia, sengon, biofuel) are cheaper Þ5 for patches along the road and higher Þ10 for patches adjacent to local community settlements in eight directions.

[2]Logging and plantation (acacia, sengon, jatropha, teak) costs are Þ5 cheaper for patches along the road and Þ10 higher for patches adjacent to local community settlements in any direction.

[3]Reducing Emission from Deforestation and Degradation Plus.

[4]Clean Development Mechanism

Annex 2. The Landscape Game Short Manual

1. Three to six persons can play. Players decide who will be land users (two to four persons), the banker (one person) and the policy maker or government (zero or one person). The roles of banker and government can be played by the same person. Players agree how long to play. Recommended time of play is 60 minutes, but participants playing for the first time may need 90 minutes to complete the game.
2. The banker distributes initial funds of 100 points to each player (we use 'Þ' for points). The government holds limited funds, e.g., Þ200, to make its policy work. Players and government may hire advisors (consultants) and they may borrow money. The banker determines the rates.
3. Initially, players are randomly located by tossing dice onto the landscape, which is divided into randomly scattered patches numbered from 1 to 100. Players begin from the patches in which their die lands. Each move is driven by the cumulative points of three dice bearing the values 1 to 6. If a player tosses three sixes, producing 18 steps, then the player can move once more. Players move towards patch no. 100, and then restart from patch no. 1, until the agreed time period of play is completed.
4. When a player arrives at a patch, various investments can be made according to patch type (e.g. forest core, forest edge and mosaic land). Each investment creates a cost at the beginning and provides return after a certain time (Annex 1). Certain patches are reserved for mining and drinking-water investments. At the patches of 'fire' (37, 80) and 'landslide' (43), the players will be charged. At the patch of 'sustainability fund' (18, 84), and 'storm' (48), the player takes a card from a stack of fund or threat cards.
5. Players can invest in the patch they are located, and also at any of the eight adjacent patches, if these have not yet been appropriated by another player.
6. The player pays the investment cost to the banker and receives a property certificate listing type of investment, cost, return and hypothec. The player puts a mark, provided by the banker, on the landscape patch. Players openly display all their certificates for other players to see. Players can sell their certificates as hypothec to the bank. Players may re-buy their certificate at Þ10 higher than the written hypothec.
7. The banker pays an investment return to the player after each completion of the cycle. One cycle consists of player moving forwards from the patch in question, through patch no. 100, and then again to the patch in question (100 steps). Certain investments need to be re-invested to sustain the return. Second and consecutive investments by the same player on a given patch generally are Þ5 lower than the first investment due to the existence of infrastructure. Investment in ecotourism gets a return when another player lands on that patch.
8. A player located adjacent to an investment property can negotiate with the owner to buy that property.
9. The government observes players' behavior and assesses landscape changes. The government can deliver policy, investment incentives and rules that apply to all players. Although players can lobby the government for specific policies, the government must be fair to all players.
10. At the end of the game:
    a. Players count their cash and tally asset values.
    b. The government may give awards to environmentally friendly good players.
    c. The player who collects the most money (including cash, assets and awards) wins.
    d. The banker tallies all players' money to determine players' productivity and sustainability.
    e. Participants discuss what lessons can be learnt from the game, including the best strategy to win, policies for managing a landscape, and the competition and collaboration among players.