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Unlocking Complexity: The Importance of Idealisation in Simulation Modelling

Mandy Haggith[1]
worldforests, 95 Achmelvich, Lochinver, Sutherland, Scotland IV27 4JB

Ravi Prabhu
CIFOR Southern and Eastern Africa Office, 73 Harare Drive, Mount Pleasant, Harare, Zimbabwe

Idealisation is the process of finding simple representations of the real-world whilst conceptualising a model. There are three ways to limit complication in a model of a complex real-world: by *focussing* the scope of the modelling process onto a clearly defined issue; by *idealising* elements of the real-world during model conceptualisation; and by *simplifying* the implemented simulation program. Careful idealisation has the greatest potential for increasing model tractability whilst generating insights during the model design process. The Forest Land Oriented Resource Envisioning System (FLORES) project deals with social forest landscapes which are highly complex. Benefits of idealisation are demonstrated using six examples from this modelling work. These examples encompass issues dealing with land tenure, forest management, economic values, social diversity, communication and collaboration. Each example illustrates a different method to achieve an idealisation which yields insights relevant for policy players. A number of lessons about idealisation are also identified: (1) sometimes it is only possible to recognise what is key by omitting it; (2) an effective idealisation is not just achieved by leaving things out, or adding them back in; it can also be achieved by restructuring the representation; (3) it is important challenge the use of different units where consistency is possible; (4) it is easier to keep a simple model simple, than to make simple modifications to a large model. Similarly, it is easier to generate insights with a simple concept for a sub-model than with a simple modification to an existing model; and (5) even the most useful idealisations may have a limited shelf-life.

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INTRODUCTION

Models are simplified representations of our understanding of the real-world, but a common problem in simulation model development is that models can easily become complicated, especially if the domain being modelled is complex or if they represent the combined understanding of many people. Both of these conditions can be found in the Forest Land Oriented Resource Envisioning System (FLORES) research project which aims to model the complex interactions between social and biophysical processes at forest margins (Vanclay 1998, Vanclay *et al*. 2003). It is not surprising therefore that FLORES models have tended to be complicated. However, complicated models are difficult to test, difficult to debug and difficult to calibrate, so they are almost impossible to bring to a stage of development which inspires sufficient confidence in their behaviour to use them as the basis of decision-making or policy advice. There is an urgent need to find ways to harness complexity in order to reduce the level of complication in models.

Reflection on the main stages of the modelling cycle suggests three main ways to limit complication in a model of a complex real-world context. During the early scoping stages of modelling this can be achieved by *focusing* the modelling process onto a clearly defined issue. Later, during model conceptualisation, complications can be limited by *idealising* elements of the real-world. A third approach is by *simplifying* the implemented simulation program.

Whilst all three of these methods are appropriate in some circumstances, careful idealisation has the most potential for increasing model tractability whilst also generating insights during the model design process. Relying too much on focus may lead to a model which is too narrow in content to be useful for long, and limits the range of issues about which insights may be generated later in the modelling process. Simplifying an implemented program is a technical task which is unlikely to involve the people upon whose knowledge the model is based. The modelling cycle and opportunities for harnessing complexity within it are presented in more detail below.

The Modelling Context: FLORES

FLORES is a unique modelling concept involving both spatially explicit representations of a forest landscape and representations of the decision-making processes of the people who live in that landscape and manage its natural resources.

Conceptually FLORES requires integration of knowledge about social forest landscapes from many different disciplines, from biophysical knowledge about forest ecology and agronomy, to anthropological and psychological understanding of decision-making processes and social structures. Technically, it requires integration of system dynamics modelling concepts and Geographical Information Systems (GIS) techniques with ideas from Artificial Intelligence (AI). FLORES therefore draws on a rich and complex body of knowledge.

A FLORES model is much more than a forest model. It is a model of the intelligence of the social forest landscape, emerging from the cumulative decisions of the people represented as living in that landscape, as they respond to political and other changes. It is intended to be used by policy players as a tool to articulate policy scenarios and to simulate the landscape-level impacts of these policies. Users are intended to express their policy scenarios by modifying scenario inputs, and the model when run is expected to respond in a plausible way. Although the model to need not predict precisely, it should be plausible enough to be provocative and this requires coverage of a broad range of social and biophysical issues.

FLORES is also more than just a single model. It is a modelling process, which has brought together many people in workshops to share their knowledge and conceptualise model components. It has involved, and will continue to involve, numerous iterations of modelling work to refine and revise models in different contexts and with different people. In some of these iterations the model conceptualisations have been dizzying in their complexity, particularly in the parts of the model which address people's decision-making and social behaviour. In these sub-models, attempts have been made to integrate knowledge from anthropologists, sociologists, economists, geographers and agronomists, in addition to local people's knowledge.

Some of the recent modelling iterations have involved developing the FLORES model within a research project on adaptive collaborative management in the Mafungautsi forest area, Zimbabwe. Most of the ideas in this paper were generated as part of this research. An earlier iteration built a FLORES model for the Rantau Pandan region of Sumatra, Indonesia. Efforts are also under way to develop FLORES models in Kalimantan, Indonesia, in Cameroon (Legg 2003), and in Bolivia.

HARNESSING COMPLEXITY IN MODELLING

A map of a landscape which is too detailed becomes difficult to read. Likewise a model which attempts to capture everything about a social system rapidly becomes intractable. The primary challenge in building FLORES is to develop a model which is less complex than the social forest landscape, which leaves out much of the detail, but which retains the key interactions and drivers of change in the landscape.

