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Localization and characterization of populations vulnerable to climate change: Two case studies in Sub-Saharan Africa

Cornelia F.A. van Wesenbeeck*, Ben G.J.S. Sonneveld, Roelf L. Voortman

Centre for World Food Studies, VU University Amsterdam, De Boelelaan 1105, 1081 HV, Amsterdam, The Netherlands

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ABSTRACT

Future climate change potentially can have a strong impact on the African continent. Of special concern are the effects on food security and the restricted adaptive capacity of Africa's poverty stricken population. Targeted policy interventions are, therefore, of vital importance. While there is a broad consensus on selection of climate and agricultural indicators, a coherent spatial representation of the populations' vulnerability is still subject to debate, basically because important drivers at household and institutional level are captured at the coarser (sub)-national level only. This paper aims to address this shortcoming by capitalizing on available spatially explicit information on households, food security institutions and natural resources to identify and characterize vulnerable groups in climate change prone areas of East and West Africa. First, we identify and localize groups with varying degrees of vulnerability, using food security and health indicators from georeferenced household surveys. Second, we characterize these vulnerable groups using statistical techniques that report on the frequency of occurrence of household characteristics, social bonding, remittances and agro-ecological endowments. Third we localize areas where climate change conditions affect production of major staple crops even after a maximum adaptation of crop rotations. Fourth, we characterize the vulnerable groups in the climate change affected areas and compare their profiles with the overall assessment to elucidate whether generic or climate change targeted policies are required. Since climate change will impact predominantly on agricultural production, our analysis focuses on the rural areas. For West Africa, we find that vulnerable groups in areas likely to be affected by climate change do not fundamentally differ from vulnerable groups in the study area in general. However, in East Africa there are remarkable differences between these groups which leads to the conclusion that in this part of Africa, poverty reducing strategies for climate change affected areas should differ from generic ones.

1. Introduction

Is climate change the final blow for Africa? This intriguing question by Ariel Dinar (2013) is the topic of many studies that analyze the effects of climate change on the welfare of the African population (Müller, Waha, Bondeau, & Heinke, 2014; Smit & Wandel, 2006). Indeed, future climate change potentially can have a strong impact on the African continent, particularly on vulnerable groups that lack the means to effectively cope with the altering conditions and do not avail of supportive social networks that can assist in mitigating harmful effects. Sub-Saharan's predominantly rain-fed agriculture is particularly vulnerable to climate change because of expected weather volatility through heavy rainfall or extended extreme droughts. Efficient policy interventions not only require the identification of most affected areas, but also have to take into account economic and biophysical characteristics that influence the ability of people themselves to respond to changing climatic conditions (Conway, 2011). Concerning the identification of vulnerable groups in SSA two important issues stand out. First, there is a substantial variation in socio-economic conditions between and within the rural population. Hence, national or regional statistics are of limited use to identify vulnerability. Second, the prevailing agro-ecology in Africa is typically characterized by spatially heterogeneous and locally homogeneous biophysical conditions (Voortman, Sonneveld, & Keyzer, 2003). Hence, vulnerability assessment requires a spatially explicit localization of vulnerable populations to define targeted interventions. This paper aims to add to the understanding

* Corresponding author.
E-mail address: c.f.a.vanwesenbeeck@sow.vu.nl (C.F.A. van Wesenbeeck).

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of households' vulnerability by analyzing georeferenced household surveys in relation to the biophysical and agronomic conditions in East and West Africa for climate change prone areas. The study focuses on two groups of adjacent countries that are representative for prevailing ecological and agricultural characteristics in West (Benin, Burkina Faso, Côte d'Ivoire, Ghana and Togo) and East Africa (Sudan, South Sudan and Uganda).[1] Below we introduce the analytical framework and describing the context of the study within the international research agendas.

1.1. Analytical framework

Because of the location specific effects, research in the past decade focused on the identification of the 'hot spots' of food insecurity of vulnerable people by increasing the spatial detail and number of relevant variables (e.g. Nelson, Abkowitz, & Camp, 2015). Yet, lack of common understanding about the fundamental concepts of the terms vulnerability and food security, spawned disagreements over data requirements and interpretation of the results of vulnerability assessments (Blaikie, Cannon, Davis, & Wisner, 1994; Hart, 2009). Hence, to avoid these controversies we first define and operationalize an analytical framework that relates food security to vulnerability.

A food secure situation exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2002). The definition eschews the emphasis on food supply and follows more closely Sen's (1981) vision that the food security situation of people is explained by their possibility to get access to assets. The interpretation of the term vulnerability respects Chambers' (1989) explanation who states that vulnerability refers to the exposure to contingencies and stress, and difficulty in coping with them (Richmond, Malcomb, & Ringler, 2015). In this definition vulnerability has an external side of risks, shocks and stress factors that cannot be controlled by individuals or households and an internal component that concerns the ability of households to respond to and cope with stressors in order to mitigate negative effects.

