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Source: Mountain Research and Development, 42(4)

Published By: International Mountain Society

URL: https://doi.org/10.1659/MRD-JOURNAL-D-21-00067

Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
published by the International Mountain Society (IMS)
www.mrd-journal.org

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Collaborative Modeling and Simulation to Mitigate High-Elevation Rangeland Degradation in Eastern Bhutan

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The contribution of overgrazing to high-elevation rangeland degradation is a problem across the Himalayan region, and it leads to tensions among users. In the alpine areas of eastern Bhutan, 2 communities of settled and seminomadic herders have been engaged in enduring open conflict over access to a large natural pasture. To reestablish a communication channel between these communities, a participatory modeling and simulation process was implemented with the concerned stakeholders. A training workshop on this collaborative approach and its key tools, particularly computer-assisted role-playing games, was attended by research and extension officers and was immediately followed by a field workshop attended by 6 herders from each community. The participants used their empirical knowledge to improve the relevance of the spatial distribution of the land degradation problem on the proposed game board. They also established a link between the features and rules of the role-playing game and the actual circumstances of the rangeland. The gaming sessions allowed the participants to share their respective viewpoints on the land degradation process in a nonthreatening environment. The assessment of the field workshop identified multiple effects regarding awareness of the problem, participants' confidence, colearning, and mutual trust. This intervention enabled the emergence of social capital ahead of the preparation of major development-oriented interventions in the watershed. This study demonstrates the pertinence of using simple but relevant abstract models, codesigned with their users, to mitigate tensions between parties in conflict over the use of renewable natural resources.

Keywords: *companion modeling; role-playing game; agent-based simulation; land use conflict; pastoralism; Himalayas.*

Received: *6 December 2021* ***Accepted:*** *22 September 2022*

Introduction

Large areas of high-elevation rangelands of the Himalayan region are critical socioecological systems (SESs), where the sustainability of vulnerable, complex pastoral livelihoods of many ethnic minority groups relies on interdependence across spatial, ecological, social, and institutional boundaries (Axelby 2007; Aryal et al 2013; Ning et al 2013; Gentle and Thwaites 2016; Pasakhala et al 2021). The land degradation of high-elevation Himalayan grasslands observed over several decades is a growing problem in a time of climate change, leading to declining rangelands, severe soil erosion, and major landslides (Dorji et al 2020; Namgay et al 2021). Rangeland degradation reduces the supply of multiple vital ecosystem services, weakens the links between social and ecological components of pastoral SESs, and threatens the sustainability of high-elevation and downstream systems (Xu et al 2009). This calls for adaptive responses and innovative solutions from society (Azevedo et al 2021). As stressed by Elinor Ostrom and her colleagues (Janssen et al 2011), the quality of common-pool resource management lies more in the possibility of communication than on the types of rules crafted or selected. There is therefore a need for methods that promote exchanges among stakeholders in general and mitigate rangeland use conflicts between sedentary and seminomadic herder communities due to ineffective institutional regimes and arrangements (Gentle and Thwaites 2016).

This is the case of the eastern Bhutanese high-elevation pastures or *tsamdrogs* (Turkelboom et al 2001; Gyamtsho 2002; Ura 2002; Moktan et al 2006; Dervillé and Bonnemaire 2010; Millar and Tenzing 2021; Namgay et al 2021). Here, land degradation is partly due to overgrazing limiting natural regeneration (Gibson 1991; Dorji 1993; Gyamtsho 1996; Gyeltshen 2010; Tenzing et al 2018). This is threatening traditional transhumant pastoralism livelihoods (Namgay et

al 2013, 2014; Dorji et al 2020). The Land Act of 1979 and the Forest and Nature Conservation Act of 1995 devolved grazing rights on grassland to individuals and communities, but lacked provisions to clarify ownership and rangeland management activities allowing sustainable use (Moktan et al 2008; Ura 2002). The Land Act of Bhutan 2007 was seen as a policy shift toward the inclusion of management and provisioning in the bundle of rights (eg leasing) of *tsamdrog* property rights, but its perception by herder communities attached to traditional rules led to confusion and anxiety (Tenzing et al 2017a, 2017b). Tenzing et al (2021) found that local knowledge and traditional practices have a role to play in avoiding land degradation and that granting of management rights is vital to encouraging rangeland maintenance activities. Genuine participatory processes with concerned stakeholders' engagement could help defuse the unintended negative impacts faced by transhumant herders whose livelihoods depend on large tracts of marginal rangelands (Namgay et al 2017, 2021). This is the case in the upper Gamrichu watershed near Radi, Trashigang district, eastern Bhutan.

Radi gewog ranks first in eastern Bhutan for resource use pressure with a livestock population of several thousand heads but the lowest grazing land area to large ruminant ratio (0.56 ha/head) in the country (Gurung et al 1999). The Sheytimi rangeland serves as grazing ground for cattle of settled Radi farmers (*Radips*) during the summer months and the cereal crop cycles, as well as yak and yak–cattle cross herds grazed by Merak transhumant pastoralists (*Brokpas*, meaning people of the grasslands; Millar and Tenzing 2021) during the autumn and winter months. This leaves very limited time for the natural pasture to regenerate (Moktan et al 2006, 2008; Ura 2002). The indiscriminate overgrazing practice has caused an open conflict between *Radips* and *Brokpas* that has prevailed over 3 decades. Cattle of opposing communities have been injured and killed (Tashi and Wangchuk 2006), and the conflict has led to several court cases (Tenzing et al 2017b).

