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Social policy analysis in conditions of social complexity

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1 Policy and complexity

Social policies are comprised by actions or statements of public authorities that are intended to influence or modify the collective behaviour of individuals. Social complexity is a condition whereby social behaviour cannot be understood simply as a scaled-up replication of the behaviour of the individuals comprising the society so that, in consequence, social behaviour cannot be forecast on the basis of individuals' characteristics and predilections alone. Social outcomes, including the outcomes from social policy initiatives, are the result of individual behaviour and social interactions in which individuals influence one another. On the basis of these considerations, it follows that social policy analysis is reasonably considered to be a branch of complexity science.

By social behaviour is meant the outcome of social processes where "social process" is itself an umbrella term covering the behaviour and social interactions of individuals and the sequence of social outcomes of that socially embedded behaviour. The behaviour and interaction are conditioned by social norms and reputations. The patterns of interaction are determined by acquaintanceship and friendship, relationships that are the result of engagement in common activities or kinship or physical proximity. The content of the interaction is naturally related to the nature of social links. Common activities may entail cooperation in the undertaking of tasks, or sharing some resource – both being characteristics of common employment. They might also entail undertaking similar tasks in parallel such as attending church or school or also in employment. Amongst acquaintances, individuals will generally like some more than others. Social psychologists have demonstrated and reported over many years that individuals tend to like best those who are most similar to themselves and individuals are most uncomfortable in disagreement with those they like best.[1] Brown (1965) called this phenomenon the consistency principle.

[1] For an older but not dated exposition of this phenomenon, see Brown (1965) and for a more recent textbook version see Fraser and Burchell (2001).

One consequence of the consistency principle is that individuals can change their habits or views as a result of the influence of those who are already most like themselves and who they like and with whom they tend to avoid disagreement. Some social policies such as those associated with climate change or water management (Downing et al., 2000) seek to create social pressure to induce the establishment of (say) energy- or water-saving social processes. This objective makes two aspects of complexity relevant to any understanding of policy processes.

One aspect of social policy as a branch of complexity science relates to the feasibility of forecasting outcomes with and without policy interventions. The common practice is to offer from one to many forecasts using statistical regressions derived from time series data and calibrated on available sample data. The value of such forecasts depends crucially on assumptions about the nature of an unobservable population distribution and the presumption that observed data are samples from that population. If there is no such population or it is distributed differently from the requirements of regression and hypothesis testing algorithms, then the presumption that forecasting models can be used to evaluate policy measures is without any scientific foundation. In conditions of complexity, the conditions of application of the parametric statistical techniques used for such forecasting cannot be taken for granted. The pattern of changes in behaviour includes a relatively small number of widespread changes amongst a large number of relatively small changes. The magnitude of any one change episode appears to depend on the situation of each individual and the particular collection of other individuals they influence and who are influenced by them. Because the small number of large changes arise endogenously in the sense that they are not due to random, external events, then as Mandelbrot (1963) pointed out many years ago, it is certainly illegitimate to remove the "outliers" (the few large changes) from the data set. But if they are not removed, then the conditions of application of standard fitting and hypothesis testing techniques are not satisfied (Fama, 1963).

A second aspect of complexity science concerns network structures as either a description of or an outcome from patterns of social interaction. The small world network is an example of a description of social networks in which nodes representing individuals are characterised by a high degree of clustering so that, within a cluster, if any node that is linked to two other nodes, those other nodes are linked directly to each other. There are also links between individuals in different clusters but these are more sparse and certainly do not include the triangular relationships found within clusters. A small world network is characterised by a higher degree of clustering than is found in networks of randomly linked nodes but the longest path (number of connecting links) between any pair of nodes is not longer than in a random network. [2] In general, the formal properties of small world and other "complex" networks have been studied by generating examples from algorithms that do not describe actual social processes. While the existence of actual small world networks has been well established in the literature (Newman, 2003), we know of no previous empirical studies of the emergence and evolution of these networks. In at least one case to be reported here, however, the existence of small world networks is found and the evolution turns out to be of the first order of importance for social policy.

It seems useful in this context to distinguish between processual complexity with its unpredictable, volatile clusters and structural complexity which is manifest by small world (among other types of) network. In section 2, issues of model design that can capture process and structural complexity are explored. Alternative relationships between policy analysts and models for analysing policy under complexity are described and considered in section 3 with an example of the development of models for policy analysis under complexity explored in section 4.

2 Complexity and policy model design

The definitions of both processual and structural complexity require that any model of the phenomena be able to represent social interactions amongst individuals. Long before complexity science came to be recognised as an umbrella for related objects of scientific investigation, social scientists developing simulation approaches recognised the importance of explaining macro level phenomena that emerged from social processes whereby individual behaviour and social interaction together produced phenomena that could not be explained by the individual behaviour alone. The seminal paper in this regard was undoubtedly by the sociologist, Nigel Gilbert (1995), who argued that the only way to capture the behaviour and interactions was by means of simulation modelling.[3] Gilbert was concerned with the emergence of social outcomes and was not addressing issues of volatility or social network topology. Nonetheless, these manifestations of complexity are emergent features in the sense of Gilbert. That is, complexity is a subset of the class of phenomena that Gilbert was arguing could be addressed only by means of what

[2] This version of the small world network is due to Watts and Strogatz (1998) but was intended to formalise an empirical result found by Milgram (1967) and by Travers and Milgram (1969). Many small world social networks have been found since the classic study by Milgram.

[3] More than a decade earlier and at a more general level, another sociologist, Anthony Giddens (1984) argued forcefully for the importance of understanding social institutions as an outcome of individual behaviour and social interaction and that, at the same time, institutions tend to constrain behaviour and interaction. This is the "double hermeneutic" and was intended to reconcile controversies amongst sociologists concerning the dominance of institutions over individual behaviour or, alternatively, institutions as simply the result of what individuals do and how they choose to relate to one another.

we would now call agent based social simulation. The agents, of course, are software entities describing the perceptions, reasoning and actions of individuals.

