Empowering Communities: power devolution in Community-Based Natural Resource Management

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ABSTRACT

Community-based Natural Resource Management is considered a democratic approach for the management of ecosystems through the development and empowerment of local communities. However, results of such initiatives have been somewhat ambivalent. One identified consideration has been on the optimal devolution of power for CBNRM programs to the communities they pertain to. In this paper, we present a System Dynamics model aiming to explore the issue of power devolution in CBNRM initiatives and how it leads to variations in their success rate. Our model was able to exhibit that communities do benefit from higher levels of power over the initiatives, although the level of coherence of the community emerges as a major factor influencing the optimal level of management at the communal level. Moreover, the "timing" when the power transference takes place is also significant: if power is transferred quickly from external actors to the community, the initiative may suffer due to the lack of proper capital formation. The interplay between target levels of power in the community and devolution timing is significant: higher target devolution benefits from slower, more adaptive forms of transference while lower target devolution benefits most from faster transference of power by external actors to the communities.

Background

Community-based Natural Resource Management (CBNRM) focuses on the collective management of ecosystems in a way which promotes their better government, while also improving human well-being. This type of management aims to devolve authority for ecosystem management to the local (community) level, thereby empowering communities to manage their own resources without permanently damaging, depleting or degrading them (Fabricius & Collins, 2007). CBNRM is considered an affirmative initiative towards management of natural resources due to its numerous benefits: it promotes conservation through the sustainable use of natural resources, enables communities to generate income and develop more secure livelihoods, and promotes community development and creation of local institutions (Fabricius, 2009). CBNRM aims at achieving these benefits through a bottom-up participatory approach based on a number of principles that

> *include putting resources under local control rather than the control of the state government, obtaining equal delivery and apportionment of socio-economic benefits and resources, and commitment involving members of community and the local institutions in managing and conserving natural resources*
>
> (Milupi, Somers, & Ferguson, 2017, p. 1121).

Indeed, one of the main objectives of CBNRM initiatives is transferring power and ownership to the communities (Shackleton, Campbell, Wollenberg, & Edmunds, 2002) which are the focal points and main implementors as well as beneficiaries of such projects through the use of natural resource under management. Power is here operationalized as "control of decision-making, control of the benefits and expenditures of the CBNRM program, distribution of responsibilities, jobs and contracts, better overall status for the community, etc" (Jones & Mosimane, 2000, p. 82) or "power to control access to resources (natural resources, human resources, information, funding)" (Rozemeijera & van der Jagt, 2000, p. 10).

Despite its inherent benefits targeted at the local level, CBNRM has come under strong criticism for failing to deliver real benefits to communities and for a high incidence of such initiatives' collapse (Fabricius, 2004; Fabricius & Collins, 2007). In several cases, specifically wildlife management programs, CBNRM failure was attributed to uneven distribution of the benefits of natural resources, lack of empowerment, low community participation and failure to resolve conflicts (Milupi et al., 2017). These micro-reasons for failure collectively represent an issue of governance of such community-based programs. Hence, governance is identified as one of the key drivers for success in CBNRM (Fabricius & Collins, 2007).

Problem Identification

CBNRM programs are grounded on the availability, development and deployment of different forms of capital, which have been identified in the literature as significant assets at the community level. Broadly, studies in CBNRM argue the need for five forms of capital: Natural Capital (ecosystem goods and services); Social Capital (social and kinship networks and reciprocity, as well as existing or emergent social institutions); Human Capital (skills, knowledge and labour force); Physical Capital (infrastructure and services) and Financial Capital (monetary funds or other financial assets) at the midst of CBNRM initiatives (Pretty, 1999, pp. 2–3 in Cuthill, 2003, p. 374). Some forms of capital are commonly available at the initiation stage of a CBNRM project, for example natural capital representing the natural resource the initiative aims to preserve and manage. Other forms of capital, such as human and social capital, despite being usually available in the target communities, still needs to be carefully developed and deployed. The "harder" types of capital, physical and financial capital, are not usually available at the time of the inception and thus need to be collected and deployed over longer periods of time. Therefore, without of course neglecting social and natural capital, an organic development of these harder types of capital is considered imperative for the successful execution of CBNRM programs, as insufficient improvement is likely to shock the CBNRM initiative resulting in immediate failure even after long period of investment, both in financial terms and as time.

The mere availability of capital is of vital importance, but studies propose the need for greater consideration of the nature of these forms capital and of the ways they interrelate at several phases in CBNRM programs (Berkes, 2004). In their synthesis of CBNRM, Kellert, Mehta, Ebbin, and Lichtenfeld (2000) discuss that a main and consistently observed obstacle has been an inability to control and monitor the behavior of complex organization that inherent the bureaucratic and localized operational structure for the governance of typical forms of capital while the goal necessitates for a structural shift. Governance has been indeed identified to play an important role both as a buffer and a catalyst for the inception, implementation and execution of CBNRM programs. Measham and Lambasi (2013) for example, observed that failure of such initiatives is linked with poor governance as well as with improper power devolution: communities with higher level of ownership tend to have more effective CBNRM programs. Similarly, it has been observed that in cases where there is little community involvement in planning or decision-making, where the benefits are not distributed to the community, and where ownership of the resources of the CBNRM program, people do not identify with or, in some cases, care to understand the purpose of the initiatives, and the overall development of the programs fails (Johnson, 1999; Shackleton & Campbell, 2001; Sibanda, 2004). This report intends to study mainly power devolution - a key component of governance, distribution of the benefits of natural resources, and community participation as the building block for successful CBNRM program.

Based on the above evidence from the history of CBNRM programs, the following research objectives were developed for this study

a. To identify how the balance of power and its devolution from state to community, or vice versa, affect the formation of the different capitals required for CBNRM for communities with different characteristics.
b. To examine the interplay of power devolution and capital formation on the acknowledgement, implementation and wellbeing of the community
c. To identify how the decision rule regarding the point in the projects timeline when external actors / facilitators transfer the power to community can influence the success of CBNRM.

Dynamic Hypothesis

As mentioned, CBNRM by its nature follows a project implementation dimension that is governed by the availability and synergy among different forms of capitals that drive the acknowledgement, implementation and realization of CBNRM activities. The five different forms of capital (natural, social, human, physical, and financial) crucial for CBNRM initiatives lead to desirable realised benefits that feed back to help further build those types of capital (Pretty, 1999, pp. 2–3). Therefore, this model undertakes the process of formation and depletion of these capitals as a primary determinant for CBNRM policy success.

We disaggregated the more general term human capital into Knowledge Capital and Human Capital separately as their effect is evident both in isolation and inclusion. Human Capital, as participation of community members, represents the fraction of the population which is actively involved in the CBNRM initiative either directly (through labour or participation in management) or indirectly (through adopting the initiative's activities), and depends on the degree of coherence in the community. Smaller or more homogeneous communities have better chances for success in CBNRM initiatives (Rosie Cooney, Roe, Dublin, & Booker, n.d., p. 25) while diverse communities "often take longer to reach consensus, tend to develop weak social cohesion and leadership, and may lack community spirit" (Thakadu, 2005, p. 209). Knowledge Capital, on the other hand refers to the accumulation of knowledge capacity inside the community in relationship to the CBNRM project. Such knowledge can represent:

a. Understanding of the potential of the CBNRM project, its strengths and weaknesses, and its relevance to the wellbeing of the community and individuals
b. Technical knowledge and skills pertaining to the specific project
c. Management capacity
d. Building of institutions and decision-making processes for the CBNRM project, etc.

Financial capital in represented as *Physical Capital* due to the fact that financial forms of capital, in their absolute forms, are less significant compared to their physical form; moreover, financial capital must be transformed into physical capital for the implementation of CBNRM policy (Carney, 1998; Cuthill, 2003; Pretty, 1999). Natural Capital is represented as a stock of Natural Resources as the main target(s) of the CBNRM initiative. All these forms of capital complement different stages of CBNRM initiative and contribute with different level of importance/weight to the capital coverage necessary for the implementation of CBNRM activities and the realization of benefits for their participants.

As identified before, the level of *Power Inside the Community* is a main driver for CBNRM initiative and, hence, for the structure under consideration. Power can represent "control of decision-making, control of the benefits and expenditures of the CBNRM program, distribution of responsibilities, jobs and contracts, better overall status for the community, etc" (Jones & Mosimane, 2000, p. 82) or "power to control access to resources (natural resources, human resources, information, funding)" (Rozemeijera & van der Jagt, 2000, p. 10). Lower levels of power to the community can lead to "apathy and disillusionment" (Johnson, 1999, p. 219; see also Johnson, 1999; Shackleton & Campbell, 2001; Sibanda, 2004) of the local population: that can be translated to lower levels of *communal commitment*. Communal Commitment describes the degree of willingness of the members of the community to inherent the idea of a CBNRM initiative and to contribute. Peoples' commitment is driven not only by the level of power, but mainly by the *realized benefits* of the policy (see, for example Murphree, 1991; Rihoy, 1992) and/or the hope of development for the betterment of community as a whole.

Regarding the timing of power transference from external actors to the community, decisions can be made according to fixed time-plans of the project's implementation at early stages of the project. Significant delays, however, can lead to such actors leaving the communities before capacity has been built (Rozemeijera & van der Jagt, 2000). A mechanism by which the levels of Human, Knowledge, and Physical capital are monitored, and external actors adjust the time to transfer the power to the community is explored. hereby referred to as the "adaptive transfer of power" mechanism.

Lastly, in the model we also considered the resistance to the initiative by members of the community who do not participate in it. Our assumption here is that, members who do not feel committed to the initiative will try to benefit from the resource in the, often unsustainable, ways they have done so in the past, creating some resistance/counteracting some of the benefits of the initiative.

Methodology and framework

To explore the devolution dynamics in CBNRM projects, a System Dynamics model was developed in line with our dynamic hypothesis. The aim for this model is to explore the above hypotheses on the critical points relating to the devolution of power in communities engaging with CBNRM projects and not to explore a case with specific characteristics As such, most parameters in the model are in fractional terms and should be properly estimated according to specific cases the model is used for. The parameters used in this model are estimated based on the literature and a detailed analysis can be found in the model documentation (see model file in supplementary material). Further development of the model will need to include calibrated data of various projects to ensure the validity of the produced behavior and the underlying structure. For now, we hope this model can act as a "blank canvas" for data to be later introduced.

