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Assessing floods and droughts in the Mékrou River Basin (West Africa): A combined household survey and climatic trends analysis approach

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Abstract. The assessment of natural hazards such as floods and droughts is a complex issue demanding integrated approaches and high quality data. Especially in African developing countries, where information is limited, the assessment of floods and droughts, though an overarching issue influencing economic and social development, is even more challenging. This paper presents an integrated approach to assess crucial aspects of floods and droughts in the transboundary Mekrou River basin (a portion of the Niger basin in West Africa) combining climatic trends analysis and the findings of a household survey. The multi-variables trend analysis estimates at the biophysical level the climate variability and the occurrence of floods and droughts. These results are coupled with the analysis of household survey data that reveal behaviors and opinions of the local residents regarding the observed climate variability and occurrence of flood and drought events, household mitigation measures and impacts of floods and droughts. Furthermore, two econometric models are set up to estimate the costs of floods and droughts of impacted households during a two years period (2014-2015) resulting into an average cost of approximately 495 euro per household for floods and 391 euro per household for droughts.

1. Introduction

Extreme meteorological events like droughts and floods represent an important limitation for the development of the poorest countries, impacting in particular the most vulnerable portion of the population. In these countries, agriculture remains the main economic activity and farming practices are mainly represented by rainfed agriculture (Rosegrant et al., 2002). Agriculture, a sector extremely vulnerable to extreme events, is the main source of income, or more often represents the self-sufficiency, of the poorest portions of the rural population in the least developed countries, as in the case of Sub-Saharan Africa (Gautam, 2006; Hellmuth et al., 2007). Extreme events cause loss of lives, damage to dwellings and vulnerable rural infrastructures, agricultural production losses, and threaten, more in general, food security and development. A recent study (Shiferaw et al 2014), for instance, found that frequent drought conditions have limited the economic growth of many African countries and frustrated the benefits derived from development strategies implemented in other economic sectors. For these reasons, in the recent past, the disaster risk management community has extensively worked on the development of

methodologies aimed at monitoring the risk prone areas and the overall vulnerability of the population threatened by the hydro-meteorological hazards. Progresses have been made in the assessment of the occurrence of extremes events, their magnitude, and the expected climate change impacts. Additional efforts were directed towards the improvement of both the assessment of risk and the estimation of the direct and indirect impacts, in particular related to loss of human lives, economic activities, infrastructures, natural and man-made capital. Technical advancement efforts allowed also an improved assessment of current mitigation measures and policies. The benefits derived from the progresses made in this discipline, however, were mainly concentrated in the most developed and technically advanced countries, where information is more easily available and mitigation strategies are more likely to be effectively implemented. In the case of the African countries,the assessment physical components of the hazard side followed the general technical development: as in the most advanced countries, in fact, the assessment of the occurrence of floods and drought has been conducted through the application of remote sensing based techniques analysing precipitation and temperature records and their spatio-temporal distribution, as for instance in the case of Ngigi et al. (2005) for a case study in Kenya.

Regarding cost estimation and impact assessment, instead, the knowledge about losses caused by past extreme events is still limited for a detailed quantitative analysis in many of the African countries. Several studies made use of household surveys to acquire qualitative and quantitative information from the local population and use the knowledge collected to estimate the damages of past hydro-meteorological events (as for instance in: Fitchett et al., 2016; Ologunorisa and Adeyemo, 2005). Depending on the key economic sectors of the case study area, various examples of cost and impact assessment could be listed. Among the most representative, could be mentioned studies analysing the following sectors: health (Schmitt et al, 2016), agriculture and food security (Ngigi et al., 2005; Shiferaw et al., 2014; Shisanya and Mafongoya, 2016) , and tourism (Fitchett et al., 2016). The analysis of the hazard components and the various impact assessments conducted in the recent past, allowed the evaluation of risk mitigation measures and adaptation strategies. Shisanya & Mafongoya (2016), for instance, analysed the effectiveness of shifts in agricultural practices; Brower et al (2009) focused on the evaluation of the installation of risk mitigation infrastructures; Oyekale (2015) analysed the implementation of more advanced forecasting and early warning systems; Halsnæs &Trærup (2009) focused on the implementation of specific integrated policies and practices for flood and drought. In some of the mentioned studies, cost-benefit and willingness-to-pay analyses were used to add quantitative evidence to the qualitative description of the case studies in object.

The objective of this paper is to assess the occurrence of floods and droughts events as well as to estimate of damage costs at the household level and finally, the current mitigation behaviours adopted by the population in the Mékrou river basin, a small catchment in Western Africa. It combines a quantitative approach for detecting hydro-meteorological hazard prone areas (through the analysis of gridded climate datasets) with a quali-quantitative analysis of a household survey. This approach allows comparing physical analysis of extreme events with human perception of the flood and drought phenomena in the

Mékrou river basin. The household survey collects sufficient information to conduct an estimation of the natural hazards impacts in terms of economic cost, and to present the most widely adopted mitigation behaviours.

Mékrou is a sub-basin of the Niger River, covering an area of 10,635 km², about 3% of the total Niger Basin surface, crossing the borders of three countries: Benin (80% of the basin territory), Burkina Faso (10%) and Niger (10%). Mean annual precipitation ranges from a maximum of about 1300 mm in the southern region and 500 mm in the north, being the wet season between June and September with an average cumulated rainfall of 700 mm. Temperature is also highly variable in space and time. Warmest and coldest months are April and September, respectively. Mean annual temperatures spatially vary between 26-30˚C, being the maximum 35-40 ˚C and the minimum 15-19 ˚C. The Mékrou catchment is located in a temperate transitional area characterized by a wet season peaking in august and a long dry season spanning the period December-April (Masih et al., 2014). During the wet season, the whole Niger River basin is subject to regular floods and extensive research has been conducted on its complex hydrology made unique by the large system of lakes and wetland known as the Inland Delta (Bader et al., 2016; Tarpanelli et al., 2017), while lower attention was given to the Mékrou sub-basin. Flood and drought events are extremely frequent (Froidurot & Diedhou, 2017), while the impacts of climate change on their frequency and magnitude is unclear (Gautam, 2006). The Mékrou basin is characterized by lack or poor infrastructural development and very low socioeconomic conditions. Agriculture is the key economic sector with the arable land used for food production, cattle farming, and production of cotton. That for, climate variability constitutes the main threat for food and economic security of the area.

The paper structure is the following: Section 2 presents the methodological framework both regarding the development and application of the household survey (section 2.1) as well as the analysis of the biophysical variables (section 2.2). The findings of this integrated approach are shown in Section 3. This section analytically presents the findings regarding precipitation patterns, temperature and river discharge in the Mékrou river basin. Moreover, it includes the main findings of the household survey concerning observed occurrence of floods, droughts and climate variability, household mitigation measures, impacts of floods and droughts and finally an econometric estimation of the costs of floods and droughts. Section 4 summarises the main findings of this approach, discusses its potential and limitations and presents the main conclusions.

2. Methodology

2.1 Households survey implementation and analysis techniques

A household survey aimed at evaluating several water related dynamics, including extreme natural hazards, was designed in 2015 and conducted in early 2016 (February to April). The survey was implemented by experts of the Joint Research Centre of the European Commission in cooperation with local universities from Benin, Niger and Burkina Faso. The information included in the household survey aims to retrieve opinions and observations based on personal judgement. A main section of this survey was to identify and assess the impacts and costs of flood and drought events, climate variability as well as household

mitigation measures. Regarding the occurrence of floods and droughts in the study area, two time periods were selected: 10 years (2006-2015) and 2 years (2014-2015). The logic behind this selection was to identify the most recent events (2 years), for which the local households could still have a fresh memory on the impacts suffered while affected. The second time period (10 years) offers a longer assessment of climate variability and occurrence of floods and droughts, which could potentially still be evaluated according to personal judgement. The whole questionnaire is included in Appendix A.

The survey process resulted to the collection of 660 randomly surveyed questionnaires retrieved from the areas of the three countries (Benin, Burkina Faso, and Niger) that are located in the Mékrou catchment (Figure 1). Specifically, 332 questionnaires were collected in 16 villages from the municipalities (called "Communes" in French) of Banikoara, Kouande, Kerou, in Benin. 148 questionnaires were collected in 6 villages from the Communes of Diagaga and Tansarga in Burkina Faso, and 180 questionnaires were collected in 8 villages from the Communes of Falmey and Tamou in Niger. The total number of surveyed households offers a more than 95% significance in the statistical findings (400 questionnaires minimum required for 95% significance rate).

Figure 1. The Mékrou river basin and the household survey area

Following the data cleaning and validation of the survey, the information collected was processed through statistical analysis including all the parameters investigated. The survey responses were evaluated using descriptive statistics aggregating data both at river basin and at country level. In this way, the findings were analysed at the river basin scale illustrating, at the same time, the differences among the three countries.

Apart from the statistical analysis, an econometric estimation was applied to estimate the costs of droughts and floods that occurred in the last two years (2014-2015). Hence, besides the cost estimation based on the sample mean, two econometric models were set up investigating the determinants of flood and drought costs following a cause-effect logic. Performing a thorough multi-variate regression among costs of floods and droughts as stated in the survey and other covariates, such as socioeconomic characteristics of the population, impacts, and mitigation measures, led to the construction of models that could be eventually used to predict the costs of future extreme hydro-meteorological events. Several types of regression models were tested, both linear and logarithmic. Eventually, linear multivariate regression models were selected since they fitted the selected variables with a higher statistical performance. Moreover, in order to ensure coherence and readability of the models, only independent variables whose P-value was less than 0.05 were selected. Additionally, correlation was tested among the independent variables in order to avoid bias in the model due to collinearity among the selected variables.

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2.2 Analysis of biophysical variables: precipitation, temperature, and river discharge

Precipitation and temperature patterns and changes are the main drivers affecting local population perception about water availability, especially in an area where the main economic activity is based on rainfed agricultural production. In the frame of household survey interpretation, quantitative estimates of these events are needed to understand the underlying direct (rainfall and discharge) and indirect (heat-waves) factors that have an impact on the respondents answers. Analysis of rainfall events above and below the long-term average distribution in conjunction with inter and intra-annual analysis are useful to depict anomaly patterns and trends, thus, they contribute to better understand, for example, main drivers of meteorological droughts. This is particularly relevant in order to compare local population perception on climate variables with quantitative estimates. Characterization of events above and below the long-term rainfall average distribution in conjunction with intra-annual precipitation analysis were studied. To complement this, we analysed river discharge regimes, as precipitation anomalies could be translated into hydrological droughts, thus, generating water resource imbalance, groundwater level decrease, reservoir depletion, etc. (Liu et al., 2016). Secondly, considering the increasing number of heat-wave events occurred during the last decade in Africa (Ceccherini et. al 2017), we have studied its magnitude and spatio-temporal evolution in the Mékrou Area of Influence to explain possible misperceptions that could arise in the surveys. The objective was to compare both precipitation and temperature stress with survey's results, offering empirical evidence of their concurrence, or eventually explaining the underlying causes of possible contrasting results.