In the real-world, complex systems are characterised by multiple inter-connections, non-linearity between 'cause' and 'effect', time delays, and feedback giving rise to uncertainty and surprise (Nicolis and Prigogine 1989, Sterman 1994, Bossel 1998). As Sterman pointed out, 'the heuristics we use to judge causal relations lead systematically to cognitive maps that ignore feedbacks, multiple interconnections, nonlinearities, time delays and the other elements of dynamic complexity' (Sterman 1994, p. 28). This leads to difficulties as cause and effect are often distant in time and space, and the delayed and distant consequences are often different from, and less salient than, proximate effects. We are thus confronted with the twin problems of causal complexity and our own cognitive limits to grasp complexity.

Illustrating behaviour in complex systems, Nicolis and Prigogine (1989) demonstrated that a new human activity launched at a particular time can grow and stabilise, or even compete successfully against similar activities. However, the same activity launched at a different time may result in a very different outcome. This, they suggested, illustrates the dangers of short-term, narrow planning based on the direct extrapolation of past experience, and the need to act in the face of uncertainty (Nicolis and Prigogine 1989). Others have described an adaptive management strategy that responds to this challenge (Holling 1978, Walters 1986, Lee 1993). As

Lee pointed out ‘Adaptive management is learning while doing. Adaptive management does not postpone action until ‘enough’ is known but acknowledges that time and resources are too short to defer some action, particularly actions to address urgent problems such as human poverty and declines in the abundance of valued biota’ (Lee 1999). Simulation modelling can be a useful way to explore the potential impacts of such actions and to assist with the explorations of future scenarios in complex systems.

The Modelling Cycle

The systems dynamics community has developed various methodologies for modelling (e.g. those of Forrester 1961, Kim 1995, Sterman 2000) all of which involve a series of steps, carried out repeatedly in a series of iterations. Although the terminology varies considerably and some versions of the modelling methodology merge two steps into one, divide one step into two, or have subcycles within the main cycle, most agree on something similar to the cycle in Figure 1. This figure has been a useful way to introduce the modelling process to non-modellers.

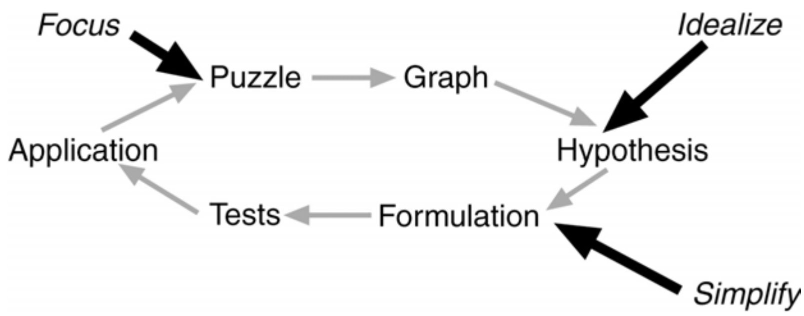

Figure 1. The modelling cycle showing where it is important to focus, idealise and simplify

Puzzle. The first stage, often called ‘problem formulation’, ‘problem identification’ or ‘model purpose’, identifies the reason for modelling. The modelling team agree on the question that the model will be used to answer, or the problem that the team is hoping to solve, or the theory that they intend to test. In many contexts where the aim of modelling is learning, the trigger is a puzzling issue, and hence the term ‘puzzle’ here as shorthand for the concept. This is an extremely important stage which can be a major challenge, particularly when large groups are involved in modelling, all of whom are likely to have their own expectations and reasons for participation. Ideally, all the members of a modelling team should commence with a clear view of a common puzzle, but in reality this view needs to be negotiated within the team at the beginning of the process. Finding a common puzzle helps the modelling team to move forward in a ‘joint enterprise’ (Wenger 1998). However, it can be difficult for multi-disciplinary teams to establish a common purpose in specific terms. In time-limited situations such as workshops, teams often can only agree at a general level, and details of the puzzle are left to be resolved in later stages of the modelling process. A general rule seems to be that a more detailed puzzle definition at this early stage (i.e. sharper *focus*) will make the rest of the modelling process easier.

Graph. Having agreed on a puzzle, it is helpful to express expectations about the eventual behaviour of the model about to be built. Sketching graphs of the changes in key system variables over time is a simple way to begin eliciting the team's knowledge about the system being modelled. It is also a way of encouraging more specific statements about the puzzle (Tufte 1983). The graphs or 'reference modes' anticipate the behaviour of the model and are extremely useful for testing and for reflecting on learning later on in the modelling process. Sketches of the behaviour of key indicators, as used within future scenarios and visioning processes (e.g. Wollenberg *et al*. 2000), are useful at this stage, both for providing graphic illustrations of hopes and expectations, and for linking modelling into participatory action planning processes. Purnomo *et al*. (2003) offer a good example of linking future scenarios with modelling in this way.

Hypothesise. A model is an explicit representation of a shared understanding and as such can be thought of as a hypothesis, or set of hypotheses, about the world. Further development of this hypothesis requires specific details of the concepts to be included in the model to resolve the puzzle, to test the theory, or to understand and solve the problem. Generating the hypothesis is thus a process of *conceptualising*, and involves identifying key model concepts and the relationships and feedback loops between them. It is usually most helpful, particularly when working in a team, to use a standard graphical modelling language to express these in a diagrammatic form. It is also helpful to use card-sorting processes for identifying key concepts before beginning to link them in a diagram.