After analyzing the conflict (the details are given in Appendix S1, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-21-00067.S1), Tashi and Wangchuk (2006) proposed a concerted effort by a neutral agency to resolve this case. Many previous meetings of stakeholders and several court rulings had been ineffective in mitigating the problem. The Renewable Natural Resource Research Center (RNR-RC) started to mobilize the community to develop bylaws acceptable to the different parties for the joint management of the *tsamdrog*. Considering the sensitivity of the enduring conflict, the RNR-RC team looked for an approach that added value to the understanding of the complex situation to reestablish a communication channel between the herder communities. Investing in multistakeholder dialogue to address natural resource competition and conflict was often advocated (Ratner et al 2018). To take concrete steps in this direction, the RNR-RC team decided to launch a companion modeling (ComMod) process. This approach (Barreteau et al 2003; Etienne 2011) is based on the collaborative design of a model representing the dynamics of an SES that can be implemented as a role-playing game (RPG) and/or a computer agent-based model (cABM). The decisions of the agents (ie the actors of the SES) are made by participants endorsing the role of the actors or are coded in algorithms specifying the decision processes (Bousquet et al 2002). This has been successfully used to mitigate a conflict over irrigation water sharing in the Lingmuteychu subwatershed of central west Bhutan (Gurung et al 2006).

The general goal of the intervention was to contribute to the improvement of collective decision-making on grassland management by the 2 herder communities in conflict. The specific goals examined in this paper were to (1) establish a common understanding on the current situation and (2) simulate alternative scenarios, based on a technical option and different modes of communication among herders, to assess their impacts on rangeland status and herders' incomes.