Some of the main assumptions of our model are the following:

- External facilitators are assumed to be willing to invest maximally at the building of necessary physical capital, without consideration of the actual success or benefits derived from the project. Likewise, limitations of facilitators on time and money required to transmit knowledge to the community are not explicitly considered. [In many ways, our model represents an "optimal scenario"]
- The actual benefits of the CBNRM initiative, in monetary terms, are not represented in the model. The assumption of benefits from sustainable and unsustainable use of the natural resource is a bold one.
- The decision by the community to reinvest the financial benefits of the initiative for the formation of further Physical Capital has been anchored to the level of Knowledge Capital. While this might be a generous assumption, the level or understanding of the potential of the CBNRM initiative and the long-term value of preservation of the available Natural Resources is expected to have a significant influence in the financial decisions the community takes.
- The capital coverage is operationalized as different combination of capital assigned with different weights. This capital coverage is a key driver of CBNRM activities as its changes with formation of capital with time.

Model Validation

Following some of the tests proposed by Yaman Barlas (eg. Barlas, 1989; Barlas & Kanar, 2000)

a) Structure Confirmation: Based on the literature cited above, the described structure above was developed. While one can argue that more causal links and feedback loops could be present, we find this structure to be descriptive of the processes we aimed to represent.

b) Parameter Confirmation The parameters used in this model are estimated based on the literature and a detailed analysis can be found in the model documentation (see model file in supplementary material). Most parameters in the model are fractional and should be properly estimated according to specific cases the model is used for.

c) Dimensional Consistency: The model exhibits dimensional consistency without the addition of parameters that do not have real-world meaning.

d) Extreme conditions and Sensitivity Tests: The tests performed make us in generally confident in our model. There was limited sensitivity to parameters other than those identified as significant for scenario testing (Community

Coherence, Degree of Initiative by the Community, and Target Power in the Community). Some, relatively limited sensitivity to parameter values around the Knowledge Capital Stock (adjustment time for knowledge acquisition, normal time of knowledge retention, and resistance factor for knowledge acquisition) were observed. The nonlinear effects of legal and moral consent on the acknowledgement rate of the CBNRM program's acknowledgment rate also exhibit some sensitivity and should be better defined at later iterations.

For ease, the main structure of the model will be here presented through a causal loop diagram (CLD) accompanied by an analysis of the main feedback loops present in the system. For the full model overview, see appendix A and supplementary material. The reader can also find the full model documentation at appendix C.

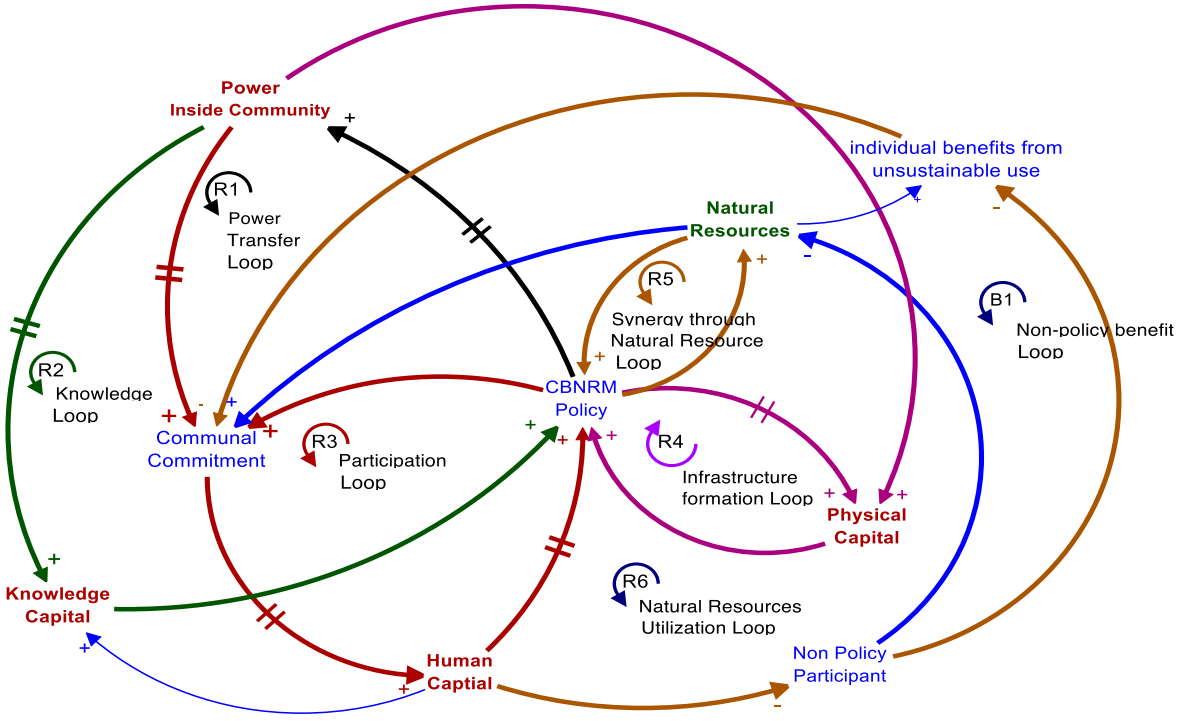

Figure 1: Causal loop diagram-Devolution Dynamics

	Name	*Description*
R1	Power transfer loop *active when adaptive transference of power is chosen*	As Power inside the community increases, Communal commitment, Knowledge gain and the overall success of the initiative increases, all of which in turn expedite CBNRM policy implementation. This loop is reinforcing in nature with substantial delays (in the transformation of communal commitment into human participation and in the building of the capitals). The decision delays in the time to transfer power are dependent on the rate of increase in capital coverage. This loop, thus, determines the effectiveness of adaptive power transfer influenced by delays in capital accumulation process
R2	Knowledge loop	This loop governs the formation of Knowledge Capital in this system. Knowledge can be gained faster from external actors when the power resides mainly outside the community but, at higher levels of power inside the community, participation in and monitoring of the project lead to direct knowledge gain, albeit at a slower pace. As Knowledge Capital increases, the overall capital coverage increases, and this results in faster implementation of CBNRM project and consequently quicker transfer of power to the community (when this transfer is adaptive).
R3	Participation loop	Human Capital participation influences the implementation rate and hence the success of the program through increasing the overall capital coverage. Delays exist in the effect of the realized benefits from the initiative's success on the change in commitment and in the actual conversion of commitment into participation. Initially, human capital participation through benefits realization increases slowly resulting in much slower decline in non-policy participation and persisting decline in natural resources but when this loop kicks in the process reverses and community programs become more effective

		As in R1 and R2 loops, higher coverage results in quicker transfer of power (when this transfer is adaptive) and higher claim on benefits from the policy, further reinforcing human capital participation.
R4	Infrastructure formation loop	This loop governs the formation of Physical Capital. This type of capital can increase through investments by external actors or re-investment of some of the programs benefits by the community itself. When the power mainly resides outside the community, capital contribution from external actors is faster but the benefits of the program are realized much slower by the community (due to the power being mainly on external actors). In this sense, external actors will continue investing to maintain the desired levels of physical capital. When power inside the community increases, the realized benefits from the policy implementation increase and so does available investment for physical capital. Increased physical capital reinforces the program's success rate leading to further investments by the community for the formation of physical capital, of course with some significant delays Since, increased physical capital from any source increases capital coverage, policy implementation is faster but as benefits for the community is restrained by the power inside the community, human capital participation is not at is optimal deferring the benefits in terms of natural resources
R5	Synergy through Natural Resources	This loop governs the shift in the commitment level of the community through the realisation of benefits arising from the success rate of the policy. R1, R2, R3 and R4 collectively determine the policy success and this loop specifically, interplays with the human capital participation loop to reinforce commitment through benefits realization from improved natural resources, policy benefits and power devolution.
B1	Non policy benefits	This loop drives the benefits from the utilization of natural resources realized by the non-policy participants - i.e. high numbers of non-policy participants decrease the natural resources through unsustainable use. This "sabotages" the success rate of the policy and the benefits of the participants, further effecting the commitment in the community and eventually leading to lower numbers of policy participants the next time around.
R1	Natural resources utilization loop	This is a balancing loop that controls the human capital and trades off the effect of R1 to R5 loop based on the time to transfer power and build commitment. Initially, when power outside the community is high, this loop dominates the utilization of natural resources depicting a worse off position for policy participation and sustainability of natural resources. However, when R1 to R5 loops get strengthen with time delay this balancing loop helps to maintain the natural resource at certain level. The depletion of natural resource and the level it settles mainly depends on the time to transfer power to the community for different characteristic of the community collectively controlled by B1 loop with interplay with other reinforcing

Table 1: Major loops

Analysis

In this section, different scenarios will be presented along two dimensions of characteristics of the community and the initiative. For a detailed description of the parameter values for the scenarios, see Appendix B.

- *Community Coherence:* the degree of social coherence in communities. The coherence of the community is expected to be a significant factor differentiating results of different power devolution strategies as it is assumed to lead to higher moral consent for the initiative within the community, as well as higher engagement and human capital participation.
- *Initiative by community:* the degree to which the CBNRM project has emerged from interactions inside the community with no external facilitation (bottom-up). The level of initiation by the community is also hypothesised to be a significant differentiator as it represents different levels of initial power inside and outside the community and directly influences commitment and engagement of the community members. It is important to note here that we keep the details of community initiation outside our model boundary at this stage and rather assume that, if the community itself acts as the initiator, there will be sufficient agreement among the members / actors within the community as to lead to higher engagement and higher probability of participation.

The key indicator for the overall success of the CBNRM initiative is measured by a Wellbeing Index. A community's wellbeing is "the combination of social, economic, environmental, cultural, and political conditions identified by individuals and their communities as essential for them to flourish and fulfil their potential" (Wiseman & Brasher, 2008, p. 358). Environmental components are also of high importance, as natural resources and changes in ecosystems have significant consequences for human wellbeing (WHO, 2005). Participation and inclusion of communities in decision making and governance are increasingly thought of as central concepts for wellbeing (for a discussion, see Cuthill, 2003). In this index, following Pretty's framework (1999), we take into account all capitals represented in our model (Knowledge, Physical, Human, Natural), the benefits from the initiative, and the Power in the community -a measure of inclusion in and ownership of the decision making process and benefits associated with a CBNRM initiative.

Baseline Scenario: average community coherence and common initiative

To present the main dynamics of the system, a scenario of a community with average levels of coherence, and an CBNRM project initiated equally from the community and the government is considered. We will particularly see the dynamics under different decisions about the devolution of power to the community: from a decision where the community maintains 50% of the power over the initiative to a decision of absolute devolution, or 100% transference of the power to the community.