Formulate. Model formulation is the process of turning the hypothesis into a simulation, usually a computer program, that can be run to explore possible solutions to the puzzle. Formulation has three stages, i.e. specification, implementation and verification. Specification takes the hypothesis and defines it in a formal language such as a set of mathematical equations, or 'pseudo-code'. Most modelling environments provide support for the process of specification of the hypothesis, helping the user to convert a model diagram into a formal set of statements, by entering equations to specify the nature of the relationships between model constructs, and quantifying all the model parameters. In FLORES there has recently been considerable emphasis on attempting to encourage and support model specification through 'adaptation' of existing models, and 'plugging and playing' with sub-models from a model library. Implementation takes the specification and converts it into an executable simulation program. Most modelling environments automate implementation (production of the 'run-time' version of the model). Verification involves checking the program for correctness, and debugging it when it fails to represent the hypothesis accurately.

Test. This step is often called 'validation' or 'model analysis' and it involves critically scrutinising the model's structure and behaviour. An important though small part of testing (strongly emphasised within FLORES) is calibration of model parameters. A broad range of other tests needs to be applied to build confidence in the model. Such tests may range from an examination of what the model contains - its relevance, consistency and credibility – to how it behaves – at extremes, over time, and by comparison with the real world. There are many excellent sources of advice and experience on testing (EJOR 1993, Barlas 1996, Vanclay and Skovsgaard 1997, Sterman 2000). Some of the better modelling environments provide useful tools to facilitate sensitivity testing and reality checks.

Apply. A validated model, in which the modelling team have confidence, is ready to be applied. In some system dynamics approaches this step is divided into two stages - policy analysis and design, followed by policy implementation. This is appropriate when the purpose of the model is to deliver a solution (a policy) in response to a problem. Soft systems methodology (e.g. Checkland 1981, Wilson and Morren 1990) provides guidance on how to use a model to guide action through a process of mapping back to the real-world. In other circumstances, such as modelling for learning, it may not be appropriate to think in terms of direct intervention as part of the modelling cycle. In some circumstances, notably when testing has revealed deficiencies, it may be appropriate to curtail this stage and return rapidly to the original puzzle and consider alternative idealisations for further iterations. This has been the case in all FLORES modelling so far. At the very least, but particularly when modelling for learning, model application should involve reflection.

Repeat. It is highly unlikely that a single iteration around the modelling cycle produces a fully satisfying outcome, though that is of course wonderful if it is achieved. However, most modelling teams encounter difficulty with some parts of the process on the first iteration, and better results can be achieved if an opportunity is provided to return to the basic puzzle and readdress it in the light of what has been learned so far. In this way the modelling process becomes a learning cycle (Kolb 1986). Trials in which the model-building cycle was reduced to a few hours, enabled up to 20 iterations during a 10-day period, and proved to be an extremely insightful process (Haggith *et al*. 2003a). Such rapid iteration around the learning/modelling cycle is not possible with a group model-building and participatory modelling processes, because with groups, it is important to allow sufficient time for sharing of knowledge between participants. Thus the bigger the group, the slower the cycle.

Focusing, Idealisation and Simplification

What can be done to address the problem of model complication and to ensure a more systematic approach to harnessing complexity in modelling processes? In the modelling cycle there are three main opportunities for addressing complexity, as shown in Figure 1. Complexity can be harnessed by *focusing*, which should happen in the first stage of agreeing the model puzzle, by *idealising* when devising the hypothesis or model conceptualisation, and by *simplifying* a model formulation.

Focus on key issues

One well recognised route for addressing complexity is to narrow the field of view of the model (Sterman 2000), by focussing on a particularly puzzling issue, and building a model which only addresses this one issue, rather than attempting to simulate the breadth of an entire social forest landscape.

An extremely important aspect of focus is setting clear and well-defined boundaries to the scope of the model. In addition, a firm commitment to a particular site, making the model specific to that site, is an effective way to avoid theoretically interesting but unnecessary entities in the model (Haggith *et al*. 2003b)

The cost of too tight a focus, however, can be narrow-mindedness, so balance is needed. This is an instance of the trade-off between tractability and expressiveness, which is a familiar and fundamental knowledge representation dilemma (Brachman and Levesque 1985).

Highly focussed models also tend not to be durable. A model constructed to address a particular problem may be discarded after insights have been generated, since the model has served its purpose. If, however, the model is intended for continued use, as has been the case for most FLORES models, then a narrow purpose may not be possible, in which case other approaches to harnessing complexity are needed.

Idealise points of complexity

Experience in developing FLORES models has shown that it is important to address complexity whilst conceptualising the model in order to produce a more useful hypothesis. Idealisation is a critical but often overlooked part of the model conceptualisation process. There are no textbooks on how to idealise or simplify systems, and this aspect of systems modelling is at best more an art than a science, and at worst an ad hoc process of leaving things out.

Idealisation involves identifying a significant point of complexity in the structures or dynamics of the system being modelled, learning something essential about this complex phenomenon, and representing its core function within the system model. A good idealisation results in insight, which pushes the modelling process forward. These insights increase understanding of the system or suggest policy directions. Idealisation often also helps in designing models which can be implemented, compiled and run more efficiently, and which are thus more usable. This is why idealisation is the key for unlocking complexity in modelling.

Simplify the model formulation

Another option for reducing model complexity is to simplify the simulation program which results from model formulation, either during or after implementation. For example, sensitivity analysis can help to identify variables which have a negligible effect on outputs, and which may be removed from the model. Alternatively, it may be possible to eliminate some kinds of model complication. For example, it may be possible to aggregate the results of simulations with weekly time-steps, in order to develop more efficient annual simulations. It may be possible to aggregate some spatial patches into zones in order to reduce the computational costs of spatial explicitness.