Intervention approach and assessment methodology

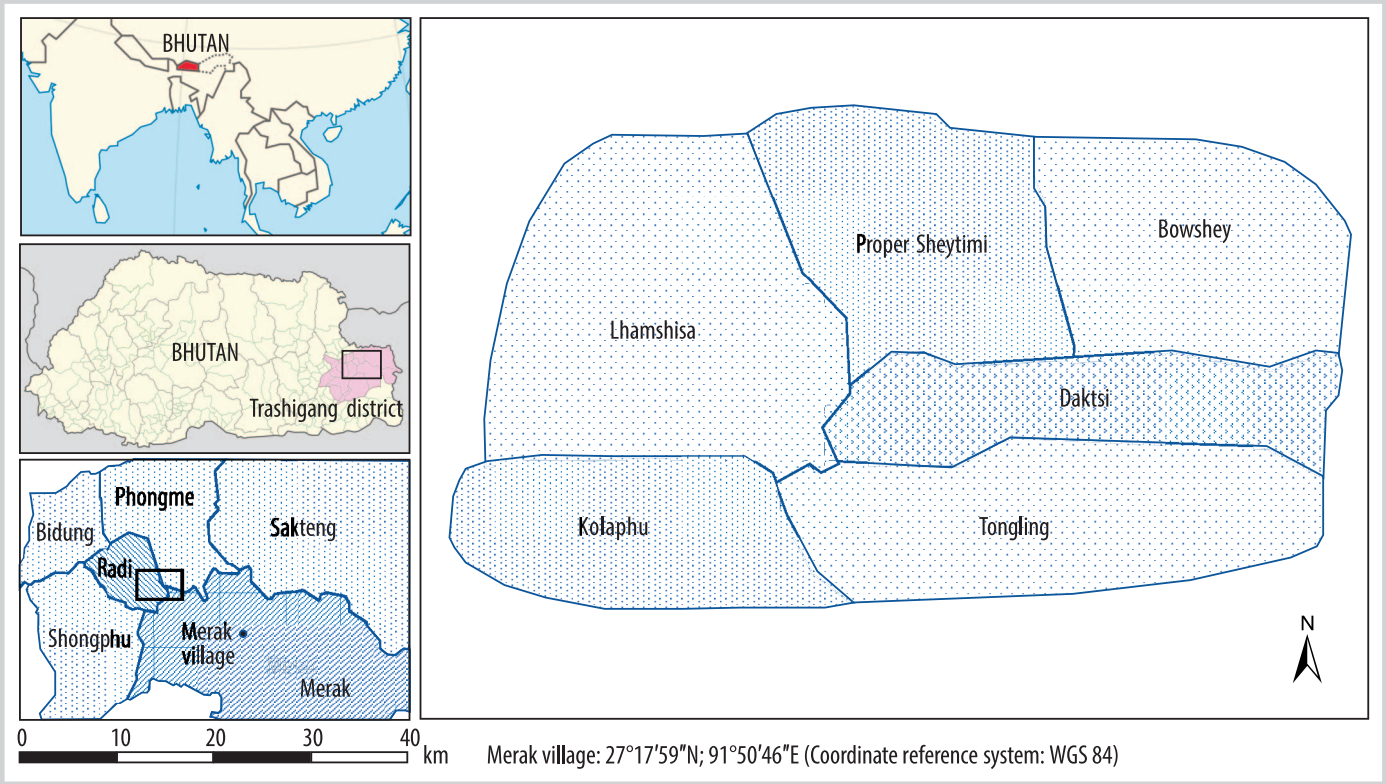
The study site

With a total area of 28.67 km^2 and 1353 mm of average annual rainfall, Radi is one of the most important rice-growing areas of Trashigang district (Figure 1). The elevation ranges from 1200 to 1800 m. Seventeen villages with a total population of 560 households farm some 760 ha of arable land. The people of Radi have up to 1000 cattle that used to graze the Sheytimi rangeland from April or May to September. After this, cattle have to stay away from the paddies and maize fields, and approximately 900 yaks belonging to the seminomadic people known as *Brokpas* replace them from October to March. Radi households are mainly rice and maize growers with only a few free-grazing cattle, while *Brokpas* live a seminomadic lifestyle with livestock and pasture as their main sources of livelihood (Figure 2). Increasing human and cattle populations and reduced vegetative cover accelerate the risk of soil erosion in this subalpine grassy area with sparsely distributed trees (many of them lopped by *Brokpas* to feed yaks during winter) and shrubs of *Rhododendron* species. Following intensive rainfall events, an impressive ravine originated from the Sheytimi rangeland (Millar and Tenzing 2021). Overgrazing and indiscriminate lopping of trees for fodder, combined with soil compaction due to trampling by livestock over a long period of time, has led to the severe degradation of most of this *tsamdrog* (Moktan et al 2008; Tenzing et al 2017b). It is considered the prime origin of accelerated land degradation (NSSC 2014) and has triggered the upstream expansion of the massive ravine and secondary landslides that led to the destruction of large patches of crucial downstream arable land of the renowned rice bowl of Trashigang (Gurung et al 1999; Wangchuk et al 1999); see Figure 2.

Approach and implementation

The core intervention was implemented in 2 main phases as follows. A 5-day training workshop attended by officers of the Ministry of Agriculture and Forests agencies was held in January 2006 at the then Natural Renewable Resource Training Institute, now College of Natural Resources, in Lobeysa. The aim was to introduce the fundamentals of the ComMod approach, methodology, and tools, and to examine the Sheytimi real-world conflict. The following week, a 5-day field workshop was organized at the Radi agricultural extension office. Six *Radips* and 6 *Brokpas* selected by the

FIGURE 1 Location of the Sheytimi degraded rangeland in the Chongdiri catchment of the upper Gamrichu watershed, Trashigang district, eastern Bhutan. (Map by authors; map of Bhutan in Asia adapted from TUBS 2011 and map of Trashigang in Bhutan adapted from NordNordWest and Government of Bhutan 2011, both licensed under CC BY-SA 3.0, via Wikimedia Commons)



local extension officer participated in this workshop, while other concerned stakeholders (extensionists, village heads, and assistants) were observers. Participants were selected because they actively engaged in previous stakeholders' meetings organized by government agencies about the management of the Radi watershed. The program included 2 days of preparation and mobilization of the participants (including a visit to the *Brokpas*' winter camp), followed by 3 half-day gaming and simulation sessions, a plenary presentation of simulation results, and a final debriefing before individual interviews of the players on the last day. The methodology for designing and using the game is further detailed below.

Codesign of the conceptual model implemented as an RPG: The codesign of a conceptual agent-based model and its implementation as an RPG were the main outputs of the training workshop organized the week before the field workshop. In the ComMod approach, an RPG consists of a staged action situation based on a stylized representation of an SES. In an interactive simulation workshop, each participant plays the role of one of the actors, reveals the values underlying individual decisions, and grasps the perspectives of the others (Edwards et al 2019).

Three short gaming sessions, with different modes of communication among the players, were implemented with the CherIng RPG. This game (described in Appendix S2, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-21-00067.S1) provides a simple and generic setting of the tragedy of the commons. This activity demonstrated the importance of rules and coordination mechanisms among stakeholders in the sustainable management of a renewable resource. Several trainees immediately established the link with the Sheytimi case, although the CherIng model is an abstract and simplified artifact referring implicitly to a resource use conflict situation.

The CherIng conceptual model was modified to replicate the structure of the Sheytimi model (the details are given in Appendix S3, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-21-00067.S1). This model was implemented as an RPG with the trainees. An associated computerized version (cABM) playing the game in silico, coded by the team modeler under the CORMAS simulation platform (Bousquet et al 1998; Le Page et al 2012), was used to calibrate the RPG.

Sheytimi RPG: Table 1 presents the main features of the Sheytimi RPG and Figure 3 shows its components. The virtual grassland of the model is made of 24 plots. The quantity of forage in a plot (0, 2000, 4000, or 6000 units) corresponds to its status (extremely degraded in white; very degraded in light blue; slightly degraded in dark blue; good, ie not degraded, in green). For abstract models not intended to represent reality faithfully but to project into reality, the absolute values of the parameters are of little importance. What matters is that their matching allows users to project meaning into the model. We thus fixed a base unit (1000) as the quantity of fodder that needs to be consumed in 1 round by a head of cattle to reach satiety. By setting the amount of fodder available on plots in perfect condition to 6000, we indicated that the carrying capacity of a plot is 6 animals. The other values (4000, 2000, 0) mean that the carrying capacity is inversely proportional to the level of degradation. As the area of a plot was unspecified, every participant was

FIGURE 2 Key features of the local sociopastoral ecosystem. (A) Landscape at the site; (B) head of the main ravine on Sheytimi pasture; (C) *Brokpa* camp; (D) pasture vegetation; (E) yak; (F) grazing cattle; (G, H) *Brokpa* yak herders. (Photos by Guy Trébuil)

left free to assign a value that fit the participant's own perception. Twelve players (6 *Radips* and 6 *Brokpas*) own 5 heads of yak or cattle each. Each animal can graze a maximum of 1000 units of forage per round of play. The only decision a herder has to make at each time step is choosing the location of the herder's own animals on the virtual grassland. The amount of forage grazed by an animal, which is directly converted to income for its owner, is set to the minimum value between 1000 and the total quantity of forage in a plot divided by the number of animals grazing on it (rounded to the nearest hundred). When this ratio is lower than 1000, the plot is considered as overgrazed and its status downgraded to the preceding level in the next time step. Symmetrically, the status of a nongrazed plot is upgraded to the next level with a probability of 0.5 in the subsequent round of play.