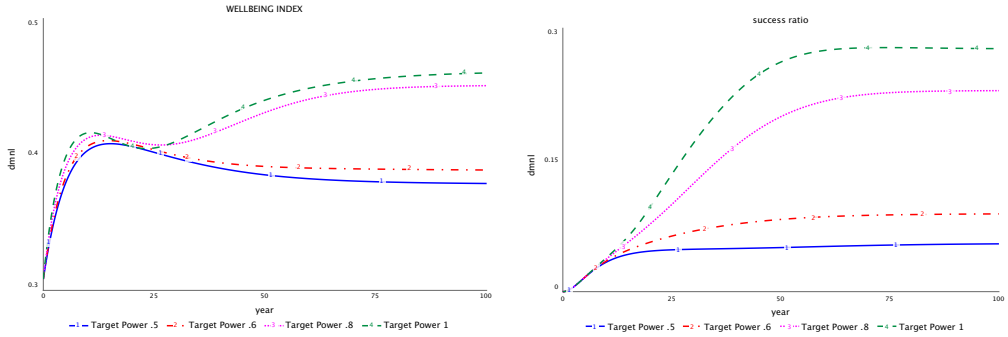

Figure 2: Wellbeing Index and Success ratio for Baseline Scenario

As we can see in figure 2, the overall wellbeing of the community presents a much better image at higher levels of power devolution. The latter lead to an increased willingness for actual participation in the initiative (Human Capital) by the members of the community. Higher participation increases the probability of overall success of the policy, leading to more benefits for the participants, and hence even more participation next time around (the reinforcing *Participation* loop). As more people decide to participate in the CBNRM initiative, the harm to the natural resource by the non-participants decreases and, with the additional positive effect of the initiative's success on the natural resource, the latter stops being depleted at the same rate *(Natural Resources Utilization Loop*). Knowledge and Physical Capital do suffer to some extend at higher values of power inside the community due to the absence of external actors which are able to invest more in Physical capital and transmit knowledge faster. However, the increases in human capital in combination with the higher authority (power) of the community to monitor their activities and learn from their experience, leads the Knowledge capital to start increasing after some years of the initiative's process (*Knowledge* reinforcing loop). Knowledge combined with the benefits acquired from the implementation of the program can be then transformed to Physical capital (*Infrastructure formation* Loop).

Both the higher willingness for participation and the increased power in the community lead participants to acknowledge more new activities relating to the program as there is high moral consent among the community members and as the community has higher authority to fight to achieve legal consent. The building of these different forms of capitals lead to higher probabilities of success for these activities, which further increases the willingness of the community to participate

Adaptive transfer of power to communities.

Our second consideration is whether adaptive rather than fixed transfer of power can lead to higher benefits from the CBNRM project. By "adaptive transfer" we mean the transference of power to the communities based on explicit monitoring of capital formation rather than at some specific, predefined point in the timeline of the initiative.

As seen in figure 3, adaptive transferring of power can increase the overall communal wellbeing, particularly when the desired power in the community is at higher levels (target value of 1, Runs 7 and 8). For low overall values of power in the community, the adaptive mechanism does not give different results. This happens as, when external actors maintain relatively high level of power, transferring the rest of it to the communities adaptively does not lead to significant differences in the formation of knowledge and physical capitals. However, when the goal is to transfer most of the power to community, monitoring the capital coverage to determine when this transference is best to be done definitely helps. For an increase in power of 30% (target power of 0.8, Runs 5 and 6), the decision regarding an adaptive transfer of power produces mixed results. Specifically, the slower withdrawal of external actors, due to the delays in the formation of capitals, have an effect in the willingness and actual participation of the community's population in the project. Similarly, at lower levels of targeted power in the communities, those delays change the optimal balance in the capital formation

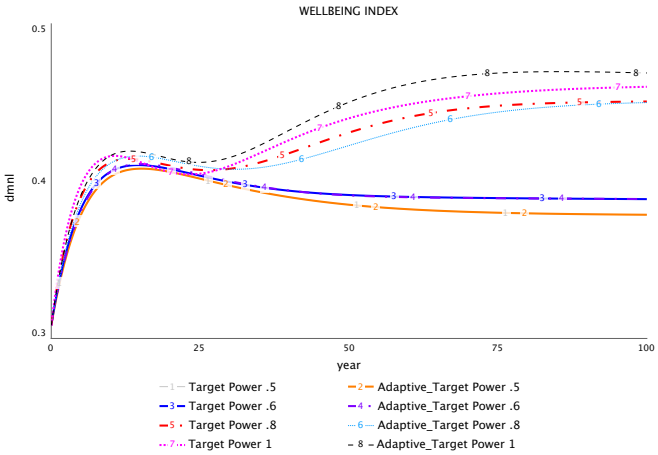

Figure 3: Wellbeing Index for Baseline Scenario with Adaptive transference of power to the community

Lower coherence Scenario

This scenario represents communities with lower level of social coherence. The CBNRM project is also in this scenario assumed to be commonly initiated by the community and external actors.

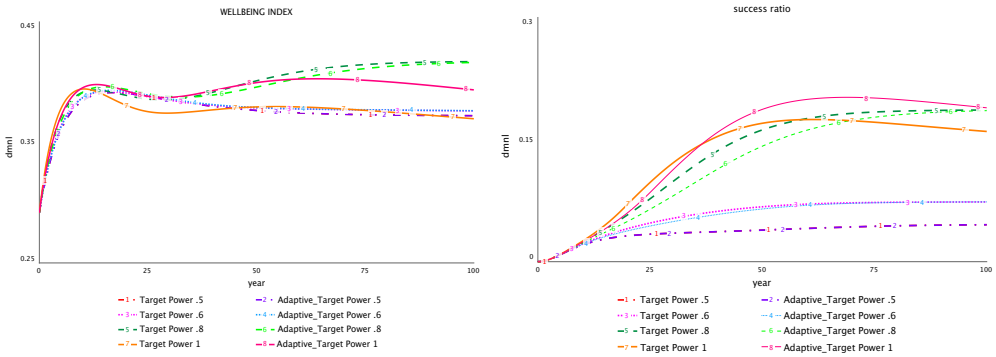

Figure 4: Wellbeing Index and Success ratio for Low Coherence Scenario

As seen in figure 4, in communities with lower coherence, higher levels of power devolution to the community do not give the optimal results. This happens because the participation of the community members (Human Capital) is hindered due to the social tensions or social distance in the community. As the diffusion of information and the networking effect by which actors already involved in the CBNRM project can "recruit" other members of the community is slower, the overall balance between the different forms of capital changes as the reinforcing *Participation* loop is not as strong. These lead to a relatively higher degree of power to external actors to be optimal for the success of the initiative and the wellbeing of the community.

The lower optimal power in the community nullifies the positive effects of the adaptive power transference policy balanced by the effect of non-policy benefit loop, B1. However, the benefits of this policy are still present at the

highest degree of power devolution in the community (100% of the CBNRM program being transferred to the community).

Bottom-Up initiation Scenario

This scenario represents CBNRM initiatives that have been mainly initiated by the community itself (bottom-up). The coherence of the community is, for this scenario, average.

In situations where the community has been the main initiator of the CBNRM program, absolute devolution of power is, again, not leading to the best possible results; however, actors outside the community

are best to maintain a small level of power (approximately 10%) for those initiatives to reach their best potential. While, in this case, the human capital is initially high due to the higher power that the community has over the project as its initiator, the slower building of the physical and knowledge capitals due to the absence of external actors who could invest and transmit knowledge (especially at the initial stages), makes the overall dynamics of the program to oscillate much more at highest levels of power transference to the community and to reach eventually not the optimal values. The benefits of the adaptive transference are, again, nullified due to the less than absolute final power to the community.

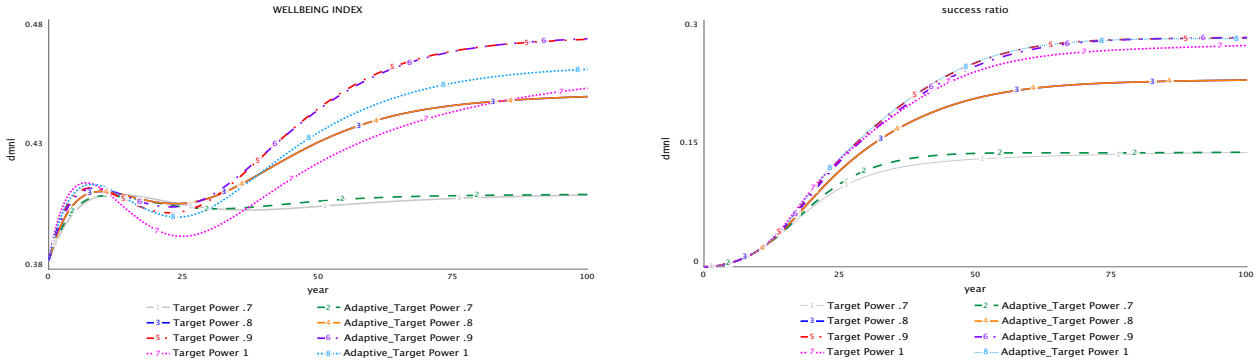

Figure 5: Wellbeing Index and Success ratio for Bottom-Up initiation Scenario

Summary of analyses

Additional scenarios for different values of community coherence and initiator status of the community or external actors have been tested (for a presentation of the parameter values for those different scenarios, see Appendix B). Through the different scenarios we aimed to investigate what is the optimal level of power to be transferred to the community and whether the mechanism of adaptive transference of that power produces better overall results in the success of the CBNRM program and the wellbeing of the community. The summarized optimal results for each of the scenarios are presented in Table 2.

In all cases, communities and CBNRM programs benefit more from higher levels of power devolution to the community. Moreover, in communities with higher social coherence, absolute or almost absolute devolution of power can lead to better success for the program and better overall wellbeing for the members of the community.

In communities with lower levels of social coherence, it is suggested that the communities should optimally control a high degree of power but not an absolute one: a 100% transference of power to the community seems to not be best managed by its members, when those are connected with weaker social ties or where conflicts prevail. Specific programs or consideration needs to be given to the building of coherence amongst the different actors in the community before absolute power over the initiative can be transferred.

	Low Communal Coherence	**Average** Communal Coherence	**High** Communal Coherence	
Low Initiative by the community	80%	100%	90 to 100%	*Optimal Power to community*
	Only at 100 % power transference	*YES*	*YES*	Adaptive transfer?
Average Initiative by the community	80%	100%	90 to 100%	*Optimal Power to community*
	Only at 100 % power transference	*YES*	-	Adaptive transfer?
High Initiative by the community	80 to 90%	90%	90 to 100%	*Optimal Power to community*
	Only at 100 % power transference	*Only at 100 % power transference*	-	Adaptive transfer?

Table 2: Optimal level of power with adaptive or non-adaptive transfer

Moreover, the degree to which the communities themselves have initiated the CBNRM programs seems to be another important factor: when communities have been the main initiators, absolute devolution of power might not work as well. Without the support of external actors, especially at the initial stages of the program, full power over the program leads to somewhat less optimal results than cooperation with external actors. Such external actors can of course be sought after by the community itself, however it is important that funding and knowledge is facilitated.

