Jul 1st, 12:00 AM

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International Environmental Modelling and Software Society (iEMSs)
2012 International Congress on Environmental Modelling and Software
Managing Resources of a Limited Planet, Sixth Biennial Meeting, Leipzig, Germany
R. Seppelt, A.A. Voinov, S. Lange, D. Bankamp (Eds.)
http://www.iemss.org/society/index.php/iemss-2012-proceedings

Using social psychology theory for modelling farmer decision-making

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Abstract: Many agent-based models (ABMs) use typologies to classify diverse actors into few simplified conceptual categories (e.g., hobby farmer, commercial farmer) with uniform decision-making strategies. This approach usually assumes that a representative agent can belong to only a single conceptual category at any one time. However, Social Psychological Theory (SPT) asserts that individual actors' identities are constructed of multiple hierarchical self-concepts that drive decisions and behaviour. Identities may also change through time. Recent empirical and theoretical work has used this theory to investigate agricultural transitions and cultural change, but its use in an agent-based framework has yet to be explored. To investigate the potential of using SPT in ABMs of natural resource use and show proof of concept, we present an exemplary agent-based modelling framework that explicitly represents multiple and hierarchical agent self-concepts. Using the model we explore dynamics of change in farmer self-concepts and agricultural land use for different macro-structural conditions (i.e., the social network of agents, land resources, agricultural policy and political economy). Initial results suggest that productivist farmer identities are stubborn to change, the spatial distribution of land resources influences identity change, and rules for social network formation influence likelihood of agents' identity change. These results suggest it will be fruitful to continue to explore the use of SPT in ABMs of natural resource use.

Keywords*: agent-based model; social network; identity change; agricultural transitions; land use*

1. INTRODUCTION

Agent-based models (ABMs) of natural resource use frequently adopt typologies to classify diverse actors into few simplified conceptual categories. This classification is needed to reduce the complexity of real-world decision-making so that it can be represented in a simulation model. For example, in ABMs of land use, farmer classes such as 'hobby farmer' or 'commercial farmer' are often used to define distinct agent decision-making strategies (e.g., Millington et al. [2008], and see Valbuena et al. [2008] for a review). This approach usually assumes that although agents may move between different classes, class types are exclusive and an agent may only belong to a single class at any one time.

However, Social Psychological Theory (SPT) asserts that individual actors' decisions and behaviour are influenced by their identity, which in turn is constructed of multiple hierarchical self-concepts [Stryker and Burke 2000]. Actors may draw on different parts of their hierarchically-structured identity in different situations, resulting in different decisions and behaviour. This theory implies that classifying actors into exclusive agent class-types is over-rigid. Furthermore, SPT argues that an actor's identity will change slowly through time if the individual cannot exhibit behaviours that express how they believe their identity should be perceived. Thus, when behaviour cannot be made to match identity, identity will change in response to others' expressed identities within the individual's social network [Burke 2006]. Social psychology theory therefore provides an alternative approach to pre-classifying exclusive agent types for representation in ABMs, and one that allows a more socially- and psychologically-informed representation of behaviour change.

As far as we are aware, SPT has not been implemented in ABM. To demonstrate the proof of concept that this is possible, in this paper we describe an abstract ABM that uses SPT and describe initial results from using it.

2. MODEL DESCRIPTION

To describe the ABM we use the ODD+D protocol proposed in the working paper [Müller et al. 2012] for the workshop ‘Human decisions in agent-based models (ABM) for natural resource use - need for protocols’ corresponding to the session in which this paper is presented.

2.1 Purpose

The model was developed to identify and explore how farmers (farm households) might be represented in ABMs of land use/cover change and natural resource use without pre-classifying farmers into exclusive agent types. The model is designed primarily for scientists and policy-makers as an exemplary demonstration that social psychological theory of multiple identities can be applied in principle using ABM.

2.2 Entities, State Variables and Scales

Agents represent individual farmers (farm households). Grid cells in the model environment represent the farmland through which farmers can express behaviours, farmers’ homesteads and farmer meeting points.

