What to do in urban farming? A multi-agent network approach, validated by a scenario game

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Abstract. Multi-agent systems can be used to model complex socio-ecological systems by a bottom-up approach of dynamic knowledge representation, where rather simple, autonomous, interacting agents with individual behavior are embedded in social and spacial structures. Individual-based simulations, supported by microdata as well as theoretical deliberations, can represent real world phenomena and exhibit complex behaviours and macro-scale patterns. In this paper, we show an application to the domain of urban farming, thereby contributing to the research on realistic decision-making of diverse agents in complex human-nature systems. The model and its use in a simulation serve as a decision support system for local actors such as municipal advisory councils to investigate and highlight the synergies and trade-offs of measures taken to achieve the UN Sustainable Development Goal (SDG) number 2, "End hunger, achieve food security and improved nutrition and promote sustainable agriculture". We describe the processes and behaviours of agents in the context of urban beekeeping, as a special, bounded subdivision of urban farming. We look at the motivations and factors that influence the decisions taken by the local actors and focus on the target that small scale farmers double their income and productivity. To validate the assumptions made while specifying the agents behaviours and for the development of practically relevant scenarios, we have developed a participatory concept in the form of a scenario planning workshop and game. Results of the workshop are presented and discussed.

1 Introduction

The UN has formulated the Sustainable Development Goals (SDGs), "the blueprint for world development" in a way that "meets the needs of the present without compromising the ability of future generations to meet their own needs."[33]. These goals prominently include zero hunger, good health and well-being, sustainable cities, responsible consumption and production, clean water and halting diversity loss. Industrialized agriculture has a major impact on achieving these goals. The synthesis report of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) initiated by the World Bank and co-sponsored by WHO, FAO and UNESCO [20] provides an in depth analysis of the overall situation regarding agriculture (in 2008) and formulates options for action. The report calls for a paradigm shift, to focus on small scale farmers and on protecting the natural resource base. The suggested options for action are (1) promoting small-scale farmers by improving their access to knowledge, technology, credit, more political power and better infrastructure, (2) strengthening local markets and (3) encourage sustainable low impact practices by providing incentives for the responsible management of natural resources.

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In view of the ongoing process of urbanisation worldwide it stands to reason to look at cities as places for implementation of these options, through urban agriculture (UA). However, relying on cockpit-ism, as Hajer et al formulate it in [17], the top-down steering of national governments to implement the actions needed to achieve the SDGs, has in the past decades shown to be of limited effectiveness. The fact that the food system is rarely addressed when governments plan the provision of their people with basic supplies might have been a contributing factor [31]. A bottom-up strategy for change, carried by citizens, civil society initiatives, cities and innovative companies, could lead to a new dynamic in the process of reaching the SDGs.

Indeed we see a growing number of initiatives worldwide that work towards promoting small-scale farmers, strengthening local markets and encouraging sustainable low impact practices on a local level. In cities around the world people start to take action in their neighbourhoods, contributing to local food supply by greening and caring for more than just their private gardens or balconies. Grey street corners, vacant lots, abandoned houses or flat roofs, as well as private gardens or public parks are used as urban farming, gardening and beekeeping areas [32].

Despite a rather celebratorial tone in literature about these initiatives, there is little published material on the quantity of their impact on achieving the SDGs. Most researchers acknowledge that urban farming and beekeeping affect multiple aspects that go beyond food security, such as raising awareness for healthy eating, subjective well-being, improving health in the same way as sports, biodiversity, climate resilience, water management and green infrastructure([28],[48],[18],[12],[27]). There is a lively and ongoing debate on the scale and significance of UA in these diverse and interlinked dimensions. The fact that a holistic view of targeting goals stands in contrast to the specialisation trends commonly seen in supply chains for education, food, health care and recreation seems to impede the evaluation of measurable impact ([47],[15], [36]), as well as the doubtful quality of the indicator framework of the SDGs ([19], [21], [46]).

In our research project we work on contributing to the debate by developing a computer simulation. The simulation is intended to be used as a decision support systems for local actors such as municipal advisory councils to investigate and highlight the synergies and trade-offs of measures taken to achieve the aforementioned SDGs, as well as a software-in-the loop testbed for the development of a decision support system for urban beekeepers working locally and practically on achieving the SDGs.