Regarding the optimal timing to transfer the power of the CBNRM initiative to the community, our analyses suggest that, when the decision is to transfer all the power to the community, monitoring the level of capital coverage to decide when to give the power to the communities leads to better results, except in cases where the community is highly coherent. In such cases, the delays involved in the adaptive mechanism actually lead to depletion of willingness and participation by community members. On the other hand, when external actors are maintaining some of the power over the resources and benefits of the CBNRM project, the adaptive transference mechanism does not lead to improved results but might even slightly hinder them.

Implementation Challenges, Limitations, and Future Directions

Implementation Challenges

Transferring power to the communities is not an easy decision. Governments or other external actors might wish to keep the ownership of the resources and benefits from the CBNRM initiatives instead of transferring those to the communities themselves. Our analysis shows, however, that the overall success of the programs depends highly upon the level of power that is vested with the communities. As such, it is in all actors' best interest to share this power with the communities, as, particularly at the government level, they can indirectly benefit from the better success of local-level CBNRM programs and, most importantly, from the overall sustainable usage of the targeted natural resource. The positive effects of increasing the level of power in the communities are more significant for the long-term wellbeing of the country and the population than specific monetary benefits from one CBNRM program. Communities themselves need also be informed and properly communicated regarding the benefits of such initiatives in order to be willing to take on high levels of responsibility.

Evidently, the *degree of coherence in the community* leads to significant effects on the success of an initiative and the optimal levels of power to be transferred to the communities. It is therefore imperative that the level of coherence in the community in question is carefully evaluated when decisions are made regarding the optimal power transference

in CBNRM initiatives. Facilitators of such initiatives need to work with the communities to improve the level of social coherence before the transference of power can lead to successful results.

Limitations and Future Directions

In the development of the model, we decided to create a structure that can be used by practitioners in different contexts, countries, and CBNRM initiatives to make decisions and, most importantly, communicate the dynamics and benefits of power devolution. As such, many of the variables and the assumptions behind them were determined based on literature on CBNRM programs and not through particular case study/ies. Further iterations of the model should aim to include specific data to test the structure and produced behavior.

A number of variables in the model should be determined by participants/initiators of CBNRM project bearing in mind that values used in the presented model might not be applicable to the particular situation. The level of community coherence, for example, has been in this model represented as a simple value to be assessed by facilitators. Further iterations of the model should target to study the development of this coherence prior to and during the course of the CBNRM initiative, taking into consideration the important power dynamics inside communities (as, for example Cavana et al., 2018; Nandalal & Simonovic, 2003) and how benefits from CBRNM projects might lead to conflicts, resistance, mismanagement etc. that can hinder their success.

Growth of population, investment decisions by external actors & the community, details of knowledge acquisition, and benefits from sustainable or unsustainable uses of natural resources have not been considered and our model presents, on some levels, a much more optimistic picture.

Conclusions

In the CBNRM literature, it has been identified that different forms of capital along with the level of power devolution to the target communities influence the success of CBNRM initiatives. The community, being at the core of such projects both as main implementor as well as beneficiary, bridges the connection between power devolution and the formation of different capitals.

> *For community conservation to be successful, there has to be a sense of responsibility and ownership, or proprietorship devolution at the community and resource-user level. Without this, incentives for conservation become marginal and ad hoc*
>
> (Barrow & Murphree, 1998, p. 216)

Our model was able to exhibit that communities do indeed benefit from higher levels of power over CBNRM initiatives, mainly due to the effect of such power in the development of commitment at the local level and the involvement of a larger portion of the targeted population. The coherence of the community emerges as a factor influencing how high a degree of power a community can best manage: more coherent communities can benefit most from higher levels of power, while less coherent communities seem to face issues with managing the initiative 100% on their own.

However, if the power is transferred fast from external actors to the community, this can lead the initiative to suffer due to the lack of proper capital formation. Especially when the target levels of power devolution are lower, it is better than external actors transfer this power to the community faster, while at higher levels, their assistance in the building of the capitals becomes more important. When the communities are receiving full power over the initiative, it is beneficial that the transferring of such power happens in an adaptive way; that is, with mechanisms that monitor the level of capital formation before external facilitators decide to leave the community to its own resources.

Importantly, the significance that the level of coherence of the community and the degree of bottom-up initiation seem to have in the success rate of CBNRM projects and the optimal decisions on power devolution suggests that these variables need to be carefully assessed and, if necessary, nurtured before the initiatives are transferred to the hands of the people.

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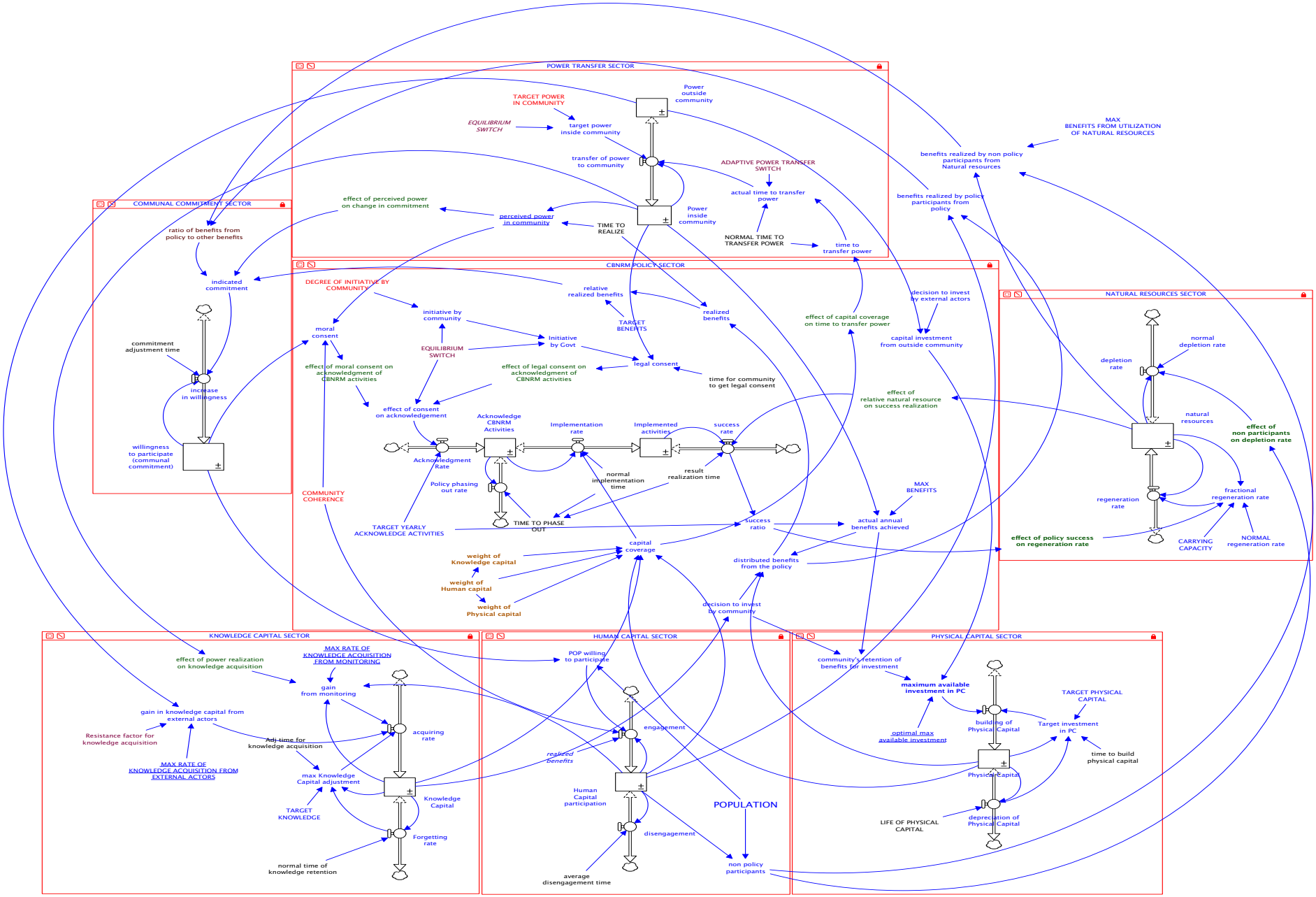
APPENDIX A: Simulation Model and detailed Causal Loop Diagram



APPENDIX B: Run Specs and Scenarios

Run Specs

(Following the minimum simulation reporting requirements proposed by Rahmandad & Sterman, 2012).
Software: Stella Architect 1.8.3
Integration method: Euler's
DT = 1/64
Time Units: Years
Simulation Start time: 0
Simulation End time: 100

Scenarios

Baseline Scenario:

Community coherence: 0.5
Degree of initiative by the community: 0.5

Lower coherence Scenario: average community coherence and common initiative

Community coherence: 0.3
Degree of initiative by the community: 0.5

Higher initiative by the community Scenario: average community coherence and high initiative by the community

Community coherence: 0.5
Degree of initiative by the community: 0.8

FURTHER TESTED SCENARIOS			
	Low coherence	Average coherence	High coherence
Low Init. by comm.	Community coherence: 0.3 Degree of initiative by the community: 0.3 Saved as Runs 1	Community coherence: 0.5 Degree of initiative by the community: 0.3 Saved as Runs 2	Community coherence: 0.7 Degree of initiative by the community: 0.3 Saved as Runs 3
Average Init. By comm.	Community coherence: 0.3 Degree of initiative by the community: 0.5 Saved as Runs LC	Community coherence: 0.5 Degree of initiative by the community: 0.5 Saved as Runs BL	Community coherence: 0.7 Degree of initiative by the community: 0.5 Saved as Runs 4
high Init. by comm.	Community coherence: 0.3 Degree of initiative by the community: 0.9 Saved as Runs 5	Community coherence: 0.5 Degree of initiative by the community: 0.8 Saved as Runs HI	Community coherence: 0.7 Degree of initiative by the community: 0.9 Saved as Runs 6