The use of software agents to capture complexity distinguishes agent based social simulation from the ideal of agent based computing as specified in a classic paper by Wooldridge and Jennings (1995) who were concerned that agent interaction should be minimal in order to avoid unpredictable emergent phenomena at system level. Their concern is readily understood in the context of traditional computer science where software development starts with a requirements analysis to determine clearly what the program should do, then a process of verification to ensure that its design is formally capable of satisfying the requirements, then validation of the program code to ensure that it actually does what is required. The practical purpose of this process is to provide software that yields predictable outcomes in all cases. This is an obviously desirable aim for safety-critical programs or for programs intended to perform clearly defined and well understood tasks. However, where complexity is a genuine issue, the context in which software is used might itself be subject to unpredictable volatility and the inability of software agents to interact densely and to influence one another in the evolution of their behaviour could render that design paradigm inappropriate. Plausibly, densely interacting, mutually influencing agents with complicated reasoning capabilities are appropriate in such naturally complex software environments as grid computing or information filtering (Moss, 2000). Nonetheless, in general we would expect agent based social simulation models that allow for social complexity to be designed with the capacity for agents to interact and influence while more conventional agent based software would limit those capacities.

If social simulation models are to be used for policy analysis, it is of course important that they should describe with some accuracy the social context, the characteristics of the behaviours of individuals in different circumstances and the relationships amongst those individuals. At the same time, prediction cannot be relied upon in conditions of complexity. Whilst, in these conditions, models cannot be relied upon to yield accurate predictions, they are still formal systems and, as such, capture relationships and outcomes that are precise and unambiguous. Precision is useful in ensuring that analysts have to state their assumptions clearly and that they do not rely on emotive phrasing to justify actions that have no basis in understanding or experience.

In conditions where precision but not accurate prediction can be expected of model-based analyses, the value of the models can be no more than to generate clear scenarios. In order to explore the policy space flexibly and broadly, the models need to be open. That is, it must be possible for model operators to explore a wide range of specifications of behaviour and social interaction. This is not just a matter of setting parameter values but of specifying the ways in which individuals reason about their circumstances, how they filter their perceptions, how they choose their friends and other elements of a model that are structural rather than parametric. In order to ensure insofar as possible that the models are actually relevant to the policy context, it is essential to constrain the model design with evidence. Where direct evidence is not available so that some assumptions have to be made about what the direct evidence would look like, then those assumptions need to be constrained by some criteria of plausibility. Who is to decide what is plausible? There are two tests that can be applied here. One is the legal test – would a reasonable person believe that the persons deciding on the plausibility of an assumption are both sufficiently expert and independent of the modelling process. The other test is simply whether the assumptions are deemed plausible by the client – those for whose use the model is being designed and implemented. If the model is to be used for policy analysis, then the clients are the policy analysts and perhaps the politicians who actually introduce and implement the policy. For the modeller to make assumptions without reference to independent experts or clients leaves open the possibility that the chosen modelling technique rather than descriptive accuracy is driving the model design and therefore the model outputs.

3 Analyst integration or segregation

Approaches to policy analysis in general are based on either qualitative research or statistical (including econometric) and mathematical modelling. Most qualitative research is not formal while all statistical and mathematical models are of course formal in the sense that they are constructed using techniques with proved logical (in this case, mathematical) properties.

Core approaches to qualitative research are soft systems methodology (Checkland, 1981) and grounded theory discovery (Glaser and Strauss, 1967) – both of which have been developed in relation to the analysis of organisations.[4] Practitioners of these approaches seem to dismiss formal approachs as "mathematical modelling" that is inherently remote from reality and the problems that qualitative researchers are addressing. Nonetheless, they have in common three features that are of interest to policy modellers: they start from detailed, evidential accounts of the target organisations; eliciting the evidence requires the participation of stakeholders; relationships among stakeholders are of primary concern. These features are shared by several projects involving the development of agent base social simulation models for purposes of social policy analysis. First among them chronologically (and ongoing) is companion modelling (Bousquet et al., 1999; Becu et al., 2003; Barreteau et al., 2003), an approach that involves iterations between

[4] For a description of the relationship among soft systems, grounded theory discovery and agent based modelling, see Pahl Wostl and Hare (2004).

stakeholder engagement and, in particular, role-playing games for purposes of knowledge elicitation and model evaluation. A similar approach was undertaken in the EU projects FIRMA[5] and CAVES[6]. Amongst the models produced for purposes of policy analysis, those reported by Downing et al. (2000), Alam et al. (2007) and Ernst et al. (2007) defined their agents on declarative, rulebased inference engines which captured the qualitative descriptions of relationships and behaviour provided by stakeholders and did so using their own language and terminology. Effectively, we can see a spectrum of models ranging from those that are most qualitatively expressed to those that are least qualitatively expressed because they use numbers (for example real numbers to represent opinions (*e.g.* Deffuant, 2006)). The evidence based models are all closer to the qualitative end of this notional spectrum and therefore (because they are also concerned with relationships amongst distinct individuals) unambiguously closer to the informal approaches taken by the qualitative researchers concerned with organisational and management studies.

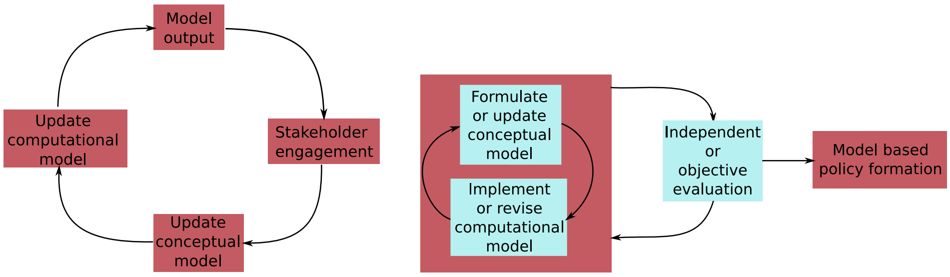
Mainstream economic and econometric models share none of the three features of qualitative and social simulation modelling indicated above. That is, the modellers do not start from detailed narrative evidence (dismissed by economists as "anecdotal evidence"), they to not engage stakeholders in the elicitation of the evidence used and, apart from some economists producing agent based models otherwise constrained by mainstream economic concepts, they assume away individual differences and influences so that social interaction has no role in their analyses.

The role of social interaction could not be more important because it brings up issues of emergence, complexity, social norms, reputation, influence – itself not an exhaustive list of important social phenomena. Of these phenomena, the most relevant for the present discussion is complexity and its implications for the role of policy analysts in the development and use of the policy models.

