Ecological Complexity 32 (2017) 53–73

Contents lists available at ScienceDirect

Ecological Complexity

journal homepage: www.elsevier.com/locate/ecocom

Original Research Article

Assessing the risk of seasonal food insecurity with an expert-based Bayesian Belief Network approach in northern Ghana, West Africa

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ARTICLE INFO

Article history:
Received 17 January 2017
Received in revised form 31 August 2017
Accepted 10 September 2017
Available online xxx

Keywords:
Climate variability
Driving forces
Expert knowledge
Participatory approaches
Population growth

ABSTRACT

Food insecurity is still a major global concern. Population growth, poverty, climate variability, and low agricultural productivity, among others, are threatening food provision. Rural areas in West Africa are particularly vulnerable due to low financial and physical capacity and high dependency on agriculture. Programs to support food provision exist, but their effects bear uncertainties under different weather and land use scenarios. Our study focuses on the regional assessment of food provision in the Upper East Region in northern Ghana under land use changes and different weather scenarios by using a Bayesian Belief Network. Especially in the beginning of the rainy season, there is a high risk of food insecurity. Therefore, seasonality needs to be considered in a modeling approach. In addition, we estimated the vitamin A supply indicating the risk of malnutrition. Improving agricultural programs, increasing income by off-farm activities, reducing post-harvest loss, reducing soil erosion, expanding irrigated areas in the dry season and increasing market demand were assessed in order to support food security. The Bayesian Belief Network specifically handles uncertainty and different data types and allows the visualization of complex socio-ecological interactions to communicate to different expert groups, mainly scientists and field officers. A combination of literature, calculations and expert knowledge was required to fill the knowledge gaps in the West African context. About 95 experts were involved in the Bayesian Belief Network development process. An important finding was that an increase in household income, for example by off-farm income, might be better support for people than agricultural programs for providing a contribution to food security under weather uncertainty, provided that income is partly spent on fertilizer. The same is true under increasing population and decreasing total cropland. The likelihood of food provision in the following rainy season was 15% to 55% lower than in the dry season. In addition, the vitamin A provision was far below the demand in all scenarios.

1. Introduction

Food insecurity still belongs to the global challenges (WHES, 2015). Especially in the sub-Saharan region, the risk of food insecurity remains on a high level due to constantly increasing population, poverty, conflicts, diseases, climate variability, low agricultural productivity, and malnutrition (WHES, 2015). Most of the diets of people in Africa lacks the required nutrients such as iodine, iron and vitamin A (Lopriore and Muehlhoff, 2003; WHES, 2015) thereby leading to stunting, wasting, underweight and

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http://dx.doi.org/10.1016/j.ecocom.2017.09.002

micronutrients deficiency disorder. In Ghana, in 2014, 19% of children under 5 years were stunted, and 11% were underweight (DHS, 2014). Stunting and underweight rates decreased between 2003 and 2014 but stay high in northern Ghana (33% are stunted; DHS, 2014). In addition, micronutrients, such as vitamin A, vitamin E and zinc could contribute to reduction in the morbidity of malaria (Nussenblatt and Semba, 2002; Scrimshaw, 1992).

Besides being prone to food insecurity, people in low-income countries are more directly dependent on natural resources than in high-income countries (UNDP, 2005). Rain-fed agriculture dominates farming in Africa, which makes it highly vulnerable to weather conditions (FAO, 2009). Particularly, food insecurity is caused, in part, by extreme weather events (Lesk et al., 2016), which are likely to increase in West Africa (Salack et al., 2016; Sylla et al., 2016). Therefore, attention should be given to climate change when discussing the realization of the development goals (Beg et al., 2002; UNDP et al., 2011). One of the Sustainable Development Goals is the ending of hunger through increased productivity of small-scale farmers and improved irrigation schemes. Sub-Saharan Africa might not meet this target on time due to economic and political instability, population growth and environmental problems (MDG Report, 2015).

Often, the combination of social and ecological factors affects food insecurity (IPCC, 2014; Reenberg 2001). A comprehensive analysis often requires a combination of qualitative and quantitative data from social and natural science (Busch et al., 2012; Rindfuss and Stern, 1998). An assessment of causal interdependencies within the context of food insecurity could help to identify the triggers of such effects and analyze the effectiveness of countermeasures. Furthermore, given the increased probability for extreme weather events, identification of seasonal changes in food provision is crucial in order to tailor policies to specific periods (Wilhite et al., 2014).

