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Agent-based model simulations of future changes in migration flows for Burkina Faso☆

Dominic Kniveton [a,*], Christopher Smith [a], Sharon Wood [b]

[a] Department of Geography, School of Global Studies, University of Sussex, Brighton BN1 9QJ, United Kingdom
[b] Representation & Cognition Group, School of Informatics, University of Sussex, Brighton BN1 9QJ, United Kingdom

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ABSTRACT

Attempts to quantify the numbers of migrants generated by changes in climate have commonly been calculated by projecting physical climate changes on an exposed population. These studies generally make simplistic assumptions about the response of an individual to variations in climate. However, empirical evidence of environmentally induced migration does not support such a structural approach and recognises that migration decisions are usually both multi-causal and shaped through individual agency. As such, agent-based modelling offers a robust method to simulate the autonomous decision making process relating to environmental migration. The Theory of Planned Behaviour provides a basis that can be used to effectively break down the reasoning process relating to the development of a behavioural intention. By developing an agent-based model of environmental migration for Burkina Faso from the basis of a combination of such theoretical developments and data analysis we further investigate the role of the environment in the decision to migrate using scenarios of future demographic, economic, social, political, and climate change in a dryland context. We find that in terms of climate change, it can be seen that that change to a drier environment produces the largest total and international migration fluxes when combined with changes to inclusive and connected social and political governance. While the lowest international migration flows are produced under a wetter climate with exclusive and diverse governance scenarios. In summary this paper illustrates how agent-based models incorporating the Theory of Planned Behaviour can be used to project evidence based future changes in migration in response to future demographic, economic social and climate change.

1. Introduction

Climate change has become widely accepted as a challenge that the global community will face in the not-too-distant future and some already face today. Although uncertainty remains as to the precise nature and extent of these changes, scientific evidence suggests that they are inevitable (Boko et al., 2007). The likely manifestations of climate change include rising sea levels, deforestation, dryland degradation and natural disasters. Such environmental events and processes are expected to pose significant challenges for society in terms of their effect on development and livelihoods, settlement options, food production and disease. As well as the large volume of research aimed at investigating the nature and occurrence of future climate change, much current research focuses on the challenges posed to society by climate change and the adaptations necessary for human populations to withstand them. One such adaptation strategy is the migration of people away from affected areas.

Studies of climate-induced migration in the past have commonly calculated the numbers of 'environmental refugees' by projecting physical climate changes, such as sea-level rise, on an exposed population (TERI, 1996; Nicholls and Tol, 2006; Warren et al., 2006). These studies assume that a person's ability to cope with variations in climate is proportional to growth in Gross Domestic Product (GDP). In reality migration responses are the result of a far more complex combination of multiple pressures and opportunities that shape the behavioural decisions of individuals. Previous approaches to understanding such behavioural decisions have not successfully isolated environmental influences from the multitude of other structural transformations that influence migration at the individual or household level. Modelling techniques present the only way to effectively simulate such a behavioural process and consider the scale of mobility as a result of climate change. By applying an agent-based modelling technique to the migration and climate change nexus, the influence of environmental factors upon the migratory

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* Corresponding author. Tel.: +44 01273 877757.
E-mail addresses: d.r.kniveton@sussex.ac.uk, kafw3@sussex.ac.uk (D. Kniveton).

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response may be better understood. In creating such a model, the sensitivity and detail of the migratory process to climate variability and change may be further investigated and assessed.

Located in dryland Africa, Burkina Faso is one of the poorest countries in the world with a population (and economy) largely dependent upon rain-fed agriculture and cattle-raising for subsistence and development. Historically, migration forms one of many livelihood strategies employed to cope with environmental stresses and shocks of which (a lack of) rainfall induced drought is the most common. While there remains large uncertainty relating to the magnitude and even sign of changes in rainfall under different climate change scenarios in the future (Boko et al., 2007) Burkina Faso provides an appropriate case-study for investigation into the issue of environmentally induced migration due to the vulnerability of its population to changes in rainfall.