There are two ideal-types of modeller-analyst relationship. One is typified by the iterations between stakeholder engagement and, in particular, role-playing games involved in companion modelling. An alternative ideal-type is for the policy analysts (the stakeholders for whom the models are being developed) to stand outside the modelling process and to receive the model outputs without prior engagement in the model development process. In the latter case, some objective or perhaps independent validation of the model will be required. Where standard statistical models are concerned, reports of the results of standard hypothesis testing procedures may (and usually do) suffice for the model users. Models that represent individual

[5]Freshwater Integrated Resource Management with Agents,funded under the fourth Framework Programme (*cf.* Downing et al., 2000; Pahl Wostl and Hare, 2004)

[6]Complexity Agents Volatility Evidence and Scale, funded under the sixth Framework Programme (*cf.* Alam et al., 2007; Ernst et al., 2007)



(a) Deep stakeholder engagement

(b) Independent policy analysts

Figure 1: Ideal-types of analyst role in modelling

behaviour qualitatively and capture dense social interaction in ways that give rise to unpredictable bursts of volatility do not necessarily satisfy the conditions of application of standard hypothesis testing procedures. In these cases, independence of the model users from the modelling process requires a different approach to validation.

Though the phases of model and policy development are unlikely to be as clearly differentiated as indicated in figure 1, the broad differences between the approaches with deep stakeholder participation and with stakeholders as clients are clearly distinguished. In many cases, there will be an element of independent validation alongside stakeholder participation or there will be some revision of models and re-validation in response to client-analysts use and user evaluation of the model. The archetypical model captured by figure 1b is statistical or econometric. In developing such models, statistical data is acquired and regression or clustering[7] algorithms applied to the data. Several formulations of the statistical model are likely to be tried and the best fitting model then chosen. The objective evaluation takes the form of standard hypothesis testing so that the model and test results can be presented to the clients (the policy analysts). In some cases, such as with respect to macroeconometric models, there is an *a priori* conceptual model based on experience and judgement used to constrain the computational (in this case, statistical) model.

Not just companion modelling but also a model based Foresight or scenario building procedure typifies the process captured by figure 1a. The core idea here is to engage the stakeholders as domain experts or sometimes as intermediaries between modellers and experts to formulate the conceptual model. In companion modelling exercises (e.g. Barreteau et al., 2001; Becu et al., 2003), role playing games are typically used to engage stakeholders in the formation of the conceptual model and the validation of the computational model. Another approach is to engage stakeholders in generating narrative scenarios which are used to formulate conceptual models. The

[7] For example, principle components or cluster analyses based on correlation matrices.

formalisation of the conceptual models as computational models underlies simulation experiments that produce more formal, though still a type of narrative, scenario of the sort reported below in section 4.1.1. The virtue of these more formal scenarios is that they lend a degree of precision that cannot be captured informally. They also automate scenario generation so that the resulting scenarios can suggest previously unconsidered possible outcomes of a policy initiative.

It is clearly important to identify the conditions in which one or the other of these ideal-type arrangements – or elements of each – is apposite. To do so, we start by considering two extreme cases: econometric models and companion models.

3.1 Segregation

A virtue of econometric modelling is that the models can be assessed by independent evaluators looking at goodness-of-fit and hypothesis testing statistics – normally R^2 statistics and confidence intervals. As long as standard modelling procedures have been used and the statistics calculated using conventional algorithms, both modellers and clients have a common standard of reference in deciding how well the model fits the data. Of course, the choice of variables and how they are combined in the structural equations of an econometric model reflect some underlying conceptual framework and different schools of economic thought are quite likely to combine the variables in different ways. It is also the case that in the one test of the goodness of fit of models using post-publication data (Mayer, 1975), the models that performed best on pre-publication data fared worse on data not available at the time the models were designed and implemented. Nonetheless, forecasting models can be used to run simulations under a variety of assumptions about the future values of exogenous variables to calculate corresponding values of the endogenous variables of interest for policy purposes.

Because the policy analysts and the modellers – to the extent that they are distinct – have a common understanding of the measures of the goodness of a model, there is no necessity for the analysts to participate in model development or model validation. They might specify the conceptual basis of the model and so the broad structure of the structural equations, the details of the implementation can be left to the modellers and the process of validation can be left wholly to them. In these circumstances, modeller-analyst segregation is wholly justified.

3.2 Integration

Companion modelling is a manifestation of qualitative research that is extended by its use of agent based modelling to generate scenarios for participating stakeholders. The use of role playing games and various qualitative techniques for knowledge elicitation and analysis are common to companion modelling, soft systems methodology (Checkland, 1981), grounded theory discovery (Glaser and Strauss, 1967) and the like. All of these approaches are notable for engaging the stakeholders and none are feasible without stakeholder participation in the design of the conceptual framework and, in the case of companion modelling, constraining the model design and evaluating the output from the implemented, computational model.

3.3 Choice and context

It remains to consider whether policy analysis benefits from this sort of participation by policy analysts and, if so, whether there are distinct classes of policy that so benefit and, if there are such classes, whether policy analysts are likely to want to participate and, should they want to participate, what forms of participation best suit them and the modellers.

3.3.1 When are there benefits?

Qualitative social research in the area of business and management has grown up around the practice of stakeholder participation. Both grounded theory and soft systems methodology were developed as a process of knowledge elicitation and organisation. The benefits are claimed to lie in enhanced understanding of the organisational context, capacities and relationships. The companion modellers have extended this sort of approach by the use of models to generate scenarios of possible future trajectories. In common with the Foresight approach, the purpose of the scenarios is to explore issues, threats, opportunities and appropriate responses to them. The purpose is *not* prediction.

Pahl Wostl and Hare (2004) reported that stakeholders involved in the development of water management policies in Zurich occasionally became impatient with the process because they could not see clearly where it was going. Pahl Wostl and Hare suggested that this was partly the fault of the researchers since, in the nature of research, they were themselves learning about the process and were therefore unable clearly to describe the outcome. This reported experience and the author's own experience confirm the obvious: the stakeholders (including policy analysts) and the modellers must have a clear and clearly shared interest in the outcome from the qualitative research process. This shared interest can turn on recognition of the importance of social interaction.

A (and perhaps the) key distinction between traditional economic and econometric styles of modelling on the one hand and qualitative research and agent based social simulation modelling on the other hand is the importance of social interaction. Economists and econometricians assume social interaction away by specifying "representative agents" as some kind of average individual or, alternatively, they assume that all individuals share the same, correct model of the economy or financial market or whatever other economic context is being investigated. Evidently, detailed capture and description of social interaction and its effects is the critical feature distinguishing qualitative research and complexity science from conventional (essentially economic and econometric) social modelling.