Whilst these kinds of measures can dramatically enhance tractability of the model, they can also introduce new problems. Firstly, they can hide important issues, for example, spatial aggregation of a forest could lead to results which show acceptable levels of harvesting of some resource but hide the fact that the resource is being over-used in some locations and under-used in others. Secondly, scale is fundamental to many model constructs, and aggregation to different temporal and spatial scales can produce different model behaviour. For example, if people have access to information (such as resource prices) on a daily basis, they may make quite different decisions than if they only have access to information on an annual basis, for example in choosing market locations for products.

In addition, it is often technically taxing to simplify the implementation of a model, and thus this tends to be done by technicians rather than by the people whose knowledge the model relies on. Simplification is therefore much less likely to produce conceptual insights among modelling group participants than idealisation.

COMPLEXITY IN FLORES

In the FLORES project, real-world complexity has often been reflected in complicated models. It is instructive to reflect on how this has happened. The complications within the model have a number of dimensions:

Diversity of issues. The model addresses a wide range of social factors, including livelihoods, demographics, livestock, consumption, marketing and health, and biophysical components, including wood and non-wood forest products, grass, crops, fire, water and soil. This leads to many social and biophysical sub-models, which, even though individually simple, interact with each other in complex ways.

Spatial granularity. FLORES models have been built with a commitment to spatial explicitness, which has involved dividing the landscape into field-sized patches, often resulting in several hundred instances of the biophysical elements of the model.

Social granularity. Several nested layers of social structure are required to capture individual, household, village and district level decision-making processes. FLORES modellers have attempted to model at (or below) the household level. This results in hundreds of social agents.

Temporal granularity. Some of the processes involved have been modelled with weekly time steps, others with annual time steps.

Another factor compounding these dimensions is uncertainty. Many of the interactions represented in the model can only be represented with low levels of confidence in the mathematical nature of their relationships. Many parameters are likewise estimated with high levels of uncertainty. A commitment to quantitative simulation modelling has required intrinsically qualitative issues (such as social capital) to be quantified.

Stepping back now, it is appropriate to ask how such levels of complication appeared in FLORES models in the first place. Most of the modelling work did not set out to address a specific real-world problem or puzzle, which would provide a reference to resolve the relevance of model variables. On the contrary, FLORES has attempted to produce a 'generic representation of the interactions between people and the biophysical resources at the forest frontier' (Vanclay 1998). This presumes that it is possible to build a single model that is sufficiently comprehensive to be used for a wide range of as yet unspecified policy questions. This assumption has overlooked the 'mantra' of system dynamics modelling - to model the problem, not the system[2]. This lack of focus on a particular puzzle as the purpose of the modelling enterprise has been the underlying cause of the level of complication in FLORES models.

More recent modelling work has explored the benefits of a more tightly focused puzzle. One instance relied on a participatory modelling process with local people from villages near to the Mafungautsi forest, Zimbabwe, focusing on the puzzle of whether a community should dig or cut broom grass. The result was a much simpler model than those from the FLORES project. In addition, the model could be implemented and tested within a period of two days, resulting in rapid insights (Standa-Gunda *et al*. 2003). In other work to model the spread of ideas around a

[2] Thanks to Richard Dudley for helping us to realise this.

community (Haggith *et al*. 2003a), a similarly tight focus allowed many alternative model formulations to be examined. This would not have been possible with the diversity of issues usually addressed in FLORES models. This nimbleness, however, comes at the price of models which are myopic. The broom grass model does not address how people might weigh up a range of alternative resource-use options. The model of ideas spreading does not include any biophysical impacts.

Another cause of excessive complication in the FLORES project has been undue haste in building models. There has often been insufficient attention to methodology and a disproportionate effort on model formulation with too little time spent on the other steps in the cycle. Many of the problems encountered in the FLORES project can be attributed to insufficient consensus while scoping the exercise, and too much enthusiasm for moving on quickly to the model conceptualisation stage. Graphing, or the production of reference modes, has generally received little attention, and this has helped to mask the lack of agreed focus on specific issues.

Another complicating factor is the nature of the FLORES modelling teams. These have usually been multi-disciplinary, large (up to 50 people working simultaneously in some workshops) and transient (different participants at different times and locations). People have tended to come together from different cultural backgrounds, with different intellectual approaches, and varying worldviews. Rarely has there been a concerted attempt to develop a common 'Weltanschauung' (*sensu* Checkland 1981) or view of the world, to enable a shared understanding in a genuinely inter-disciplinary way. The team members' different backgrounds and insufficient mutual experience have not allowed effective negotiation of common meanings for the concepts being introduced into the model. In other words, it has been difficult to develop a 'community of practice' (Wenger 1998).

In workshop situations, this lack of coherent community of practice has led to two problems. Firstly, at the early stage of working together, there has been eagerness to ensure full participation by all. Thus model diagrams sometimes have been used as places for people's voices to be heard, and this has encouraged the addition of variables as a way of agreeing that someone's area of expertise is indeed relevant to, and should therefore be used in, the model. Secondly, we have often known each other so little, that we have been too polite to purge incompatible or irrelevant concepts from the model. The result has been model diagrams, informally referred to as 'spaghetti' or 'horrendograms', that are untenably complicated and inherently incoherent.