2.2.1 Precipitation pattern analysis

Annual and seasonal rainfall descriptive statistics were analysed jointly with the results of a Seasonal Kendall test for monotonic trend (SK) applied over precipitation data derived from the Climate Hazards Group Infrared Precipitation with Station data v. 2.0 (hereafter CHIRPS). This database has a spatial resolution of 0.05º, corresponding to approximately 5 km (at the equator) and covers all longitudes in the latitude range 50°S-50°N spanning a time horizon included in the period 1981-present days (Funk et. al 2014). The SK test used is based on Hirsch and Slack (1984) and it was applied over two different time ranges: the entire time series (about 35 years), and over the last ten years, the period considered in the household survey. The test is a modified version of the previously SK test proposed by Hirsch et al. (1982), and attempts to reduce variables serial dependence, being seasonal precipitation data serially correlated. Both are based on the non-parametric Mann-Kendall test (Mann 1945, Kendall 1975, Warren and Gilbert 1987). Magnitude of trends are calculated by means of Sen´s Slope Estimator and Kendall tau as the rank correlation coefficient.

Additionally, in order to identify precipitation anomalies, we calculated the Standardized Precipitation Index (hereafter SPI) proposed by McKee et.al (1993; 1995). This index could be applied over different time scales, each providing information about the impact of a given anomaly on the availability of water resources (WMO 2012). In this study, the 3 months and 6

months SPI (hereafter SPI-3 and SPI-6) were calculated, associated respectively to meteorological and agricultural droughts. For the purpose of this paper, being the Mékrou communities' economy mainly based on rainfed agriculture, we focused on the precipitation anomalies over the wet season, presenting the SPI-3 for the period June-August (JJA), and the SPI-6 for the period included between April and September (AMJJAS). The results are given in units of standard deviation, indicating how far a given precipitation event is below (drier events are associated with a negative SD) or above (wetter event, positive SD) the long term normal distribution. SPI values could then be interpreted following a classification scheme where standard deviations are categorized into different classes, each associated to different levels of wet or dry anomaly. In this case we have divided the values following the seven categories proposed by Agnew (2000), where previous thresholds defined by McKee et al. (1993) were replaced by alternative classes (Figure S1). Finally, in order to get a general overview of the anomalies in the different administrative units, we calculated the area percentage affected by each class over the entire time series.

2.2.2 Heat-wave analysis

Russo et al. (2015) defined the Heat-wave Magnitude Index daily (hereafter HWMId), as the maximum magnitude of the heat-waves in a year, where a heat-wave is defined as a period equal or higher than three consecutive days with maximum temperature above a daily threshold calculated for a 30-year long reference period. The index is based on daily maximum temperatures taking the intensity and duration of the event into account. In our case, the source used to retrieve the maximum daily temperatures is the ERA-Interim reanalysis dataset (Berrisford et al., 2011; Dee et al., 2011) available from 1979 onwards, with an approximate spatial resolution of 80 km at the equator. The index was applied to study these events for the last 35 years across the study area.

2.2.3 Discharge in the Mékrou river

In order to have a quantitative estimation of water availability within the Mékrou river basin, the hydrological model SWAT (Neitsch et al., 2011) was setup and calibrated to assess annual and monthly river discharge. The SWAT model integrates all relevant eco-hydrological processes including water flow, surface runoff, percolation, lateral flow, groundwater flow, evapotranspiration, transmission losses, nutrient transport and turn-over, vegetation growth, land use, and water management. SWAT subbasins were delineated using the ArcSWAT interface with a Digital Elevation Model with a 90 m spatial resolution, resulting in 32 subbasin for the whole area.

The historical discharge data recorded at the Barou gauge station (outlet of the river basin) and at the Kompoungou (draining area is about 56% of the river basin) gauge stations were used for model calibration. Lack of data availability represents a huge limitation for the hydrological analysis of the basin. The mentioned discharge observations, in fact, cover a limited and not overlying period (1990-2000 for Barou and 2004-2013 for Kompoungou) and are not complete. We used SWAT-CUP program

and manual setup to calibrate outflow in the two monitoring stations reaching satisfactory efficiency statistics (Moriasi et al., 2007) at monthly scale. In Barou NSE (Nash–Sutcliffe model efficiency coefficient, (Nash and Sutcliffe, 1970) is 0.87 and linear regression R2 is 0.88 and in Kompoungou NSE is 0.77 and R2 is 0.71. We used the SWAT modeled discharges to consider an extended time period, required in particular to take into account climate variability, and to cover areas of the basin where observations are not available.

3. Results

3.1 Biophysical variables: precipitation, temperature, and river discharge

3.1.1. Precipitation and heat-wave patterns

Mean Annual Precipitation in the study area varies from 500 mm in the northern administrative units (Bottou, Tamou, Kirtachi and Falmey), to about a maximum of 1000-1300 mm upstream in the southern portion of the basin (Kouandé, Kérou and Banikoara (Figure S2). Generally, rainfall is highly variable in time and space, and follows a cyclical trend of wet and dry periods. The mean monthly precipitation for the wettest month (August) in the southern and northern regions varies between 200 mm and 300 mm, respectively, with the driest months (November-February) being close to zero.

In the period under consideration, mean annual temperature ranged between about 30º C in the North to 26.5º C in the South. April was the warmest month, with a maximum temperature of 40º C in the North and 35º C in the South. Minimum temperature in the coldest month (September) ranged between 19º C in the North and 15º C in the South, presenting the semi-arid region the highest range of variation of about 25ºC. Comparing the precipitation patterns over a short- (2007-2016) versus a long-term (1981-2006), it was possible to identify a slight decrease of rainfall during August and September, while a moderate increase was detected during June and July (Figure 2). Long and short term Seasonal Kendall analysis, performed at a significance level $\alpha = 5\%$, however, was not able to identify any significant trend (Figure 2). Some spatial differences were identified analysing the last 10 years: in that regards, negative slopes were detected in the southern regions of Benin.

Figure 2. Comparison of seasonal distribution of precipitation for the first 25 years of the time series versus the last 10 years (left) and Seasonal Mann-Kendall results (right).

3.1.2 Precipitation stress analysis

The results of the SPI-3 and SPI-6 analysis highlighted a period of moderate to extreme droughts during the earlier part of the 1980s; this could be also noticed in mean monthly precipitation values, where the overall rainfall amount from 1981 to 1985 is noticeably below the long-term average (Figure 3). After this period the positive or negative anomalies were found to be

more erratic, presenting an alternated series of positive and negative events, such as some severe wet anomalies in the southern regions in 2003 or drought events in the north regions in 1997. Regarding last ten years, there are few drought anomalies affecting at least 40% of the administrative areas. In particular, the northern portion of the basin in Niger (communes of Tamou and Kirtachi) was affected by a moderate to severe drought event during 2011, while in 2014 a similar event hit the southern portion of the basin in Benin (Banikoara, Kérou, Pehúnco and Kouandé). On the other hand, severe to extremely wet anomalies, were recorded predominantly during the years 2003, 2005, and 2007 in the entire Mékrou Area of Influence. Summarizing the results derived from the analysis of the SPI, we found that the decade considered in the household survey was mainly characterized by precipitation in line with the long-term average. The anomalies were not particularly intense and most frequently related to wet conditions if considering the meteorological precipitation stress indicator (SPI-3 - 18 wet versus 15 dry anomalies), while a predominance of dry conditions was recorded when considering the agricultural precipitation stress (SPI-6 17 dry versus 14 wet anomalies) (Figures S3 and S4).

Figure 3. Temporal monthly precipitation profile for the Mékrou Area of Interest

3.1.3 Heat-waves

The spatio-temporal evolution of the heat-wave magnitude index HWMI between 1981 and 2015 is presented in Figure 4. Despite some isolated events during 1987-1988 and some other extreme in 1998, the analysis highlighted a constant increasing trend of the heat-waves' magnitude starting in 2004. The spatial pattern, instead, is not clear, being the whole Mékrou Area of Influence affected. In 2005 the HWMI was found to be higher in the central and northern part of the basin, while in 2006 the highest values were recorded in the southern part, and in the northern in 2010 (Figures S5 and S6).

Figure 4. HWMI index computed for 1981 to 2015 on the Mékrou

3.1.3 River water flow trends

The annual river discharge resulting from model simulation for the period 1995-2012 is presented in Figure 5. The first 5 years of the simulation period (1990-1994) were discarded to consider an adequate model spin-up period.

Figure 5. Mékrou river daily average discharge at Barou station as modelled in SWAT in the period 1995-2012. Dashed line indicates the average of the total period under consideration.

Modelled discharge in the period under consideration averaged around 24 m^3/sec, corresponding to an average annual water flow of about 760 Mm^3 (ranging from 190 to 1400 Mm^3 respectively in 1997 and 2008). Spatial distribution of the water resources follow the topography of the basin, making the headwaters, where annual discharge remains below 100 Mm^3,

particularly subject to inter- and intra-annual variability (Figure S8). High annual variability of the river discharge is an important issue for the sustainable water use in the basin, especially considering that agriculture is the main economic activity and the lack of water storage infrastructures in the basin. Intra-annual discharge variability in the Mékrou river basin follows the precipitation seasonal patterns: most abundant flows are reached after the rainy season period (July-November), being the peak flow reached in the period Aug-Sep-Oct (Figure S7).

3.1.4. Analysis of the population perception on the occurrence of extremes events and climate variability

The household representatives stated their personal opinion on the occurrence of specific extremes events in the Mékrou basin during the last ten years (2006-2015) (Table 1). The selection of this 10 years framework allows and relatively mid-term assessment of the past climatic events. Regarding the occurrence of droughts, 86.8% of the households declared an increasing trend in the period under consideration. This percentage is lower in Niger but still considerably high (71.5%). In addition, the vast majority of the local population (88.5%) estimates that the levels of rainfall decreased during the last ten years. This result is particularly evident in Benin and Burkina Faso (93.7% and 95.3% respectively). Not only the rainfall decreased but also, according to the local population, (92.7%) the seasonal distribution changed. In fact, the majority of the respondents (83%) states that the rainy season started with a delayed onset during the last 10 years, whereas almost the totality (91.8%) declared an earlier end of the season. Regarding heat-waves, 76% of Mékrou's interviewed population (62% in Benin) stated that periods of intense heat-wave became longer during the last 10 years. Regarding the number of events experienced, an increasing number of drought events were recorded and appeared in frequency mainly from none to 6 events. On average, local population experienced approximately 4 drought events if considered the whole Mékrou basin (Table 2). The number is higher in Burkina Faso (4.8 events) and slightly lower in Niger (3.4 events).