On purely scientific grounds, demonstrations that social processes cannot be appreciated, understood or influenced unless social interaction is taken explicitly into account should provide the common interest for social scientists and social policy analysts. The problem here is that the background and interests of the policy analysts do not necessarily lead them to appreciate the scientific value of new approaches. For example, at the completion of the CCDeW Project,[8] analysts for the participating water supply companies were shown that, in conditions of complexity, the econometric demand analysis techniques they were using might well be inappropriate. Their responses, individually and collectively, were that the underlying science was of little concern to them. Their interest was only in what would satisfy the regulator with least effort and expense. And the regulator (Ofwat: The UK Water Services Regulation Authority) was similarly uninterested in exploring the scientific basis and conditions of application of the econometric models used to forecast water demand.

The policy analysts (eventually for Zurich water engineers and consistently for UK water engineers) evidently do not see much practical benefit from from modelling techniques that take explicit account of social interaction and the consequent complexity of the social processes that will determine the outcomes of their policy initiatives. Their requirements are effectively threefold:

1. A simple check list
2. Answers!!!
3. In an integrated process, increasing levels of detail

Evidently, the conditions for there to be benefits from the integration of policy analysts into the model development process include:

1. The importance of social interaction in the social processes affected by relevant policy initiatives.
2. Understanding by policy analysts of the consequences of social interaction.

[8]CCDeW: Climate Change and the Demand for Water. The final report by Thomas Downing *et al.* is available via `http://www.sei.se/oxford/ccdew/`.

The importance of social interaction for the choice of analytical technique has long been clearly demonstrated. It renders suspect the presumption that the conditions of application of standard goodness-of-fit and hypothesis testing algorithms are satisfied. Moreover, techniques such as grounded theory discovery and soft systems methodology that have been devised to analyse situations in which social interaction prevails are also suitable for providing the evidence needed for evidence driven, agent based social simulation modelling. Because this bundle of qualitative research and social simulation starts from such different premises and produces such different outputs from those of conventional social modelling, there is an understandable gap between the expectations of policy analysts and modellers capturing issues associated with social interaction and social complexity. The question of whether policy analysts will want to participate in procedures using evidence driven, agent based models depends in the first instance on whether this expectations gap can be bridged.

3.4 Why might analysts want to participate?

The expectations that are relevant here turn on the purpose of the modelling and the policy analysis. Procedures for policy analysis that depend on economic or econometric models are based on the presumption that the models yield predictions of outcomes from policy initiatives. In some cases,[9] a "meta-modelling" approach is used whereby a set of econometric models, each based on different assumptions, are used to simulate future trajectories and then the set of those trajectories are assumed to define a sample of possible actual futures with frequency distributions of possible outcomes. Whether a traditional modelling or meta-modelling approach is followed, the core idea is that the models have some element of truth.

The alternative, which coheres with the qualitative research approaches, is to develop scenarios that do not constitute predictions or elements from some sample set of probable futures. Like soft systems methodology or grounded theory discovery, the purpose of the scenarios is to guide the stakeholders in the development of their understanding of the social processes involved in determining the outcomes of the stakeholders' decisions. Foresight methods are used to constrain scenario development by assuming some qualitative features of the situation can be partially ordered. This approach is consistent with agent based modelling (Barthelemy, 2006) though it is more impressionistic based on less detailed evidence than scenarios developed in conjunction with evidence driven, agent based modelling.

Evidently, the objective of policy analysts participating in a qualitatively rich, model based policy process must be to explore and learn to understand

[9] Of which the Stern report on the economics of climate change (Stern, 2006) is a good example

the social processes and form views of how those processes can mediate between policy measures and policy objectives. They must, however, recognise and take into account the consequences of complexity including the possibility of unpredictable bursts of volatility. How to bring this about is not an issue that has been explored to date.

Perhaps one reason for the ongoing gap between scientists developing evidence driven, qualitatively rich, agent based models is that a key objective for the scientists is to do good science while the key objective for the policy analysts is to define effective policies and the scientists have not successfully explained to the policy analysts why the science is good science and how good science is necessary for the design of effective policies.

3.5 How might analysts want to participate

There is no lack of literature on forms of stakeholder participation in policy exercises.

4 Policy modelling for complexity: three examples

4.1 HIV/AIDS in Ga-Selala

Ga-Selala is a village in the Tubatse Municipality, Sekhukhune District, Limpopo, South Africa, located approximately 200km north of Pretoria. It comprises of approximately 1700 households with on average 7 persons per household. HIV/AIDS is one of the major stressors for people´s livelihoods, together with climate variability, water scarcity and food insecurity, leading to a high vulnerability. Over 90% of the population in Sekhukhune is rural and there are very few jobs in the villages. Agriculture alone is not sufficient; most people in Ga-Selala have stopped growing crops altogether due to lack of water. People therefore tend to migrate to find employment.

There are, however, large reserves of platinum, chrome, gold and palladium in the district and mining is a rapidly growing part of the Sekhukhune economy. Whilst this promises better employment opportunities for the local population it comes with associated costs.

In contrast to many other countries in Africa, South Africa has a social support system providing grants to at least some of the people in need. In the case study area, grants and remittances from migrant workers are the main source of income; pension grants have been found to support entire households (Ziervogel et al., 2005). Death of the family member receiving the grant or sending money home can therefore have a devastating effect on a household, to the point of dissolution. Orphan children are usually accommodated by a household in the extended family. Other strategies for coping with stressors such as resource sharing or pooling of finances also rely on social networks in the community.

HIV/AIDS is threatening to destroy this social 'safety net' by killing off a major part of the employable population. The risk of contracting HIV/AIDS in the region is exacerbated by the recent influx of mine workers.

4.1.1 The Meyer-Alam models

Two models have been developed for the case study: a procedural model, which represents decision processes algorithmically (Alam et al., 2007), and a slightly more fine-grained declarative model, in which decision processes are governed by a set of rules. Both models are similar in that their agents represent individuals who are characterised by age, gender, marital status, health status etc. A group of (usually but not necessarily related) agents live together in a household, pooling and sharing all income and available resources. Each household has a head responsible for decisions that affect the household as a whole. Thus agents assume one of two different roles:

- Household member
- Household head

Agents belong to social networks, which both constrain their interactions with each other and evolve through these interactions. The models differentiate between family und kinship links, neighbours, friends, sexual partners and groups like churches, burial societies and savings clubs (stokvels).

