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Using Bayesian belief networks to analyse social-ecological conditions for migration in the Sahel

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ABSTRACT

In order to understand the impact of climatic and environmental changes as well as socio-economic drivers on human migration, it remains a challenging task to find a method to analyse the knowledge from different scientific disciplines in an integrated way.

The Sahel region with its high ecological dynamic has a long history of migratory movements. Within this work, we integrate and analyse socio- and natural-scientific data from two Sahelian study areas in Mali and Senegal using Bayesian belief networks. The core of the network's structure is formed by four main motives to migrate which are education, family, visit and curiosity and sustenance and employment. It is assumed that these motives determine the spatial and temporal patterns of migration. On the basis of submodels for each migration motive, we identify the decisive factors that constitute the socio-economic and ecological conditions with a combination of sensitivity analyses and train-and-test validation method. In combining these factors, the model avoids implying monocausal dependencies and allows an analytical view on the likely consequences of different settings of social-ecological conditions on migration. Furthermore, we use the model to estimate the consequences of alternative future developments in contrasting scenarios.

The results show that changing environmental conditions lead to changing patterns of migration, regarding its duration and destination. These patterns can be very specific for different motives and their underlying factors. One principal result of the analysis is that uncertainty in the main income sources correlates with an increase of short-term migrations in order to increase the households' possibilities for income generation. Nevertheless, socio-economic conditions show a greater impact on the people's decision to migrate than environmental conditions.

1. Introduction

Inter- and transdisciplinary sciences demand methods that are able to integrate knowledge gained from different (scientific) disciplines. Furthermore, methods usually have to be suitable for a huge complexity of processes and interrelations. An issue, where this complexity is apparent is the coherence between environmental conditions, socio-economic circumstances and human migration.

The extent to which the implications of environmental changes caused by climate change are influencing population movements had already been investigated before the publication of the recent IPCC Fifth Assessment Report (IPCC, 2014), which played an important role in bringing the topic into public and political focus. Reasons for migration or escape range from natural disasters (like floods or hurricanes) through conflicts over resources to increasing water scarcity and degradation (Foresight, 2011; Theisen et al., 2011; UNEP, 2011). There are numerous contributions to the political as well as to the scientific debate about the impacts of (climate driven) environmental changes on people's movement. Almost as numerous as the studies, reports and articles are the underlying concepts of migration and terms describing population movements driven or influenced by environmental changes (Black et al., 2011; IPCC, 2014; Renaud et al., 2011). Consequently, estimating the number of people moving because of environmental changes leads to large differences, depending on definitions and time periods (Hummel et al., 2012).

Especially within the context of slow-onset effects like degradation, the Sahel region is often in the focus of interest. Being determined by changing climatic and anthropogenic influences, the Sahel is an ecologically highly dynamic region, ranging from desertification to (re-) greening trends. While the

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scientific debate about desertification already started in the first half of the 20th century and was reinforced by severe droughts in the 1970s and 1980s, the opposing observation of a (partial) re-greening is relatively new and mainly due to improved technologies of remote sensing (Dardel et al., 2014; Herrmann et al., 2005). Recent studies conclude that "neither the re-greening nor the desertification paradigm can be generalized as both are present at a local level." (Brandt et al., 2014)

Being embedded within the micle project ('Migration, Climate and Environmental Changes in the Sahel'), this study spatially covers the circle of Bandiagara in Mali and the department of Linguère in Senegal (Fig. 1). Being predominantly rural, migratory movements have been and still are normal phenomena of everyday life in both regions. Especially for (half-) nomadic herders, seasonal and circular migration is a way to cope with the unstable natural conditions. But also non-herders that have a different lifestyle, like farmers or fishermen, migrate in search of further sources of income, better working conditions or possibilities to sell their products (Hummel et al., 2012; UNEP, 2011). These different social and environmental influences and their possible interactions are likely to cause differing motivations to migrate. Thus, we presume that depending on the motives for migration the connections between social-ecological conditions on the one hand and migration and its spatial and temporal patterns on the other vary. Although a direct causal link between such complex phenomena like climate change and migration does not exist, due to the outlined sensitivity of the Sahel to environmental changes, it can be assumed that slow-onset effects will have a notable impact on migratory movements (UNEP, 2011).