Concerning flood events, the opinions are less homogeneous over the whole Mékrou area. The majority (62%) of the respondents stated that floods frequency did not increase over the past 10 years. This trend is quite heterogeneous among the three countries: 84.9% of the households in Benin agreed with the majority, the responses are discordant in Burkina Faso, whereas in Niger 72.2% of the respondents found an increasing flood frequency in the period under consideration. When asked about the numbers of flood events experienced, almost one third of the families stated that no flood events occurred. The remaining replies are mostly distributed among 1 (23.3%), 2 (17.4%) and 3 (13.1%) events. As for the change of the events frequency, this occurrence is different when looking across the three countries. In Beninese part, 60.7% of the population did not experience any flood during the last 10 years. On the other hand, the larger flood event numbers are recorded primarily in Niger, followed by Burkina Faso (Table 2) . In Benin, only an average of 0.7 flood events was declared during the last 10 years, 1.8 in Burkina Faso and 3.5 in Niger. The combination of these results suggests that the Nigerien portion of the Mékrou basin was the most prone to flood events in the period under consideration.

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Table 1. Observed climatic changes during the last 10 years: 2006-2015

Table 2. Statistical Analysis of reported number of floods and droughts during the last 10 years

3.2 Floods and Droughts Household Mitigation Measures

This section provides an empirical analysis of the household mitigation measures. The respondent had the choice among 13 mitigations strategies aimed at coping with changes in temperature and rainfall patterns. 8 out of the original 13 strategies were considered negligible due to a positive response rate lower than 10%, including: practicing off-season agriculture; application of more intensive irrigation; raising less livestock in order to increase crops; raising less small ruminants for switching to more cattle; raising less cattle and switching to camels; raising less sheep for switching to goats; adoption of specific techniques to regenerate the necessary grass cover for the livestock; and rent or mortgage land.

The mitigation measures that recorded a positive a response rate above 10% are: change of crop seeds; terracing the soil or using other methods to protect against erosion; plantation of more trees; emigration of at least one household member; practicing more often non-agricultural activities as sources of revenue (Table 3). Changing crop seeds is a quite common strategy mainly to adapt to rainfall changes and is widely applied in Burkinabe and Nigerien areas (for around 60-65% of respondents), but also in Benin in a smaller extent (34%). The practice of terracing the soil for preventing erosion is mostly applied in the Beninese part of the Mékrou river basin. The plantation of more trees is a common adaptation practice across the basin, due to both changes in precipitation (31%) and changes in temperature (20%). Emigration appears as an adaptation strategy to mitigate the economic losses resulting from the impacts of changes in rainfall patterns. Around 25% of households saw one of its member migrating due to temperature and rainfall changes. Secondary, 16.4% of Beninese respondents state that at least one member migrated in the last 10 years due to rainfall changes. Finally, an important number of households, primary in Benin (around 35%) and secondary in Niger (around 15%), are practicing more often non-agricultural activities as source of revenue to cope with the loss of income due to both rainfall and temperature changes.

Table 3. Household mitigation measures

3.3 Floods and Droughts impacts and their cost-assessment

The local population of Mékrou has additionally indicated the occurrence of extreme events during a two years period 2014-2015. The relative recent occurrence of these events, some of them still ongoing, allows a more thoughtful estimation of the impacts and associated costs. The vast majority of the respondents stated that they had not experienced any flood occurrence during the last two years (Table 4). However, it can be identified specific areas in Burkina Faso where almost one out of three households signalled having faced a flood event. Aligning with the frequency of reported events, the impacts of the floods are

proportionally more common in Burkina Faso. The most commonly reported impacts regard the losses of agricultural production, damages to the houses and loss of livestock (Table 5).

Similarly, the same analysis was applied for the recent drought events. The vast majority (76.7%) stated that they have not experienced any drought event during the last two years. However, more droughts are reported compared to floods. This is more prominent in Niger (Table 4), where only a few droughts are reported, while in Benin one fourth of the population has experienced droughts during the last two years. In Burkina Faso almost half of the households have experienced droughts during the last two years. The impacts of the recent drought are mostly recorded in Burkina Faso and Benin (Table 5) presenting a different profile. In Burkina Faso the impacts refer exclusively to losses of agricultural production, while in Benin still the majority indicates the loss of agricultural production but states also malnutrition and loss of livestock as result of the recent droughts.

Table 4. Experienced extreme flood events during the last two years (2014-2015)

Table 5. Impacts of extreme floods and droughts to the households

The cost of the recent floods is higher in Burkina Faso (Table 6), where the average cost for an affected household in 334326 FCFA (West Africa Francs) (approximately 495 Euro in 2017). However, we observe a difficulty from the households to estimate the costs of the recent floods, especially in Benin and Niger where the majority of the affected households were not able to provide a cost estimation. The average cost of the recent droughts, 256440 FCFA (~391 Euro), is almost the same in Burkina Faso and in Benin (Table 6) lower than the average cost of the recent floods. Again, in this case a difficulty is evident from the households to estimate the costs of the recent droughts, especially in Benin where the majority of the affected households were not able to provide a cost estimation.

Table 6. Estimated costs of the recent flood and droughts (in FCFA)

3.4 Cost assessment of floods and droughts: an econometric estimation

Additionally to the simple statistical analysis of the floods and droughts, associated costs were used to fit two econometric models. A wide series of independent variables of the household, such as socioeconomic conditions and mitigation measures e.g. have been used to find the determinants of the extreme events costs and estimate the costs of floods and droughts. Using several regression models and combination of independent variables two models were set up including exclusively highly significant independent variables (P-value less than 0.05). Table 7 presents the total of the independent variables including their scaling and their correlation. The latter is important for the coherence of the multivariate models, since low correlation among the independent variables excludes the existence of multicollinearity.

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Table 7. Selected independent variables for modelling costs of floods and droughts

Regarding floods, the multivariate regression model Table 8 includes as independent variable the self-stated economic status (ECONSTAT) of the households as a qualitative alternative to the household income. The model reveals a strong economic status effect meaning that the richer the households are, the higher are the economic impacts of flood. The negative sign is due to the structure of the variable scaling (1 meaning rich and 5 much worse economic condition than the other households). Additionally, two of the main flood impacts, loss of crop productivity (CropProdLoss) and loss of livestock (LivestockLoss) were included in the model as independent variables and were found significant. According to the multivariate regression model, the average cost of floods per household during the flood events of the last two years (2014-2015) was equal to 390.92 euro.

Table 8. Costs of floods – Multivariate linear regression model

Similarly, a multivariate regression model was applied to estimate the costs of droughts (Table 9). The independent variable related to loss of livestock was found to have a strong effect in this model too. However, drought costs are found to significantly depend on the total crop production of the households (PRODCROP). According to this regression model, the estimated cost of droughts per household that experienced drought events during the last two years (2014-2015) was 494.76 euro.

Table 9. Costs of droughts - Multivariate linear regression model

4 Discussion and Conclusions

This paper combines the results of a household survey and climate data analysis to assess floods and droughts as well as climate variability in the Mékrou river basin in West Africa. The opinions and perceptions of household representatives revealed a strong climate variability at a ten years period (2006-2015). It is worth mentioning that 83% of the population, during this period, noticed a delayed onset of the rainy season. In addition, 91% of the population observed also an anticipated end of the wet season. Moreover, 88.5% of the respondents reported a general reduction of the precipitation during the ten years period under consideration, and 75.9% reported an increase in magnitude and frequency of the extreme heat events. This tendency is partially confirmed by the analysis of the climatic variables, mainly based on precipitation and temperature data. The findings of the analysis confirmed the increase of both frequency and magnitude of the heat-waves in the area of study. The climatic variability was also found noticeably high, but the Mann Kendall analysis failed in finding statistically significant trends in the precipitation patterns. It was not possible to identify clearly a shift of the intra-annual temporal distribution of the precipitation, neither indicating a slightly delayed onset nor an anticipated end of the rainy season.

Regarding the occurrence of floods and droughts, the survey-based findings revealed a substantial differentiation among these two events. Especially concerning droughts, 86.8% of the population reported that dry periods were more frequent during the ten years ranging between 2006 and 2015, while 23.3% experienced an extreme drought event during the last two years (2014-2015) resulting in 3.93 extreme drought events in average. Flood events were reported to be less than drought events by the local population. More than 60% of the respondents stated that flood frequency did not change during the period 2006-2015, and only 10.3% of the population experienced an extreme flood event during 2014-2015 (in average 1.69 extreme flood events per household). The judgement of the local population was confirmed by the findings of the analysis of the climatic factors regarding flood events. The analysis of the extreme precipitation in past 30 years, in fact, did not report a significant increasing trend in flood events. Similar conclusions, but this time in disagreement with the impressions of the local population, were derived from the analysis of the dry periods. This difference among perceived occurrence and observed droughts could be explained by the misperception of the local population confounding the observed increasingly frequent heat-wave events as more frequent droughts. However, the analysis of the meteorological (SPI-3) and agricultural (SPI-6) drought indicators, confirmed the occurrence of a number of dry periods that could be in line with the ones reported by the local population in the portion of the basin laying within the borders of Benin and Niger. On the other hand, the analysis of the SPI failed to find significant dry periods in the Beninese portion of the Mékrou.

The household survey analysis reported additional important findings regarding the measures adopted by the household of the Mekrou river basin to mitigate floods and droughts. Among a list of options the most significant household mitigation measures were identified among change of crop seeds, plantation of more trees, practicing more often non-agricultural economic activities, while, especially in Niger, a considerable part of the population migrates due to the losses in agriculture caused by

the decreased rainfall. Indicative are also the findings regarding the impacts of floods and droughts and their costs. For those households that experienced an extreme flood during 2014-2015 the most frequent impacts were reported to be crop production losses, damages to houses, and loss of livestock. At the same time, the loss of crop production, malnutrition, and loss of livestock were the most important impacts of extreme droughts. Additionally, to specifying the impacts of extreme floods and droughts, their total costs per household was estimated. The cost assessment is two-folded based on the sample estimations as well as on the results of the application of two linear multivariate regression econometric models. The average costs caused by flood events in the period 2014-2015 was estimated in 522 Euro per affected household basing on the average declared losses, while it was quantified in 494.76 Euro by the regression model. Regarding the cost assessment of extreme droughts the average value of the sample as well as of the regression model was 390 Euro per household. This study confirmed the difficulty in the natural hazard cost estimation at the household level, even in case of recent events. A considerable percentage of the household representatives (27% for floods and 38% for droughts) were not able to provide an estimation of the costs of the extreme events that they recently experienced.

Regarding the methodological approach of this work, the combination of the household survey data analysis with the study of the climatic variables could provide an integrated assessment of floods and droughts, especially in cases like the Mékrou river, where the accessibility to reliable information is very limited. The survey approach, in particular, could provide data at household level that could be used for a detailed qualitative and quantitative assessment of natural hazards like floods and droughts. Potential limitations of this approach mainly refer to the information biases and misperceptions of the local population that could influence the objectiveness of their responses. Furthermore, such survey approach depicts the opinions at a specific time framework and, therefore, should be periodically repeated to better validate the findings. This implies the need of increased financial and human resources dedicated to this purpose. The benefits of this approach are mainly represented by the information support to decision makers and local governments: this could potentially lead to a more effective and efficient design of floods and droughts mitigation policies and measures.

