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Assessing the benefits of weather and seasonal forecasts to millet growers in Niger

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ABSTRACT

West African farmers need to take every year crucial decisions based on some characteristics of the rainy season such as the onset, the offset, the cumulated rainfall or the occurrence of dry spells. Knowing these parameters in advance may therefore be of interest for them. This paper aims at assessing the impacts of 10-days and seasonal forecasts on Niger millet growers' cropping practices and their income. To do so, we apply an ex-ante approach based on the crop model SARRA-H coupled with an economic model that simulates the choice of cropping strategies among 24 available. The approach takes explicitly risk aversion into account and focuses on two different kinds of typical farmers with restricted and large adaptation capacities, in reference to the availability of viable decision options sensitive to forecast information. Results show (i) that 10-days forecasts alone or a combination of 10-days and seasonal forecasts could be quite beneficial for all types of farmers (e.g. median income change with 10-days forecast ranges from +1.8% to +13% according to adaptation possibilities), (ii) that in most of the cases farmers with access to fertilizers and larger arable land benefit more from forecasts and (iii) that even if seasonal forecasts are not really beneficial alone, they are when used in combination with 10-days forecasts. Despite these positive results, one has to underline that income losses may occur in about 20% of cases when using these forecasts, which may be a limiting factor to their effective adoption.

1. Introduction

Agriculture in Niger is the most important economic sector (25.7% of total GDP in 2007, BAfD/OCDE (2008)) and is also very vulnerable to many factors such as price volatility (Araujo Bonjean and Simonet, 2011; Gérard, 2011), soil fertility depletion (Abdou et al., 2012) or climate variations as crops are mainly rainfed (Alhassane et al., 2013). As described by Mertz et al. (2010), climate variations are the main factor explaining the past crop yield decrease according to farmers of the sudano-sahelian zone. This decrease due to past changes was also demonstrated by Barrios et al. (2008) across Sub Saharan Africa. Moreover, some years with exceptional dry conditions (e.g. 73/74 and 83/84) are according to World Bank (2013) the most risky factor for agriculture and may lead to dramatic food crisis with huge impacts on livelihoods and economy: for instance, Niger Gross Domestic Product suffered a −18% drop after the 1984 drought, according to Kandji et al. (2006).

As underlined by the Global Framework for Climate Services (GFCS), climate information is a very promising tool to cope with rainfall variability (WMO, 2013). Indeed, West African farmers need to take every year crucial decisions based on some characteristics of the rainy season such as the onset, the offset or the cumulated rainfall. Giving them in advance such information would be very profitable for them (Patt et al., 2005; Roncoli, 2009) in particular if they have the capacity to adapt their strategy in response to the forecast (Roudier et al., 2014). Among all the potential information that would be relevant for farmers and that are predictable, the tercile of the cumulated rainfall over the rainy season (i.e. if it is going to be rather wet, normal or dry) is according to Hansen et al. (2011) one of the most common parameter that is forecast in West Africa (WA). Some studies have already shown the potential positive impact of this seasonal forecast in WA (Roudier, 2012; Sultan et al., 2010) but few of them focused on other types of forecasts, like short term forecasts. However, Hellmuth et al. (2007) demonstrated with in situ trials the power of using such forecasts.

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Moreover, being able to predict the tendency of the coming 10-days period would be crucial information for farmers for sowing, harvesting or weeding and could be of major interest in area with low adaptation capacity to seasonal forecasts (Roudier et al., 2014).

The idea of this paper is thus to compute the respective benefits of 10-days forecast, seasonal forecasts and their combination for millet growers in Niger. We therefore aim at comparing the impact of each kind of forecasts on farmers' income in order to give insights about the climate information that are the most suitable for farmers. Moreover, we distinguish the impact of such forecasts on two types of farmers: with high and low adaptation capacities in reference to the availability of viable decision options sensitive to forecast information. This is fundamental in order to study if those with limited adaptation options – and not only an average farmer – benefit more or less from the forecasts.

Finally we focus in this paper on the uncertainty of the results as (i) a wrong forecast can be harmful in such a region without safety nets and (ii) our calculation use several arbitrary parameters. We thus use four different combinations of models to produce 10-days and seasonal forecasts and define 96 sets of parameters to perform a sensitivity analysis.

In this article, we first describe the datasets used and the model we build to simulate farmers' choices (Section 2), then we analyze the cropping strategies that farmers would use with forecasts, according to the model (Section 3.1) and the corresponding income change (Section 3.2). We finally focus on the sensitivity analysis (Section 3.3) to assess the reliability of our results.