Agents make decisions on the individual level and – if they function as a household head – on the household level. The latter concern the acquisition and distribution of food, borrowing food from relatives and/or neighbours if necessary, membership in burial societies, payment of school fees and the advertisement of piece jobs whenever the household is in need of and can afford hiring a worker. Decisions on the individual level regard applying for such piece jobs, migration to look for work outside the village, membership in stokvels, friends, sexual partners, marriage and building a house after marriage.

The declarative model makes use of so-called endorsements and individual tags in the agents' decision making.[10] Endorsements can be thought of as labels used by an agent to describe certain aspects of other agents. The model incorporates both positive labels like is-kin, is-neighbour, same-church, is-friend, similar, reliable, capable and negative labels like unreliable, incapable or untrustworthy. Some endorsements are static in that, once applied, they don't change over the course of the simulation (e.g. is-kin),

[10]Endorsements were first devised by Paul Cohen (1985) as a device for resolving conflicts in rule-based expert systems. Scott Moss (1995) modified and extended their use within a model of learning by social agents. This latter version of endorsements has been adapted for the declarative model.

while others are dynamic and may be revoked or replaced according to an agent's experiences (Werth et al., 2007). All agents use the same list of endorsements but differ in how they assess them.

To do so, agents rely on a so-called endorsement scheme which associates each label with a weight to express how much store an agent sets by this particular aspect of a person. Weights are modelled as integer numbers between 1 and n for positive labels and -1 and $-n$ for negative labels, respectively. This allows for computing an overall endorsement value for a person, applying the following formula:

$$E = \sum_{w_i > 0} b^{w_i} - \sum_{w_i < 0} b^{|w_i|} \qquad (1)$$

where b is a number base and w_i the weight of the i^{th} label. Agents are assigned random endorsements schemes at creation, which differ not only in the weights they assign to the labels but also in the values used for n and b.

The overall endorsement value allows an endorsing agent to choose the preferred one(s) among a number of endorsees. To form the friendship network, for example, agents first determine which other agents are similar to themselves. This is based on abstract tags (to model character traits), which are assigned randomly to agents at creation. These tags are used to compute a similarity index (the number of similar tags), which in turn is used to generate "similar" and "most-similar" endorsements. Agents then compute the endorsement value for all known other agents and choose the ones with the highest values as their friends. Similar processes are applied to decide upon sexual partners and applicants for piece jobs.

4.1.2 Policy implications

Officials and elected members of the municipality are intending further development of mining in the district for the economic benefits will bring to such villages as Ga-Selala. The benefits anticipated by the municipality include the provision of employment opportunities for the villagers, expenditure by miners brought in from other parts of South Africa and Mozambique on rent and meals and perhaps wider opportunities for education. However, the cost could be high to the point of being catastrophic. Although there is clearly a significant incidence of HIV/AIDS related illness in Ga-Selala, the incidence of infection amongst miners is significantly greater. Moreover, it is common in the village for both men and women to have three to six sexual partners. It follows that increased incidence of HIV/AIDS is a likely outcome of mining development in the area in the ownership of the chief of Ga-Selala.

An important question in relation to the mining development policy therefore concerns the effects of HIV/AIDS on the sustainability of the vil-

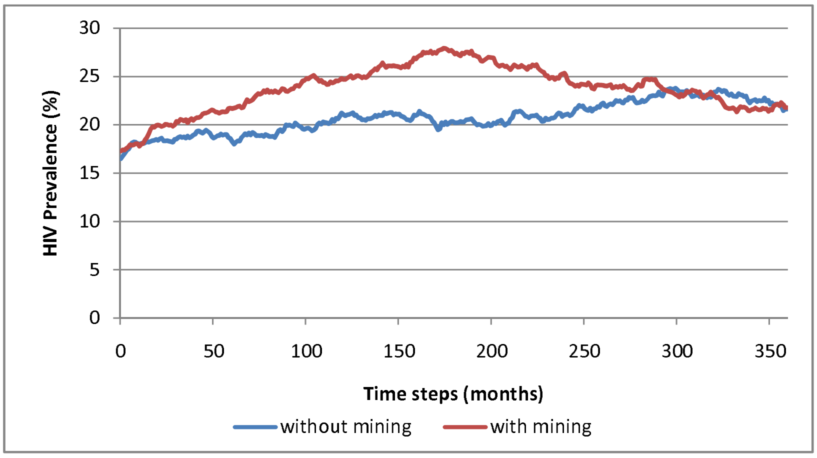


Figure 2: HIV prevalence in the village population over thirty years.

lage. Sustainability here has a precise meaning turning on the social support networks of the village.

Commonly important social networks amongst the black population in South Africa include networks based on kinship, church membership, savings and funeral clubs as well as the ubiquitous sort of friendship networks linking individuals with common tastes, interests and opinions. These social networks support systems of borrowing and lending food, helping to care for the ill, support for funeral expenses (which for cultural reasons are enormous in relation to incomes).

One question to be addressed is whether the effectiveness of these social support networks is undermined by HIV/AIDS and, if so, what will be the effect of mining development in the district on HIV/AIDS incidence and therefore on the social support networks and the viability of villages such as Ga-Selala.

Simulations with the models indicate that the mining development policy will have the anticipated negative effects if it is not combined with measures to constrain the spread of HIV (e.g. promotion of condom use, screening for STDs amongst mine workers) and/or the onset of AIDS (e.g. free anti-retroviral drugs).

Figure 2 shows the development over time of HIV prevalence in the village population with and without mining as results from typical simulation runs. Both cases assume that no preventive measures are applied. As can be seen, mining and the related influx of mine workers accelerates the spread of HIV significantly. While even in the scenario without mining the prevalence of HIV reaches the same level after about 25 years, the final decrease in prevalence in the mining scenario is mainly due to a considerable decrease in population, as many more villagers die from HIV-related diseases.