Farmers have a self-identity which is composed of four sub-identities in an *identity standard*. These four sub-identities are: ‘producer’ (P), 'diversifier' (D), ‘conservationist’ (C) and ‘agri-businessperson’ (A) (from Burton and Wilson [2006]). Each of these sub-identities has a salience within the overall farmer identity. The total of all four sub-identities’ salience equals 1.0 with values for each sub-identity specifying its relative importance towards overall agent identity.

Farmers express their identity through distinct behaviours. Behaviours are expressed by the state of the land (grid cells) the farmer owns. This set of grid cells, and their associated expressed behaviours are known as a farmer’s *expressed behaviour*. There are four possible behaviour states for the grid cells: P, D, C, and ‘no expressed behaviour’ (N). The maximum number of behaviours a farmer can express (i.e., grid cells not in ‘no expressed behaviour’ state, *maxBehaviours*) is 20, and the minimum number is equal to the initial land area (number of grid cells) owned (*minBehaviours*). The identity that a farmer’s *expressed behaviour* reflects is represented as a standard, in the same format as their identity standard (i.e., a list of four values with sum = 1.0). This standard is called the *expressed identity standard*.

The four values in the *expressed identity standard* are calculated as follows:

$$sumBehaviours = (countP + countD + countC) \quad (1)$$

where *countP* is the number of grid cells owned by a farmer in state P, *countD* for D and *countC* for C, and:

$$A = \frac{sumBehaviour - minBehaviours}{sumBehaviours + (sumBehaviours - minBehaviours)} \quad (2)$$

where *A* is the value for A in the *expressed identity standard*. Values for P, D and C in the *expressed identity standard* (denoted as *P*, *D*, and *C*) are given by;

$$X = \frac{countX}{(sumBehaviours)} \cdot (1\text{-A}) \quad (3)$$

where *X* is either *P*, *D* or *C* (and *A* is calculated above in Eq. 2). As conceptualised by Burton and Wilson [2006], these equations assume that the agri-business identity is associated with maximisation of production (i.e. using all available land).

Farmers have a social network of other farmers that influences their self-identity. The model user can specify if farmers must always consider their direct neighbours in space as members of their social network, or if they can be dropped from the social network. Reflecting the *expressed behaviour* of their social network, farmers have a third standard named *social expressed behaviour*. This standard has the same format as the others and is calculated as the mean *expressed identity standard* of all farmers in the farmer's social network.

Farmers evaluate the cumulative difference of the four sub-identities between their *identity standard* and their *expressed identity standard* and between their *identity standard* and their observed *social expressed behaviour*. These cumulative differences are named *personal identity error* and *social identity error* respectively.

Farmers have economic state variables: *wealth*, *income*, *costs*, *profit* and *yield*. *Wealth* is the total economic value a farmer has accumulated through time. *Income* is the economic value accrued from the *expressed behaviour* in a given timestep. *Costs* is the economic value lost by *expressed behaviour* in a given timestep. *Profit* is the difference between *income* and *costs* in a given timestep. Farmers also have a binomial (true/false) state variable that records whether they have visited a 'meeting point' in a given timestep.

Land owned by a farmer is represented by grid cells. These grid cells have one state variable, the behaviour it expresses for the farmer owning it. Each grid cell also has two attributes which are constant during a single simulation run: i) the identity number of the farmer to which it belongs and ii) its *yield* value. *Yield* may be spatially uniform or variable, but is always temporally constant (an unrealistic assumption made to simplify this initial proof-of-concept model). Farmers also own a homestead grid cell. This is the same as other grid cells owned by the farmer, but does not express a behaviour. Farmers are distributed spatially on the grid with uniform spacing between them. 'Meeting points' are unique grid cells that do not have any of these other variables or attributes.

Exogenous factors are i) values farmers receive (prices) for different expressed behaviours, and ii) the yield of their land. The model is spatially explicit but abstract (does not represent a real world landscape). Farmers have a distinct and invariable location in space relative to one another. Units of time are not specified but one timestep could be equivalent to one year. There are no assumed spatial units but one grid cell could be equivalent to 1 ha.