We base our modelling assumptions about possible change scenarios on the suggestions of IAASTD and the SDGs to provide access to knowledge, infrastructure and technology, strengthen local markets, manage resources and foster well-being through recreation. In its idea of integrating all of these dimensions, our simulation follows a nexus approach [14].

2 Related work

In an interdisciplinary team with backgrounds in cultural science, psychology, biology and computer science, we develop an agent-based model of urban beekeeping as a special, bounded subdivision of urban farming. We look at the motivations and factors that influence the decisions taken by the local actors. As is the strength of agent based models, those local models can scale and make macro-scale patterns observable, allowing the model to be a decision support tool in diverse contexts, local as well as regional or even national. Stakeholders can use the model to increase their understanding of the impact urban beekeeping and urban farming has on the fulfilment of the SDGs and simulate the effects of their own decisions. Even if the scope of their actions is local, they can observe the macro-scale effects their actions cause. Since the achievement of the SDGs can only be successfully reached if a societal change takes place, the model can also be used to better understand that transformation process and offer insight into what might happen if "business as usual" is carried out.

In [35], Ostrom stresses the fact that reliable theoretical models of social-ecological systems are needed to enhance efforts to achieve sustainability. While the feasibility of multi-agent simulations (MAS) for the analysis of sociological systems has been demonstrated [6], An reviews decision making models in MAS in the context of coupled human and natural systems [3] and arrives at the conclusion that modelling approaches still have room for improvement in achieving a realistic interaction between humans and natural system components. This is in agreement with Milner-Gulland [30], who identifies a need for more research effort to incorporate dynamics of decision-making into simulations, if these are to be used as a valuable tool for creating incentives for a behavioural change of stakeholders in agricultural settings. In their review on achievements and challenges of social-ecological MAS, Schulze et al. similarly conclude that there are some elements in need of improvement: They name the representation of human decision-making as well as the sharing of models to foster their transferability [40]. In their review of decision support systems for natural hazard risk reduction [34] Newman et al. report that only 9 out of 101 systems include the functionality to simulate the effects of decision-making into the future.

With our system, we contribute to the effort of modelling realistic decision-making of diverse agents in complex human-nature systems.

2.1 Concept map

The ideas and beliefs about the system and its dynamics held by the modellers after an initial research phase are depicted in the concept map in figure 1. The system's scope is that of one neighbourhood of the city of Bremen, Germany, with roughly 20.000 inhabitants, covering an area of about 8 square kilometres.

Within this area, not only humans live, but also several honey bee colonies under the care of beekeepers. Contrary to other popular models [4], [45],[39], we do not consider individual bees, but view the whole colony as a superorganism [41]. The bee colonies produce honey, which they consume themselves, but which is also harvested by the beekeepers as an agricultural product. The nectar needed to make this honey comes from forage growing within

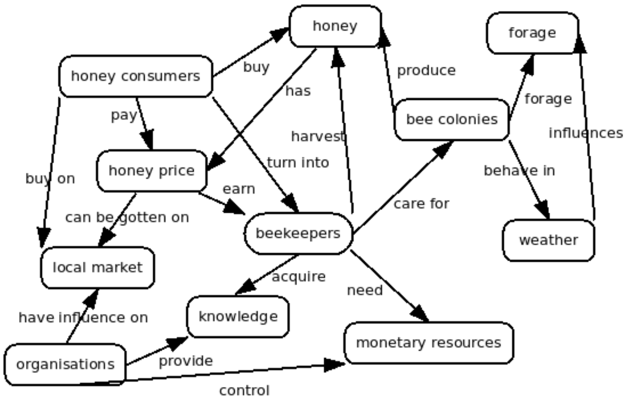

Figure 1. Concept map of urban beekeeping on neighbourhood level

the neighbourhood. This forage is influenced by the weather. The honey is consumed by the beekeepers themselves and sold to be consumed by other humans. Those humans can make the choice to become beekeepers themselves. Under which circumstances this can happen, is a main question the model tries to answer. Honey has a price, which is a source of income to the beekeeper and is subject to supply and demand. Organisations such as the local municipal council, the beekeeping association, veterinary office, community garden projects or environmental protection NGOs have influence on beekeepers by providing access to knowledge for example through organizing courses, by allocating funds for financial support, passing laws and rules for beekeeping (such as the maximum number of bees allowed in a certain area) setting up farmers markets or choosing the plant selection for the city greens.