TABLE 1 Features of the Sheytimi RPG.

Features	Characteristics
Participants	6 *Radips* (farmers) and 6 *Brokpas* (herders)
Board	Sheet of paper with a matrix of 4 × 6 = 24 plots. Repositionable colored cards to account for the level of land degradation (status) of plots (bare soil in white, high degradation in light blue, low degradation in dark blue, no degradation in green)
Game set	Paper frames (for fencing to limit access), colored pins (5 yaks or cattle per player), small cardboard replica of the board 4 × 6 matrix (to locate the animals), dry cheese and sweets (to materialize incomes)
Sequence of a round of play	The status of the 24 plots is disclosed, players allocate animals to each plot, location of animals is aggregated, incomes are calculated, status of plots are updated according to grazing pressure
Time steps	1 year per round of play and 5 rounds of play per gaming session

FIGURE 3 Components and materials of the Sheytimi RPG. (A) Pins representing grazing animals; (B) player's individual sheet to locate player's 5 animals; (C) game board with animals and fenced plots; (D) dry cheese = BTN 2000 (US$ 24); (E) chewing gum = BTN 200 (US$ 2.40). (Photos by Guy Trébuil)

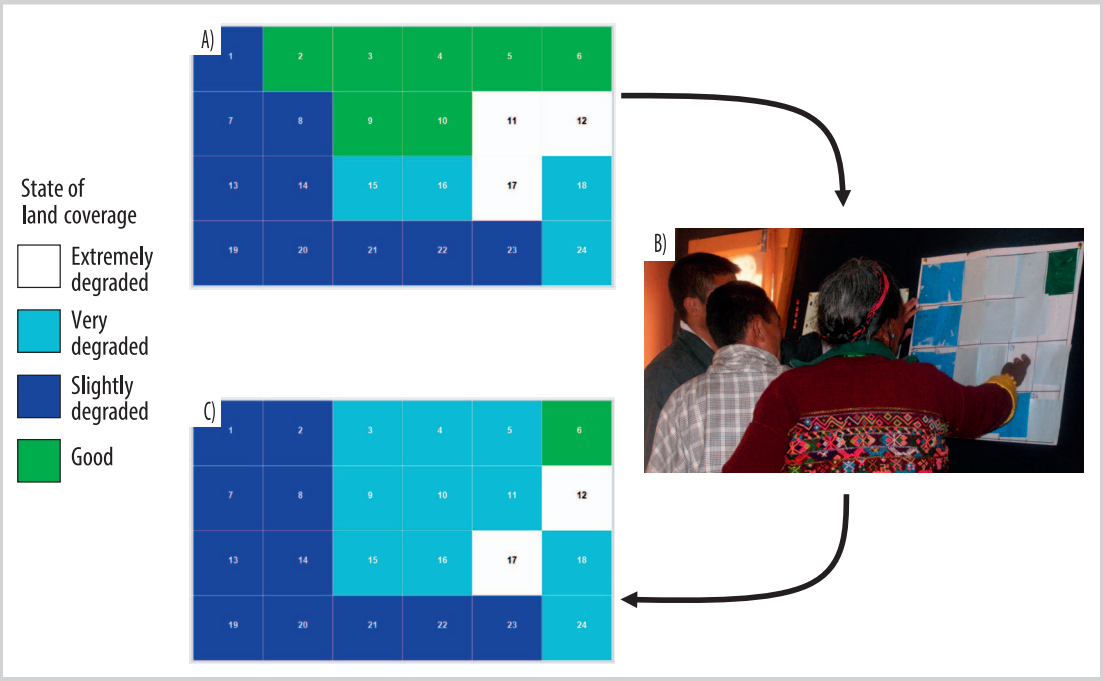
An RPG round of play, including exchanges among players (described in more detail below), takes about 30 minutes to complete, and the duration of a gaming session does not exceed 3 hours to avoid player fatigue. During RPG sessions, the role of the computer is secondary but helps to save time and therefore maintain a lively atmosphere. In each round of play, the game manager registers the players' decisions indicated on the small cardboard replica of the RPG board, where 5 colored pins indicate the location of their animals (Figure 3), and then calculates the players' incomes. On completion of this task, the process of degradation or rehabilitation of each plot is activated and the computer interface displays the new spatial distribution of the 4 levels of land degradation among the 24 plots. The game board is updated manually before launching the next round of play. The complementary use of the autonomous cABM tool playing the game in silico is also useful to display the evolution of agro-ecological (change in the state of the resource) and socioeconomic (income distribution) indicators over a session to feed the subsequent plenary discussion. The cABM's ability to replay the sessions step-by-step also supports an in-depth analysis of players' decisions and stimulates comments and exchanges during the final debriefing.

Gaming and simulation workshop: The main activities of the workshop were 3 successive gaming and simulation sessions played with different modes of communication. Fencing for pasture regeneration and rotational grazing was a technical option introduced in the second session. The fencing option was mentioned in the preliminary field study before the workshop and introduced at the request of the participants, who, based on their long experience with this technique, considered that "good fences are key to sustainable pasture management" in this area (Wangdi and Norbu 2018). These border structures used to be built to ensure social harmony by reducing conflicts due to livestock trespassing. The sessions proceeded as follows.