2.3 Process Overview and Scheduling

In each timestep, farmers:

i) decide whether to change the behaviour of a single grid cell in their expressed behaviour to maximise or satisfice profit and/or reduce *personal identity error* (see section 2.5 for details);
ii) evaluate *personal identity error* (see section 2.2 for details);
iii) if a change in behaviour was made in i), visit an appropriate meeting point and add a randomly-selected farmer at the same meeting point to their social network (see this section below for details);
iv) evaluate *social identity error* (see section 2.2 for details);
v) update *identity standard* to reduce *personal identity error* or *social identity error* (see this section below for details);
vi) evaluate *personal identity error* (see section 2.2 for details); and
vii) decide which, if any, other farmers they will remove from their social network (see section 2.5 for details), and if a removal occurs evaluate *social identity error* (see section 2.2 for details).

At the start of each timestep the value farmers receive for expressing a given behaviour is potentially updated (depending on the scenario being investigated).

All farmers visit meeting points synchronously after completing steps i) and ii) depending on their behaviour change. Farmers visit the meeting point that corresponds to the behaviour change they have made (e.g., if they have changed a behaviour to 'conservationist' they visit the conservationist meeting point). The model user can specify whether there is a single 'producer' meeting point, or four (one in each corner of the model grid). At each meeting point, each farmer in turn randomly selects one of the other farmers at the meeting point to be added to their social network. The selected farmer reciprocally adds the selecting farmer to their social network. Both farmers then leave the meeting point so that they do not add any other farmers to their social network and are not added to other farmers' social networks. This is completed until all farmers have left the meeting point, or there is only one farmer remaining (in which case this last farmer leaves without adding any other farmer to their social network). Meeting points are used to represent the social links farmers make when engaging in a given behaviour (e.g., see Burton and Wilson [2006])

In step v), if a change in behaviour was made in step i) (or if no change was made because *personal identity error* = 0 and profit > 0) farmers update their *identity standard* to reduce *social identity error*. However, if no change in behaviour was made in step i) (and *personal identity error* > 0), *identity standard* is updated to reduce *personal identity error*. To update standards and reduce error, the value of one sub-identity is increased by 0.01, and a second decreased by 0.01.

2.4. Theoretical and Empirical Background

The model has been developed in the context of social psychology theory outlined in Stryker and Burke [2000] and Burton and Wilson [2006]. The assumption of profit maximisation is based on classical economic theory, and the assumption of satisficing (profit vs. identity) is based on Simon [1955]. Farmer decision assumptions are related to the definitions of the four sub-identities as developed and described by Burton and Wilson [2006]. The basis of the four sub-identities used in the model is data and theorisation by Burton [1998] and Burton and Wilson [2006]. Burton [1998] collected data through interviews with individual farmers.

2.5 Individual Decision-Making

The subjects of decision-making are individual farmers, and the objects of decision-making are the units of land area (grid cells). Decisions are made about individual units of land area to ensure farmer wealth remains positive and to minimise *personal identity error*.

Farmers' decisions about whether to change the behaviour of a single grid cell in their *expressed behaviour* (see i) in 2.3) is driven by their economic circumstances, their *identity standard*, and their *personal identity error*. The state of these variables will determine if farmers use a maximising or satisficing strategy to evaluate change in their *expressed behaviour*.

To choose a strategy, farmers first check if the agri-businessperson sub-identity is ranked most or second-most salient in a given timestep, and if so will seek to maximise profit in that timestep. If the agri-business person sub-identity is ranked lower in a farmer's identity standard, that farmer will estimate their profit (income – costs) for their current *expressed behaviour*. If profit is negative, the farmer will again seek to maximise profit in that timestep. Otherwise, the farmer will use a satisficing strategy, seeking to reduce *personal identity error* while ensuring profit for the timestep is not negative.

Once the strategy has been chosen, all possible changes in expressed behaviour for a single grid cell are evaluated and that which best meets the desired criteria (profit maximisation or *personal identity error* minimisation) is selected.