For the operationalization of internal vulnerability, our study relies on the Food and Nutrition Security Conceptual Framework (CFSVA, WFP, 2009) that links food security and vulnerability to households' asset endowments, livelihood strategies and political, social, institutional, economic, and, in our study, also the agro-ecological and climatic environment. This leads to a holistic view on the determinants of an observed food security status, and on the capacity of households to deal with adverse external shocks. Section 2.1 operationalizes the internal vulnerability concept within this study.

External vulnerability is modeled as the negative impact of climate change on availability of food, caused by reduced yields of crops in areas where soil moisture availability declines. Section 2.3 motivates the use of a specific measure of climate change – changes in the Length of Growing Period (LGP) in our study.

The link with policy making is established by focusing on the dominant characteristics of vulnerable groups in the area as a whole and specifically in climate change prone areas. As most of our explanatory data are integer-valued, the use of regression techniques to identify the impact of specific characteristics becomes cumbersome. Therefore, we propose a specific maximum likelihood prediction method for our multivariate analysis that is referred to as 'polling' (Keyzer & Pande, 2010). Technically, it involves the joint analysis of a (potentially large) number of integer-valued variables, such as the ones commonly generated by surveys through the coding of answers provided. Common techniques like regression analysis are difficult to use when explanatory factors are categorical and their combination values are large in number relative to the number of observations and the number of real-valued variables. Indeed in this situation, it is no longer possible to follow the common dummy variable approach that allows for one equation per binary factor and let all coefficients on the real-valued determinants differ freely across equations. The practice in such situations is to treat binary factors as dummies in specified structural forms, say, on the intercept or on selected real-valued variables. Yet, the inevitable consequence is that the functional specification becomes arbitrary since the range of possible forms soon gets too wide to evaluate all possible options. Hence, we conclude that there is little scope for identification of the correct functional form in the presence of more than two or three categorical variables, and this justifies the use of an alternative method that aims to identify dominant associative patterns. Section 2.2 provides the technical details of the method.

1.2. Context of the study

Early vulnerability studies analyzed climatic patterns to identify where the most significant variation in weather conditions would occur (e.g. Körner, 1998; Soussana, Casella, & Loiseau, 1998). Later the focus shifted to spatial assessment of available soil moisture and its potential impact on crop and livestock production (e.g. Fischer, van Velthuizen, Shah, & Nachtergaele, 2002; Thornton et al., 2006; Voortman, Sonneveld, Langeveld, Fischer, & van Velthuizen, 1999). Yet, as meaningful and informative as these earlier studies were, they are of limited use for the identification of appropriate policy interventions because they forgo the diversity of socio-economic characteristics (Findlay & Maani, 1999) that, jointly with biophysical conditions, determine people's ability to cope with climate change (Hinkel, 2011). Indeed, climate-related hazards and vulnerability will require the integration of socio-environmental, meteorological, and health data (Houghton, Prudent, Scott, Wade, & Luber, 2012). Therefore, the latest research on identification of intervention areas aims to combine biophysical and agronomic information with availability of adaptation strategies (Davies, Midgley, & Chesterman, 2010; Smit & Wandel, 2006; Smithers & Blay-Palmer, 2001) and perceptions (Tripathi, Sengupta, Patra, Chang, & Jung, 2014). For many countries in Africa, however, data on important drivers at the household and institutional level are only available at the national scale (e.g. UNDP, 2007). Studies that include these nation-wide measures of average food security status or income (e.g. Jankowska, Lopez-Carr, Funk, Husak, & Chafe, 2012; Liu et al., 2008; Wu et al., 2010) essentially focus the analysis on identifying and comparing larger geographical areas under climate change threat rather than singling out the vulnerable segments of the population *within* these areas (e.g. Batisani & Yarnal, 2010). Yet, last decade witnessed an increasing availability of data at sub-national or cluster level which improved spatial accuracy of vulnerability assessments (Bandyopadhyay, Kanji, & Wang, 2012). The final step identifies the specific local anthropogenic and biophysical factors that explain the vulnerability to climate changes impacts (Maantay & Becker, 2012). It is in this spirit (e.g. Frazier, Thompson, & Dezzani, 2014) that our research aims to uncover and explain the geographic associative patterns between vulnerable groups and climate change effects so as to inform decision makers about where, when and how to intervene.

The paper is organized as follows. Section 2 describes the data and methodology used in this study. In addition, it presents and

[1] A socio-economic and biophysical description of both areas is detailed in SOW-VU, 2013.