Top-Level Model:
Acknowledge_CBNRM_Activities(t) = Acknowledge_CBNRM_Activities(t - dt) + (Acknowledgment_Rate - Implementation_rate - Policy_phasing_out_rate) * dt
INIT Acknowledge_CBNRM_Activities = 0
UNITS: dmnl
DOCUMENT: The stock of Acknowledged activities measures the fraction of activities that have been identified and agreed upon by the community in relation to a Community-Based Natural Resource Management (CBNRM) project. These acknowledged activities are either implemented by the community or phase out if they do not manage to get implemented.
Human_Capital_participation(t) = Human_Capital_participation(t - dt) + (engagement - disengagement) * dt
INIT Human_Capital_participation = EQUILIBRIUM_SWITCH*0+ (1-EQUILIBRIUM_SWITCH)* initiative_by_community*COMMUNITY_COHERENCE
UNITS: dmnl
DOCUMENT: The Human Capital represents the fraction of the population which is actively involved in the CBNRM initiative either directly (through labour or participation in management) or indirectly (through adopting the initiative's activities). The initial value for the Human capital is given by the value of the initiative by the community and the value of the coherence in the community. The assumption is that, communities which have already initiated the project will have already members engaged in the project. If the coherence is however very low, those members might be less than in cases of communities with high degree of communication amongst their members. The SWITCH in the initial value ensures than no participants can be part of the project's capital since there is no active project
Implemented_activities(t) = Implemented_activities(t - dt) + (Implementation_rate - success_rate) * dt
INIT Implemented_activities = 0
UNITS: dmnl
DOCUMENT: Implemented are those activities that have been implemented by the community but not, as yet, produced results.
Knowledge_Capital(t) = Knowledge_Capital(t - dt) + (acquiring_rate - Forgetting_rate) * dt
INIT Knowledge_Capital = TRADITIONAL_KNOWLEDGE_IN_COMMUNITY
UNITS: dmnl
DOCUMENT: Knowledge Capital refers to the accumulation of knowledge capacity inside the community in relationship to the CBNRM project. Such knowledge can represent: a) Understanding of the potential of the CBNRM project, its strengths and weaknesses, and its relevance to the wellbeing of the community and individuals; b) Technical knowledge and skills pertaining to the specific project; c) Management capacity; d) Building of institutions and decision-making processes for the CBNRM project, etc. Knowledge capital increases through acquisition of knowledge and decreases as people forget the knowledge they have acquired. The initial value for the knowledge capital is assumed to be equal to the traditional knowledge already existing in the community.
natural_resources(t) = natural_resources(t - dt) + (regeneration_rate - depletion_rate) * dt
INIT natural_resources = .8
UNITS: dmnl
DOCUMENT: The stock of Natural Resources represents the natural resource(s) that is the main target(s) of the CBNRM initiative. The resource regenerates through the regeneration rate and depletes through the depletion rate. In the conceptualization used, higher values of the Natural Resource are considered better (the "goal" of any policy is for the natural resource to increase). The initial value of 0.8 represents the current level of the natural resource and the equilibrium state of the natural resource if no human effect is considered (either effects due to the CBNRM project or due to the population depleting the resource).
Physical_Capital(t) = Physical_Capital(t - dt) + (building_of_Physical_Capital - depreciation_of_Physical_Capital) * dt
INIT Physical_Capital = 0
UNITS: dmnl
DOCUMENT: The stock of Physical Capital represents the fraction of the necessary physical capital for the realization of the CBNRM project. Physical capital increases through building and decreases through depreciation
Power_inside_community(t) = Power_inside_community(t - dt) + (transfer_of_power_to_community) * dt
INIT Power_inside_community = initiative_by_community
UNITS: dmnl
DOCUMENT: The stock of power in community represents the degree to which the community has ownership of the CBNRM program and the relative decisions, benefits, and responsibility. It also represents the level of "ownership" of or rights over the natural resource which is to be managed by the program. The initial value of this power depends to the extent to which the community itself has been the initiator of the project.
Power_outside_community(t) = Power_outside_community(t - dt) + (- transfer_of_power_to_community) * dt
INIT Power_outside_community = (1-initiative_by_community)
UNITS: dmnl

DOCUMENT: The stock of power outside the community represents the ownership of the CBNRM program by higher-level actors or institutions outside the community (e.g. government, regional level, NGOs, international donors).
"willingness_to_participate_(communal_commitment)"(t) = "willingness_to_participate_(communal_commitment)"(t - dt) + (increase_in_willingness) * dt
INIT "willingness_to_participate_(communal_commitment)" = 1/3
UNITS: dmnl
DOCUMENT: The stock of Willingness to participate / communal commitment provides a measure of the degree willingness of the population to participate in the CBNRM project.
Acknowledgment_Rate = effect_of_consent_on_acknowledgement*TARGET_YEARLY_ACKNOWLEDGE_ACTIVITIES
UNITS: dmnl/year
DOCUMENT: The number of activities that can be acknowledged by the community yearly is determined by the normal value of yearly acknowledged activities and the effects of both moral and legal consent on this normal value.
acquiring_rate = (gain_in_knowledge_capital_from_external_actors+gain_from_monitoring)*max_Knowledge_Capital_adjustment
UNITS: Per Year
DOCUMENT: The rate of acquiring knowledge is the sum of the knowledge gain from actors outside the community (e.g. NGOs, government officials) and the knowledge gained from monitoring and reflection on the project itself by the community. The maximum value of Knowledge Capital adjustment ensures that the stock of Knowledge Capital does not reach a value above 1 (100%)
building_of_Physical_Capital = MIN(Target_investment_in_PC, maximum_available_investment_in_PC)
UNITS: 1/year
DOCUMENT: The building of Physical capital takes the smallest of the values of either the target investment in physical capital or the maximum available investment in physical capital. The MIN function ensures that, no matter the investment capability, the Physical Capital stock will never reach a value higher than 1 (100%)
depletion_rate = (normal_depletion_rate*natural_resources*effect_of_non_participants_on_depletion_rate)
UNITS: dmnl/year
DOCUMENT: The depletion rate of the natural resource is determined by the current level of the natural resource, the normal depletion rate, and the effect of those community members not participating in the CBNRM initiative on the depletion of the natural resource.
depreciation_of_Physical_Capital = Physical_Capital/LIFE_OF_PHYSICAL_CAPITAL
UNITS: 1/year
DOCUMENT: The physical capital in place depreciates over the average lifetime of the capital
disengagement = Human_Capital_participation/average_disengagement_time
UNITS: Per Year
DOCUMENT: People participating in the initiative do disengage after some average disengagement time.
engagement = (COMMUNITY_COHERENCE*realized_benefits*POP_willing_to_participate)*(1-Human_Capital_participation//POP_willing_to_participate)
UNITS: Per Year
DOCUMENT: The rate at which people in the community can engage with the CBNRM project is given by a formulation close to the one usually used to describe epidemics (the SI model, see Sterman, 2000, pp. 300–303). The assumption behind the current formulation is that the population already participating in the CBNRM project (the stock of the Human Capital participation) can “infect” the remaining population who is already willing to participate. The community coherence represents how likely it is those “infected” and those “susceptible” can interact, and the value of the realized benefits from the project is used to describe the probability that those “susceptible” will be convinced to actively join the project (the higher the benefits, the more likely they will get “infected”).
Forgetting_rate = Knowledge_Capital/normal_time_of_knowledge_retention
UNITS: Per Year
DOCUMENT: The rate of forgetting is given by the value of the knowledge that has already been acquired over the normal or average time this knowledge can be retained: the smaller the time of knowledge retention, the higher the rate of forgetting.
Implementation_rate = (Acknowledge_CBNRM_Activities*capital_coverage)/normal_implementation_time
UNITS: dmnl/year
DOCUMENT: The number of activities that can be implemented by the community yearly is determined by the number of activities already acknowledged by the community and the coverage, in terms of capital, that is available to the community. If the capital coverage is nonexistent (value of 0), then the acknowledged activities cannot be implemented. If the capital coverage is 100% fulfilled (a value of 1), then all the acknowledged activities will be implemented over the normal time it takes for their implementation.
increase_in_willingness = (indicated_commitment-"willingness_to_participate_(communal_commitment)")/commitment_adjustment_time
UNITS: per year

DOCUMENT: The Willingness to participate / communal commitment changes according to an indicated value of Willingness to participate / communal commitment over the necessary time for the commitment to be adjusted.
Policy_phasing_out_rate = (Acknowledge_CBNRM_Activities/TIME_TO_PHASE_OUT)
UNITS: dmnl/year
DOCUMENT: Acknowledged activities, if not implemented, are not expected to remain under negotiation in the community indefinitely. The rate at which activities are removed from consideration depends on the number of acknowledged activities and the time it takes for them to phase out
regeneration_rate = fractional_regeneration_rate*natural_resources
UNITS: dmnl/year
DOCUMENT: The regeneration rate is determined by the current level of the natural resource and the fractional regeneration rate.
success_rate = MAX(0, Implemented_activities*effect_of_relative_natural_resource_on_success_realization/result_realization_time)
UNITS: dmnl/year
DOCUMENT: The rate at which implemented activities produce results depends on the availability of the natural resource in question. If the natural resource is depleted then the activities cannot be implemented, while, if the natural resource is at its initial level, the implemented activities will produce results over the normal results realization time. The MAX function does not allow the stock of Implemented activities to go negative (there is no such thing as negative Implemented activities)
transfer_of_power_to_community = (target_power_inside_community- Power_inside_community)/actual_time_to_transfer_power
UNITS: Per Year
DOCUMENT: The transfer of power from actors and institutions outside the community is adjusted according to a target value over the necessary time for the transferring of this power.
actual_annual_benefits_achieved = success_ratio*MAX_BENEFITS*Power_inside_community
UNITS: dmnl/year
DOCUMENT: The benefits the community achieves annually through the implementation of the project are the product of the success of the program (as measured by the success ratio), the maximum possible benefits the community could receive from the program, and the degree of ownership of the program by the community (Power in community): if the community has no ownership, then the benefits are assumed to not be realized by the community.
actual_time_to_transfer_power = ADAPTIVE_POWER_TRANSFER_SWITCH*time_to_transfer_power+ (1- ADAPTIVE_POWER_TRANSFER_SWITCH)*NORMAL_TIME_TO_TRANSFER_POWER
UNITS: year
DOCUMENT: The actual time for power to be transferred to the community is either equal to the normal time to transfer power (when the switch or policy is OFF), or the adjusted time to transfer power to the community (when the switch is ON)
ADAPTIVE_POWER_TRANSFER_SWITCH = 0
UNITS: dmnl
DOCUMENT: This switch activates the policy of an adaptive transferring of power to the community.
Adj_time_for_knowledge_acquisition = 3
UNITS: years
DOCUMENT: The time it takes for knowledge to be acquired at the community level. While the actual acquisition of knowledge can be considered much faster, this adjustment time represents the slower process of collecting, organizing, and sharing available knowledge, negotiating and bringing together different actors/fractions in the community, as well as the time it takes to agree upon and build procedures and establish institutions or defined decision-making processes.
average_disengagement_time = 25
UNITS: years
DOCUMENT: The average time it takes for a person who has engaged in the CBNRM initiative to disengage. Here, we assume that people who actively get involved in such initiatives, do not disengage very fast. Due to lack of sensitivity of the system to this value, a more precise determination of it is not considered necessary.
benefits_realized_by_non_policy_participants_from_Natural_resources = (natural_resources*MAX_BENEFITS_FROM_UTILIZATION_OF_NATURAL_RESOURCES)/non_policy_participants
UNITS: dmnl/year
DOCUMENT: The benefits that are realized by the fraction of the community not participating in the initiative represents the benefits that individuals in the community can achieve through utilizing the natural resource in ways that are different or opposing to the CBNRM initiative. The value of those benefits is given by the level of the Natural Resource and the maximum benefits through its utilization distributed amongst the non-participants in the initiative.
benefits_realized_by_policy_participants_from_policy = distributed_benefits_from_the_policy//Human_Capital_participation
UNITS: dmnl/year
DOCUMENT: The benefits that are realized by the members of the community which are participating in the project is given by the total value of benefits which are distributed over the number of people participating in the initiative.