To decide if a farmer should be removed from another farmer's social network (see vii) in 2.3), farmers compare the highest ranked sub-identity in their *identity standard* with the highest-ranked sub-identity in the other farmer's *expressed behaviour*. If the sub-identities do not match, the farmer is removed from the social network **unless** the checking farmer shares the highest-ranked sub-identity in *expressed behaviour* **or** the checked farmer is a direct neighbour in space and the user has specified that spatial neighbours must always remain in a social network (see section 2.2). These rules assume that farmers will not respect the identity and behaviour of farmers who do not share their most salient sub-identity (Burton and Wilson [2006]), but also that there may be situations when *expressed behaviour* does not match *identity standard*.

Farmers use utility functions to decide behaviour change, a decision tree to decide if another farmer should be removed from their social network, and a random choice function when selecting new farmers to add to their social network.

Farmers do not adapt their behaviour to changing socio-ecological conditions, but social norms play a role in decision-making. Farmers sense the social norm (i.e., the *identity standard* of other farmers) of their social network indirectly via *social expressed behaviour*. This may in-turn influence their behaviour change (see above this section). Temporal aspects do not play a role in the decision process, but spatial aspects may do if multiple meeting points are enabled and *yield* is spatially variable. Uncertainty is not represented explicitly and farmers assume that the observed expressed behaviour of other farmers accurately represents their *identity standard*.

2.6 Learning
Neither individual nor collective learning are represented in the model.

2.7 Individual Sensing
Farmers can sense the *yield* of their land, prices for each of P, D and C behaviours, and others' *expressed behaviour* in their social network (potentially this network can be global, if all other farmers are in the farmer's social network). Farmers are assumed to be able to accurately observe the behaviour of farmers in their social network and farmers incur no cost for sensing or cognition.

2.8 Individual Prediction
Farmers do not predict future conditions or consequences of their decisions.

2.9 Interaction
Interactions among farmers are represented indirectly via their sensing of one another's *expressed behaviour*. These interactions depend on farmers' social networks (which in turn may be influenced by space). There is no explicit communication between farmers and there is no co-ordination structure.

2.10 Collectives
Farmers form social networks that affect and are affected by individuals. Farmers' social networks can be pre-defined by the user (local neighbourhood or randomly generated) but change through simulation and become an emergent property.

2.11 Heterogeneity
Farmers can be heterogeneous in all attributes except *maxBehaviours* and *minBehaviours*.

2.12 Stochasticity
The selection of farmers for addition to social networks (when at meeting points) is random. Farmers' initial *identity standard*, *expressed behaviour* and social network can be stochastically generated (see 2.15).

2.13 Observation
Numerous state variables can be observed. Here we examine the number of behaviours expressed in the model landscape for each sub-identity, mean sub-identity salience values, social and personal identity error and spatial maps of farmer expressed behaviour.

2.14 Implementation Details

The model is implemented in NetLogo 4.1.2. The model is available online at http://www.landscapemodelling.net/NetLogo4_1/iEMSs12_model.html.

2.15 Initialization

Initial *identity standard* can vary randomly between farmers, can vary stochastically between farmers with a specified farmer mean value, or can be uniform across all farmers with *identity standard* specified by the user. Initial *expressed behaviours* of farmers can be identical to individual farmers' *identity standard* or can be set independently in the same ways just described for identity standards.

2.16 Input Data

The model can be used with time series of prices for each of the behaviours P, C and D.

3. METHODS

To explore the behaviour of the model, we examine combinations of price scenarios (i.e., changes in price through time), spatial distributions of yield, and rules for social network change. We ran the model for 200 timestep, replicating each combination of conditions 10 times with *minBehaviours* = 10 and *maxBehaviours* = 20. Farmers' initial *identity standard* and *expressed behaviour* are generated stochastically (and independently) with mean and standard deviation of values for producer of 0.8 and 0.1, 0.2 and 0.1 for agri-businessperson, and values of 0.0 for conservationist and diversifier.