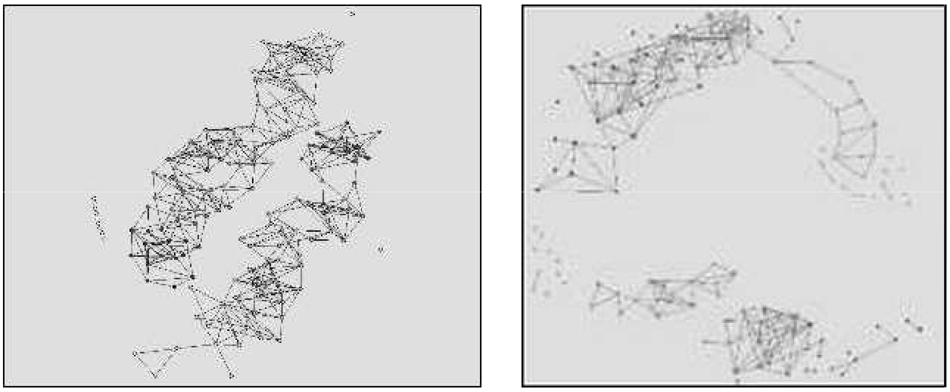


Figure 3: Friendship network after 5 years (left) and 25 years (right).

A particular issue of policy concern is the effect of mining development on the sustainability of the village as represented by the continuing viability of its social support networks. A measure of this viability is the completeness of the social network amongst individuals where the links between nodes representing individuals indicate that at least one of the two considers the other to be a close friend. Figure 3 shows that in a typical model run covering 25 simulated years and allowing for birth and mortality rates as given by WHO data, there are two separate friendship networks after five years but these break up into smaller, isolated clusters after 25 years. The reason that there are two separate subnetworks in the early stages of the simulation run is that social norms in Ga-Selala do not allow friendship links (as distinct from sexual partnerships) between men and women. It seems likely that the breaking up of friendship (and therefore social support) networks is due to early deaths in the population.

4.2 Land reclamation in the Odra River Valley

The Odra River Valley in the area of Wrocław, Poland had, until World War II, a sophisticated and effective flood control system that used the flood waters to fertilise and irrigate agricultural land. This system was maintained for their common benefit by the local landowners. After World War II, the system fell into disuse and disrepair. A policy issue for the current authorities is to trigger a collective effort of the involved farmers to transform this neglected Land Reclamation System (LRS) to a functioning, collectively managed system. A sequence of models called Sonare have been designed and implemented in order to investigate relevant policy options.

4.2.1 Sonare models

Assumptions Farmers have individual perceptions of their economic success over a past sequence of years. The economic success is determined by the farmers' profit from their farming activities. Farmers evaluate their profit with respect to a certain (fixed) threshold below which the profit of a year is considered "too low". Profit is composed of production costs, costs of LRS maintenance (if maintaining), attained yield from a farmer's field (which is influenced by climate conditions and the global effectiveness of the LRS), and compensation payments in case of crop losses. Farmers are embedded in a social network; their opinion about LRS maintenance (pro/con) is propagated over the network links and perceived by others. The sum of all influences received over the social network links constitutes a farmer's perception of social support of his opinion concerning LRS maintenance. We consider two decision scenarios: In the Selfish Scenario farmers decide about whether to contribute to the LRS maintenance solely based on their economic success, i.e. they disregard all social aspects. In the Social Scenario farmer's balance their decision equally between individual economic success and perceived social support.

Simulation All simulations start from the *status quo* observed in the Odra region: The LRS is not functioning and none of the farmers is willing to start maintaining it. There are no economic incentives for maintaining the LRS because farmers who experience crop losses in wet years are fully compensated.

The first 10 years of the presented simulation runs are "warm-up years" that simulate the status-quo and initialise profits, profit memories and social support perceptions of the farmers. Starting from simulation year 11 an LRS initiator becomes active. This actor (someone from an NGO, a mayor, etc.) observes the individual profits of the farmers and starts to promote LRS maintenance (by exerting social influence) if a certain proportion of farmers (here 10%) have very low profits. The activity of the LRS initiator is only relevant in the Social Scenario because in the Selfish Scenario Farmers disregard all social influences.

In addition, also starting from year 11 one of five compensation policies takes effect:

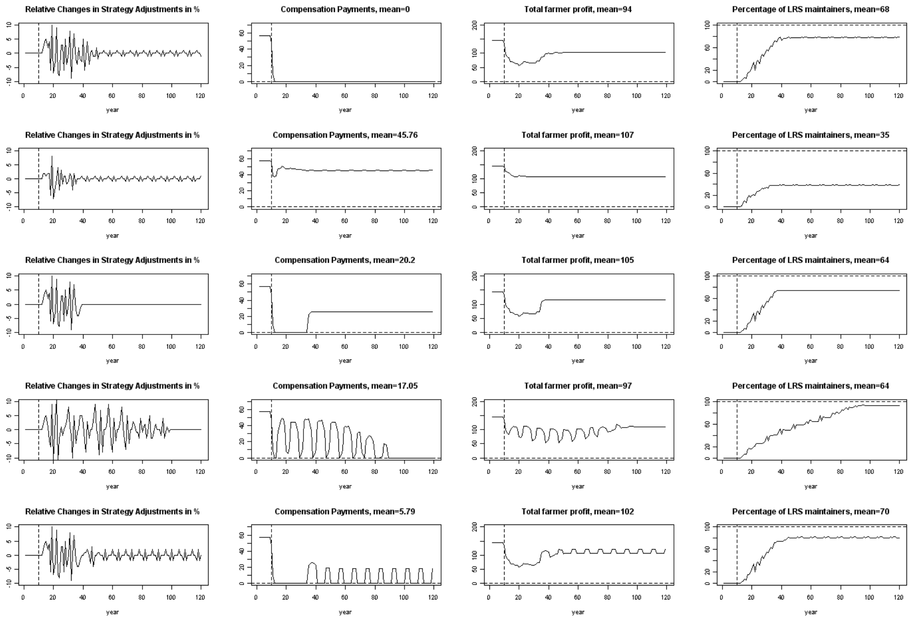


Figure 4: Simulated dynamics for Selfish Scenario, compensation policy 0 to 4 per row

Compensation Policy	
0	pay no compensation
1	pay compensation always to all farmers
2	pay compensation always to farmers who maintain LRS
3	pay compensation only if LRS initiator promotes maintenance to all farmers
4	pay compensation only if LRS initiator promotes maintenance to farmers who maintain LRS

Unlike during the initial 10 (*status quo*) simulation years when farmers are always fully compensated, the compensation policies assume an upper limit of compensation that is paid to an individual farmer – in fact farmers are not always fully compensated. All simulation runs use the same maximum value.

