ODD for the collective action institution design principles ABM

Model implementation

The model is implemented in NetLogo 6.2.0.

It is available at https://github.com/aashisjoshi/collective-action-institution-principles-ABM

Purpose

Our model aims to capture a generic societal context of unequal vulnerability and climate change impact in a stylized form. The key drivers of system behaviour we want to represent are inequity among people in the ability to access resources, the relative costs associated with living and obtaining the resource, and the welfare levels that people want to attain and maintain by consuming the resource. Within a societal context where the norm to engage in collective action exists, we can then evaluate the effects of other contextual factors and policy measures that influence the design and implementation of a collective action institution that redistributes essential resources to facilitate a sufficient level of welfare among community members.

In particular, we are interested in evaluating the effects of the following conditions and policies (or rules) on realization of a collective action institution that is effective at redistributing essential resources:

- The impact of social and political barriers to equitable participation (or inclusion) in decision-making (re. operating the collective action institution);
- The impact of the urgency of the decision-making process, i.e. the level of societal impact or damage needed to motivate it; the impact of the tax structure or policy that funds the collective action institution, as well as the nature of the institution in terms of how it can translate individual contributions to public benefits; and
- The impact of the duration for which the collective action institution functions after being set up, i.e. its operational lifetime, which determines its overall cost, the time period for which it is accessible to those in need, and the frequency with which the decision to set up the institution is made.

Entities, state variables, and scales

People, resource patches and units, resource bank are the three entities represented in the model. The state variables that characterize them are:

1. People

Attribute/variable name	**Brief description**
resource access	A person's resource access value determines the amount of resource units they are able to harvest (and consume), and therefore the welfare levels they are able to attain.

energy balance	The welfare level of a person at any point during a model run. Consuming the resource leads to energy gain.
desired energy balance	The energy balance value that people desire to achieve. People will seek the resource when their energy balance goes below this level.
minimum acceptable energy balance for sufficiency	The minimum level of welfare that is considered sufficient for people. If a person has an energy balance lower than this, they are not taxed.
starting energy balance	Each person is endowed with an energy balance with a random value between the minimum acceptable energy balance for sufficiency and their desired energy balance at the start of a run.
metabolic cost	A cost of living energy expense that people incur each tick.
travel cost	An energy expense that people incur each time they move a unit distance.
in governing group?	If a person's resource access attribute is equal to or greater than the social inequity index, then they are part of the governing group that decides whether or not to set up the resource bank.

2. Resource units

Attribute/variable name	**Brief description**
energy gain per resource unit	The amount of energy or welfare that a person gains when they consume a resource unit.
energy cost per resource unit	The amount of energy or welfare that a person has to expend to harvest and consume a resource unit.
impact sensitivity	The rate at which resource units regenerate during periods of the climate change impact is determined by this attribute. It is set at fixed value.

3. Resource patches

Attribute/variable name	**Brief description**
resource production capacity	The number of resource units that each resource patch can (re)generate. It decreases during periods of the (climate change) impact.

The spatial and temporal scales in the model are not absolute but rather relative between people in the community depicted, and are the result of people being located at different distances from the resource region as well as the resource bank. This means that those who are nearer to these can access them quicker and incur a lower energy expense, which is an advantage over those who are located farther away. This advantage largely cancels out at the community level, however, as peoples' ability to consume the resource and increase welfare levels is mostly determined by their

resource access attribute value, and people are located randomly irrespective of their resource access.

Process overview and scheduling

1. During any given tick, the community is either experiencing the climate change impact event or not. This depends on the frequency and duration of the impact event (set in the code).
2. During periods (ticks) of the climate change impact event, resource units regenerate slower than compared to periods where the impact isn't taking place. This leads to a periodic scarcity of the essential resource.
3. People lose a certain amount of welfare or energy each tick as a metabolic cost. If their energy (welfare) level goes below a certain value that they want to maintain, they will travel to the resource region to harvest and consume resource units. Traveling also incurs an energy (welfare) cost.
    a. The amount of resource units that each person can harvest is determined by the value of their resource access attribute, which follows a normal distribution from 0 to 1 centered around 0.5.
    b. People also incur a wear-and-tear cost for each tick that they spend outside their home patch. When this cost becomes greater than the metabolic cost per tick, people return to their home patch to rest and replenish. When they do so, their wear-and-tear level is reset to zero.
4. If a person's welfare (energy) level goes below the sufficiency threshold and they do not have enough energy to travel to the resource region, they will travel to the resource bank to obtain welfare funds, if it has been set up.
    a. If they welfare level goes to zero, they perish or become inactive for the rest of the duration of the run.
5. People can belong to either the governing group that takes the decision whether or not to set up the resource bank, or the non-governing group that isn't allowed to participate in the decision. A person belongs to the former group if their resource access attribute value is greater than or equal to the social inequity index.
6. If the norm of engaging in collective action to set-up the resource bank exists (is turned on), then people in the governing group will periodically take this decision. This periodicity is determined by the decision period parameter, which represents the operational lifetime of the resource bank.
    a. The governing group will decide to set up the resource bank if the percentage of people in that group with an energy balance lower than the minimum sufficiency threshold is equal to or greater than the value of the decision threshold parameter.
    b. To set up the resource bank, all people with an energy balance greater than the minimum sufficiency threshold are taxed a share of their energy balance. This share is determined by the tax policy chosen during the run.
    c. The resource bank gets set up if the amount of energy funds collected via tax is equal to or greater than the cost of setting up the resource bank.