Modeling is a suitable tool to assess socio-ecological systems and there exist different modeling approaches (Kelly et al., 2013). For example, system dynamics are strong in feedback loops (Barlas, 1989), Agent-Based Models (ABMs) focus on representation of the interactions between autonomous entities in a system (Bousquet et al., 1999; Janssen, 2002; Le et al., 2008), cellular automatons emphasize the impact of spatial interactions on land systems (Fürst et al., 2010; White and Engelen, 1997) and Bayesian Belief Networks (BBNs) reflect the complex interactions of system components (Varis, 1997).

In this study, the choice of our model is on the premise that it should be flexible in order to integrate varying data types. Further, the model should be able to handle data gaps and uncertainty because of missing information and data in our research context. Progress in the collection of scientific data in West Africa has been made in different projects, for example in AGRHYMED (www.agrhymet.ne) and WASCAL (www.wascal.org), but data is still fragmented in location, time of investigation, and scientific focus, among others. BBNs are regarded as a suitable tool to tackle the above-mentioned scientific challenges, thereby contributing to system understanding and scenario analysis. BBNs have their strengths in the analysis of different kinds of uncertainty, and due to the explicit consideration of uncertainty, predictions are closer to the (uncertain) reality (Reichert and Omlin, 1997).

In the context of Africa, the BBN as modeling approach has been used by CIFOR in Zimbabwe to estimate people's vulnerability and to assess countermeasures (Campbell et al., 2002). They investigated the relation between rainfall, production and income. Household vulnerability was highly sensitive to the macro-economy and to the rainfall regime. Additionally, in Ghana, Banson (2016) used BBNs to estimate performance in agricultural businesses with different interventions (e.g. access to extension service, the construction of dams and roads) at national level. However, the study did not analyze direct consequences for food provision and did not address land use changes and different weather scenarios under seasonal changes.

1.1. Purpose of the study

We assessed seasonal food security by using a BBN integrating a variety of different data types, methods and considered multiple driving forces of land use and land cover change (LULCC), different weather scenarios and measures against food insecurity, an approach yet to be operationalized in the West African context. Our study exemplifies the assessment of seasonal food security (the relation between food demand and provision) in the rural agricultural system of the Upper East Region in northern Ghana in order to gain insights into seasonal differences (systemic changes), to inform about uncertainties and to provide a discussion basis for decision-making. Potentially, the final BBN can be used for policy recommendations. In this study, food insecurity implies the likelihood that people (as subsistence farmers) are not able to harvest enough food to meet their minimum dietary energy. It was out of scope to measure vulnerability or coping capacities like financial assets or social networks in order to buffer food crises.

Furthermore, vitamin A deficiency is a major public health problem in West Africa (Lopriore and Muehlhoff, 2003). Therefore, in addition to food as basic energy supply, we consider the lack of vitamin A provision as risk for malnutrition. Our study differs from Banson (2016) because we concentrated on a specific agricultural system, region and agricultural interventions. Furthermore, to our knowledge, no analysis has been done with a BBN, which considers seasonal differences of food demand and provision under different scenarios.

The study was guided by the following research questions:

i) What are the seasonal differences in food provision?
ii) Which land use and weather scenarios have the greatest impact on seasonal food insecurity in the Upper East Region?
iii) Which measures are most suitable to contribute to food security?

2. Methods

2.1. Study area: the Upper East Region in northern Ghana

Between 1990 and 2015, Ghana has made progress in reaching the Millennium Development Target by halving the proportion of people who suffer from hunger (MDG Ghana, 2012, page 20). However, the northern regions are still behind the national average. Key challenges for attainment of the target are traditional farming methods, high dependency on rain-fed agriculture, high poverty rates and large family sizes in the northern regions (MDG Ghana, 2012).

The Upper East Region (UER) is located in the transition zone between the Sudanian and Guinean Savanna Zone (Fig. 1) and stretches over 8842 km^2 (3.7% of Ghana, GSS, 2008). Rural population densities are high with 103 people/km^2. About 80% of the rural population is engaged in small-scale rain-fed subsistence farming (Birner et al., 2005). Most important crops are maize, sorghum, and millet; these are intercropped mainly with groundnuts or beans. Vegetables, especially tomatoes and onions (Dietz and Millar, 1999), and rice are grown in irrigated areas or rain-fed lowlands.

The region is characterized by a distinct seasonality. In the rainy season (May – October), all rain-fed crops are grown and harvested. During the dry season, only irrigated crops can be cultivated, mainly located at the Vea and Tono dam which makes