Some of the team dynamic problems can be resolved by facilitation which pays greater attention to the group and its working practices, for example building on the experiences of others working on group modelling, such as Richardson and Anderson (1995), Vennix (1996) and Anderson *et al.* (1997). However, literature on organisational culture (e.g. Phillips and Phillips 1993, Wenger 1998) suggests that achieving full consensus is difficult in multi-disciplinary teams. Methodological assistance is needed to make full use of the richness of combined intellectual resources to generate insights that clarify rather than complicate conceptualisations.

Despite all of these shortcomings in the FLORES process, there have also been occasions when substantial progress has been made by unlocking a complex issue and achieving a consensus on a simple way of representing it. These idealisation breakthroughs can be moments of valuable insight.

IDEALISATION: EXAMPLES AND DISCUSSION

Six idealisations made during FLORES modelling are now examined. Each idealisation is introduced by articulating the point of complexity which it was aimed at addressing, followed by an exploration of what insights were gained as a result, and ending by reflecting on what can be learned about idealisation as a process.

Representing Tenure Relationships

At the heart of FLORES models is the feedback between social processes and biophysical resources. Systems of resource tenure are fundamental to this feedback (Fortmann and Bruce 1988, Colchester and Lohmann 1993), so a central question has been how to represent in the model the forms of tenure that modulate people's access to natural resources. Resource tenure systems are inherently complex: they take many forms and are internally rich in structure, they are dynamic, and they change in unpredictable ways, sometimes slowly, sometimes abruptly. Traditional systems of tenure of forest communities involve multiple and overlapping rights, including rights to access common pool resources.

All FLORES models use tenure to define which land patches can be accessed by the decision-making agents, which are villages and households (and in some versions, individual people). Tenure is represented as a binary relation linking households in villages with land patches. Different rights to different resources are modelled by defining rules for resource access as part of this tenure relation. The models also contain a 'tenure register' which contains a full listing of all the instances of the tenure relation.

The tenure relation has had an interesting history during the FLORES project, and has varied througha range of tenure representations, from very rich to highly impoverished, encompassing two extremes:

1. A fully generic tenure relation defined in the specification of an early FLORES model was highly expressive but proved intractable to implement. It included leasing arrangements, many forms of inheritance, distinctions between *de jure* and *de facto* rights and various kinds of change over time.
2. A tenure relation used in a skeletal FLORES model involved only exclusive land ownership, which although tractable is not expressive enough to handle shared resources.

The representation of tenure in the Mafungautsi model, perhaps the most satisfactory FLORES model, is a compromise between these two extremes. It involves three tenure relationships, and the resource rights associated with each:

1. *Exclusive access*. Some land patches represent arable fields. Each field patch belongs to a single household which has exclusive cultivation rights.
2. *Village commons*. Some land patches belong to a village, but not to a particular household in that village, and all households in the village can pursue activities on them. Households do not have rights to cultivate this land but they do have grazing rights.
3. *Open access*. Other common land, such as state land, belongs to no particular household or village. These patches of land can be perceived and acted on by

anyone. By default, all households have rights to collect all forest products and graze on these patches, but it is possible to add simple rules which can further restrict rights to specific resources.

This version of the tenure relation omits many issues – it does not involve individual people within households, it does not model inheritance or land transfer arrangements, and it does not cover rental, lease or share-cropping arrangements. However, participants felt that it captured the crux of the matter of tenure, and represented the bare minimum with which they could articulate the local system of resource access by local people to the natural resources of the Mafungautsi area. The minimum requirement of this relation is that it can distinguish between patches of land over which people have exclusive rights, common land shared within a village, and land shared between villages. In addition, it is vital to include rules for access rights to particular resources on these shared lands.

The search for an adequate but minimal tenure relation in the FLORES model has made clear that multiple and overlapping resource access rights is a fundamental concept in understanding social forest landscapes. Evading the concept with simplistic tenure relations (e.g. by admitting land ownership only) degrades the model.

By including commons and open access, common pool resource management issues can be addressed and situations such as the 'tragedy of the commons' can be explored. This means that the model can be used for examining policy questions about how systems and institutions for sharing of resources influence people's livelihoods. For example, in Zimbabwe, the impact of various resource access options selected by village resource management committees can be explored by adapting the resource access rules and examining the impacts.

This idealisation for tenure required several iterations. The first attempt to conceptualise the issue was awkward, but the importance of the issue was recognised. Over subsequent iterations the representation of the issue fluctuated enormously. A detailed specification was produced, but was too complex to implement, and even a cut-down version led to an intractable model. A drastic simplification reducing tenure to exclusive land ownership was unable to express key land-use patterns in the study area. The compromise described here has been reached by clearly identifying that the model needs to handle the issue of shared resources, but without the earlier complexity. The lesson here is that sometimes it is only possible to recognise what is pivotal is by cutting it out.

Modelling Labour Allocation

By carrying out resource management activities, people induce changes on the landscapes that they inhabit. These changes take place at many spatial and temporal scales and the resulting big picture of interactions between the social and biophysical systems is immensely complex. Some activities are regular and frequent, such as firewood collection, whilst others are occasional, such as clearance of forest. Many activities have indirect effects, such as herding livestock from one area to another, so that the impact of the action can be as important in the place where the activity has ceased as where it has commenced. In addition, many activities are spontaneous and unpredictable. People are highly diverse in their land-based activities, with variation by gender, age, wealth and social status. People's activities vary with the seasons, according to needs, opportunities and constraints, and according to strategic decisions. Some involve the application of effort (such as digging), some involve moving resources around (such as applying manure) and some involving triggering a continuing process (such as lighting a fire). Many are of course combinations of all of these. The aim of producing a generic FLORES model posed a major challenge in idealising the impact of people on their natural resources into a tractable representation.