Design concepts

Basic principles: The model is based on the premise that:

- The ability to access and consume essential resources is inequitably distributed among societal members.
- Resources are limited (and often scarce), and their availability and regenerative capacity diminishes due to the consequences of ecological overshoot, such as climate change.
- Obtaining (or extracting) resources incurs a cost (in energy), as does operating institutions that facilitate their redistribution.

Emergence: The effectiveness of the resource bank in redistributing welfare from people with more than the minimum sufficient energy balance to those with a balance less than this threshold emerges from the interplay of model parameters such as the social inequity index, decision threshold, decision period (operational lifetime of the resource bank), and the cost of the resource bank as well as agent attributes such as peoples' energy balance, and the number of people remaining active (and therefore able to contribute to the resource bank).

Adaptation: If the resource bank has been set up, then people with an energy balance (welfare level) greater than the minimum sufficiency threshold will donate some of their energy balance to the resource bank, while people with an energy balance lower than the sufficiency threshold will travel to the resource bank to obtain energy funds.

Objectives: Each person tries to achieve a desired level of welfare and wants to maintain at least a minimum level for sufficiency.

Learning: N/A

Prediction: N/A

Sensing: N/A

Interaction: At the start of each decision period, i.e. when the operational lifetime of the resource bank has passed, people in the governing group, whose inclusivity is determined by the social inequity index parameter, decide whether or not to set up the resource bank based on the value of the decision threshold parameter.

Stochasticity: Variation of outcomes results from the randomly drawn values (from a normal distribution, and within a range) of the resource bank set-up cost, the decision threshold and the decision period. Sources of stochasticity are the random normal distribution of the resource access attribute of people, their starting energy balance, and their distance from the resource region and the resource bank.

Collectives: People either belong to the governing group which makes the decision on whether or not to set up the resource bank, or to the non-governing group which is barred from participating in the decision. Those who have a resource access value equal to or greater than the social inequity index will be part of the governing group.

Observation: The main observable is the percentage of people who remain active (or haven't "perished") over the course of a run. In addition, it is interesting to observe the number of times and the duration for which the resource bank has operated, and the welfare redistribution is has facilitated.

Initialization and input data

The model isn't calibrated and initialized with any real world data. The model does not use input data to represent time-varying processes. The range of outcomes from the model arises from the relative valuations of its parameters and entity attributes.

The global parameters in the model are:

Parameter	Value	Unit
population	400	people
social inequity index	random-float 0.00-1.00	
decision threshold	random-float 0-100	% of people
resource impact sensitivity	0.97	
tax policy	flat rate or progressive	
aggregation technology	summation or threshold	
impact periodicity	25	ticks
impact severity	0.7	
starting resource production capacity	5	resource units per resource patch
starting metabolic cost	0.2	energy units per tick
starting travel cost	starting metabolic cost / 4	energy units per tick
starting exertion cost	starting metabolic cost / 5	energy units per tick
minimum acceptable energy balance for sufficiency	400	energy units
decision period	(1 + random-float (2 * (impact-periodicity + impact-duration)))	ticks
resource bank cost	random 0.00-1.00	
resource bank operation cost per decision period	((population / 20) * (resource-bank-operation-cost / 2) * minimum-acceptable-energy-balance * decision-period)	energy units

The attributes that characterize people are:

Parameter	Value	Unit
resource access	random 0.00-1.00	

desired energy balance	(minimum-acceptable-energy-balance * exp (resource-access))	energy units
starting energy balance	(minimum-acceptable-energy-balance + random-float (desired-energy-balance - minimum-acceptable-energy-balance))	

The attributes that characterize resource units are:

Parameter	Value	Unit
energy gain per unit	minimum-acceptable-energy-balance (for sufficiency)	energy units
energy cost per unit	(minimum-acceptable-energy-balance / 20)	energy units
impact sensitivity	(resource-impact-sensitivity) ^ (1 / 5)	

Sub-models

The following functions are used:

- The number of resource units that a resource patch is able to (re)generate is a function of the severity of the climate change impact event.

  resource-production-capacity = (starting-resource-production-capacity * (1 - impact-severity))

- The metabolic cost for people is also affected by the impact event.

  metabolic-cost = (starting-metabolic-cost * exp (impact-severity))

- As is the energy cost of travelling across a patch.

  travel-cost = (starting-travel-cost * exp (impact-severity))

- During a climate change impact event, the likelihood of a resource unit regenerating depends on its sensitivity to the impact event.

  if (ticks - harvest-time) >= (1 + tan (impact-sensitivity * 90)) then regenerate resource unit

- The number of resource units that a person can harvest and consume is determined by their resource access attribute.

  harvest-capacity = (resource-access * resource-production-capacity)

- A person is part of the decision-making (or governing) group if their resource-access >= the social inequity index.

- The decision to set up the resource bank is reached when the number of people in the decision-making group with (energy-balance < minimum sufficiency threshold) >= decision-threshold.

- The amount of (energy or welfare) tax collected from a person whose energy balance is higher than the sufficiency threshold (minimum acceptable energy balance) under a flat rate tax policy:

  energy-surplus-to-donate = (0.5 * (energy-balance - minimum-acceptable-energy-balance))

- The amount of (energy or welfare) tax collected from a person whose energy balance is higher than the sufficiency threshold (minimum acceptable energy balance) under a progressive tax policy:

  energy-surplus-to-donate = (resource-access * (energy-balance - minimum-acceptable-energy-balance))