Day 1: Workshop presentation and outdoor ice-breaking game to set a playful atmosphere encouraging contact among the participants. The ethnographic field study found that contact between the 2 herder communities had been loose in recent past. A brief presentation of the Sheytimi RPG features and rules by the facilitator was followed by a mock session. There was discussion on the improvement of the RPG and its underlying model.

Day 2: A first business-as-usual gaming session was held with *Radips* and *Brokpas* playing separately. There was free communication at the group level. This was also considered a cautious initial step because of the existing animosity between the 2 groups of herders found in the preliminary field study. In a second gaming session, *Radips* and *Brokpas* played separately again but could fence plots by positioning pink cardboard frames on the board (see Figure 3). Finally, in a third session, the 12 participants managed the board together and could fence plots (Appendix S4, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-21-00067.S1).

FIGURE 4 Modification of the game board: an initial version (A) was jointly modified by the *Radips* and *Brokpas* (B) at the beginning of the workshop to produce an updated version (C). (Photo by Guy Trébuil)



Day 3: A plenary presentation and discussion of the results of the simulated scenarios was held, including replay of a session using the cABM tool. After that, individual interviews were conducted with the participants.

The expectations of the facilitating team were to (1) better understand how and why herders make their grazing decisions and what internal and external factors influence them, (2) observe the rangeland use system emerging from the collective management of the board and its consequences for land degradation and income distribution, and (3) identify suitable entry points for interventions to improve the system.

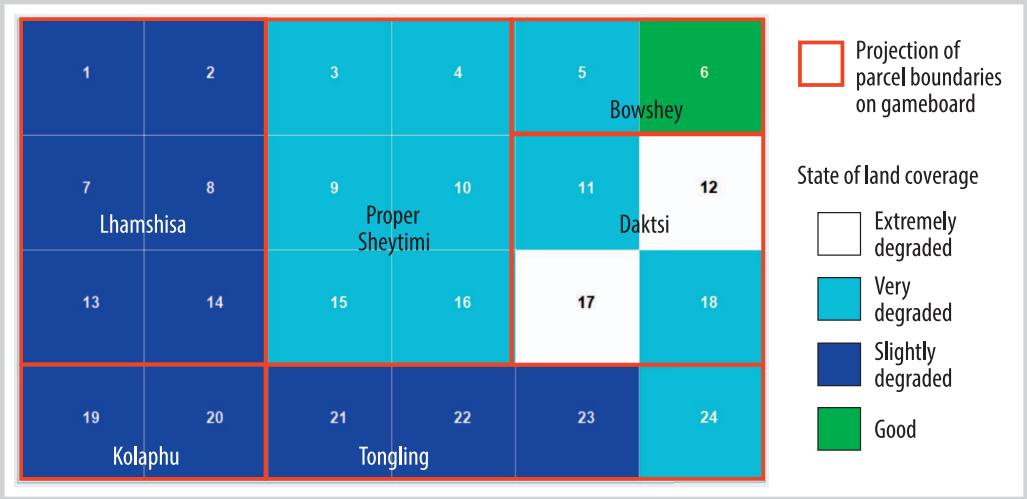
Assessment methodology: Individual interviews of the 12 participants were conducted at the end of the workshop to assess its activities, their effects, and the artifacts used (interview guidelines are given in Appendix S5, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-21-00067.S1). Topics such as the effectiveness of the workshop regarding communication, sharing of viewpoints, progress toward a common understanding of the overgrazing problem, and the emergence of new perspectives regarding promising innovations to foster the regeneration of the rangeland were covered. The outcomes of the ComMod activities were also assessed by a student observer in the training and field workshops. The student observer also carried out an ethnographic analysis of the situation over 3 weeks prior to the intervention and an ex post evaluation during the 3 weeks following its completion. This field study characterized each group of herders (*Radip* or *Brokpa*, holding certificates allowing them to graze at Sheytimi grassland or not), their past and current relations (exchanges, barter system), and specific interests and perspectives regarding rangeland management (access, livestock population, expectations from joint negotiation, and desirable outcomes).

Transformative results

Reconfiguration of the game board

The trainees discussed different ways to represent the rangeland spatial heterogeneity on the game board (Figure 4). After the CherIng game was used, an initial version of the board (and cABM spatial interface) was agreed upon to be proposed at the start of the field workshop. During the initial mock session of the RPG, the participants were asked to point to aspects they disliked or found confusing. The high level of abstraction and simplification of the actual grassland circumstances was not rejected by the players, but both parties found that the spatial distribution of the plots had to be improved based on their empirical knowledge. A plenary discussion took place to change the composition and structure of the game board. An influential *Radip* went to the board to modify the facilitator's proposition (Figure 4). Then, a *Brokpa* female leader joined him to suggest the locations of the 4 levels of land degradation among the 24 plots of the game board. Their final joint proposition displayed a more degraded rangeland and was selected as the initial state of the rangeland at the beginning of the 3 gaming sessions. This improved structure of the game board based on the expert knowledge of the herders was inspired by the toponymy of the different parcels of the Sheytimi and their respective land degradation statuses, as shown in Figure 5. During the individual interviews, 90% of the participants declared that the serious game was easy to understand and matched reality. This showed that the herders were taking the activities seriously and were

FIGURE 5 Relationship between the different parts of the rangeland, the level of land degradation, and the structure of the game board designed by herders.



interested in using simulation artifacts they could relate to actual circumstances.