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Author Contributions

Vasileios Markantonis, Celine Dondeynaz and Cesar Carmona Moreno designed the household survey and analysed the data. Fabio Farinosi, Iban Ameztoy, Marco Pastori, Luca Marletta and Abdou Ali performed the analysis of the climate data. Vasileios Markantonis, Celine Dondeynaz, Fabio Farinosi and Iban Ameztoy prepared the first draft of the manuscript. All authors discussed the results and commented on the manuscript at all stages.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

Alcamo, J., Florke, M. and Marker, M.: Future long-term changes in global water resources driven by socio-economic and climatic changes, Hydrol. Sci. J., 52(2), 247–275, doi:10.1623/hysj.52.2.247, 2007.

Bader, J.-C., Belaud, G., Lamagat, J.-P., Ferret, T. and Vauchel, P.: Modélisation de propagation d'écoulement entre lits mineur et majeur sur les fleuves Sénégal et Niger, Hydrol. Sci. J., 1–20, doi:10.1080/02626667.2016.1148815, 2016.

Berrisford, P., Dee, D., Poli, P., Brugge, R., Fielding, K., Fuentes, M., Kållberg, P., Kobayashi, S., Uppala, S. and Simmons, A.: The ERA-Interim archive Version 2.0, ERA Rep. Ser. [online] Available from: https://www.ecmwf.int/en/elibrary/8174-era-interim-archive-version-20, 2011.

Brower, R., Akter, S., Brander, L. and Haque, E.: Economic valuation of flood risk exposure and reduction in a severely flood prone developing country, Environ. Dev. Econ., 14(3), 397, doi:10.1017/S1355770X08004828, 2009.

Ceccherini, G., Russo, S., Ameztoy, I., Marchese, A. F. and Carmona-Moreno, C.: Heat-waves in Africa 1981-2015, observations and reanalysis, Nat. Hazards Earth Syst. Sci., 17(1), 115–125, doi:10.5194/nhess-17-115-2017, 2017.

Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J.-J., Park, B.-K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N. and Vitart, F.: The ERA-Interim reanalysis: configuration and performance of the data assimilation system, Q. J. R. Meteorol. Soc., 137(656), 553–597, doi:10.1002/qj.828, 2011.

Fitchett, E. J. A., Seale, A. C., Vergnano, S., Sharland, M., Heath, P. T., Saha, S. K., Agarwal, R., Ayede, A. I., Bhutta, Z. A., Black, R., Bojang, K., Campbell, H., Cousens, S., Darmstadt, G. L., Madhi, S. A., Meulen, A. S., Modi, N., Patterson, J., Qazi, S., Schrag, S. J., Stoll, B. J., Wall, S. N., Wammanda, R. D. and Lawn, J. E.: Strengthening the Reporting of Observational Studies in Epidemiology for Newborn Infection (STROBE-NI): an extension of the STROBE statement for neonatal infection research, Lancet Infect. Dis., 16(10), e202–e213, doi:10.1016/S1473-3099(16)30082-2, 2016.

Froidurot, S. and Diedhiou, A.: Characteristics of wet and dry spells in the West African monsoon system, Atmos. Sci. Lett., 18(3), 125–131, doi:10.1002/asl.734, 2017.

Funk, C. C., Peterson, P. J., Landsfeld, M. F., Pedreros, D. H., Verdin, J. P., Rowland, J. D., Romero, B. E., Husak, G. J., Michaelsen, J. C. and Verdin, A. P.: A Quasi-Global Precipitation Time Series for Drought Monitoring., 2014.

Gautam, M.: Managing Drought in Sub-Saharan Africa: policy perspectives. Invited Paper Prepared for a Panel Session on Drought: Economic Consequences and Policies for Mitigation, in IAAE Conference, Gold Coast, Queensland, Australia., 2006.

Halsnæs, K. and Trærup, S.: Development and Climate Change: A Mainstreaming Approach for Assessing Economic, Social, and Environmental Impacts of Adaptation Measures, Environ. Manage., 43(5), 765–778, doi:10.1007/s00267-009-9273-0, 2009.

Hellmuth, M. E., Moorhead, A., Thomson, M. C. and Williams, J., Eds.: Climate Risk Management in Africa: Learning from Practice, International Research Institute for Climate and Society (IRI) - Columbia University, New York, USA. [online] Available from: https://iri.columbia.edu/wp-content/uploads/2013/07/Climate-and-Society-No1_en.pdf, 2007.

Hirsch, R. M. and Slack, J. R.: A Nonparametric Trend Test for Seasonal Data With Serial Dependence, Water Resour. Res., 20(6), 727–732, doi:10.1029/WR020i006p00727, 1984.

Hirsch, R. M., Slack, J. R. and Smith, R. A.: Techniques of trend analysis for monthly water quality data, Water Resour. Res., 18(1), 107–121, doi:10.1029/WR018i001p00107, 1982.

Kendall, M. G.: Rank correlation methods, Oxford Uni., New York, NY, USA., 1975.

Liu, X., Zhu, X., Pan, Y., Li, S., Liu, Y. and Ma, Y.: Agricultural drought monitoring: Progress, challenges, and prospects, J. Geogr. Sci., 26(6), 750–767, doi:10.1007/s11442-016-1297-9, 2016.

Mann, H. B.: Nonparametric Tests Against Trend, Econometrica, 13(3), 245–259, doi:10.2307/1907187, 1945.

Masih, I., Maskey, S., Mussá, F. E. F. and Trambauer, P.: A review of droughts on the African continent: a geospatial and long-term perspective, Hydrol. Earth Syst. Sci., 18(9), 3635–3649, doi:10.5194/hess-18-3635-2014, 2014.

McKee, T., Doesken, N. and Kleist, J.: Drought Monitoring with Multiple Time Scales, in 9th AMS Conference on Applied Climatology, Dallas, TX, USA., 1995.

McKee, T. B., Doesken, N. J. and Kleist, J.: The relationship of drought frequency and duration to time scales, Prepr. 8th Conf. Appl. Climatol., 179–184, 1993.

Moriasi, D.N., Arnold, J.G., Van Liew, M.W. Van, Bingner, R.L., Harmel, R.D., Veith, T.L.: Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations. Trans. ASABE 50, 885–900. doi:10.13031/2013.23153, 2007.

Nash, J. E., Sutcliffe, J. V. : River flow forecasting through conceptual models part I — A discussion of principles. J. Hydrol. 10, 282–290. doi: 10.1016/0022-1694(70)90255-6, 1970.

Neitsch, S. L., Arnold, J. G., Kiniry, J. R. and Williams, J. R.: Soil and Water Assessment Tool Theoretical Documentation, Texas Water Resour. Inst. Tech. Rep., (46), 647 [online] Available from: swat.tamu.edu/media/99192/swat2009-theory.pdf, 2009.

Ngigi, S. N., Savenije, H. H. G., Rockström, J. and Gachene, C. K.: Hydro-economic evaluation of rainwater harvesting and management technologies: Farmers' investment options and risks in semi-arid Laikipia district of Kenya, Phys. Chem. Earth, Parts A/B/C, 30(11–16), 772–782, doi:10.1016/j.pce.2005.08.020, 2005.

Ologunorisa, T. E. and Adeyemo, A.: Public Perception of Flood Hazard in the Niger Delta, Nigeria, Environmentalist, 25(1), 39–45, doi:10.1007/s10669-005-3095-2, 2005.

Oyekale, A.: Access to Risk Mitigating Weather Forecasts and Changes in Farming Operations in East and West Africa: Evidence from a Baseline Survey, Sustainability, 7(11), 14599–14617, doi:10.3390/su71114599, 2015.

Rosegrant, M., Ximing, C., Cline, S. and Nakagawa, N.: The role of rain-fed agriculture in the future of global food production., EPTD - Environ. Prod. Technol. Div., (90), 2002.

Russo, S., Sillmann, J. and Fischer, E. M.: Top ten European heat-waves since 1950 and their occurrence in the coming decades, Environ. Res. Lett., 10(12), 124003, doi:10.1088/1748-9326/10/12/124003, 2015.

Schmitt, L., Graham, H. and White, P.: Economic Evaluations of the Health Impacts of Weather-Related Extreme Events: A Scoping Review, Int. J. Environ. Res. Public Health, 13(11), 1105, doi:10.3390/ijerph13111105, 2016.

Shiferaw, B., Tesfaye, K., Kassie, M., Abate, T., Prasanna, B. M. and Menkir, A.: Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options, Weather Clim. Extrem., 3, 67–79, doi:10.1016/j.wace.2014.04.004, 2014.

Shisanya, S. and Mafongoya, P.: Adaptation to climate change and the impacts on household food security among rural farmers in uMzinyathi District of Kwazulu-Natal, South Africa, Food Secur., 8(3), 597–608, doi:10.1007/s12571-016-0569-7, 2016.

Tarpanelli, A., Amarnath, G., Brocca, L., Massari, C. and Moramarco, T.: Discharge estimation and forecasting by MODIS and altimetry data in Niger-Benue River, Remote Sens. Environ., 195, 96–106, doi:10.1016/j.rse.2017.04.015, 2017.

Warren, J. and Gilbert, R. O.: Statistical Methods for Environmental Pollution Monitoring, Technometrics, 30(3), 348, doi:10.2307/1270090, 1987.

WMO: Standardized Precipitation Index - User Guide - WMO-No. 1090., 2012.

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
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Natural Hazards and Earth System Sciences
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Discussions

TABLES

Table 1. Observed climatic changes during the last 10 years: 2006-2015

	BENIN		BURKINA FASO		NIGER		Mékrou Basin	
	count	**%**	**count**	**%**	**count**	**%**	**count**	**%**
Change of the rainfall quantity								
No change	8	2.4%			4	2.2%	12	1.8%
Less rain	311	93.7%	141	95.3%	132	73.3%	584	88.5%
More rain	13	3.9%	7	4.7%	44	24.4%	64	9.7%
Total responses	332		148		180		660	
Distribution of the rainfall in the year								
No change	21	6.3%			4	2.2%	25	3.8%
Better distribution	16	4.8%	2	1.4%	5	2.8%	23	3.5%
Worse distribution	295	88.9%	146	98.6%	171	95.0%	612	92.7%
Total responses	332		148		180		660	
More frequent droughts								
YES	297	89.5%	147	99.3%	128	71.5%	572	86.8%
NO	35	10.5%	1	0.7%	51	28.5%	87	13.2%
Total responses	332		148		179		659	
More frequent floods								
YES	50	15.1%	76	51.4%	130	72.2%	256	38.8%
NO	282	84.9%	72	48.6%	50	27.8%	404	61.2%
Total responses	332		148		180		660	
Delay in the start of the rainy season								
YES	248	74.7%	139	93.9%	161	89.4%	548	83.0%
NO	84	25.3%	9	6.1%	19	10.6%	112	17.0%
Total responses	332		148		180		660	
Rainy season finishes earlier								
YES	293	88.3%	146	98.6%	163	92.6%	602	91.8%
NO	39	11.7%	2	1.4%	13	7.4%	54	8.2%
Total responses	332		148		176		656	
Periods of extreme heat								
No change	34	10.2%	10	6.8%	15	8.5%	59	9.0%
Shorter	75	22.6%	7	4.7%	17	9.7%	99	15.1%
Longer	223	67.2%	131	88.5%	144	81.8%	498	75.9%
Total responses	332		148		176		656	