capital_coverage = (weight_of_Knowledge_capital*Knowledge_Capital+weight_of_Human_capital*Human_Capital_participation+Physical_Capital*weight_of_Physical_capital)
UNITS: dmnl
DOCUMENT: The coverage in terms of capital is defined as a weighted average of the three capitals, namely Knowledge, Human, and Physical capital.
capital_investment_from_outside_community = Power_outside_community*decision_to_invest_by_external_actors
UNITS: dmnl/year
DOCUMENT: Investment from outside the community (government, international donor, private companies, etc.) is determined by the level of the power over the CBRNM project that resides with those actors and their decision rule regarding investing in Physical Capital.
CARRYING_CAPACITY = 1
UNITS: dmnl
DOCUMENT: The carrying capacity of the Natural Resource is 1, or 100%
commitment_adjustment_time = 2
UNITS: years
DOCUMENT: The time it takes for changes in commitment to be realized is assumed to be 2 years.
COMMUNITY_COHERENCE = .5
UNITS: dmnl
DOCUMENT: Represents the degree of coherence in the community. In communities where there are, for example, many different fractions of population (most evidently represented by tribes in the countries of the KAZA area), conflicts or traditionally not good relationships between those fractions can lead to lower values of coherence. Smaller or more homogeneous communities have better success chances at success in CBNRM initiatives, as “cultural heterogeneity and ethnic friction” are also identified as important characteristics of a program’s success (R. Cooney, Roe, Dublin, & Booker, n.d., p. 25) “More diverse communities often take longer to reach consensus, tend to develop weak social cohesion and leadership, and may lack community spirit” (Thakadu, 2005, p. 209).
community's_retention_of_benefits_for_investment = actual_annual_benefits_achieved* decision_to_invest_by_community
UNITS: dmnl/year
DOCUMENT: The benefits the community decides to invest in building of Physical Capital for the CBNRM project are the product of the actual benefits the community has achieved through the project and the decision rule by the community regarding the investment of those benefits.
decision_to_invest_by_community = Knowledge_Capital
UNITS: dmnl
DOCUMENT: The community’s decision to invest the money they earn to the building of necessary physical capital is assumed here to be directly and linearly influenced by the knowledge capital in the community such that, the more knowledge the community has about the management of the CBNRM project, the more likely they are to make the decision to invest in building of physical capital.
decision_to_invest_by_external_actors = 1
UNITS: dmnl/year
DOCUMENT: The assumption of the model is that external actors’ investment decision is to cover the expenses for the establishment of the necessary for the program Physical Capital. A value of 1 means that external actors are willing to cover the costs necessary for the Physical Capital to reach a value of 1 (100%).
DEGREE_OF_INITIATIVE_BY_COMMUNITY = .5
UNITS: dmnl
DOCUMENT: The degree to which a CBNRM program is initiated by the community itself (bottom-up) is an important factor to the program’s implementation. As such, the value for this initiative is a factor that needs to be determined depending on the initiative in question.
distributed_benefits_from_the_policy = IF Physical_Capital=1 THEN actual_annual_benefits_achieved ELSE (1-decision_to_invest_by_community)*actual_annual_benefits_achieved
UNITS: dmnl/year
DOCUMENT: The benefits from the CBNRM initiative that are realized by the community is given by the actual benefits achieved by the initiative minus the fraction of those benefits that are invested in Physical Capital. In the case that the Physical capital has achieved its maximum value (1 or 100%), then all the realized benefits will be distributed in the community.
effect_of_capital_coverage_on_time_to_transfer_power = GRAPH(capital_coverage)
Points: (0.000, 1.997), (0.100, 1.987), (0.200, 1.928), (0.300, 1.736), (0.400, 1.252), (0.500, 1.000), (0.600, 0.891), (0.700, 0.849), (0.800, 0.800), (0.900, 0.800), (1.000, 0.800)
UNITS: dmnl
DOCUMENT: The effect of capital coverage on time to transfer power to the community represents a monitoring mechanism by which external actors decide when to transfer power to the community based on the level of the Physical, Human, and

Knowledge capital already achieved. The effect is formulated such that a 100% coverage in terms of all three capitals (capital coverage = 1) will result in a 20% decrease of the normal time to transfer power, while lower levels of capital coverage will increase the time to transfer power to a maximum of double its value. The time to transfer power to the community is equal to its normal value when the capital has reached a 50% coverage.
effect_of_consent_on_acknowledgement = EQUILIBRIUM_SWITCH*0+ (1-EQUILIBRIUM_SWITCH)*(effect_of_legal_consent_on_acknowledgment_of_CBNRM_activities*effect_of_moral_consent_on_acknowledgment_of_CBNRM_activities)
UNITS: dmnl
DOCUMENT: Represents the effect that both moral and legal consent have on acknowledgment of CBNRM activities. The effects are here assumed to be in a multiplicative relationship such as, if the legal consent is nonexistent (a value of 0), moral consent on its own cannot lead to any acknowledgment of activities and vice versa (for the choice between additive and multiplicative effects, see Sterman, 2000, pp. 528–9).The equation is formulated so that when the equilibrium switch is ON (value of 1), no consent can be obtained for non-existent activities
effect_of_legal_consent_on_acknowledgment_of_CBNRM_activities = GRAPH(legal_consent)
Points: (0.000, 0.000), (0.100, 0.014), (0.200, 0.063), (0.300, 0.139), (0.400, 0.201), (0.500, 0.292), (0.600, 0.427), (0.700, 0.611), (0.800, 0.875), (0.900, 0.976), (1.000, 1.000)
UNITS: dmnl
DOCUMENT: Legal consent can represent a barrier to implementation of CBNRM projects. If there is no legal consent for CBNRM activities, then those activities cannot be acknowledged by the community (a value of 0 legal consent gives an effect of 0 on acknowledgment rate). Small changes in legal consent have a small -less than linear- effect on the acknowledgement rate while, after a 50% legal consent, small changes in legal consent lead to larger effect on the acknowledgment rate -more than linear-. The effect of legal consent on acknowledgment saturates at high values.
effect_of_moral_consent_on_acknowledgment_of_CBNRM_activities = GRAPH(moral_consent)
Points: (0.000, 0.000), (0.100, 0.031), (0.200, 0.094), (0.300, 0.226), (0.400, 0.392), (0.500, 0.538), (0.600, 0.663), (0.700, 0.826), (0.800, 0.920), (0.900, 0.981), (1.000, 1.000)
UNITS: dmnl
DOCUMENT: As in the case of the legal consent's effect on the acknowledgment rate, lack of moral consent by the community will lead to no acknowledged activities (a value of 0 concern again gives an effect of 0 on acknowledgment rate). The relationship, however, between moral consent and acknowledgment rate is assumed to be somewhat "steeper" than the one of legal consent: even lower values of moral consent can lead to more than linear increases in acknowledgment rate. This effect slows down at high levels of moral consent (above 80%)
effect_of_non_participants_on_depletion_rate = GRAPH(non_policy_participants)
Points: (0.000, 1.000), (0.100, 1.004), (0.200, 1.018), (0.300, 1.061), (0.400, 1.112), (0.500, 1.198), (0.600, 1.318), (0.700, 1.671), (0.800, 1.866), (0.900, 1.964), (1.000, 2.000)
UNITS: dmnl
DOCUMENT: Community members who do not participate in the CBNRM initiative can influence the depletion rate of the natural resource by either illegal or opposing to the policy activities, or by simply misusing the natural resource due to lack of knowledge. If a small percentage of people do not participate in the CBNRM program, the depletion rate for the natural resource will be equal to its normal value, while high percentage of non-policy participants in the community can lead to a maximum of two times the normal depletion rate. The effect is much "steeper" at higher values of non-participants due to a "herding effect": the more people see others misusing the natural resource, the more likely it is that they will do so as well.
effect_of_perceived_power_on_change_in_commitment = GRAPH(perceived_power_in_community)
Points: (0.000, 0.004), (0.100, 0.032), (0.200, 0.099), (0.300, 0.190), (0.400, 0.381), (0.500, 0.655), (0.600, 0.774), (0.700, 0.857), (0.800, 0.925), (0.900, 0.988), (1.000, 1.000)
UNITS: dmnl
DOCUMENT: The assumption for the effect of perceived power in the community to the commitment of the community members is that, the higher the community perceives the power over the initiative to be within the community, the more willing they will be to participate in that initiative. If all the power lies outside the community (perceived power of 0 value), then the community will not be motivated (or willing) to participate to the CBNRM initiative due to the sense of empowerment that it offers the community as a whole. The effect is moreover perceived to be saturating at higher and lower levels of perceived power, such that small differences at the higher and lower ends will not lead to smaller differences in community commitment.
effect_of_policy_success_on_regeneration_rate = GRAPH(success_ratio)
Points: (0.000, 1.0000), (0.100, 1.0014), (0.200, 1.0014), (0.300, 1.0014), (0.400, 1.0140), (0.500, 1.0644), (0.600, 1.1359), (0.700, 1.2269), (0.800, 1.3599), (0.900, 1.4692), (1.000, 1.5000)
UNITS: dmnl
DOCUMENT: The policy is assumed to incorporate a positive effect on the regeneration of the natural resource. The success of the policy (represented by the success ratio), initially, does not effect the regeneration rate, as it is assumed that low success cannot lead to mich change in the resource regeneration rate. However, average levels of success can start having significant

impact on the average regeneration rate with a maximum effect being assumed to increase it by 50% when the policy is 100% successful.

effect_of_power_realization_on_knowledge_acquisition = GRAPH(Power_inside_community)

Points: (0.000, 0.000), (0.100, 0.008), (0.200, 0.044), (0.300, 0.145), (0.400, 0.297), (0.500, 0.522), (0.600, 0.671), (0.700, 0.851), (0.800, 0.932), (0.900, 0.976), (1.000, 0.996)

UNITS: dmnl

DOCUMENT: The higher the power the community has over the CBNRM project and its resources, the higher the effect of this power on the community's capability to acquire knowledge. Communities having a lot of power over the initiative can more effectively monitor and thus acquire further knowledge capacity. Communities without any power are not able to develop and exploit monitoring mechanisms. The effect is assumed to saturate at higher and lower levels of power such that, small differences in power do not result in large differences in knowledge acquisition.

effect_of_relative_natural_resource_on_success_realization = GRAPH(natural_resources/INIT(natural_resources))

Points: (0.000, 0.000), (0.100, 0.008), (0.200, 0.044), (0.300, 0.083), (0.400, 0.127), (0.500, 0.206), (0.600, 0.297), (0.700, 0.448), (0.800, 0.619), (0.900, 0.806), (1.000, 0.996)

UNITS: dmnl

DOCUMENT: The relative to the initial value of the Natural Resource effects the rate at which activities of the CBNRM program can be successful. It is assumed that, if the level of the Natural resource is maintained at the same level as when the initiative started, the activities will be successful as they would normally be (at the maximum possible rate). Decreases in the natural resource however, will lead to less than optimal success rate for the project, as it is assumed to be dependent on the availability of the natural resource. Extreme decreases in the natural resource (relative value approaching 0) are expected to nullify any success of the project.

