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Investigating rural poverty and marginality in Burkina Faso using remote sensing-based products

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ABSTRACT

Poverty at the national and sub-national level is commonly mapped on the basis of household surveys. Typical poverty metrics like the head count index are not able to identify its underlaying factors, particularly in rural economies based on subsistence agriculture. This paper relates agro-ecological marginality identified from regional and global datasets including remote sensing products like the normalized difference vegetation index (NDVI) and rainfall to rural agricultural production and food consumption in Burkina Faso. The objective is to analyze poverty patterns and to generate a fine resolution poverty map at the national scale. We compose a new indicator from a range of welfare indicators quantified from Georeferenced household surveys, indicating a spatially varying set of welfare and poverty states of rural communities. Next, a local spatial regression is used to relate each welfare and poverty state to the agro-ecological marginality. Our results show strong spatial dependency of welfare and poverty states over agro-ecological marginality in heterogeneous regions, indicating that environmental factors affect living conditions in rural communities. The agro-ecological stress and related marginality vary locally between rural communities within each region. About 58% variance in the welfare indicator is explained by the factors of rural agricultural production and 42% is explained by the factor of food consumption. We found that the spatially explicit approach based on multi-temporal remote sensing products effectively summarizes information on poverty and facilitates further interpretation of the newly developed welfare indicator. The proposed method was validated with poverty incidence obtained from national surveys.

1. Introduction

Subsistence farming is an important agricultural practice in many African states. For instance, in Burkina Faso approximately 92% of the country workforce is actively associated with the agricultural sector, of which 80% are small holder farmers who live in rural areas and have less than 1 ha of land (USAID, 2009). Agricultural production is largely constrained by a range of biophysical factors related to soil properties, rainfall and water availability (West et al., 2008). The agro-ecological conditions vary spatially and respond to a highly local physical environment. In Burkina Faso, more than 80% of the total population lives in rural areas, of which 94% is considered poor (USAID, 2009). The lack of local infrastructure often restrains rural households to apply sustainable farming practices since it limits the farmer's access to market and services (Alasia et al., 2008; Gatzweiler et al., 2011). This suggests that rural poverty in Burkina Faso can be related to the agricultural productivity and that it can be characterized from the spatial distribution of agro-ecological potential.

Traditionally, poverty as opposite to welfare is mapped by analyzing a range of socioeconomic factors obtained from targeted household surveys. Such surveys assess household capital assets, e.g. income, expenditure, food consumption, and other living conditions. Using these, indices are obtained to estimate the incidence of poverty. For example, the head count index (HCI) is the percent of the population in an area living below an established poverty line, i.e., a normative level of income or expenditure. To extrapolate these surveys towards an entire region, various small area estimation techniques have been developed (Hoddinott and Quisumbing, 2003; Benson et al., 2005). These techniques make predictions by relating the household welfare status from targeted household surveys to the household characteristics from national census, and apply the relation to households with same characteristics. A clear insight into the likely causes of the situation is often missing, because factors of marginality are not included during poverty mapping (Hyman et al., 2005; Robinson et al., 2007). Also, these techniques depend on the availability of national censuses that take place only once in several years due to their high operational costs.

To locate marginal areas, alternative approaches analyze environmental constraints (e.g., soil erosion, droughts) using remote sensing (RS) data and products (Parkins and MacKendrick, 2007; Alasia et al., 2008). Being able to acquire up-to-date data over a large area by utilizing the high spatial and temporal coverage

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provided by RS, these approaches can quantify the increased susceptibility of specific areas to become marginal due to extreme events of environmental constraints. However, the environmental approaches are primarily concerned with marginality and they rarely quantify its impact on livelihood status. Following this, Nelson et al. (2012) related RS products with household level expenditure obtained from survey data to explain the poverty patterns in Uganda. Although this approach advanced traditional poverty mapping, it is insufficient to interpret the observed relations, because a single aspect of poverty (e.g., income, expenditure, and other living conditions) is usually not enough to explain welfare and marginality, particularly in rural economies based on subsistence agriculture (Gatzweiler et al., 2011).

In this paper, a geographically explicit approach is presented for studying poverty and marginality at a fine resolution and over a larger area. We investigate both agro-ecological marginality from RS-based products and welfare and marginality from household conditions. By studying these conditions over a large area, we aim at better understanding the factors that determine household marginality. In this way, this paper advances current environmental procedures of poverty mapping creating a more dynamic method that can be effectively utilized by policy-makers to reduce poverty (Nelson et al., 2012).