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Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

Table 2. Statistical Analysis of reported number of floods and droughts during the last 10 years

	Mékrou Basin	Benin	Burkina Faso	Niger
	Floods			
Mean	1.690141	0.727554	1.783784	3.458333
Standard Deviation	2.067303	1.158314	1.431143	2.644289
	Droughts			
Mean	3.933962	3.827692	4.797297	3.361963
Standard Deviation	2.829325	2.951433	2.722942	2.489043

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Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

Table 3. Household mitigation measures

	BENIN		BURKINA FASO		NIGER		Mékrou Basin	
	count	%	count	%	count	%	count	%
Change of crop seeds								
Action taken due to temperature								
YES	50	16.2%	29	19.6%	5	2.8%	84	13.2%
NO	259	83.8%	119	80.4%	175	97.2%	553	86.8%
Action taken due to rainfall								
YES	110	34.0%	99	66.9%	110	61.1%	319	48.9%
NO	214	66.0%	49	33.1%	70	38.9%	333	51.1%
Terracing the soil or using other methods to protect against erosion								
Action taken due to rainfall								
YES	77	23.8%	26	17.6%	19	10.6%	122	18.7%
NO	247	76.2%	122	82.4%	161	89.4%	530	81.3%
Plantation of more trees								
Action taken due to temperature								
YES	84	27.2%	33	22.3%	8	4.4%	125	19.6%
NO	225	72.8%	115	77.7%	172	95.6%	512	80.4%
Action taken due to rainfall								
YES	112	34.6%	39	26.4%	51	28.3%	202	31.0%
NO	212	65.4%	109	73.6%	129	71.7%	450	69.0%
Emigration of at least one household member								
Action taken due to rainfall								
YES	53	16.4%	12	8.1%	46	25.6%	111	17.0%
NO	271	83.6%	136	91.9%	134	74.4%	541	83.0%
Practicing more often non-agricultural activities as sources of revenue								
Action taken due to temperature								
YES	100	32.3%	11	7.4%	32	17.8%	143	22.4%
NO	210	67.7%	137	92.6%	148	82.2%	495	77.6%
Action taken due to rainfall								
YES	119	36.6%	14	9.5%	20	11.1%	153	23.4%
NO	206	63.4%	134	90.5%	160	88.9%	500	76.6%

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
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Discussion started: 20 June 2017

Table 4. Experienced extreme flood events during the last two years (2014-2015)

	BENIN		BURKINA FASO		NIGER		Mékrou Basin	
	count	%	count	%	count	%	count	%
Floods								
YES	9	2.7%	51	34.5%	8	4.4%	68	10.3%
NO	322	97.3%	97	65.5%	172	95.6%	591	89.7%
Droughts								
YES	83	25.5%	66	44.9%	3	1.7%	152	23.3%
NO	243	74.5%	81	55.1%	177	98.3%	501	76.7%

Table 5. Impacts of extreme floods and droughts to the households

	BENIN	BURKINA FASO	NIGER	Mékrou Basin
	count	count	count	count
Impacts of floods				
Damage to the house	3	24	5	32
Loss of agricultural production	8	44	7	59
Injury or death of a household member		1	3	4
Loss of livestock		16	4	20
Impacts of droughts				
Loss of agricultural production	74	66	3	143
Malnutrition of at least one household person	41	4	2	47
Loss of livestock	20	4	3	27

Table 6. Estimated costs of the recent flood and droughts (in FCFA)

	Mékrou Basin	**Benin**	**Burkina Faso**	**Niger**
Costs of floods				
Mean	324563 (~495 EURO)	40,000	334,326	160,000
Standard Deviation	373159		378071	
Costs of droughts				
Mean	256440 (~391 EURO)	262,184	252,803	0
Standard Deviation	324224	257676	362150	0

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Discussion started: 20 June 2017

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Discussions

Table 7. Selected independent variables for modelling costs of floods and droughts

Variable	***Scaling***	***Correlation***
ECONSTAT	1. Rich, 2. Relatively rich, 3. Average, 4. Below average, 5. Much worse than average	CropProdLoss: -0.0786 LivestockLoss: -0.134
CropProdLoss	0 (no impact), 1 (impact)	LivestockLoss: -0.017
LivestockLoss	0 (no impact), 1 (impact)	PRODCROP: 0.212
PRODCROP	Numerical Value	

Table 8. Costs of floods – Multivariate linear regression model

Number of obs = 48				
Independent Variables	Coef.	Std. Err.		P>z
ECONSTAT	-128548.5	47850.09	-2.69	0.01
CropProdLoss	287269.9	129224.5	2.22	0.031
LivestockLoss	359272.4	92753.99	3.87	0

Table 9. Costs of droughts - Multivariate linear regression model

Number of obs = 98			
Independent Variables	Coef.	Std. Err.	P>z
PRODCROP	14.08011	3.643078	0
LivestockLoss	137261.8	74243.4	0.068
_cons	130367.5	39952.2	0.002
Cost Estimate / household	324563256441 (FCFA)	494.76390.92 (EURO)	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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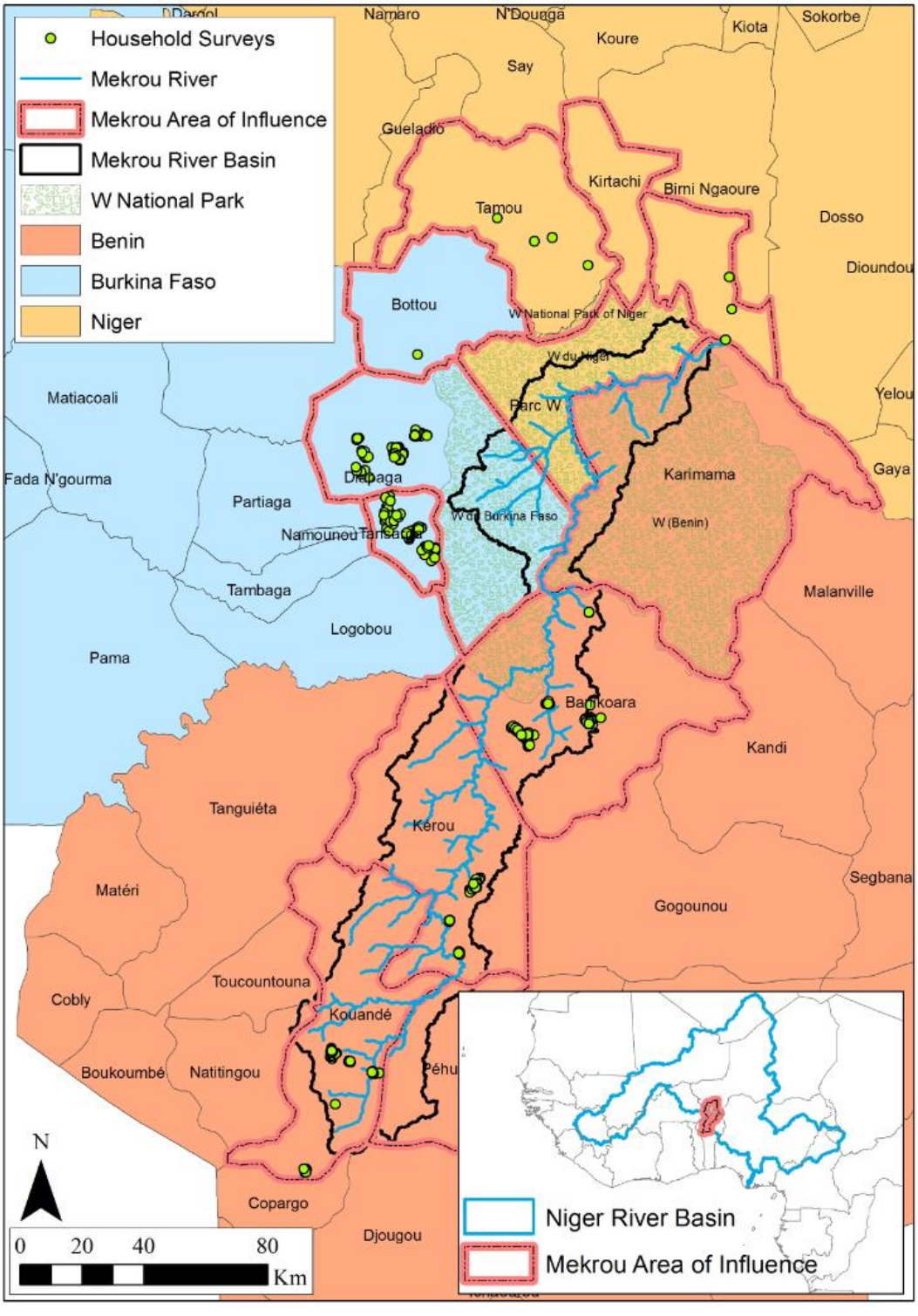
Open Access
Discussions

Figure 1. The Mékrou river basin and the household survey area



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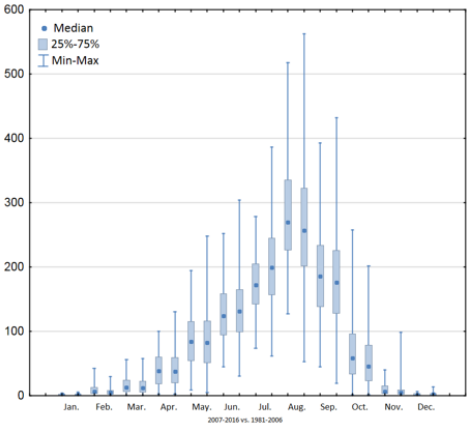
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

Figure 2. Comparison of seasonal distribution of precipitation for the first 25 years of the time series versus the last 10 years and Seasonal Mann-Kendall results.