3 System selection and structural model

When determining the system structure and boundaries, specifying what are external factors and which aspects will be neglected, we followed one central assumption: bees are not confined to an area controlled by the beekeeper. They are free to forage in an area around their hive, limited only by their biologically possible flight distance [13]. The beekeeper is not in charge of actively providing sufficient and divers forage. Therefore, there exists a nexus of city planning, management of public green, owners of private gardens, food supply, public health and beekeeping. In our model, there are four main types of agents: (1) humans: a human can either be a beekeeper, or a honey consumer. He/she can change this status via changing his/her relationship to a bee colony. (2) Bee colonies: bee colonies are under the care of a beekeeper, although they do not deliberately chose to do so. (3) Tile: the urban area is divided into a grid of tiles which have all the same size, but differ in forage. (4) Organisation: although it would be possible to decompose any organisation into individual humans, we modelled them as distinct entities with their own behaviours. As described above, there is a wide range of organisations, such as the municipal council and the veterinary office.

The weather is modelled as an external influence. It effects the bee's behaviour (for example, they do not fly in the rain or in low temperatures), the beekeepers behaviour (who cannot perform an inspection during winter, for example) and the growth of the forage. Since the honey price is also influenced by the price on the world market and not only on the supply and demand locally, it is modelled as an external factor.

While bee colonies, beekeepers, honey consumers and tiles can be regarded as the basic, essential components of the system, the choice on which organisations to include has proven to be less straight forward. In an initial survey, we had identified over 60 possibly significant organisations. From these, we chose a subset with the aim to balance significant impact with traceability of model behaviour.

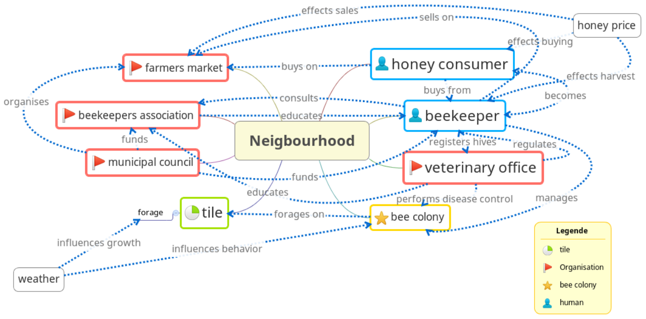

Figure 2. Structural model map

4 Global behaviour

To get a grasp on the global system behaviour, we started out by recalling those questions the model should foremost provide answers for. One of the targets of achieving goal no. two of the SDGs ("End hunger, achieve food security and improved nutrition and promote sustainable agriculture") [19] is that small scale farmers double their income and productivity. So the model should provide insight and allow simulations of scenarios under which circumstances the beekeepers already operating in the neighbourhood could do so. Therefore, we included the deliberate actions performed during beekeeping and modelled how these effect the health of the colonies and, as a consequence, the number of hives in possession of a beekeeper, as well as the honey yield. We argue that "resilient agricultural practices" (target 2.4 [19]) include the marketing of the produce, a resilient strategy of selling honey. We therefore want the model to be able to show the dynamics of a local market, for example how the relationship of supply and demand of honey fluctuates. Secondly, we wanted to investigate under which circumstances a person would take up beekeeping. We concentrate on three main motivations: (1) establishing a small scale urban farm as a major source of income, (2) producing honey to become self sufficient and (3) as a recreational activity, which has the same benefits as sports or gardening, especially in older adults [9]. As it has been shown in numerous studies, sport is significantly related to well-being, which links urban beekeeping to the SDG target 3.4 of goal no 3, "Ensure healthy lives and promote well-being for all at all ages"[19], p. 4 . In the remainder of this paper, we focus on the processes and actions related to the first question.

4.1 Processes and deliberate actions

The processes governing the system behaviour can be grouped into five categories, reflecting the entity groups mainly involved. This categorisation is somewhat arbitrary and intended to be an auxiliary means in the model description. The following section provides a brief overview.