In all the FLORES models, there is a sub-model within the social agent (usually at the household level) to resolve which activities will be undertaken on each patch of land to which rights are held. The activities may be cultivation of crops, animal husbandry, collection of non-timber forest products, logging, or hunting. The key step in this idealisation process was the decision that all actions by agents on the resources would be modelled in units of person-days of labour, rather than in terms of kilograms of manure spread, hectares of ground cultivated, or cubic metres of timber cut. The representation of activity planning was therefore reduced to allocating labour to various actions on various patches of land.

There are many different algorithms for labour allocation (using norms or priorities, for example) and several approaches have been tried in different versions of the FLORES model. One way of handling labour allocation, if time allocation survey data are available, is to allocate labour according to a ‘norm’, which is the table of mean times allocated to different actions by different labour classes (e.g. women, men, children and elderly people). Different ‘lifestyle’ choices lead to the use of different norms. This has the benefit of being well-grounded in data; however, it is a rather inflexible approach because behaviour of each individual is constrained to mindlessly following the pattern described by the norm. This approach was used for the first FLORES model built for Rantau Pandan in Sumatra.

The Mafungautsi model uses a different algorithm to enable each agent’s activities to be planned differently according to their particular household conditions. Labour allocation is driven by priorities set by each household which can change from year to year according to strategic decisions. This gives greater flexibility and scope for modelling changing behaviour patterns, but is not so easy to verify with time allocation data.

By idealising people’s activities to ‘number of days spent’ on a small set of actions, modelling of activities is made tractable because the activities are all measured in the same unit, viz. person days of time per week. The actual list of actions varies from site to site but the logic of the activity planning sub-model does not vary. This simplifies the feedback loop involving people and their natural resources.

As the FLORES project has constructed models for various locations, this idealisation has led to some interesting reflections by group members on the relative labour and land availability in different parts of the world. In particular, there is stark contrast between Rantau Pandan in Indonesia where labour is relatively plentiful but land is a major constraint and Zimbabwe where labour for subsistence farming activities can be much more of a constraint for families. This has led to the insight that significant impacts on natural resources and on people’s livelihoods can result from policy decisions which influence the availability of labour, for example, upgrading of roads that reduce travel times to fields or markets, and health services which reduce time lost through illness. Technologies can also have a major impact, for example, chainsaws can radically alter the amount of timber a single person can harvest. In Mafungautsi, choice of technique for harvesting broom grass may affect the labour efficiency of harvesting.

Ultimately, however, a weekly labour allocation model alone cannot adequately explain land-use change. Major landscape-level changes, such as forest clearance, result from strategic decisions that people make to change the way land is used, or change the way they make their livelihood.

By contrast with the tenure example, this idealisation was reached rapidly in the first FLORES modelling workshop and it has never been abandoned. In this workshop, several subgroups were conceptualising different sub-models, one of which was the 'household' model, and all but one of the rest were biophysical models which required inputs from the 'household group'. The household group was overwhelmed by requests by the biophysical modelling groups for variables ranging from 'number of pigs hunted', to 'kg of fertiliser and % potassium, nitrogen, and phosphate' to 'availability of chainsaws'. This led to a proposal for an in-principle agreement by the biophysical groups to conceptualise their sub-models assuming inputs from the social part of the model which consisted only of time allocated to named activities, such as 'time spent hunting', 'time spent logging'. This proposed idealisation caused heated debate, but eventually was accepted as reasonable. The lesson here is to question the units used by variables in the model and to challenge the use of different units where the same unit can suffice.

Representing the Benefits Gained by Households

One of the most controversial areas of forest policy relates to the valuation of forests and natural resources, particularly with respect to the spiritual and cultural values attached to these resources by local people. Such values cannot be fully quantified (e.g. Daily *et al*. 2000), and yet they are vital to an understanding of resource use. It is also increasingly understood that monetisation (reduction to merely economic terms) of environmental values such as biodiversity or carbon sequestration gives a distorted view of their worth, which can lead to perverse policies (Sheil and Wunder 2002). Furthermore, there are philosophical and moral objections to representing the value of natural resources to people living in a non-monetary culture in terms of dollar-values.

The challenge was to find a representation of the diverse benefits obtained by local people from their natural resources which was simple and yet not monetary. Moreover, in order to satisfy the economists in the group, this representation needed to be usable as a proxy for money.

The idealisation adopted was the use of a common currency called 'dosh', which represents 'daily ordinary subsistence per household'. The main feedback to households as a result of their application of labour to the land is in the form of yields and all yields and consumable resources are converted into units of dosh. One unit of dosh may be thought of as a certain amount of cash, it may be an amount of a subsistence food, or an amount of any other commodity that can be exchanged (sold or swapped) to meet the basic subsistence requirements of an average household.

Dosh solves the problem of how to calculate summary values such as wealth, or manage conversion rates between different commodities, which arises when multiple different units are being used for the commodities. It solves the problem of 'adding apples and oranges', which in FLORES terms is the problem of adding two tonnes of timber, 6,500 Zimbabwean dollars and seven sacks of maize. This idealisation means that all commodity quantities are in the same unit in the model, and can thus be easily aggregated. It is thus an example of the same kind of idealisation used in substituting labour for activity (described above).

The concept of dosh has been, however, considerably more controversial than the labour idealisation. It is important to see that ‘dosh’ is not the same as cash as it does not devalue as the years go by. It therefore solves the problem of handling inflation in the model. However, this benefit is a problem to some people, who consider that aggregating all forest values in terms of money is somehow inherently the best and only rational form of aggregation. Despite the global proliferation of non-cash currency systems it seems that many people have a deep belief that the only acceptable common currency is cash.