Simulation results Figures 4 and 5 show sets of diagrams of the simulated dynamics for different combinations of decision scenarios and compensation policies. Figure 4 illustrates the effects of the 5 different compensation policies on the Selfish Scenario; Figure 5 shows the Socially Active Scenario.

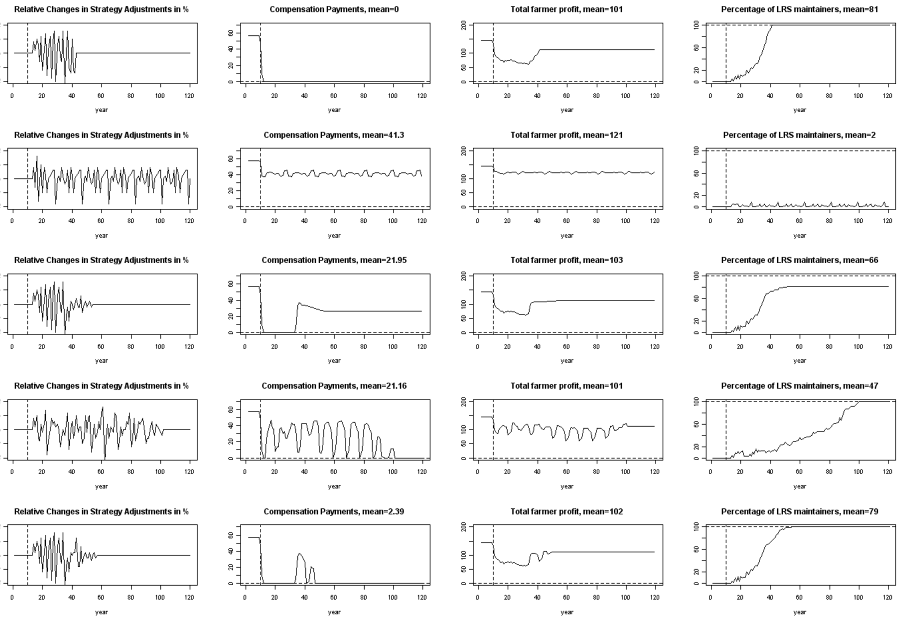


Figure 5: Simulated dynamics for Social Scenario, compensation policy 0 to 4 per row

In the diagrams, dashed vertical lines mark the end of the warm-up years, the displayed mean values cover only years 11 to 120, i.e. the years when the respective compensation policies become active. Strategy adjustments summarise opinion shifts in either direction. Relative changes are the differences of these percentages relative to the previous year (first differences). Compensation payments and total farmer profits are shown as rolling means over 3 years. The following table compares the calculated mean values as indicators for the different scenario combinations:

	Selfish Scenario			Social Scenario		
Compensation policy	Total compensation (p.a.)	Total profit (p.a.)	Average mobilisation(%)	Total compensation (p.a.)	Total profit (p.a.)	Average mobilisation(%)
0	0	94	68	0	101	81
1	46	107	35	41	121	2
2	20	105	64	22	103	66
3	17	97	64	21	101	47
4	6	102	70	2	102	79

The next table shows the relative reductions of compensation payments and profits when comparing to the warm-up years (full compensation):

4.2.2 Policy implications

Compensation Policy 0

- Cutting back compensation payments to 0 introduces a phase of economic stress (decrease in profits). This breaks up the initially passive behaviour of the farmers and triggers a phase of volatility in the opinion dynamics.
- In the Selfish Scenario a majority of around 80% gets mobilised to maintain the LRS. For the remaining portion of farmers the (reduced) economic stress does not offer sufficient incentives to maintain the LRS.
- In the Social Scenario (with timed social activity of the LRS initiator) the economic stress induces a mobilisation of 100% of the farmers, whereas during the warm-up years (full compensation of all crop losses) the social influence of the LRS initiator does not suffice to mobilise farmers

Compensation Policy 1

- In the Selfish Scenario a minority of the farmers (around 40%, located upstream) starts to maintain the LRS because the reduced maximum amount of compensation does not equalise their crop losses. The remaining farmers may well live with the compensation paid and the benefits from the partly installed LRS.
- In the Social Scenario the permanent flow of compensation prevents the LRS initiator from breaking-up the social coherence between the farmers. A small proportion of (upstream) farmers have high crop losses in wet years which makes them start to maintain but in subsequent normal years social pressure makes them shift back to passive behaviour (see relative changes). In total almost none of the farmers maintain; profit is mainly generated by compensation payments.
- In the Selfish Scenario a higher total of compensation is paid because those farmers who invest in the LRS have a higher chance of getting compensated. Here, compensation is partly a subsidisation of LRS maintenance.

Compensation Policy 2

- In both decision scenarios the selective input of compensation payments to farmers maintaining the LRS reduces the total payments required and provides sufficient economic incentives to mobilise a majority of around 80% of the farmers.

Compensation Policies 3 & 4

- For both decision scenarios the "pulsed" input of compensations further reduces the total payments.
- When pulsed compensation is paid to all farmers (policy 3) in both decision scenarios nearly 100% of the farmers are mobilised. In addition, compensation payments decrease over time and fall to zero at the end of the simulation.
- When pulsed compensation is paid selectively to LRS maintainers (policy 4) in both decision scenarios compensation inputs are further reduced while in the Selfish Scenario profits increase and in the Social Scenario remain constant.

4.3 Family farming in the Grampian Region

A recent policy document (Scottish Executive 2007) describes the overall aims of policy in rural Scotland as follows:

> Our strategic aims and approaches, within an overall policy of sustainable development, are to:
>
> - broaden and strengthen the rural economy, including the skills base;
> - protect, maintain and develop our natural and cultural assets;
> - improve the accessibility and quality of services people and businesses depend on;
> - address the challenges and opportunities of population change;
> - promote social and economic inclusion;
> - help to build resilient, sustainable rural communities;
> - improve stakeholder engagement;
> - improve focus, delivery and measurement of progress towards the main outcomes.

There has been a change of Scottish Government since this document was published, but these aims have not been changed. The Scottish Government is now intending to introduce a Bill setting ambitious targets for reducing greenhouse gas emissions, so this aim (already implicit in the commitment above to "sustainable development") can also be considered as an explicit aim in the context of Scottish rural policy.