Bee behaviour

- A bee colony *consumes honey*: depending on the number of bees in the hive, the honey stock of the colony diminishes.
- If the weather permits, the colony *forages*: dependent on the day of year, ambient temperature, precipitation, available forage and number of colonies in the vicinity, the honey stock is replenished.
- In late spring, the colony procreates through *swarming*: half the colony leaves to find a new home. The other half stays and keeps on living in the same hive.
- In the *hiveDynamics* process the dynamic change of colony strength is managed. It depends on food supply and the biological rhythm of the queens egg laying rate (external factor).
- A colony can *die*: it will leave an empty hive.

Beekeeper processes

- In order to get information about the status of the colony, their health, food supplies and so on, the beekeeper performs an *inspection* process. The more skilled a beekeeper is, the more likely the information obtained by inspection is valid and the less likely it is the colony will take harm from the inspection.
- If the beekeeper believes the colony to be low on honey, he/she can *feed* it by providing sugar syrup as a supplement.
- If a colony swarms, the swarm flies away and any human who sees it can *catch the swarm*.
- We have simplified the different colony making techniques into one *create colony* process, where an equal fraction of all of the hives in care of the beekeeper is taken and combined to form a new colony.
- Each new colony a beekeeper decides to manage must be *registered* with the veterinary office.
- If a colony is sold or perishes, it must be *unregistered* with the veterinary office.
- If preparation to swarm are observed upon an inspection, the beekeeper can *prevent swarming*.
- Sometimes, colonies do not develop as desired and they have a smaller number of bees in fall then is optimal for overwintering. A beekeeper has then the option respond by *combining* two weaker colonies, merging them into one.
- If the colony has managed to create a sufficiently large amount of honey, the honey can be *harvested*.
- Threats to health, such as the infestation with the parasite varroa destructor, can be amended by *treatment* with medication.
- A beekeeper can always opt to *sell a colony*. He/she must find a buyer for the colony. We simplified our model so that only beekeepers from the same or directly adjacent neighbourhoods can buy colonies. There is no mail order.
- A beekeeper needs to *buy supplies*, such as medication, sugar syrup or a hive for the colony to live in. This will diminish his/her funds.
- A beekeeper can *sell honey*. We model a beekeeper to always consume what he/she needs for her own subsistence first and sell excess only. A sale can be made through direct contact between beekeeper and customer. This can happen on the local farmers market, or through a private meeting.
- When a farmers market is in the neighbourhood, the beekeeper can *sell on farmers market*. This will require the funds to pay for a stand and the time to spend it on the market exclusively.

Human processes Some processes apply to all agents of the human class, whether they keep bees or not.

- Every human will *eat* an individual amount of honey every simulation timestep. The statistical consumption per capita in Germany is modelled to be normally distributed, giving each human a fixed consumption amount (grams per day).
- Any human can *buy a colony* off a beekeeper in the same or immediately adjacent neighbourhood. This will turn the human into a beekeeper.
- If offered by an organisation, a human can *apply for funding* to either start or subsidize beekeeping.
- If offered, any human can *attend a beekeeping course* to increase his/her knowledge on beekeeping.
- Humans *meet*, a random number m [0..50] of humans from its neighbourhood, sequentially. If a consumer and a beekeeper meet, a honey transaction occurs if the consumer is willing to buy and the beekeeper has honey in stock. If the human has a stand on a farmers market, the number of people he/she meets increases significantly (depending on the size of the neighbourhood).

Tile processes Tiles add spacial structure to the model. Every human and every colony has a location, on a tile.

- On the tile, forage *grows* depending on the weather.

Organisation processes In the current neighbourhood, there are four organisations. The veterinary office, a farmers market, the municipal advisory council and a beekeepers association.

- The veterinary office *sets the maximum number of hives* which are allowed in the neighbourhood and keeps track of the current holdings.
- The farmers market *charges a fee* for any person wanting to sell. This includes setting the timespan for which the fee is paid.
- The market also *defines opening hours*, which can rage from some hours every day to much less frequent.
- The municipal advisory council can *grant beekeeping funds* to humans applying for them.
- The beekeepers association *holds beekeeping courses* to give humans access to beekeeping knowledge and improve their skills.