Although this idealisation has been controversial, it has struck a chord with some users who view subsistence values as at the heart of resource valuation in many contexts. In addition, given the recent rapid deflation of the Zimbabwean dollar on the parallel market, and the massive fluctuations in the Indonesian rupiah during the late 1990s, the use of a neutral currency has had considerable practical attraction for its ability to ‘hold its value’ over simulation runs of years or decades.

The dosh idealisation has had an interesting side-effect. The simple fact of having a new and controversial term for this concept has triggered attention to the question of what are the benefits which flow from natural resources to the local community. This has enabled people to engage with the model right at its heart in the main feedback loop between the social and biophysical aspects.

However, like any currency, not everything is convertible to dosh. In particular, capital assets (social capital, land, labour) are hard to measure in dosh. In the Cameroon FLORES process (Legg 2003), this idealisation has not been used, and all commodities are explicitly and separately represented. It will remain to be seen if this allows for greater power in exploring the impacts of fluctuations in individual resources. The lesson here is that even the most useful idealisations may need to be viewed as having only limited shelf-life.

Livelihood Strategies

Communities are immensely heterogeneous and people manage their resources differently according to their needs, constraints, opportunities and access rights. It was recognised that there is a strategic element to people’s activity planning which cannot be reduced to labour allocation.

In early FLORES models there was no strategic behaviour at all, but making sense of actions like land clearance required long-term and infrequent decision-making to be simulated. The Mafungautsi model idealises strategic decisions as annual events leading to a prioritised list of activity options. These activity options reflect different ways to make a living, hence a strategy is a prioritised basket of available livelihood options, such as cash cropping, subsistence cropping, animal husbandry, bee-keeping, market gardening, non-timber forest product (NTFP) collection, construction and woodwork. The prioritisation is derived from household needs (food, clothing, school fees) and the available resources (various forms of capital, i.e. labour, finance, land, livestock and social capital). It generates different priority orderings of the livelihood options for different households. This idealisation characterises a strategic decision as the re-ordering of priorities (which will then be reflected in terms of investment of labour and other resources). It allows a household to decide to invest in bee-keeping by making this a higher priority than previously, or to respond to a change in a resource (for example, an influx of cattle from a dowry) by increasing the priority of animal husbandry to the household.

This livelihood strategy approach has become the basis of a card-game played with villagers in Mafungautsi as part of action research in this area. The players are each dealt a set of cards representing different resources and requirements, and continue to draw and discard cards until a player has a ‘hand’ representing a feasible livelihood strategy where their resources meet all of their needs. All players must then discuss and agree whether that person has a feasible livelihood, at which point the remaining players play on. The resulting data has been used to parameterise and validate the model.

This representation of asset-based strategic decisions is similar to the model of ‘sustainable rural livelihoods’ based on human, social, natural, physical and financial capital (Carney 1998). In combination, the seven different livelihood options generate a huge variety of different strategies and the list of five key capital resources generates a huge variety of different household conditions. Simple heuristics (rules) can express the way different conditions lead to different strategies. This has led to the insight that strategic heterogeneity (people all doing different things) can be as much due to people putting different emphasis on the various elements in their basket of available options, as to differences in which options are actually available. However, in some cultures there are genuine differences in terms of availability of certain strategic options.

The idealisation of modelling livelihood strategy as a list of prioritised options arose in the following way. Early attempts to handle strategic decision-making assumed that it involves choice (selection of one of a number of alternative lifestyles), and explored some alternatives to optimisation as the only way to model the rational choice involved. The move to viewing strategic decision-making as prioritisation came about as a result of a facilitated workshop exercise to conceptualise the linkages between a number of different decision elements. The set of livelihood options and resources was extremely small (four of each) and participants were desperately keen to add more items to each category. However the facilitator was adamant that this was not permitted and that the purpose of the exercise was to clarify the nature of the linkages between resources and livelihood options, not to be comprehensive. It was in this exercise that the insight arose to move from treating livelihood options as alternatives, to seeing them as a re-arrangeable and potentially expandable basket. The lesson is that a good idealisation is not just achieved by leaving things out, or adding them back in, it can also be achieved by restructuring the representation.

Making a Model ‘Learn’ from Experience

Once a simple form for strategies in the model was devised, plausible mechanisms for generating them could be investigated. People use their past experience to form their strategies – they learn from the past and adapt their future strategies accordingly. People also learn from each other, by communicating with each other, by copying, and by working together. The final two points of complexity begin to tackle these two issues, building on the model constructs already developed.

Learning or adaptation of strategies has been idealised by using records of a small set of performance indicators from past time-steps to mimic memory. In addition, past strategies are remembered. Each year, when a new strategy is devised, it is compared with past strategies. If a strategy which has been used before is being considered, the performance indicators are then checked. If an alternative strategy has previously produced better performance, then the indicators are used to selectively recall and repeat successful strategies.

As a result of this simple tactic, 'good' strategies can emerge without the decision-making agents having explicit causal knowledge of the influences in the model between certain activities and biophysical effects. Some of these strategies may be counterintuitive. For example, the following rather paradoxical result is possible. Less time spent harvesting X (e.g. thatch grass) may increase the yields from that activity, because it makes time for other activities (e.g. animal husbandry), that indirectly boost the production of X (e.g. by herding cows away from the thatch grass), thus increasing yields per unit of effort. It is surprising that this simple 'Pavlovian' reaction enables indirect causal impacts to be learned.