3.1 Price Scenarios

We use two price scenarios, A and B. In scenario A the price received for the expression of a conservationist behaviour starts at zero, increases to 1.2 at timestep 120 and then decreases to 0.5 at timestep 200. The price received for productionist behaviour remains constant through time at 0.75. In scenario B, conservationist price changes as it does in Scenario A, but price for productionist behaviour oscillates from 0.42 to 1.08 with period of 80 timesteps (with starting value 0.75 and initially increasing). In all scenarios value for diversifier is constant at zero (i.e., the diversifier sub-identity is not considered in these simulations).

3.2 Spatial Distribution of Yield

We examine three different spatial distributions of *yield*: i) uniform in space, ii) a gradient across the modelled environment from high (1.0) to low (0.5) and iii) 'quartered', with the model environment split into four quarters each with different *yield* (0.50, 0.66, 0.83, and 1.00). In each spatial distribution the mean farmer *yield* is 0.75.

3.3 Social Network Change

To examine the influence of differences in how farmers can change their social network we consider two different rules: i) farmers' immediate neighbours in space (Moore neighbourhood) must always be in their social network, and ii) farmers may remove any and all other farmers from their social network.

4. RESULTS

4.1 Price Scenarios

When we compare price scenarios A and B (with spatially uniform *yield* and farmers unable to remove immediate neighbours from their social network) we observe that in scenario A (dashed line, Fig 1 a, c and e) farmers are stubborn to change away from a productivist identity. In price scenario A, *personal* and *social identity error* is very low and farmers are not pushed to change identity. However, in price scenario B (solid line, Fig 1 a, c and e), the variable price for expressed producer sub-identity behaviour leads many farmers to switch to conservationist behaviours, which in-turn increases their *personal* and *social identity error* and drives change in their identity.