4.2 External influences

As mentioned before, the ability to successfully manage a bee colony largely depends on the conditions found in the environment and surroundings of the colony. The area covered by bees in search for forage is approximated by a circle with a 2km radius [13], an area whose vegetation is not under the management of the beekeeper. The question on how many bee colonies a city can sustain is influenced by the management of city greens, whether private gardens are short trimmed grass or blooming orchards and rooftops covered with vegetables [43]. As those land use scenarios are complex enough to inspire their own dedicated models [8], we have simplified our model and postponed the inclusion of land-use mechanisms for now. The amount of forage available is an external influence, correlated to the weather.

5 Implementation and scenarios

The model is implemented in Java, using the open source artemis-odb framework and libGDX. It is structured as an entity-component-system architecture, where each agent is an entity and all actions available to the agents are implemented as systems. All data is stored in components. At each time step, every agent performs an action. Based on this action, the dynamic change of the world is simulated. The reasoning of each agent is implemented probabilistically, as a Partially Observable Markov Decision Process (POMDP) [24]. Each agent holds a model of the world, its beliefs, that he/she updates through perceiving the environment. Each agent has a unique transition model, of how he/she thinks the world states will be altered through (future) actions, and an observation model of how observations are related to world states given an action. Since these transition functions are not necessarily identical to the transition of the world model, the agents need to update their beliefs based on observations. A reward function for each agent specifies the desired world states the agent would like to find itself in. Foundation for the reward function is the theory of homeostasis [5] and active inference [16]. For bees, this simply means that they aim to keep beekind alive as long as possible. They will gather food whenever possible. Encoded in their genes is the ancestral knowledge that the highest probability of survival for a swarm is given in May.

Beekeepers do have a much more complex range of behaviours then bees. They base their decision on the following quantities: numberOfColoniesInCare: how many colonies do they manage. For each colony, they hold beliefs about its: health, numberOfBees, honeyStock. She/he updates these beliefs through inspections. Her/his skill and uncertainty about her/his beliefs determines how often and good she/he performs the inspection and how valid the information is. She/he knows the precipitation, ambient temperature, season and time of day. The beekeeper knows the price of honey, how much he/she consumes herself per day and how much honey he/she has in stock, already harvested. She/he has monetary funds which she can spend to buy colonies, medication, syrup, farmers market access, hives. Funds are replenished by selling honey, selling colonies or applying for funding. Since we are regarding the productivity of the beekeepers, we need to consider how much time a certain beekeeping action takes. If a beekeeper is more skilled, he/she can perform certain actions faster. For simplicity, we have taken one hour as the smallest possible time duration. Every beekeeper is modelled to have a time contingent of 14 hours per day. If he/she is employed, this reduces to 4 hours on weekdays. Since some actions do not scale linearly (it takes proportionally less time to harvest 10 colonies than 2, due to the high effort of cleaning up the equipment), we have omitted the details here.

In this very focused world view, the world state which each beekeeper holds as his/her beliefs can be modelled as a vector with 17 variables. Not all possible combinations of parameter values represent reachable parts of the state space, and neither do transitions between all states exist (there is no $s_{season} = winter \rightarrow s'_{season} = fall$, nor $s_{numberOfBees} = 8000 \rightarrow s'_{numberofBees} = 45000$, for example). The beekeeper has the choice between 20 actions (including *do nothing*), each applicable to a subset of states. We have utilized a point-based approach [42] for the computation of the reward function and consequently the planning of action policies, iteratively sampling only a subset of reachable belief states. The values of the reward function are computed qualitatively and are individual for each agent. As it is the model's purpose to evaluate the economic aspects of beekeeping, we implemented the goal states of "doubling the income" and "doubling productivity". This was done using relational operators, as it is not an exact quantity the farmers aim for: the goal state is much more realistically formulated as $s^{\tau}_{funds} >= 2 * s_{funds}$, as earning a little more would certainly be appreciated and respectively $s^{\tau}_{honeystock} >= 2 * s_{honeystock}$, with τ being the time horizon for which the beekeeper has constructed a plan of action. Depending on the beekeepers personality, other aspects of the state vector are included in the reward function through adjustments of the weight vector $\overrightarrow{w}$. For example, some beekeepers will weigh the health of the bees highly, so that their decision making will result in a compromise between profit, harvested amount of honey and the health of their bee colonies. More details on the inclusion of personality traits into decision-making can be found in [22]. The model has an interface to receive real world data that is collected through the sensor nodes which were developed and distributed through the citizen science project Bee Observer. Currently, about 150 sensor nodes have been distributed. The beekeepers record their observations through a web-app, and this data can also be accessed by the model. The digital-twin set-up of the whole system is described in more detail in [23].