The rather dramatic change in the behaviour of agents in the model as a result of this simple representation of learning emphasises that initiatives which support memory are likely to be useful. Such initiatives might involve monitoring, using local people to keep records of past activities and indicators. Processes which develop shared indicators may help to ensure that mutually useful memories are stored, although it may not be easy to interpret these indicators for policy purposes.

This idealisation came about by a different method from the others which all emerged from group model building workshops. In this case, two expert modellers were given the challenge of 'coming up with the simplest way they could think of to incorporate memory into strategic decision-making'. The result was explained to the modelling group and they agreed to its inclusion in the model. The result was actually therefore an elaboration of an existing implemented simulation model.

The Importance of Social Networks

Emergent strategies are even more likely to appear in a population of agents if they can communicate among each other, thus increasing the likelihood of spotting successful strategies. Communication in rural communities has been little studied, but research (e.g. Standa-Gunda *et al*. 2003) shows that there are numerous social networks used for passing information around and learning from each other. Of particular interest are the networks used for passing new ideas or innovations. The new science of 'memetics' is showing that cultures act as complex evolutionary systems, with cultural units or 'memes' like ideas, tunes, phrases or techniques operating as populations which reproduce, spread and evolve, using social networks as their pathways for transmission (Lynch 1996).

In a recent FLORES model, social networks/groups have been modelled using a relation between agents to represent a social relationship. This might indicate the two agents being in the same group, or being related by kinship, or being friends or going to the same church, or being in some kind of collaboration such as working together. Different configurations of the relation give different network patterns which can represent, for example, a single church or political party, multiple exclusive churches, hierarchical kinship groups, or clubs.

A few types of social issues have been modelled using this social network relation. It enables a straightforward type of peer pressure on strategic decision-making, by making the priorities of the group influence the priority setting of individual agents. It also enables modelling of social capital, and diffusion of ideas. The combination of memories of performance indicators with the use of the network relation for information passing between households is the beginning of a representation of social learning (Kolb 1986).

In the Mafungautsi model, group membership influences social capital, which is a resource that influences strategic decisions. Whilst recognising that social capital is sometimes an unpopular concept because it has been used in ways which erroneously reduce social values to numbers, it is a useful modelling idealisation. Social capital is represented in the model as a capital asset which is increased by interacting with other people, at levels proportional to the social capital of those people, and which is reduced through random 'sin' or 'accident' events, and through a transaction cost of maintaining friendships. Social capital can be both an individual level attribute (for example as a measure of an individual's relationships with other people and embeddedness in social networks), but also an attribute of a community as a whole. It is meaningful at both levels of abstraction. At the individual level it is a means for communication and collaboration. At the community level it may be a good measure of communication and collaboration.

The experiments with a network-group relation influencing social capital have generated interesting behaviour. Different configurations of the network lead to very different results, some leading to overall increases in social capital in the community, others leading to banding, in which some groups of people have low levels whilst others have high levels of social capital.

Experiments with this relation have led to insights about the way in which ideas spread around the community. The dispersal of a new idea seems to depend not so much on the 'quality' of the idea, but the holder of that idea, and whether they are likely to be imitated (Haggith *et al*. 2003a). This has led to some ideas about the choice of people for agricultural extension and other information-oriented tasks.

It seems that significant trends can emerge at the community level through the interactions of individual agents. This requires a better understanding of these interactions and social configurations. Policy which is 'network-savvy' may therefore be effective. For example, in Mafungautsi, a cotton company has engaged large numbers of farmers in cotton growing through facilitating the development of cotton-clubs which are networks for farmers to share knowledge, learning together about this new technology.

This understanding of how best to model social networks was derived by working with simple stand-alone models quite separate from main FLORES effort in order to identify the elements which need to be included within FLORES. This is in direct contrast to the formulation of the learning idealisation described above, which was modeller-led. Although a complicated model can provide the context in which it becomes clear that a new idea needs to be added, it is difficult to explore a range of alternatives by modifying a large model. Hence if the modelling task involves exploring a range of alternatives, it is best to try to model the alternatives in isolation, make the decision about what works best, and only then modify the main model. By doing this it is possible to retain ownership of the ideas within the modelling group, and it is much easier to make consensus decisions among alternative representations. The lesson here is that it is easier to keep a simple model simple, than to make simple modifications to a large and already formulated model. It is also easier to generate group insights with a simple sub-model than with a modification to an existing model.

CONCLUDING COMMENTS

Real-world complexity can be unlocked through idealisation during model conceptualisation. This paper has offered six examples to illustrate that this process can generate insights which are relevant to natural resource management and policy. Although there is no textbook method for achieving insightful idealisations, a number of examples have illustrated some lessons about how modelling teams can seek idealisations.

Our results also make it clear that successful idealisation depends to a large extent on carrying out modelling in a coherent methodological framework involving multiple iterations around a modelling cycle. There are other opportunities in such a cycle to harness complexity, notably by focusing on a well-defined puzzle or problem early in the process, and by simplifying simulations during or after model formulation. However, our experience shows that the process of idealisation has the most potential for helping modelling teams to generate insights into the complexities of the real-world.

The process of idealisation remains, nonetheless, more of an art than a science, and further systematic research is needed to provide reliable methods, for groups of natural resource managers in particular, to rapidly and extensively explore idealisations. Participatory modelling processes involving facilitated idealisation can also inspire and empower local participants to unlock the complexity of the systems on which they depend for their livelihoods.

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