Last 10 years (2007-2016)

			Mann-Kendall trend test for monthly environmental time series by Regions				Seasonal Sen's slope and intercept	
id	country	region	Kendall Score (S)	variance of S	two-sided p-value	Kendall's tau statistic	value of Sen's slope	intercept
1	Benin	Banikoara	-49	1491.6670	0.2045	-0.0913	-0.00250	35.238
2	Benin	Pehunco	-42	1500.0000	0.2782	-0.0778	-0.06025	68.334
3	Benin	Karimama	-21	1456.3330	0.5821	-0.0400	0.00000	20.684
4	Benin	Kounde	-36	1500.0000	0.3526	-0.0667	-0.04139	65.821
5	Benin	Kerou	-40	1498.0000	0.3014	-0.0742	-0.02008	42.826
6	Burkina Faso	Tansarga	-10	1389.3330	0.7885	-0.0197	0.00000	24.686
7	Burkina Faso	Bottou	46	1371.3330	0.2142	0.0915	0.00000	16.893
8	Burkina Faso	Diapaga	18	1456.0000	0.6371	0.0343	0.00000	23.632
9	Niger	Parc W	43	1379.6670	0.2470	0.0852	0.00000	16.875
10	Niger	Kirtachi	26	1229.3330	0.4584	0.0587	0.00000	8.492
11	Niger	Tamou	66	1355.3330	0.0730	0.1326	0.00000	10.338
12	Niger	Boboye	12	1419.3330	0.7501	0.0232	0.00000	9.178

All Time Series (1981-2016)

			Mann-Kendall trend test for monthly environmental time series by Regions				Seasonal Sen's slope and intercept	
id	country	region	Kendall Score (S)	variance of S	two-sided p-value	Kendall's tau statistic	value of Sen's slope	intercept
1	Benin	Banikoara	259	64624.3300	0.3083	0.0344	0.00052	31.010
2	Benin	Pehunco	349	64679.0000	0.1700	0.0462	0.01184	57.116
3	Benin	Karimama	-74	62939.3300	0.7680	-0.0100	0.00000	18.261
4	Benin	Kounde	421	64679.0000	0.0978	0.0557	0.01200	58.271
5	Benin	Kerou	397	64666.3300	0.1185	0.0526	0.00518	40.286
6	Burkina Faso	Tansarga	321	61339.6700	0.1949	0.0444	0.00000	24.718
7	Burkina Faso	Bottou	78	61251.3300	0.7526	0.0108	0.00000	13.290
8	Burkina Faso	Diapaga	324	62905.3300	0.1964	0.0440	0.00000	20.995
9	Niger	Parc W	112	59376.0000	0.6458	0.0160	0.00000	12.023
10	Niger	Kirtachi	-149	56234.3300	0.5298	-0.0225	0.00000	6.679
11	Niger	Tamou	79	59789.0000	0.7466	0.0112	0.00000	8.413
12	Niger	Boboye	-132	61726.0000	0.5952	-0.0182	0.00000	7.091

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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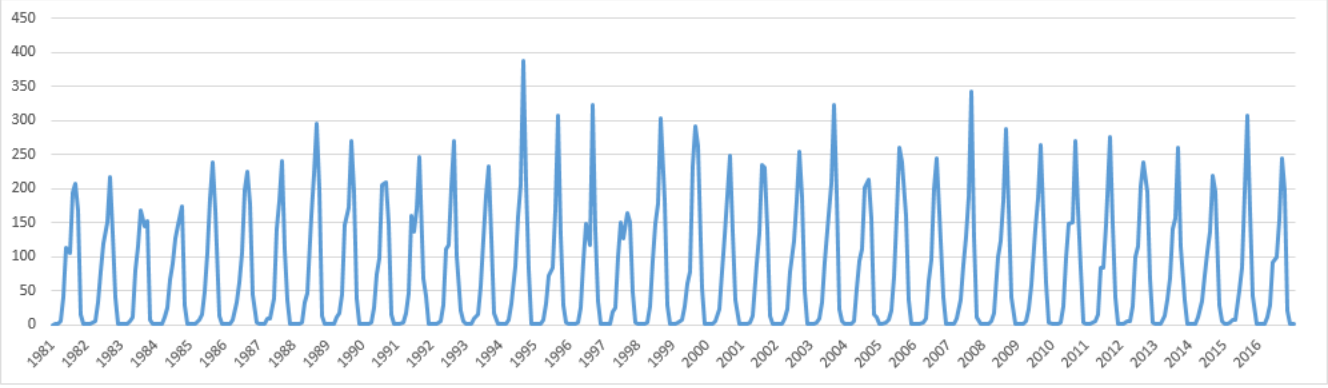
Figure 3. Temporal monthly precipitation profile for the Mékrou Area of Interest



Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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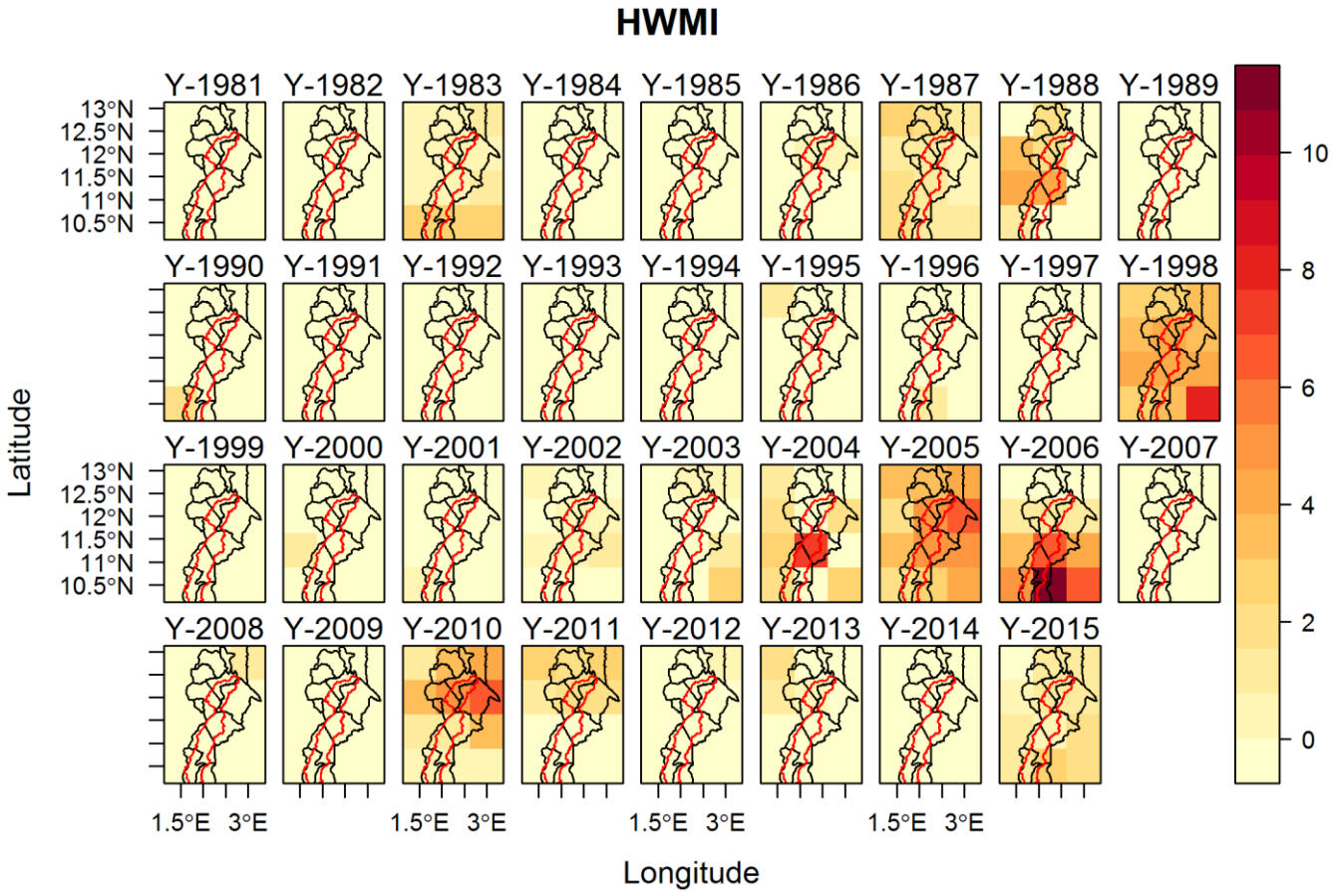
Figure 4. HWMI index computed for 1981 to 2015 on the Mékrou



Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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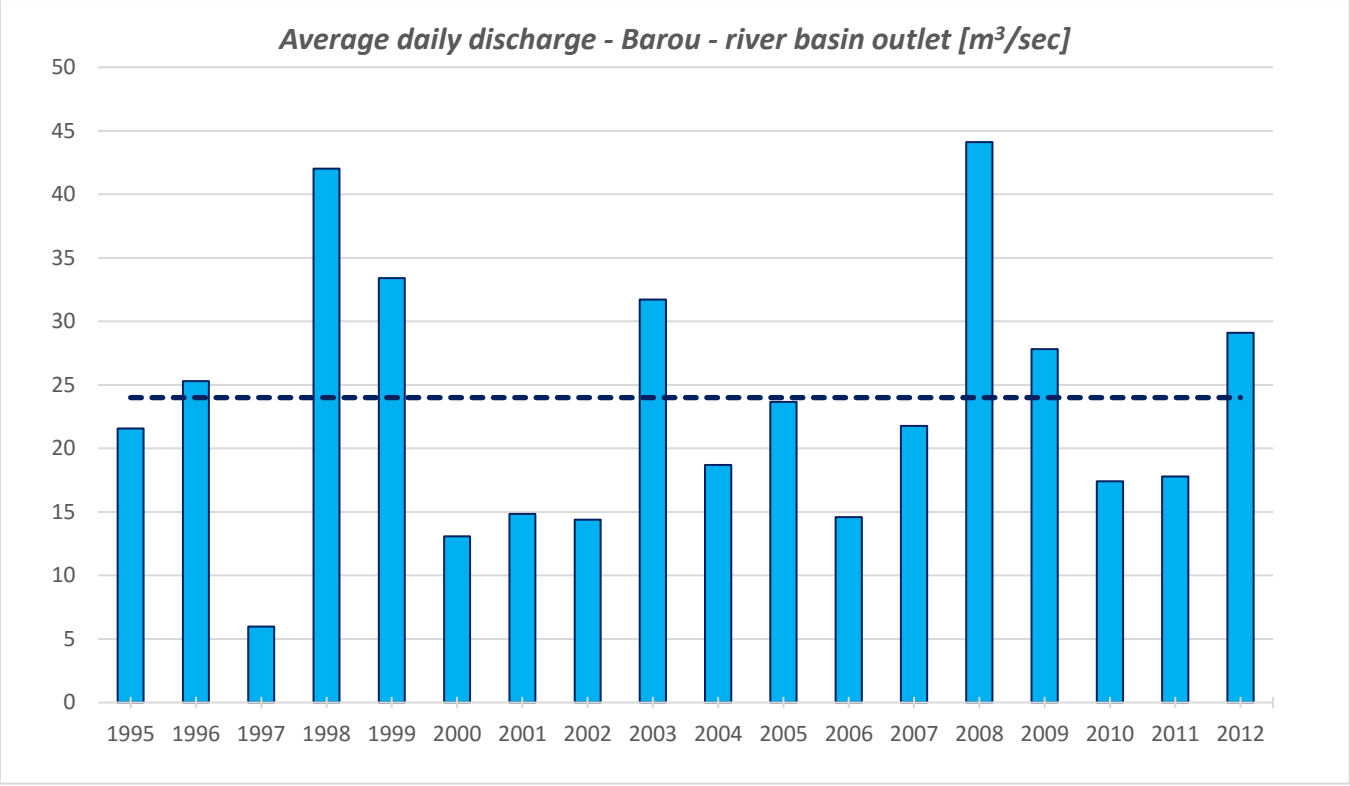
Discussions

Figure 5. Mékrou river daily average discharge at Barou station as modelled in SWAT in the period 1995-2012. Dashed line indicates the average of the total period under consideration.