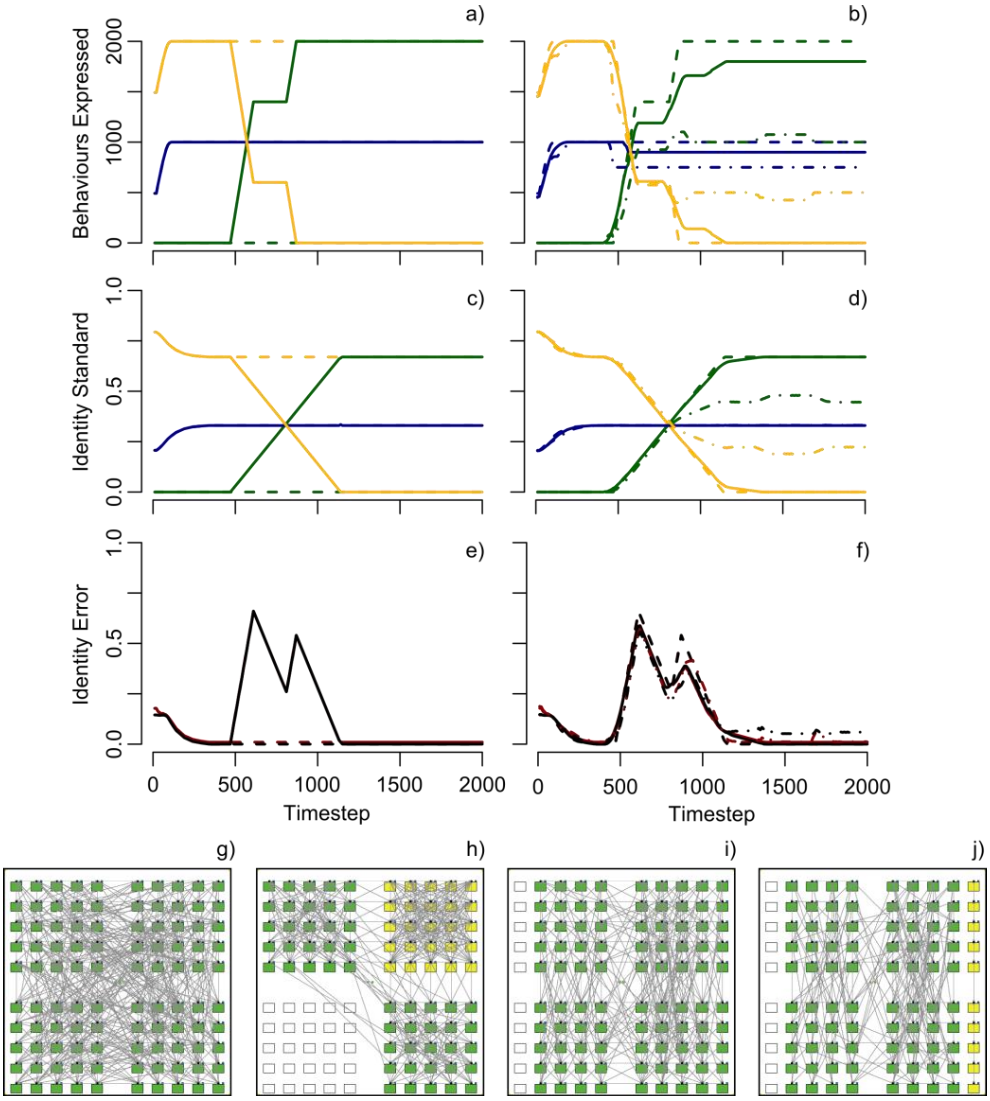

Figure 1. Results for price scenarios, spatial distribution of yield and rules for social network change. In all panes (except e and f) yellow is producer sub-identity, green is conservationist and blue is agri-businessperson. In e) and f) red is *personal identity error* and black is *social identity error*. In a), c) and e) dashed lines are price scenario A and solid lines are price scenario B. In b), d) and f) dashed lines are 'uniform', solid are 'gradient' and dot-dashed are 'quartered' spatial distribution of yield. Lines are means for 10 simulation replicates. Panels g) to j) are spatial maps of farmers and their social networks (links between farmers shown by grey lines) in the final timestep of an example simulation (created using random number seed = 322; see text for scenarios).

4.2 Spatial Distribution of *Yield*

When we compare the effects of the spatial distribution of *yield* (for price scenario B and with farmers unable to remove immediate neighbours from their social network) we see that 'quartered' spatial distribution of *yield* leads to many fewer farmers adopting conservationist behaviour and identity despite similar mean values of *social* and *personal identity error* (Fig 1 b, d, and f). Examining spatial effects of different patterns of *yield* show no farmers go out of business when *yield* is uniform at 0.75 (Fig 1 g), 25% go out of business on low *yield* land and 25% maintain producer identity and behaviour on high *yield* land (Fig 1 h), and 10% go out of business with the remainder shifting to a conservationist identity when *yield* increases from low to high (left to right across Fig 1 i).

4.3 Social Network Change

To examine the influence of farmers being (un)able to disregard their immediate neighbours' behaviour we compare runs for price scenario B with gradient spatial distribution of *yield*. When farmers are not able to disregard their immediate neighbours' behaviour, all farmers that stay in business switch to a conservationist identity (Fig 1 i). However, when farmers are able to ignore immediate neighbours, those on the highest *yield* land maintain producer identity and behaviour (Fig 1 j).

5. CONCLUSIONS AND RECOMMENDATIONS

This paper has provided an exemplary demonstration of how social psychology theory might be used in ABM, in this case for representing agricultural land use decision-making. Initial results from this simple implementation suggest that productivist farmer identities are stubborn to change, spatial distribution of land resources influences identity change, and rules for social network formation influence likelihood of agents' identity change. These results imply the use of social psychology theory in ABM could be beneficial and should be investigated further. Future work should examine the expression of self-concepts in more realistic ways than the direct land-use changes used here (e.g., influencing decision strategies).

ACKNOWLEDGMENTS

An Early Career Fellowship from the Leverhulme Trust supported this research. The comments of two anonymous reviewers helped improve a previous draft.

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