Within this broad context, we note that while Scottish agriculture accounts for only a small proportion of economic output, it does play a key role in maintaining rural communities, and many of the landscapes which provide recreational opportunity for Scots and others, and generate considerable income from tourism. Over recent decades there has been a move towards ”post-productivism” (refs) in rural and agricultural policy: the recognition that agriculture has functions other than maximum production at minimum cost; and that it must operate within environmental constraints. However, in the light of currently increasing global food prices, it is certainly prudent to retain food-producing capabilities, and therefore the skills base and socio-cultural networks which support them. Whatever the reasons, Scottish agriculture, and in particular upland livestock farming, have been heavily subsidised through the CAP and other EU schemes since the UK joined the EU at the start of 1973; and without this support, would certainly have developed very differently. Changes to the CAP regime in 1992, 1999 and 2005 have been among the most important factors in decision-making by Grampian farmers.

4.3.1 Fearlus Upper Deeside model

A validated version of the Upper Deeside model is available, it will be used in policy-relevant scenario studies of the future of Upper Deeside agriculture over the period to 2050. This will concentrate on studies of the circumstances under which particular types of policy instrument are likely to be useful, what their drawbacks are likely to be, and how farmers' social and informational networks are likely to modulate their effects. The model will be applied, with a range of assumptions about future economic, demographic and climatic scenarios over the period to 2050, initially to examine possible Scottish Government policies to encourage land use practices that will reduce net Scottish greenhouse gas emissions, while maintaining economic and social sustainability. Initially, the model will be applied in Upper Deeside, then in other parts of the Grampian region, and finally in other rural upland regions of Scotland. Potential policies to be investigated will be determined in discussion with policymakers; possibilities include regulations on land use or land management practices, taxes, individual or collective incentives for adopting particular practices or reducing greenhouse gas emissions, when these can be measured with sufficient accuracy, agro-environmental schemes, informational campaigns).

The version of the FEARLUS modelling system developed in the course of CAVES has also been linked to a model of biodiversity change, SPOM, developed in the course of a separate project for the Scottish government. The FEARLUS-SPOM combination will be used in policy-relevant studies of the effect of different spatio-temporal patterns of land use on biodiversity levels.

4.3.2 Policy implications

The qualitative interviews themselves produced a number of clear indications for policymakers, with regard to the likely responses to policy initiatives of upland livestock farmers in the Grampian region, and perhaps more generally in Scotland:

- Differential response to policy based on farmer type must be taken into consideration. The main types encountered in the study area can be listed as entrepreneurial, traditional, pluriactive, and lifestyle/hobby/environmental. The entrepreneurial farmers are those most likely to keep their management practices up to date, and to respond to new information. Traditional farmers may follow the lead of the entrepreneurial minority once an innovation has been seen to be successful. Pluriactive and lifestyle/hobby/environmental farmers are likely to have small farms, and will not tend to be models who other farmers will follow.

- Informational campaigns need to be properly targeted, but could make use of existing farmer informational networks. *Analysis of access to information revealed network structures that were complex and diverse, reflecting the specific commodities and business structures of the farmers involved.* For example, a beef producer would likely attend beef cattle sales and information events, whereas a sheep producer would attend sheep-based events. As most producers in the study site produced both commodities, there was considerable overlap in these information networks at a basic level. However, should a third 'commodity' – such as a diversification activity – be added, engagement in other networks reduced of necessity, given the time constraints of the farmer. Farmers must in any case be selective, as there are more information-based events than a single farmer could attend. Choice of information resources also reflects the personal preferences of the farmer: some farmers prefer to gather information from paid advisors, others from livestock shows, and others from travelling input salespeople. Most farmers utilised a combination of these resources. Access to information is therefore not limited to the immediate neighbourhood of the farmer.

- Pace of response: farmers seldom make major changes on-farm based on a single year's returns. Farmers are much more likely to make changes in response to permanent or long-term market and policy shifts. It is therefore important to implement policies around which farmers can build long term plans. Economic pressures, such as the high cost of inputs, labour scarcity and declining commodity prices, have driven most commodity changes. Farmers typically act incrementally at first, gradually increasing or decreasing stocking density or acreage of a field crop. In discontinuing a commodity, typically a breaking point is reached, following the gradual decrease, in which production is stopped completely. Examples of this breaking point range from the drop in beef prices following the BSE outbreak in 1996, to the steady decline of potato prices through out the 1960s and 1970s. In both cases, discontinuing the commodity was considered for several years before it was undertaken. Due to the length of time and investment required to re-start a commodity, farmers in the study site will not typically discontinue a commodity on the basis of a single year's poor returns. Nor will they consider changing commodities when they are satisfied with current returns.

- Farmers appear to respond more quickly to 'opportunities' rather that 'needs must' situations. A 'carrot' rather than 'stick' of many current policies would appear more likely to be successful in achieving policy objectives.

- Greater success in farmer response to grant programs can be expected if these are in line with current farming priorities, and definitions of 'good farming'. Social norms proved difficult to adequately evaluate, as farmers were reluctant to admit that their decision-making was influenced by others' expectations, while key informants clearly believed this to be the case. From the study of farmers' networks, it is clear that a farmer's reference group is not always his immediate neighbours. Instead, farmers may draw social approval from members of a dispersed network, as in the case of breeding society or diversification network members, and therefore be less influenced by more locally held norms. *Farmers also refer to positive examples for reference – the 'best' farms in the neighbourhood – rather than all farms equally.*

- Although farmers are concerned about the environment, engagement in current environmental programs largely reflects a desire to recoup lost income from commodity-based payments. Although farms have increased intensity of production, the only new 'commodity' in the area is engagement in environmental programs. Farmer respondents indicated that they entered these programs primarily to benefit from resultant subsidies.

- Although most farmers in the study site have reduced their level of chemical inputs, they resist 'the last 20%' it would take to achieve organic status. However, although social disapproval from peers is an obstacle to adoption, land suitability and perceived economic benefits appear more important.

- Policies aimed either at promoting or reversing the long-term trend to larger farms are unlikely to make much difference. Land acquisition primarily involves **opportunity**, rather than a formally reasoned business plan. Land is a limited resource, only available when another landholder decides to reduce his or her holdings. Farmers therefore are very likely to attempt to purchase or rent neighbouring land (particularly if it is located immediately adjacent to existing holdings), regardless of the current financial climate, as they believe the opportunity is not likely to recur in the near future. Due to the physical limitations to transport of labour and equipment, land in close proximity to the existing holding is of high value for expansion, which is in turned believed by most farmers to be necessary for ongoing business success.

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