EQUILIBRIUM_SWITCH = 1

UNITS: dmnl

DOCUMENT: The equilibrium switch, when ON (value of 1) gives the dynamics of the system without any CBNRM project in process.

Favorable_bias = .3

UNITS: dmnl

DOCUMENT: The "favourable bias" represents the documented willingness of communities to participate in CBNRM initiatives regardless of whether the initiation of such initiatives was the community's. A value of 0.3 (30%) increase in willingness is chosen. While this value might be difficult to determine, the lack of sensitivity of our system to it indicates that there is no need to try to estimate it more accurately.

fractional_regeneration_rate = ((1-natural_resources)/CARRYING_CAPACITY)*(NORMAL_regeneration_rate*effect_of_policy_success_on_regeneration_rate)

UNITS: dmnl/year

DOCUMENT: The fractional regeneration rate is given based on a common formulation about natural resource regeneration which takes into consideration the "distance" of the current level of the natural resource to the capacity of the environment such that the regeneration rate is higher when the resource is further from the carrying capacity and slower as the resource approaches the carrying capacity. The success of the policy is assumed to influence positively the normal regeneration rate of the resource.

gain_from_monitoring = Knowledge_Capital*effect_of_power_realization_on_knowledge_acquisition*Human_Capital_participation*MAX_RATE_OF_KNOWLEDGE_ACQUISITION_FROM_MONITORING

UNITS: dmnl

DOCUMENT: The mechanism by which a community increases their knowledge capital through monitoring and learning from their actions is an important aspect of CBNRM initiatives and has been described as an important mechanism in determining their success.. The gain in knowledge that can be acquired from community monitoring and learning is considered a function firstly of the knowledge the community already has: without knowledge on how to monitor and how to manage and disseminate the results of this monitoring, the community cannot acquire any further knowledge. The power that the community has to manage the CBNRM program is another important factor, represented by the nonlinear effect of power realization on knowledge acquisition. Communities with no power to manage the program cannot establish and learn through monitoring mechanisms. Human Capital participation is also important as it represents what is referred to as "social learning". Social learning describes learning through interactions between members of a community or social network and can describe deliberate sharing of perspectives and insights, shared activities and monitoring, or the emergence of knowledge through unfacilitated social interaction (Cundill, Leitch, Schultz, Armitage, & Peterson, 2015; Cundill & Rodela, 2012). In this case, if Human Capital is non-existent, knowledge could not be acquired through the monitoring mechanism. Lastly, the maximum rate of knowledge acquisition from monitoring represent the highest possible value of learning through the monitoring mechanism.

Those factors are in a multiplicative relationship due to the assumption that, without the presence of each one of those factors, no knowledge can be acquired through monitoring (Sterman, 2000, pp. 528–529).

gain_in_knowledge_capital_from_external_actors = Power_outside_community*MAX_RATE_OF_KNOWLEDGE_ACQUISITION_FROM_EXTERNAL_ACTORS*(1-Resistance_factor_for_knowledge_acquisition)

UNITS: dmnl

DOCUMENT: Gaining knowledge from external actors depends firstly on the extend that those actors have power or responsibility over the CBNRM project: if external actors have no authority, then they are assumed to not be present to transmit any knowledge to the community. Additionally, external actors can transmit a maximum value of knowledge based on their capabilities and this knowledge is adjusted due to the resistance that might be present in the community for knowledge transmitted by actors who are outside of this community.

indicated_commitment = MIN(1, (effect_of_perceived_power_on_change_in_commitment+relative_realized_benefits+ratio_of_benefits_from_policy_to_other_benefits)/3)

UNITS: dmnl

DOCUMENT: The indicated commitment is a weighted average of the effects of perceived power at the community level, the realized benefits from the CBNRM initiative, and the comparison between the benefits of the initiative and benefits acquired through other uses of the natural resource. The MIN function ensures that the stock of Willingness to participate / communal commitment will never increase above 1.

INITIAL_COMMUNAL_COMMITMENT = MIN(1, initiative_by_community+Favorable_bias)

UNITS: dmnl

DOCUMENT: The initial value for the communal commitment is given by the value of initiative by the community adjusted upwards due to a favourable bias. The MIN function ensures that the initial value for the communal commitment does not rise above 1 (100%).

initiative_by_community = EQUILIBRIUM_SWITCH*1+ (1-EQUILIBRIUM_SWITCH)*DEGREE_OF_INITIATIVE_BY_COMMUNITY

UNITS: dmnl

DOCUMENT: The equilibrium SWITCH, when ON (value of 1), ensures that, when no project is initiated, the value for the initiative by community is constant and not equal to the value of the degree of initiative by the community.

Initiative_by_Govt = EQUILIBRIUM_SWITCH*0+ (1-EQUILIBRIUM_SWITCH)*1-initiative_by_community

UNITS: dmnl

DOCUMENT: To make certain that the value of the source of initiative does not go above 1 (100%), the degree to which a certain CBNRM initiative is determined by government, takes the value of the difference between 1 (100%) and the initiative by sources inside the community (initiative by community). The equilibrium SWITCH, when ON (value of 1, ensures that the government does not initiate any CBNRM project.

legal_consent = SMTH3(Power_inside_community, time_for_community_to_get_legal_consent, Initiative_by_Govt) {DELAY CONVERTER}

UNITS: dmnl

DOCUMENT: The legal consent represents the legal framework for the CBNRM program in general or specific activities as part of that program. Activities initiated by the government will already have achieved legal consent and, therefore, the initial value for this variable is equal to the fraction of the initiative situated with the government. However, communities can negotiate and achieve legal consent through a process assumed to be best represented by a third order information delay (SMTH3) which represent the discrete steps in the negotiation for an appropriate legal framework.

LIFE_OF_PHYSICAL_CAPITAL = 25

UNITS: years

DOCUMENT: The average lifetime of the Physical Capital chosen is 25 years. As, in this model, we do not refer to some specific form of physical capital, the choice of this value represents an average of different forms of capital with varied lifetimes (from building which can last more than 25 years to machinery which can last much less than 25 years). For cases with different average lifetime of physical capital, the variable “optimal max available investment” can be modified to represent forms of capital with that average lifetime.

MAX_BENEFITS = 1

UNITS: dmnl/year

DOCUMENT: The maximum benefits that can be achieved through the implementation of the program are 1 (or 100%).

MAX_BENEFITS_FROM_UTILIZATION_OF_NATURAL_RESOURCES = 1

UNITS: dmnl/year

DOCUMENT: The maximum benefits from the utilization of the natural resource in ways other than those proposed by the CBNRM initiative is assumed to be 1, equal to the benefits that can be achieved through the initiative. While this might not be the case, the fact that not all non-policy participants will actually benefit from other uses of the resource makes this a relatively average assumption.

max_Knowledge_Capital_adjustment = (TARGET_KNOWLEDGE-Knowledge_Capital)/Adj_time_for_knowledge_acquisition+Forgetting_rate

UNITS: Per Year
DOCUMENT: The maximum adjustment of the Knowledge Capital is the difference between the target value for the Knowledge Capital and its current level, over the necessary time for the acquisition of knowledge. The addition of the rate of forgetting makes sure that the knowledge that is being lost after some time is taken into account. This maximum value ensures that the stock of Knowledge Capital remains between 0 and 1 (0 to 100%).
MAX_RATE_OF_KNOWLEDGE_ACQUISITION_FROM_EXTERNAL_ACTORS = 1
UNITS: dmnl
DOCUMENT: The maximum amount of knowledge that external actors are assumed to be able to transmit to the community is 1. This means that, in the best possible scenario, external actors can help the community acquire 100% of the knowledge necessary to bring their knowledge capital stock to its maximum value (1 or 100%)
MAX_RATE_OF_KNOWLEDGE_ACQUISITION_FROM_MONITORING = 1
UNITS: dmnl
DOCUMENT: As with the maximum rate of knowledge acquisition from external actors, this variable represents the maximum amount of knowledge that the community can acquire through monitoring its activities. In the best possible scenario, the community acquire 100% of the knowledge necessary to bring the knowledge capital stock to its maximum value (1 or 100%)
maximum_available_investment_in_PC = (capital_investment_from_outside_community+community's_retention_of_benefits_for_investment)*optimal_max_available_investment
UNITS: dmnl/year
DOCUMENT: The maximum available investment in Physical Capital is the sum of the investment in Physical Capital by external actors and that by the community itself. The optimal maximum available investment represents the necessary investment value both actors would need to invest for the physical capital to reach and maintain its target value. The multiplication of the two ensures that a decision by the community and/or external actors to invest as much as necessary in physical capital will not lead to an infinite increase in it but will only lead to the establishment of 100% of the required for the program capital.
moral_consent = (perceived_power_in_community+COMMUNITY_COHERENCE+"willingness_to_participate_(communal_commitment)")/3
UNITS: dmnl
DOCUMENT: The degree to which a community will morally consent to a CBNRM project's activities is assumed to be a weighted average of the community's perception of their power over the project and the relevant resources, the value of coherence inside the community, and the overall willingness of the community members to participate in the project. The higher the value of any of those factors, the more likely it is that the community will morally consent to the project.
non_policy_participants = (POPULATION-Human_Capital_participation)
UNITS: dmnl
DOCUMENT: The difference between the total population of the community and those participating in the CBNRM program gives us the fraction of people not participating in the program.
normal_depletion_rate = 0.01
UNITS: 1/year
DOCUMENT: The normal depletion rate is assumed to be 0.01. This value was chosen to maintain the stock of natural resources at equilibrium without external influences.
normal_implementation_time = 4
UNITS: year
DOCUMENT: The time it takes for a policy to be implemented on average. Assumed to be 4 years.
NORMAL_regeneration_rate = 0.05
UNITS: 1/year
DOCUMENT: The normal regeneration rate is assumed to be 0.05. This value was chosen to maintain the stock of natural resources at equilibrium without external influences.
normal_time_of_knowledge_retention = 10
UNITS: year
DOCUMENT: The average time it takes for acquired knowledge to be forgotten. Assumed to be 10 years, as acquired knowledge is not forgotten very fast.
NORMAL_TIME_TO_TRANSFER_POWER = normal_implementation_time + result_realization_time {SUMMING CONVERTER}
UNITS: year
DOCUMENT: The normal or average time the responsibility is considered to be transferred to the community is the sum of the normal implementation and result realization times. This represents a relatively rational decision by external actors to transfer the power in the community in the normal time it takes for the project to produce results.
optimal_max_available_investment = GRAPH(TIME)