All in all, there is a demand for a tool for data integration that can show the complexity of migratory processes and enables the analysis of changing social-ecological conditions and their consequences with regard to migration patterns. A promising approach to meet these requirements is a Bayesian belief network (BBN). BBN as an integrated modelling method has a broad applicability due to its high flexibility in terms of the underlying data. Additionally, the network structure can portray a huge variety of different factors and their mutual relations (Aguilera et al., 2011). In spite of the tool's broad application, this work is believed to be the first implementation of BBNs on a regional scale in the field of migration. By developing two models simultaneously for both study areas, the methodological transferability as well as the generalisability of the content-related results shall be assessed. Furthermore, we use the model to identify possible future developments for different scenarios.

2. Social-ecological perspective on migration

2.1. Migration in the context of environmental change

Before regarding the socio-economic and environmental influences on migration, the definition of migrant, used in this work, shall be outlined. In compliance with the Human Development Report 2009 (UNDP, 2009) and the Foresight project (Foresight, 2011), migrants are defined as individuals who leave their place of residence and move to another country (international migrant), region, district or municipality within the country (internal migrant) for more than 3 months.

Within the debate about environmentally induced migration, consideration should be given to the used terms and definitions. In contrast to the often criticised term environmental refugee (Doevenspeck, 2011), alternative approaches differentiate between environmental emergency migrants, environmentally forced migrants and environmentally motivated migrants. The former environmental emergency migrants describes people who flee because of natural disasters, whereas environmentally forced migrants leave their home because slow-onset effects (e.g. erosion, sea level rise, degradation) destroy their basis of existence. Environmentally motivated migrants, as the final category, subsumes those people who choose to leave their home, because – in most cases as one of several causes – the environmental conditions become unfavourable, although they would have the choice to stay (Renaud et al., 2011). Obviously, this distinction is blurred and this shows the difficulty to methodologically capture all categories in one study (or even one model). In the framework of this study, slow-onset and cumulative changes of the environment are the focus, which means that environmentally motivated – and partially forced – migrants are the categories of interest.

Despite the plurality of theoretical concepts, there is still a high level of uncertainty in estimating the influence of environmental changes on migration. It is safe to say that there is no linear correlation between the severity of disadvantageous environmental changes and the likelihood of migration. This becomes even more obvious when not only the direct impacts of changing environmental conditions are considered but also their effect on other drivers of migration (e.g. economic, political, demographic, social) (Black et al., 2011; Lilleør and van den Broeck, 2011). The importance of financial (and social) resources is crucial, especially in case of international migration which is, due to the high costs, denied to the poorest (de Haas, 2008). "The poorest tend to migrate less than those who are slightly better off. This seems particularly

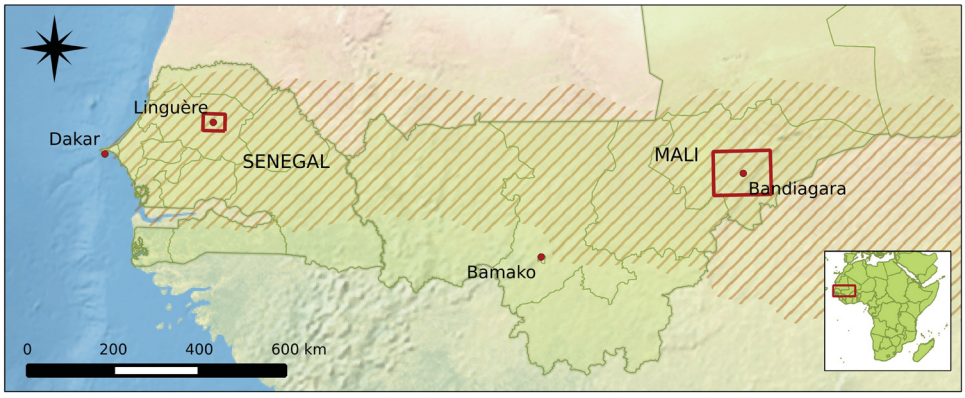

Fig. 1. Location of study areas (rectangles). The shaded area indicates the Sahel's extent, delimited by the 250 mm/a isohyet in the north and 900 mm/a in the south (based on the definition of the MEA (2005). (Data sources: DIVA-GIS, Natural Earth Data. Own cartography). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).