6 Validation through the participation of stakeholders

As suggested by Bredeweg et al. [7], a structured methodology for building qualitative reasoning models not only requires a broad understanding of the static and dynamic system behaviours and the identification of the relations between involved entities, but also includes the step: "'Specifying typical scenarios and their expected behaviours."' ([7], p. 7). As a tool for successfully achieving this aim with a high correlation of the initial modelling choices with real life behaviours, we developed a participatory concept for involving actors in this process, explicitly in defining typical scenarios and capture their behaviours. Through such a participatory approach, tacit knowledge which can be challenging to formalize, is made accessible and can be reflected upon not only from an outside perspective of the modelling researchers, but also by actors themselves [44].

Scenario planning is applied by various forms of organisations, mostly in economic context, as a means for finding strategies directed towards the future. They can be used to identify possible chains of events and the decision points in these chains [2], [38]. While they are often used with the clear idea of reaching goals and formulation explicit plans for action, it is the *process* which makes them interesting in the scope of building qualitative reasoning models.

In their reviews on scenario planning literature, Chermack et al. as well as Amer et al. have collected a number of definitions of what scenario planning is [10], [2], arriving at the conclusion that there is not crisp definition. Scenario planning is often done in a workshop setting, where a possibly diverse group of people works on developing scenarios and collaborative action strategies, to shape the future in their interest or make preparations against unwanted changes. The scenarios start out from the status-quo, form reality, and try from thereon to analyse and coherently describe possible future developments. These scenarios are not primarily attempts to make a forecast, but rather to come up with plausible and coherent versions of the future. Some of those might be highly unlikely, some might be undesirable, some might be utopistic. Contrary to the usage of the term in the context of qualitative reasoning models and simulation, where a scenario does describe the initial state of the system [7], in scenario planning literature a scenario describes the future final state of the system and sometimes even the whole dynamic process of reaching this state.

According to Kahane,[25], three prerequisites are necessary for a successful and rewarding scenario planning:

1. Participants should be aware that their situation is either not stable, not sustainable or they should be under the (subjective) impression of it being unacceptable.
2. No single actor is able to transform the situation by him-/herself, but instead they are required to work collaboratively. Each participant should be willing to find ways for cooperation.
3. Participants are not in agreement about what the problem is, nor about possible solutions. Therefore they are unable to implement changes directly.

When these are met, there exists a number of possible ways for conducting the scenario planning [11]. The six steps listed by Chermack elucidate that the planning does not only focus on the scenarios themselves, but also pays attention to the concepts and mental models participants hold to be true about the system dynamics, as well as the driving forces and relationships of entities involved and the environment.

7 Workshop and game development

To be able to translate the scenario planning process into a detailed description of model fragments, we have to find a way to document the participants views on what actions the different agents can perform, what the preconditions and consequences they have and what they consider to be good sequences of model fragments in states where the time sequence contains ambiguousness or redundant options. Following the suggestions in [29], we opted to structure the scenario planning process as a game.

Based on classical scenario-technique, the course of the process was structured into 5 phases [37],[26]:

(1) Problem analysis: In this phase, participants are asked to describe the status quo. Relevant actors, relationships, prevailing opinions and communication paths are discussed and made explicit, factual topics are regarded.

(2) Influence analysis: Factors and components that influence the system are identified and the relationship between them are described. Often this is done with a table or matrix, which describes in a first analytical step the interaction of two factors or components. Factors, which are strongly influenced by others (passively) and at the same time do highly influence other factors (actively) are regarded as key factors.

(3) Descriptor analysis: As an operationalisation process, indicators are assigned to each influencing factor. They describe, which distinctions are possible. This is often visualized by a funnel.