Points: (0.00, 0.200), (5.00, 0.0987686207873), (10.00, 0.0615859424327), (15.00, 0.0479286004073), (20.00, 0.0429122056919), (25.00, 0.0410696644498), (30.00, 0.0403928919026), (35.00, 0.0401443107202), (40.00, 0.0400530058875), (45.00, 0.0400194692681), (50.00, 0.0400071511377)
UNITS: dmnl
DOCUMENT: The optimal maximum available investment is a variable describing the optimal Physical Capital acquisition. It is equal to the capital acquisition rate in the scenario where the investment in Physical capital is equal to 1 (or 100%). As such, it represents an evaluation of how much should be invested in the Physical capital by either the community or external investors. It is used instead of the Target investment in order to represent a more realistic decision rule as actors do not necessary receive accurate information of what the target investment might be at each point in time but instead rely on previous evaluation (even though, in this case, the evaluation is more "perfect" than any evaluation could be in reality).
perceived_power_in_community = SMTH1(Power_inside_community, TIME_TO_REALIZE) {DELAY CONVERTER}
UNITS: dmnl
DOCUMENT: The community's perception about the power that lies with the community is assumed to change according to a first order information delay
POP_willing_to_participate = POPULATION*"willingness_to_participate_(communal_commitment)"
UNITS: dmnl
DOCUMENT: The value of the fraction of the population willing to participate in the initiative is given by the total value of population multiplied by the fraction of population who is willing to participate
POPULATION = 1
UNITS: dmnl
DOCUMENT: The population of the community takes a value of 1 (100%). No population growth is explicitly considered in the model.
ratio_of_benefits_from_policy_to_other_benefits = benefits_realized_by_policy_participants_from_policy/benefits_realized_by_non_policy_participants_from_Natural_resources
UNITS: dmnl
DOCUMENT: The comparison of the benefits that are realized by the participants in the CBNRM initiative and the benefits realized from the use of the Natural Resource by non-participants in the initiative. A higher the value of this ratio means that the community perceives the CBNRM initiative as preferable to other exploitations of the natural resource.
realized_benefits = SMTH1(distributed_benefits_from_the_policy, TIME_TO_REALIZE)
UNITS: dmnl/year
DOCUMENT: The community's realization about the benefits from the CBNRM initiative is assumed to be represented by a first order information delay.
relative_realized_benefits = realized_benefits/TARGET_BENEFITS
UNITS: dmnl
DOCUMENT: The relative realized benefits is the ratio of the benefits realized through the CBNRM initiative over a target value for those benefits.
Resistance_factor_for_knowledge_acquisition = 0.5
UNITS: dmnl
DOCUMENT: Communities might be biased towards external actors and their ideas, proposals on how the program should be operated, etc. Conflicts between traditional ways of "doing things" and new knowledge, or more or less tense relationships between communities and governments are examples of the social dynamics that can be represented through this factor. While this resistance by the community can change over time with specific measures taken by the external actors (see, for example Jones & Mosimane, 2000), such measures are rather complex and not the main focus of our model. As such, the variable is represented as a value that can be adjusted to represent different communities. As a baseline, a value of 0.5 is used. This value means that, of all the possible knowledge external actors can share with the community, the community as a whole will retain only half (50%).
result_realization_time = 4
UNITS: year
DOCUMENT: The time it takes for the results of an implemented policy to be realized on average. Can represent, for example, the time it would take for a new cultivation policy to produce results. Assumed to be 4 years
success_ratio = success_rate//TARGET_YEARLY_ACKNOWLEDGE_ACTIVITIES
UNITS: dmnl
DOCUMENT: The success ratio represents the success of the CBNRM project. It is the ratio of activities that have been successful over the target value of activities that could be acknowledged through the project.
TARGET_BENEFITS = 1
UNITS: dmnl/year
DOCUMENT: The target value of benefits that can be realized through the initiative is 1 or 100%. The assumption is that actors have evaluated and communicated a good understanding of the possible benefits that can be achieved through the initiative.

Target_investment_in_PC = (TARGET_PHYSICAL_CAPITAL-Physical_Capital)/time_to_build_physical_capital+depreciation_of_Physical_Capital
UNITS: dmnl/year
DOCUMENT: The target, or optimal, investment in Physical Capital is the difference between the target value for the Physical Capital and its current value over the necessary time for the capital to be built. The addition of the depreciation rate ensured that we account in this target value for the capital being depreciated in order to avoid a steady-state error (see Sterman, 2000, pp. 671–2).
TARGET_KNOWLEDGE = 1
UNITS: dmnl
DOCUMENT: The target value of knowledge the community can acquire. This value is 1 (100%) of relevant knowledge.
TARGET_PHYSICAL_CAPITAL = 1
UNITS: dmnl
DOCUMENT: The target value of Physical Capital for the implementation of the CBNRM project is 1 or 100%.
TARGET_POWER_IN_COMMUNITY = .8
UNITS: dmnl
DOCUMENT: The target value of power in the community is a main variable of interest. It represents the decision rule by actors outside the community for the level of power they wish to devolute to the community.
target_power_inside_community = EQUILIBRIUM_SWITCH*1+ (1-EQUILIBRIUM_SWITCH)*(TARGET_POWER_IN_COMMUNITY)
UNITS: dmnl
DOCUMENT: The value for the target power inside community is equal to the value assigned to the target power in community variable when the equilibrium switch is OFF (value of 0), but equal to 1 when the switch is ON to ensure that no transferring of power takes place in or out of the community.
TARGET_YEARLY_ACKNOWLEDGE_ACTIVITIES = 1
UNITS: per year
DOCUMENT: Every year, the community is assumed to have the possibility of acknowledging 100% of the project's activities.
time_for_community_to_get_legal_consent = 10
UNITS: years
DOCUMENT: A community's fight to achieve legal consent for the CBNRM program or activities tends to produce results relatively slowly. Different countries and different programs can achieve such legal consent slower or faster, however it is not expected that this value can ever be less than 5 years. Due to lack of sensitivity of the system to the value of this variable, there is no explicit need to determine with very high precision the value for this variable.
time_to_build_physical_capital = 5
UNITS: years
DOCUMENT: The time it takes for the building of Physical Capital is assumed to be 5 years. As the form of Physical capital is not explicit, an average value is used as in the case of the variable "life of physical capital".
TIME_TO_PHASE_OUT = normal_implementation_time+result_realization_time
UNITS: year
DOCUMENT: The time for activities to phase out is defined as the sum of the normal implementation time and results realization time: if the policy does not manage in this maximum time to be implemented, it is discarded.
TIME_TO_REALIZE = 1
UNITS: year
DOCUMENT: The time for the community to realize changes in power and in benefits from the CBNRM initiative is assumed to be 1 year.
time_to_transfer_power = NORMAL_TIME_TO_TRANSFER_POWER*effect_of_capital_coverage_on_time_to_transfer_power
UNITS: Years
DOCUMENT:
The adjusted time to transfer power is given by the normal time to transfer power adjusted due to the effect of the capital coverage on this normal time to transfer power.
TRADITIONAL_KNOWLEDGE_IN_COMMUNITY = .3
UNITS: dmnl
DOCUMENT: Represents traditional existing knowledge in the community regarding the management of natural resources, people, and decisions.
weight_of_Human_capital = 0.4
UNITS: dmnl

DOCUMENT: For a community based natural resource management project, the weight (or significance) of the Human capital is assumed to be slightly higher than that of the other forms of capital
weight_of_Knowledge_capital = (1-weight_of_Human_capital)/3
UNITS: dmnl
DOCUMENT: The weight of the Knowledge capital is assumed, for simplicity, to be equal to the weight of the Physical capital. Due to the maximum value of 1 of all three weights, the weight of knowledge capital is defined as half of the difference of 1 and Human capital.
weight_of_Physical_capital = (1-weight_of_Human_capital)/2
UNITS: dmnl
DOCUMENT: The weight of the Physical capital is assumed, for simplicity, to be equal to the weight of the Knowledge capital. Due to the maximum value of 1 of all three weights, the weight of Physical capital is defined as half of the difference of 1 and Human capital.
WELLBEING_INDEX = (natural_resources+Knowledge_Capital+Physical_Capital+Power_inside_community+Human_Capital_participation+success_ratio)/6
UNITS: dmnl
DOCUMENT: The Wellbeing Index is a measure of the community's wellbeing. A community's wellbeing is "the combination of social, economic, environmental, cultural, and political conditions identified by individuals and their communities as essential for them to flourish and fulfil their potential" (Wiseman & Brasher, 2008, p. 358). Most wellbeing indices include social, economic, and health components with environmental or political components, while present, being relatively underrepresented (for a review, see Kim & Lee, 2014). However, such components are of high importance, particularly in the current landscape. Natural resources and changes in ecosystems have significant consequences for human wellbeing (WHO, 2005), while participation and inclusion of communities in decision making and governance are increasingly thought of as central concepts for wellbeing (for a discussion, see Cuthill, 2003). Last but not least, social bonds between the members of the community, particularly those developed through collaboration towards a common goal, are also considered vital for improving a community's wellbeing (Kim & Lee, 2014; Pretty, 2003). In this index, following Pretty's framework (1999), we take into account all capitals represented in our model (Knowledge, Physical, Human, Natural), the benefits from the initiative as a measure of Financial Capital (using the ratio of success as a proxy), and the Power in the community as a measure of inclusion in and ownership of the decision making process and benefits associated with a CBNRM initiative. All those factors are assumed to be of equal importance in the overall wellbeing of the community.
The model has 100 (100) variables
Stocks: 9 (9) Flows: 14 (14) Converters: 77 (77)
Constants: 32 (32) Equations: 59 (59) Graphicals: 9 (9)