Comparison of scenarios

Three successive gaming sessions explored the social (mode of communication) and agrotechnical (grazing pressure, fencing) dimensions. The details of players' decisions and the evolution of the rangeland degradation over successive rounds of play for the 3 scenarios are displayed in Figure 6. Key indicators of socioeconomic (average income of each player) and environmental (state of land degradation and forage availability) dynamics were used to assess the results. In the first benchmark session, high grazing pressure caused extreme degradation on all the plots by round 5. In the second and third sessions, the players fenced several plots in each round to facilitate forage regeneration and limit land degradation. In each session, both groups of herders made joint decisions on fencing the most degraded plots and referred to what was done in reality and found in the preliminary field study. The introduction of plot fencing in the second session reduced the speed of land degradation and declining forage production. This positive effect was accentuated in the third session when the collective mode of communication among users was applied and led to more rotational grazing (Figure 7A). Figure 7B shows that the third scenario minimizing land degradation could satisfy the economic needs of each group of herders by providing higher incomes and a more equitable allocation between *Radips* and *Brokpas*.

Improved dialogue and sharing of viewpoints

The RPG sessions simultaneously promoted intercommunity exchanges among initially unreceptive *Brokpa* participants (members of the organizing team had to travel to their camp again just before the workshop to secure their participation) and were able to control a proactive *Radip* participant. This promoted a balanced communication pattern, a necessary initial step toward the mitigation of their conflict. Because of the sensitivity of the subject, there was a risk that the participants might reach deadlock due to controversial comments or unexpected actions, but this did not happen. On the contrary, observers noticed that exchanges between the 2 groups of herders continued in the evenings beyond the formal workshop activities, and 60% of them declared that setting this workshop at the Radi extension office was an appropriate choice of location. The nonconfrontational and inclusive serious gaming platform provided opportunity for free exchange of opinions while minimizing asymmetry of oral communication and language barriers.

Awareness and understanding of the problem: individual and collective learning

The results of the first session provided insights on the problem, the second stimulated exchange on a possible technical management option, and the third demonstrated the importance of joint management of the rangeland. This last session was preferred by 50% of the respondents. Around 25% found the 3 sessions equally useful to improve their understanding of the situation and acquire new knowledge on alternative practices such as rotational grazing and collective management. Most of the participants found the fencing option innovative, realistic, and useful to sustain the forage resource base. The enhanced shared awareness of the problem and discovery of ways to improve the situation promptly initiated the development of social capital among the workshop attendees ahead of the initiation of important development-oriented landscape restoration interventions in the watershed (Wangchuk et al 2009; UNDP 2013; Millar and Tenzing 2021).

Engagement and collective action

All participants agreed on the urgent need to improve grazing land management and proposed or reiterated 4 possible collective actions in the final debate as follows: (1) protect degraded areas, with 15 herders (9 *Brokpas* and 6 *Radips*) ready to protect the Daktshi area in Chongdiri subcatchment; (2) search for adaptive practices (like rotational grazing and paddocks) to avoid further land degradation; (3) stabilize river banks (with bamboo plantations and breast walls); and (4) adopt improved breeds to reduce the livestock population.

FIGURE 6 Details of herders' decisions and evolution of the rangeland degradation over successive rounds of play for the 3 scenarios.