(4) Scenario development: One common approach is to refine two extreme scenarios for further processing, one valued as positive-desirable, the other as negative-undesirable. By choosing the extremes, the wide spectrum of possible futures can be illustrated and emphasized. One way of doing this is in a systematic-formalized way, by assigning the respective extreme values to the afore operationalized indicators. If there are a large number of factors, a systematic full-fledged permutation will result in a very large number of extreme scenarios. A possible way of reducing this number is by performing an interaction analysis, where the probabilities of occurrence of extreme value combinations are taken into account [26]. If the process of development should have priority and the scenarios are meant to inspire creative thinking about changes and actions, then a creative-narrative strategy is advantageous. The implicit knowledge and the normative view, the participants' idea of how the world should be, are part of the selection process of the indicator values and value combination. When developing positive scenarios, the participants select values which are desirable in their subjective view. During the selection process, they can be guided to keep their own position and the need for change in sight. The narrative drafting serves the function of a plausibility and consistency check.

(5) Scenario-transfer: In what way the scenario is transferred depends on the objective of the planning process. In this phase, a trend analysis could be performed or a strategy or roadmap for implementation could be generated. Another possibility is to perform a *failure mode and effects analysis*. In our setting, the objective of the transfer is gaining knowledge about the actions people perform, which then can be translated to model fragments. A motivating way to engage participants is by means of a role playing game. The rules of the game and the variable constraints are extracted from the scenario, actions performed by the players/participants can serve as inputs for the model, or as a validation data base for the simulation [29].

In the next section we will describe the practical implementation of a scenario planning workshop and the resulting game for the context of urban beekeeping.

7.1 Lessons learned from the workshop

Prior to the workshop, the interdisciplinary team performed a web-based research as well as expert interviews to identify the target stakeholders. For the first implementation of the workshop, focus was placed on organisations and their behaviour. The group of participants consisted of municipal advisory council members, two environmental protection NGO's, one of them already active in urban beekeeping, a cooperative managing large green areas and active in funding local projects, as well as the beekeepers association (the veterinary office representative cancelled do to illness).

The researchers prepared a series of short talks about the IAASTD's synthesis report on the state of agriculture, the suggested actions and the SDG targets, as well as on urban beekeeping to facilitate an informed discussion about the status quo. Following these talks, we utilized a world cafe method [1], asking the participants to write down their opinions and views on key questions. In this process, the participants developed a connected graph of the key organisations influencing urban farming and urban beekeeping in Bremen, which turned out to include all present stakeholders.

The influence analysis revealed three key factors: the price of honey on the local market, the available forage and - contrary to the assumptions of the modellers - the number of beekeepers instead of the number of bee colonies.

The result of the descriptor analysis can be summarized to: the number of beekeepers is a numerical value, fit as an indicator. The veterinary office as well as the beekeepers association have a good estimate on this number. The price of honey on the local market can be calculated as an average of a few sample prices. The participants had no idea on how to design an indicator on the available forage, as the were aware of its strong dependence on the weather.

Surprisingly, the workshop participants did not develop a scenario in which their own actions were reflected and consequently did not perform a scenario transfer. Even though they had in the first phases of the workshop identified themselves as capable and influential stakeholders, they came to the conclusion that the majority of their behaviours would not have a relevant impact on the goal of doubling the beekeepers' income and productivity. They agreed that solely the beekeepers association would be able to influence these factors and suggested a separate meeting between modellers and the beekeepers association to talk about behaviours and their impacts. This ambivalence between confirming their potential power and influence on the one hand and on the other hand opting to refrain from action was previous to the workshop not reflected in the modelled behaviours. We adapted our model to these findings by giving the beekeepers association a greater action rage and revising the communication between organisations.

8 Conclusions

Our model and simulation have the potential to educate stakeholders about the dynamics of the complex system that is urban agriculture, focussing on an nexus approach. However, the workshop with stakeholders revealed that the possibility and the benefit of reliable theoretical models of social-ecological systems and their simulation as an interactive software application are not accepted as a practical tool in real world application. We have identified the need for raising the awareness level about such decision support systems. Our application should be communicated as a tool for the creative transfer of actions meant as strategies in fulfilling the target. We are now in the process of organizing workshops with focus on the other stakeholder groups to validate and refine our modelling choices based on the results as well as the validation of simulation results with real world data. Through these steps, we hope to further improve the decision support quality of our system and raise the awareness that such applications can be a valuable tool for creating incentives for a behavioural change of stakeholders.

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