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Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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Open Access
Discussions

APPENDIX A.

QUESTIONNAIRE

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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European Commission

BASSIN VERSANT DE LA MÉKROU
ENQUETE SUR LES MENAGES

Décembre 2015

JOINT RESEARCH CENTRE (JRC), UNIVERSITE DE OUGADOUGOU, UNIVERSITE ABDOU MOUMOUNI DE NIAMEY, INSTITUTE NATIONAL DEL' EAU (INAE) BENIN, GWP-AO,

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Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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Open Access
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Table des matières

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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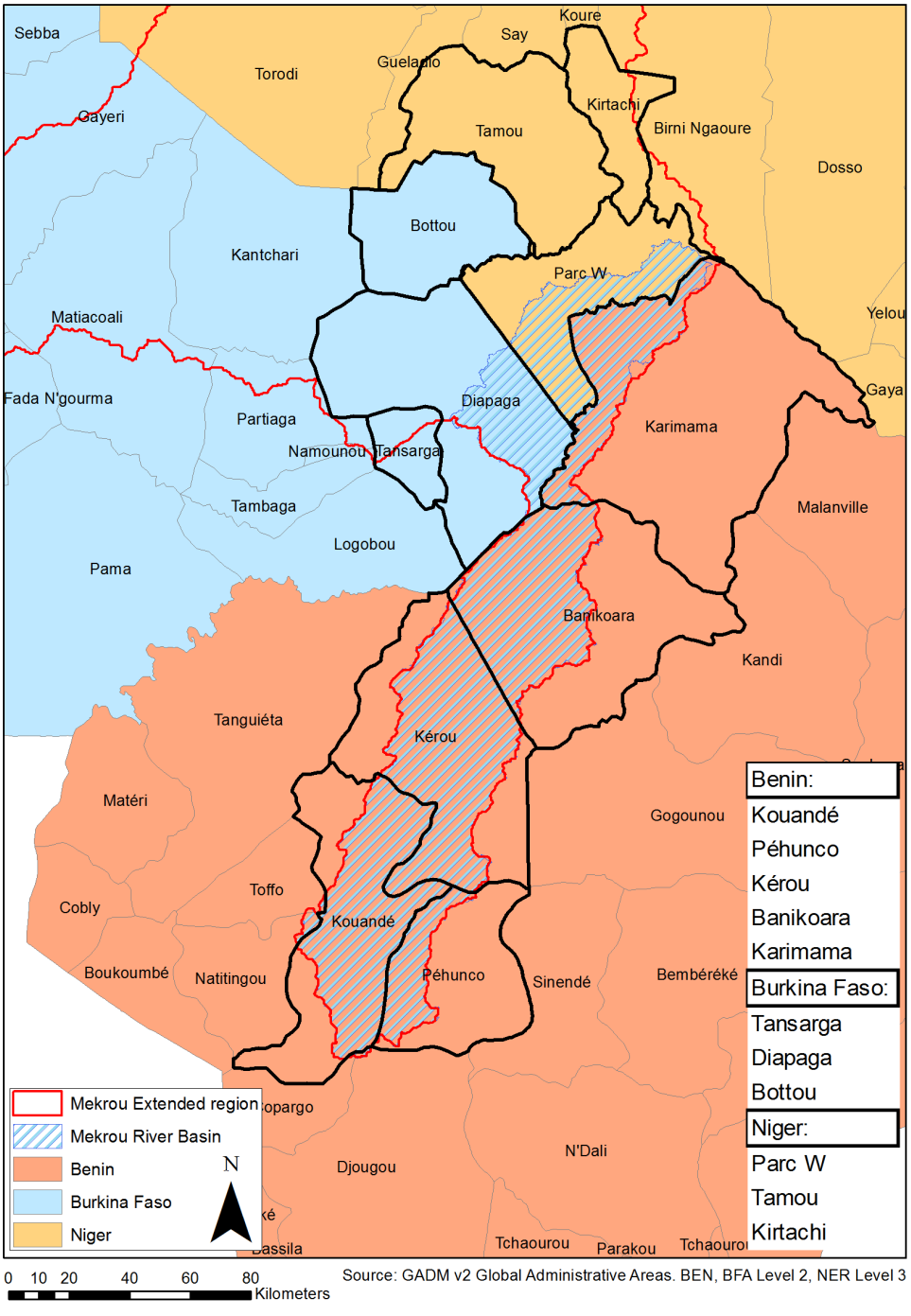
Le bassin versant de la Mékrou



Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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Discussions

Questionnaire No:

Date:

Lieu de collecte du questionnaire (pays) : _____

Village : _____

Coordonnées GPS: x) Longitude: _____ y) Latitude :_____

Nom de l'enquêteur_____

Nom du superviseur_____

(*A remplir avant de commencer le questionnaire*)

Bonjour. Je m'appelle _____. Je travaille pour<_____>.

Nous effectuons une enquête sur les ménages vivant dans le bassin de la Mékrou. Cette enquête des ménages fait partie du Project de coopération "Mékrou", a laquelle les gouvernements/autorités de gestion du Benin, du Niger et du Burkina Faso, participent en collaboration avec le partenariat de l'Eau (GWP) et le centre commun de recherche (CCR). Ce projet a pour objectif d'améliorer la planification et la gestion des eaux de la rivière Mékrou et ainsi, d'améliorer les conditions de vie de la population locale dans les 3 pays concernés par ce bassin versant. Les informations collectées à travers de ce questionnaire sont confidentielles seront uniquement utilisées par les analystes du projet Mékrou pour développer des plans de gestion plus efficaces sur ce bassin versant.

Les informations que nous collectons, nous aideront à mieux gérer la ressource en eau. Votre ménage a été sélectionné pour cette enquête. Nous voudrions vous poser quelques questions concernant votre foyer. Accepteriez-vous de répondre à nos questions, cela prend habituellement entre 90 et 120 minutes. Toutes les informations que vous nous communiquerez sont strictement confidentielles et ne seront pas transmises à quiconque à l'exception de l'équipe e d'enquête.

Vous n'êtes pas obligé de participer à cette enquête, cependant nous comptons vivement sur votre participation car votre opinion est très importante. De plus, si une question ne vous convient pas, dites-le moi et je passerai à la question suivante. Enfin, vous pouvez également interrompre l'interview à n'importe quel moment.

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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Discussions

I : CARACTERISTIQUES SOCIO ECONOMIQUES

1.1 : Caractéristiques sociaux

1. Localisation de votre foyer

1. Nom du pays	
2. Nom de la région	
3. Nom du département	
4. Nom de la commune	
5. Nom du Village	
6. Nom du quartier	
7. Nombre d'années de résidence dans ce village	

2. Age du répondant : _____ ans

3. Sexe du répondant

1. Masculin	
2. Feminin	

4. Situation:

1. Célibataire	
2. Marié(e)	
3. Veuf/Veuve	

5. Lien avec le chef du foyer :

1. chef de foyer	
2. Enfant du chef de foyer	
3. Epouse du chef de foyer	
4. Frère ou sœur du chef de foyer	
5. Père ou mère du chef de foyer	
6. Grand-père ou grand-mère du chef de foyer	
7. Petit-fils ou petite-fille du chef de foyer	
8. Cousin ou cousine du chef de foyer	
9. autre parenté	
10. sans lien de parenté	

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Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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Discussions

6. Quel est votre niveau d'étude et/ou diplôme le plus élevé?

1. non scolarise	
2. scolarisation non formelle	
3. Ecole primaire	
4. Lycée	
5. Formation professionnelle	
6. Université	

7. Quel est votre emploi? (plusieurs réponses possibles)

1. Sans emploi/mère au foyer	
2. Auto-entrepreneur/Indépendant	
3. Employé public	
4. Employé dans le privé	
5. Ouvrier/technicien	
6. Agriculteur (céréalier/maraîcher)	
7. Eleveur	
8. Etudiant	
9. Retraité	
10. Autre, spécifier:	

8. Listez le nombre de personnes inclus dans votre foyer par âge

1. Nombre total de personnes dans votre foyer	
2. *dont* enfants de moins de 5 ans (strictement)	
3. *dont* enfants 5 ans et plus (moins de 18 ans)	
4. *dont* adultes (plus de 18 ans)	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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1.2 : Variables économiques

9. Combien de personnes de votre foyer, vous inclus, a un revenu (quelque 'il soit)?

1. Nombre d'hommes ayant un revenu	
2. Nombre de femmes ayant un revenu	

10. Indiquez la tranche de revenu qui correspond au REVENU MENSUEL TOTAL de tous les membres de votre foyer, vous inclus?

1. 0 - 25 000 FCFA par mois	
2. 25 001 - 50 000 FCFA par mois	
3. 50 001 - 75 000 FCFA par mois	
4. 75 001 - 100 000 FCFA par mois	
5. 100 001 - 125 000 FCFA par mois	
6. 125 001 - 150 000 FCFA par mois	
7. 150 001 - 200 000 FCFA par mois	
8. 200 001 - 300 000 FCFA par mois	
9. 300 001 - 500 000 FCFA par mois	
10. 500 001 - 700 000 FCFA par mois	
11. 700 001 - 1 000 000 FCFA par mois	
12. Plus de 1 000 001 FCFA par mois	
13. Je ne sais pas	

11. Type de logement actuel ?

1. Appartement dans un immeuble, Studio	
2. Chambre	
3. Case traditionnelle isolée ou dans une concession	
4. Maison individuelle de type traditionnel	
5. Maison moderne	
6. Autre	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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12. Propriété de votre logement : (sélectionnez 1 option) – Montrez les options

1. Propriétaire	
2. Location	
3. Logement chez un proche	
4. Logement fourni par l'employeur	
5. Usufruit, logement gratuit	
6. Autre, préciser	

13. Votre foyer est-il connecté au réseau électrique ?

1. Connecté au réseau électrique	
2. Pas connecté au réseau électrique	

14. Si connecté, quel est le montant de la facture d'électricité du mois dernier (FCFA)?_____

15. Si connecté, nombre d'heures par jour pendant lesquelles vous avez eu de l'électricité ?_____

16. Le foyer est-il connecté au réseau d'eau ?

1. Connecté au réseau d'eau	
2. Pas connecté au réseau d'eau	

17. Si connecté, quel est le montant de la facture d'eau du mois dernier (FCFA)?_____

18. Si connecté, nombre d'heures par jour pendant lesquelles vous avez accès à l'eau du réseau?_____

19. Comment caractérisez-vous le niveau économique de votre foyer en comparaison avec le niveau de vie de votre village?

1. Aisé/riche	
2. Relativement aisé	
3. Moyen	
4. Moyenne basse	
5. Bien en dessous de la moyenne	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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II-NUTRITION ET SECURITE ALIMENTAIRE