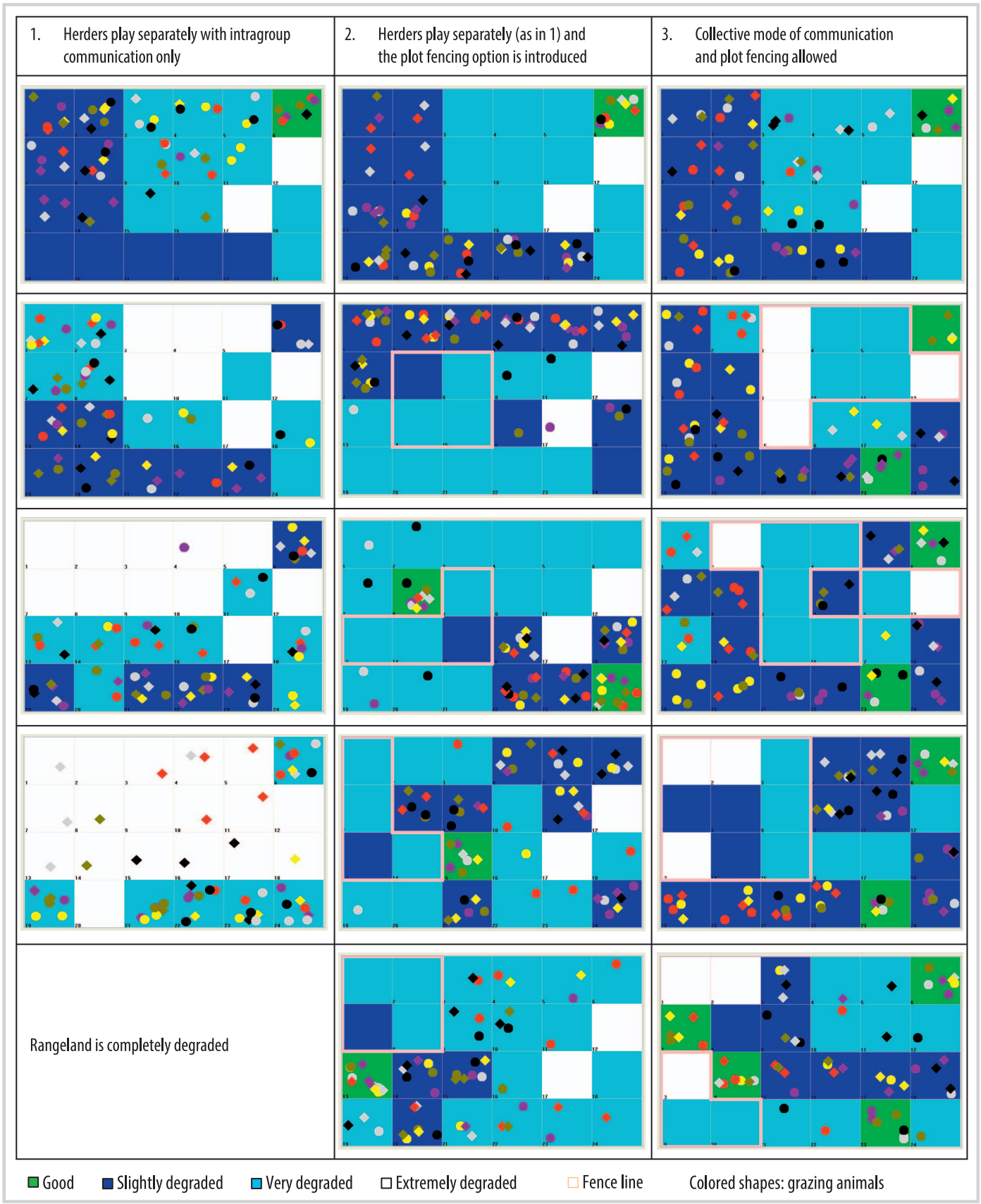
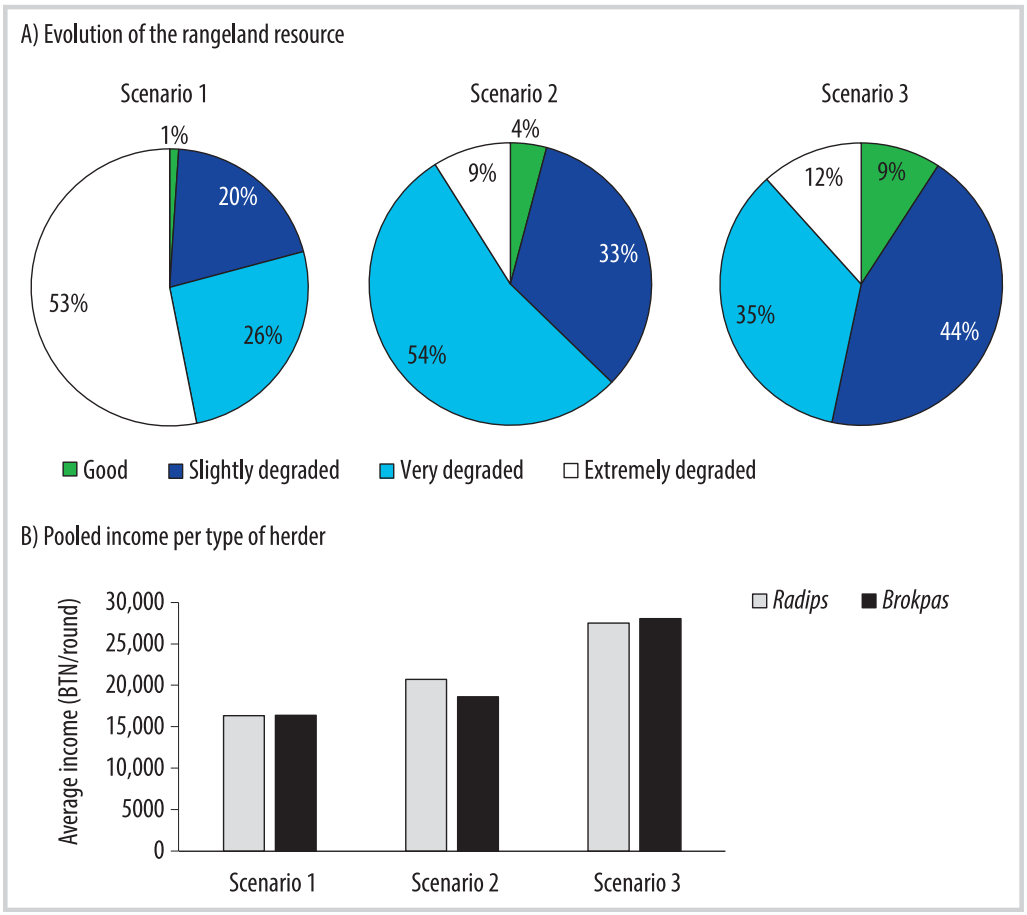


FIGURE 7 Aggregated environmental and economic results for the 3 scenarios. (A) Evolution of the rangeland resource; (B) pooled income per type of herder. BTN 1 = US$ 0.012.



Lessons learned

Enabling factors and opportunities

Access to grazing land is of paramount importance to all herders; the focus on this helped to mobilize the participants. The integration of local understanding and expert insight of the context into the simulation tools added to the interactive engagement of participants. Being able to rely on a local facilitator was also crucial, as it can be tricky to make implicit viewpoints explicit to all the participants while maintaining a playful atmosphere. The use of local artifacts and terms in the RPG enhanced its simplicity of use. The opportunity for the participants to modify the board facilitated the engagement of reluctant herders and promoted ownership of its outcomes.