In practice, our main objective is to use RS products and other regional data sets for extrapolating poverty quantified from the targeted household surveys. The study is illustrated using data from Burkina Faso where agricultural surveys are collected annually targeting only representative communities countrywide. We developed a composite index from several welfare aspects observed from household surveys. This index and the RS products are used to map poverty at the national scale.

2. Background

2.1. Study area

This study is conducted using data from Burkina Faso, which is ranked among the poorest countries of the world (USAID, 2009). Agriculture contributes to 31% of the GDP and to 60% of the exports that are the main source of growth of the national economy. The livestock sub-sector accounts for 25% of agricultural GDP and 8% of total national GDP (USAID, 2009). Several environmental and socio-economic factors affect agricultural production like the spatial variation in both frequency and intensity of rainfall during the crop growing season (West et al., 2008). Administratively, the country is divided into 13 regions and 351 districts, which are split in about 7000 rural communities. The term terroir refers to a rural community in which small-holder farmers make their livelihood (AGRISTAT, 2010). A terroir is a well-defined land management system which not only constructs a physical area, but also a social construct and the notion of natural resources and biophysical conditions. Thus, it constitutes a communal farming system in which farmers contribute their individual parcels and adopt common policies for agricultural production. In this study, we used terroir community as the level to quantify poverty and marginality in Burkina Faso. AGRISTAT (AGRISTAT, 2010) conducts targeted household surveys for one representative terroir community per district.

The head count index (HCI) is available for 1994, 1998, 2003 and 2009. In 1994, the country's first surveys for household living conditions were conducted on the basis of agro-climatic regions. Later in 1998, they shifted to the administrative regions. The HCI was compiled based on the poverty line of 1 USD (United States Dollar) adult^{-1} day^{-1}. In 2010, HarvestChoice compiled HCI maps (gridded) from surveys carried out between 1998 and 2003 by establishing a poverty line of 1.25 USD adult^{-1} day^{-1} (Wood et al., 2010). These studies consistently show that the North, South Central, Central Plateau, Boucle du Mouhoun, East Central, and Southwest regions are typically affected by poverty, with a rate of incidence well above the national average (Fig. 1). The HCI is close to the national average in the West central, Eastern, and Cascades regions, whereas the other regions are relatively less affected by poverty.

2.2. Mapping communal welfare in Burkina Faso – our approach

This study defines marginality as a function of cause–effect relations between stressor and asset variables. Stressors are often exogenous factors that directly or indirectly affect the agricultural production of rural communities (Alasia et al., 2008). In this study, the agro-ecological stress on rural communities was characterized by analyzing RS products as explained in Section 3.1. To quantify the impact of RS-based stressors on communal welfare status, we focused on household assets related to the agricultural outcomes in a rural community. The asset variables were obtained from Georeferenced household surveys as explained in Section 3.2. A rural community was considered to be marginal if it encountered high stress on agricultural production, eventually resulting into low household assets. Therefore, to quantify communal welfare and marginality at the national scale, the stressor and asset variables were linked by using spatial regression as explained in Section 3.4. To quantify poverty and marginality, we made the following assumptions:

1. A high agricultural production in rural Burkina Faso helps to increase farmers welfare in that they can meet daily food requirement: poor farmers will suffer from food insecurity and food insecure farmers will be poor farmers (de Graaf et al., 2001).
2. Households in a rural community combine individual lands for cultivation and face similar agro-ecological and socioeconomic conditions (Bigman et al., 1999). Farmer's marginality therefore vary considerably between the rural communities and only to a lesser degree result into income differences between individuals within communities.
3. We define four levels of marginality: high marginal, low marginal, low welfare, and high welfare. The agricultural production in rural communities, and consequently, the intensity of poverty and food insecurity decreases from high marginal to high welfare levels.

3. Materials and methods

3.1. Extraction of stressor variables

The following stressor variables were derived from RS data:

The normalized difference vegetation index (NDVI), calculated as $(NIR - R)/(NIR + R)$, where NIR is the spectral reflectance in the near-infrared where canopy reflectance is dominant, and R is the reflectance in the red portion of the electromagnetic spectrum where chlorophyll absorbs strongly (Tucker, 1979). NDVI has been used to estimate leaf area, percentage cover and biomass. Therefore, NDVI variability may be linked to the factors that limit plant growth. The limiting factors of plant growth (i.e. stressors on agricultural production) may be poor soils, limited water availability, etc. Therefore, in this paper, NDVI has been considered as a measurement of amalgamated plant growth that reflects various stresses on agricultural production. For 2009, a time series of SPOT VEGETATION NDVI composite (S10) products were obtained from (Joint Research Centre, 2012). This product is derived from 10-day data and mapped onto a 1 km latitude–longitude grid.