2. Area of study, data and methodology

2.1. Area

We focus here on fifteen villages located in Niger in a rather small area around Niamey (Fig. 1). These villages receive between 400 and 600 mm per year during the rainy season which lasts mainly from June to September, with a high spatial and year-to-year variability (Salack et al., 2011). In this area, smallholder agriculture represents the main source of activity. This activity is rainfed and characterized by low mechanization and low inputs rate such as chemical fertilizers or pesticides. The main crop is by far pearl millet [*Pennisetum glaucum* (L.) R. Br.] which is generally grown on sandy soils with low organic matter (Bationo et al., 2005).

2.2. Data

2.2.1. Observed data

We use daily rainfall observed data collected by the French Institute for Research and Development (IRD) for years 1990/2012, for the fifteen locations previously defined. All rainfall time series have less than 10% of missing data for years 1990/2012; a tolerance threshold generally used to select such stations (Romero et al., 1998). Missing data are filled using the coefficient of correlation weighting method described in Teegavarapu and Chandramouli (2005). Since data availability is restricted to 1990/2010 for meteorological data such as temperature or wind, we use a climatology computed on the available time period that is repeated each year of the 1990–2012 period.

2.2.2. Short term forecast

We use in this paper ensembles forecasts coming from the recent THORPEX Interactive Grand Global Ensemble (TIGGE) database (Bougeault, 2010) that provides ensemble forecast results of seven operational Numerical Weather Prediction (NWP) centres. Because of time computation issues, we decide to select only two ensembles out of these ten, based (i) on years available (2008/2012 needed) and lead-time (10 days needed), and (ii) on their skill score (Appendix A2). We therefore chose namely (i) the European Centre for Medium-Range Weather Forecasts (ECMWF), constituted by 50 members which cover years 2008–2012 at a spatial resolution of approximately 0.5*0.5° and (ii) the UK Meteorological Office (UKMO), constituted by 23 members (1.25° × 0.83°). In both cases, hindcasts are daily and we take into account here the 10-days cumulated rainfall hindcast. Following Roudier et al. (2014), we assume that farmers receive a deterministic forecast of the coming 10 days based on two categories: <10 mm (not enough rain to be beneficial for crops, see Sivakumar (1992)) or >10 mm (potentially beneficial). Note that to take into account a potential bias in the model forecasts, we do not use directly the raw model outputs. Indeed, we first compute for each station the observed rainfall quantile corresponding to 10 mm and then we calculate the rainfall forecast related to this quantile.

In order to produce this deterministic forecast based on the ensemble members, we first select two different methodologies: the first one is, for one particular day, the mode, i.e. the rainfall category which is the most predicted by the ensemble members of each model (ECMWF or UKMO, see Table 1). The second one is the median of the predictions (we avoid using the average to give less power to potential outliers). However, these two methodologies result on average, for years 2008/2012 and from May to July, in the same forecast in 98% of cases. We therefore keep in the rest of the study only the forecast based on the median for UKMO and ECMWF.

2.2.3. Seasonal forecast

We use here two kinds of probabilistic seasonal forecasts coming (i) from the regional climate outlook PRESAO (French acronym for Seasonal forecast in West Africa) and (ii) from the CNRM (National Center for meteorological research). PRESAO produces every year since 1998 a forecast based on information coming from several institutions (WMO and ACMAD, 1998). We use here these historical forecasts that are available on ACMAD website for years 2008/2012. CNRM forecasts are hindcasts produced using the CNRM-CM model (v. pre-6) with ARPEGE-Climat V6 for the atmosphere and SURFEX V7 for the surface (see Voldoire et al. (2013) for the CNRM-CM5 version). Both of them finally provide the probability of occurrence of each cumulated rainfall tercile (namely below normal, normal and above normal).

2.3. SARRA-H

We use here the process-based crop model SARRAH[1] (V33) that is designed to simulate agricultural yields under tropical conditions, especially in WA, where it has already been used in several studies simulating potential dry cereals yields (Dingkuhn, 2003; Baron, 2005; Mishra, 2008) under current framers cropping practices. This model was calibrated and validated for different millet cultivars based on multi-years on-field trials in several West African regions including the area of Niger studied here (Traoré et al., 2011). More details about SARRAH are given in Appendix A4.

2.4. Methodology

We focus here on four different types of scenarios defined by the forecasts available: (i) no forecast available for farmers (control situation, "Ctrl"), (ii) only a probabilistic forecast of the forthcoming season cumulated rainfall ("SF"), (iii) only a deterministic 10-days forecast of the rainfall category available every day ("10d") and (iv) a combination of these two forecasts ("SF + 10d"). Details for each

[1] Freely available at: http://sarra-h.teledetection.fr/.