This case confirmed the usefulness of simple disposable abstract models, codesigned with their users, to mitigate tensions (Le Page and Perrotton 2017). A suitable level of abstraction establishes a distance from the issue and interpersonal tensions. It is commonly assumed that abstraction is best suited for scientists and that involving local stakeholders in a modeling process requires the design of realistic representations. But, in spite of the distance to the complex actual conflicting circumstances, the main interactions represented in the Sheytimi model were sufficient to make sense and motivate the herders to use it. Ninety percent of the respondents confirmed that they could relate the game board to their livestock rearing practices. As a participant declared: "It seems we knew everything—from centuries living here, but the game exposed us to what we did not—collectively we can sustain the resource and enhance our livelihood."

As the extent of involvement and constructive interactions increased over the field workshop, there was an improvement of the mutual trust among stakeholders. This permitted the organization and smooth implementation of the final third collective gaming session with disclosure of local strategies in real-life situations and unrestricted knowledge sharing among the 12 herders. This is important, as the degree of trust among individual participants influences long-term interdependence in situations of social dilemmas, higher levels of trust resulting in increased cooperation among stakeholders (Chaudhuri et al 2002; Millar and Tenzing 2021).

Challenges and problems encountered

Forty-two percent of the respondents suggested pursuing the process and increasing its legitimacy by inviting local leaders to participate in future sessions. Their involvement was needed to develop actionable collective rangeland management. Involving observers had definite benefits to legitimizing the process. Building their role could have fostered a stronger contribution, especially in relation to the landscape restoration projects under preparation in this watershed. A working link of such activities to administrative

and legal proceedings is crucial for outcomes to be translated into subsequent land management decisions.

This short intervention had a modest objective. Because of the complexity of the conflict, one could not expect a lasting impact on the search for a solution, but it succeeded in establishing a dialogue between the main parties. More time would have been needed for a longer critical analysis within each group of herders to reach clues to a more concrete strategy for improved land management.

Discussion and way forward

In critical situations where past public interventions to resolve conflicting situations have failed, community members have reservations about achieving tangible outcomes from new involvements. Such initial pessimism was a challenge for this action research intervention to bring together stakeholders engaged in an enduring land use conflict. The intervention succeeded in establishing a communication channel between the 2 parties and bringing their insights to a common level of understanding. The ComMod process facilitated the joint assessment of a technical option and the emergence of a collective rangeland management strategy. Colearning among the participants was facilitated by gaming tools used as boundary objects to enhance knowledge sharing in a companionship environment conducive to mutual trust. In similar but longer processes, transformative knowledge has been produced leading to socially acceptable concrete strategies and practical collective measures to move toward desirable situations (Gurung et al 2006). A more ambitious and longer ComMod process would have further involved the Sheytimi pastoralists in planning and decision-making processes to reach a socially and environmentally acceptable user rights arrangement. Tenzing (2017b) underlines that this is still the way forward: "Fostering tenure security through mechanisms such as demarcation and fencing of rangeland boundaries, granting clear property and ownership rights and written group constitution and bylaws that build on traditional collective action are needed to reduce conflicts."

This intervention also demonstrated the usefulness of an abstract simple model and its implementation as a role-playing tool to break the ice between stakeholders a priori not prepared to manipulate such stylized representations of their landscape and animal-rearing practices. The herders adapted this boundary object by mobilizing their Indigenous knowledge to make it more relevant and used it seriously during successive gaming sessions. The simple conceptual model, representing what matters, without undue complexity, could easily be modified to make it relevant in other mountain regions facing similar situations. The use of a cABM simulation tool is not compulsory, as demonstrated by fruitful past case studies relying on RPG tools only (Boissau et al 2004; Gurung et al 2006). However, the ability of cABM tools to rapidly replay long gaming sessions is useful to upscale the outcomes by sharing what happened in field workshops with decision makers. Blending the existing policies and governance environment with local management options during the formalization of coherent scenarios is an appropriate way to promote impacts at multiple spatial levels while boosting the legitimacy of collaborative modeling and simulation processes.

Past applications of the ComMod approach in Asia (Gurung 2006; Barnaud et al 2010) demonstrated its ability to balance local power relationships and provide more inclusive and level playing fields for negotiation. Raising awareness, confidence, and trust in emerging social networks and communication platforms helps to mainstream the disadvantaged section of society. The outcomes of this and other ComMod case studies in mountain areas have shown that this collaborative simulation approach could respond effectively to the urgent need for practice-oriented and transdisciplinary knowledge systems to deal with the complexity of current renewable resource management problems in times of accelerated global change.

ACKNOWLEDGMENTS

The authors thank the Council for RNR Research of Bhutan, Ministry of Agriculture and Forests, for supporting this research and allowing the team to undertake this training and fieldwork, and the College of Natural Resources in Lobeysa for allowing the training of field staff on its campus.

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Supplemental material

APPENDIX S1 History of the Sheytimi rangeland conflict and past unsuccessful interventions.
APPENDIX S2 Description of the CherIng generic RPG.
APPENDIX S3 Structure of the Sheytimi conceptual model.
APPENDIX S4 Gaming sessions in action at Radi site.
APPENDIX S5 Guidelines for the individual interview of the participants in the Sheytimi gaming sessions held at Radi Block Office.

Found at: https://doi.org/10.1659/MRD-JOURNAL-D-21-00067.S1.