This paper presents the development and testing of an agent-based model (ABM) designed to replicate 1970–2000 climate migration in Burkina Faso and simulate migration flows forwards to 2060. Originally developed for use within commercial industries, the appeal of ABMs to social science has come about through their potential to facilitate generative explanations of the complex interactions evident in human systems through the unforeseen interaction of multiple agents (Epstein, 2005). ABMs therefore present a viable alternative approach to previous empirical approaches by considering the migration decision in terms of the rules of behaviour that govern the response of individuals to complex combinations of multi-level stimuli. Previous approaches to using ABMs in the social sciences have included work by Silveira et al. (2006) to investigate rural–urban migration and Ziervogel et al. (2005) to assess the role of seasonal climate forecasts on the behaviour of small-holders in Lesotho. The agent-based model we present has been developed using existing theoretical developments in the fields of human migration and climate change adaptation. These theoretical foundations are combined with advances in the field of social psychology to develop a conceptual basis for agent cognition in the model. Agents in the modelled environment of Burkina Faso interact with one another and their environment to develop intentions to adapt to changes in rainfall through migration. The likelihood of an agent migrating is affected by both their individual attributes and their placement in a social network within which changes in rainfall are discussed.

2. The decision to migrate

Migration has always been a fundamental component of human history. Following years of academic consideration the topic has been the subject of much theoretical debate. Such notions as those of the 'push' and 'pull' factors of origins and destinations and the "intervening obstacles" that stand between an individual and their migration aims (Lee, 1966) have been developed to provide a simplistic analysis of migrant motives. The decision made by an individual to move from one location to another is however a personal choice formed as a result of a unique combination of circumstances. While in-depth survey-based approaches have been developed that work to disentangle the multiple factors influencing migration at the household/individual level, they do not allow predictions of migrant numbers in the future or under different conditions from those under which the original surveys were performed. However, dynamic approaches such as agent-based modelling provide a means to adjust various parameters to further investigate situational changes and future scenarios.

In modelling the migration decision, an agent can be used to represent either an individual or a household and is programmed to act on the stimuli they receive throughout the simulation. The agents used in an ABM are situated within a simulation environment that, in this instance, represents their geographic location within Burkina Faso. As they move around the environment agents come into contact and communicate with other agents whose circumstances and migration history may differ from their own. Through such agent-agent interaction, one individual may affect the later choices of another by, for example, sharing a positive experience (and access) of migration to location *l*, under rainfall conditions *rc*. An individual agent can therefore learn from their surroundings, personal experience and that of other agents through a rational thought process and adapt their behaviour accordingly. In order to represent agent-related processes and incorporate them into an agent-based model, we first develop a conceptual basis for individual decision making within the model.

Grothmann and Patt (2005) present a process model of private proactive adaptation to climate change (MPPACC) which separates out the psychological steps to taking action in response to perceptions of climate. The MPPACC provides a useful basis from which to develop a conceptual model of the reasoning undertaken by an agent in their migration decision. In seeking a basis from which to develop the MPPACC into a conceptual model to suit an ABM we draw upon theoretical developments made in the field of social psychology.

The Theory of Reasoned Action was developed by Fishbein and Ajzen (1980) as an expectancy-value model that recognises attitudes as just one determinant of behaviour. The theory proposes that the proximal cause of behaviour is 'behavioural intention', a conscious decision to engage in certain behaviour. Making up this behavioural intention is the individual's attitude towards the behaviour and their subjective norm (belief that a significant other thinks one should perform the behaviour and the motivation to please this person). By extending the theoretical model to incorporate the additional parameter of perceived behavioural control, Ajzen (1991) proposes the Theory of Planned Behaviour. Intended to aid prediction of behaviours over which a person does not have complete voluntary control, perceived behavioural control was conceptualised as the expected ease of actually performing the intended behaviour. Including attitudes towards behaviour, a subjective norm and perceived behavioural control (as well as the beliefs held by an individual that make up these components), the Theory of Planned Behaviour can be used to effectively break down the reasoning process relating to the development of a behavioural intention in the context of the migration decision.

3. Conceptual model of migration adaptation to rainfall change

In Fig. 1 the Model of Migration Adaptation to Rainfall Change (MARC) displays the conceptual basis from which the ABM has been developed. Notably, the position of the role of rainfall variability and change is such that, rather than being identified as a separate driver of migration, it is shown as influencing the other drivers of migration. This follows the insights of fieldwork and analysis of survey data where only 27 of the 3517 households interviewed identified rainfall as a driver of migration; yet the statistical analysis of Henry et al. (2004) showed a statistically significant relationship between migration outcomes and rainfall variability. Thus the conceptual model indicates that rather than directly determining migration, rainfall's impact on migration is expressed via its influence on the other drivers of: differential employment opportunities; limited access to natural resources; national policies and incentives; ecological vulnerability, political instability and infrastructure. These drivers have social, economic, demographic, political and environmental dimensions and one of the functions of the ABM is to implicitly model the marginal influence of changes in rainfall on these drivers to explore how individual behaviour aggregates to a macro level response.