20. Rations alimentaires des 7 derniers jours

1. Dans les 7 derniers jours, avez-vous été inquiet de savoir s'il y aurait suffisamment à manger 1. OUI ☐ 2. NON ☐	2. Dans les 7 derniers jours, pendant combien de jours, vous ou un membre de votre foyer a dû:					3. Combien de repas, petit-déjeuné inclus, ont été pris chaque jour par votre foyer durant les 7 derniers jours?		4. Dans les 12 derniers mois, avez-vous été dans la situation où vous n'aviez pas suffisamment de nourriture pour l'ensemble de votre foyer? 1. OUI ☐ 2. NON ☐ ► Si **OUI** allez a la **Question #21**
	2.1. Manger des aliments moins chers que d'habitude?	2.2. Réduire sa quantité de nourriture à chaque repas ?	2.3. Réduire le nombre de repas par jour?	2.4. Réduire les rations alimentaires des adultes pour augmenter celles des enfants ?	2.5. Demander de la nourriture à un tiers (famille, amis…)?	3.1. Adultes	3.2. Enfants **(6-59 mois)** LAISSEZ VIDE SI LE FOYER NE COMPREND AUCUN ENFANT	
	__(Jours)	__(Jours)	__(Jours)	__(Jours)	__(Jours)	__(Nombre)	__(Nombre)	

21. Rations alimentaires des 12 derniers mois

1. Durant quel mois avez-vous des problèmes ces 12 derniers mois? METTRE 1=OUI pour indiquer chaque mois ou votre foyer n'a pas pu couvrir ces besoins alimentaires						2. Quelles ont été les causes de cette situation de carence/difficulté alimentaires? LISTER 3 CAUSES MAXIMUM PAR ORDRE D'IMPORTANCE EN UTILISANT LES CODES SUIVANTS. 1ier ____ 2ieme ____ 3ieme _____
DEC (2014)	JAN (2015)	FEV (2015)	MAR (2015)	APR (2015)	MAI (2015)	**01** Faibles récoltes en raison de la sècheresse **02** Faibles récoltes en raison des attaques d'insectes **03** Faibles récoltes en raison du manque de terres disponibles pour les cultures **04** Faibles rendements dus au manque d'entrants (engrais) **05** Faibles rendements dus à la mauvaise qualité des sols **06** Prix élevés des produits sur le marché **07** Difficulté d'accès au marché à cause de coûts élevés de transport **08** Manque de ressources financières **09** Peu de produits disponibles sur le marché **10** Conséquences d'inondations **11** Autre (spécifier)_____
JUIN (2015)	JUIL (2015)	AOUT (2015)	SEP (2015)	OCT (2015)	NOV (2015)	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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Discussions

22. Consommation alimentaire des 7 derniers jours

PRODUITS	a. Est que votre foyer a consommé [DENRÉES] durant ces 7 derniers jours ? **1=OUI** **2=NON**	Quelles sont les quantités et la valeur des denrées consommées et achetées par votre foyer durant les 7 derniers jours? 01=Botte 05=Kg 09=Tas 02=Sachet 06=Gramme 10=Autre 03=Panier/seau 07=Pièce 11=Bol 04=Centilitre 08=Litre 12=(spécifier) : _____		
		b. QUANTITE	**c. UNITE**	**d. MONTANT PAYE en FCFA**
1. Céréales et produits céréaliers (Millet/farine de millet, sorgho, fonio, maïs/farine maïs, pain, pates, farine de blé, etc.)				
2. Riz				
3. Tubercules & plantains (Pommes de terre, patate douce, yams, plantain, manioc, taro, etc.)				
4. Légumes et graines (Dolique a œil noir, haricots, noix de terre & pate de noix, etc.)				
5. Poisson				
6. Viande rouge (Boeuf, agneau, gibier, etc)				
7. Volaille (Poulet etc.)				
8. Fruits (mangue, orange, citron, pastèque, melon, ananas, dattes, etc.)				

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

9. Lait et produits laitiers (lait frais, lait en poudre yaourt, fromage, etc.)				
10. Huile et graisses (Beurre, Huile de palme, d'arachide, de noix de terres, etc.)				
11. Desserts et Confiseries (Sucre en poudre, en cubes, miel, sucreries, gâteaux, biscuits chocolat etc.)				
12. Boissons non alcoolisées (thé, café, jus de fruit etc.)				
13. Boissons alcoolisées (bière, vin et spiritueux)				

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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Open Access
Discussions

III-USAGE DE L'EAU PAR LES MENAGES

23. D'où provient *principalement* l'eau que boivent les membres de votre foyer? (**1 reponse**)

Sources d'approvisionnement améliorées en eau	
1. Eau du robinet dans le domicile	
2. Eau du robinet dans la cour ou sur la parcelle	
3. Borne-fontaine/fontaine	
4. Puits tubé/puits foré = forage	
5. Puits creusé protégé = puit cimente	
6. Source protégée	
7. Citerne d'eau de pluie	
Sources d'approvisionnement non améliorées en eau	
8. Puits non protégé = puit traditionnel	
9. Source non protégée	
10. Charette avec petite citerne / tonneau	
11. Eau en bouteille	
12. Camion-citerne	
13. Eau de surface (rivière, réservoir, lac, étang, ruisseau, canal, canal d'irrigation)	
14. Autre. Préciser	

24. Où se situe cette source d'approvisionnement d'eau?

1. Dans votre logement	
2. Dans votre parcelle	
3. Ailleurs	

25. Quelle est la distance (en mètres) qui sépare votre maison de la principale source d'approvisionnement en eau de boisson ?

Distance en mètres	
2. Je ne sais pas	

26. Combien de temps faut-il pour s'y rendre, avoir de l'eau et revenir ?

Temps en minutes	
2. Je ne sais pas	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

27. Habituellement, faites-vous quelque chose pour rendre l'eau plus saine à boire?

1. Non, je ne fais rien du tout	
2. Oui, la faire bouillir	
3. Oui, ajouter de l'eau de javel/chlore	
4. Oui, utiliser l'aquatabs	
5. Oui, la filtrer à travers un linge	
6. Oui, utiliser un filtre (céramique/sable/composite/ etc.)	
7. Oui, désinfection solaire	
8. Oui, la laisser reposer	
9. Autre, Préciser.	

28. Quels sont les problèmes rencontrés en termes d'approvisionnement en eau? (plusieurs réponses possibles)

1. Eau sale/de basse qualité (en termes de goût, couleur, odeur…)	
2. Irrégularité de l'approvisionnement	
3. Autre, spécifier :	
4. Pas de problème	

29. Pouvez-vous donner une estimation de la consommation journalière en eau de votre foyer tous usages confondus (boisson, hygiène, cuisine… etc.) ?

Consommation journalière en eau (en litres)	
2. Je ne sais pas	

30. Pouvez-vous donner une estimation de ce que coûte votre consommation journalière en eau de votre foyer, tous usages confondus (boisson, hygiène, cuisine… etc.) ?

Coût des dépenses pour la consommation journalière en eau (en FCFA)	
2. Je ne sais pas	

31. Quel type de toilettes les membres de votre foyer utilisent-ils habituellement? **(1 reponse)**

Installations d'assainissement améliorées	
1. Chasse d'eau raccordée - tout à l'égout	
2. Chasse d'eau raccordée - fosse septique	
3. Chasse d'eau raccordée - latrines à fosse	
4. Chasse d'eau raccordée - autre chose	
5. Fosse d'aisance améliorée et autoventilée	
6. Fosse d'aisance avec une dalle	
7. Latrines sèches (à compost)	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

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Open Access
Discussions

Installations d'assainissement non améliorées	
8. Chasse d'eau sans raccordement	
9. Fosse d'aisance sans dalle ou fosse en plein air	
10. Latrines à seau	
11. Toilettes ou latrines suspendues	
12. Pas d'installations (brousse, champs)	
13. Autre. Préciser:_____	

32. Combien de ménages utilisent ces toilettes ?

1. Seulement mon foyer	
2. 1 autre foyer/famille en plus du mien	
3. 2 à 5 foyers/familles en plus du mien	
4. Plus de 5 foyers/familles en plus du mien	

33. Est-ce qu'un ou plusieurs enfants de **moins de 5 ans** ont eu la diarrhée au cours des deux dernières semaines ?

	Enfant 1	Enfant 2	Enfant 3	Enfant 4	Enfant 5
1. diarrhée au cours des deux dernières semaines **sans** sang dans les selles	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
2. diarrhée au cours des deux dernières semaines **avec** sang dans les selles	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
3. pas de diarrhée au cours des deux dernières semaines **(si OUI est coché a question 1 ou 2 pour un enfant, répondez aux points 4, 5, 6, 7, 8, 9)**	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
4. Lui a-t-on donné à boire moins que d'habitude, environ la même quantité ou plus que d'habitude ?	Moins ☐ Pareil ☐ Plus ☐	Moins ☐ Pareil ☐ Plus ☐	Moins ☐ Pareil ☐ Plus ☐	Moins ☐ Pareil ☐ Plus ☐	Moins ☐ Pareil ☐ Plus ☐
5. Avez-vous recherché des conseils ou un traitement à l'hôpital / clinique	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
6. Avez-vous recherché des conseils ou un traitement auprès d'un centre médical	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
7. Avez-vous recherché des conseils ou un traitement en pharmacie	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
8. Avez-vous recherché des conseils ou un traitement au marché	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
9. Avez-vous recherché des conseils ou un traitement ailleurs	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐

OUI=1, NON=2, Moins= 1, Pareil= 2, Plus= 3

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

34. Est-ce qu'un ou plusieurs enfants de **plus de 5 ans** ont eu la diarrhée au cours des deux dernières semaines ?

	Enfant 1	Enfant 2	Enfant 3	Enfant 4	Enfant 5
1. diarrhée au cours des deux dernières semaines **sans** sang dans les selles	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
2. diarrhée au cours des deux dernières semaines **avec** sang dans les selles	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
3. pas de diarrhée au cours des deux dernières semaines	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
(si OUI est coché a question 1 ou 2 pour un enfant, répondez aux points 4, 5, 6, 7, 8, 9)					
4. Lui a-t-on donné à boire moins que d'habitude, environ la même quantité ou plus que d'habitude ?	Moins ☐ Pareil ☐ Plus ☐	Moins ☐ Pareil ☐ Plus ☐	Moins ☐ Pareil ☐ Plus ☐	Moins ☐ Pareil ☐ Plus ☐	Moins ☐ Pareil ☐ Plus ☐
5. Avez-vous recherché des conseils ou un traitement à l'hôpital / clinique	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
6. Avez-vous recherché des conseils ou un traitement auprès d'un centre médical	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
7. Avez-vous recherché des conseils ou un traitement en pharmacie	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
8. Avez-vous recherché des conseils ou un traitement au marché	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐
9. Avez-vous recherché des conseils ou un traitement ailleurs	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐	Oui ☐ Non ☐

OUI=1, NON=2, Moins= 1, Pareil= 2, Plus= 3

35. Selon vous, quel est le principal problème par rapport l'approvisionnement en eau dans le bassin versant de la rivière Mekrou ?

1. Fuite/rupture de canalisations	
2. Insuffisance d'eau pendant la saison sèche	
3. Déforestation qui réduit l'importance des réserves d'eau souterraines	
4. Le mode de gestion et d'allocation de l'eau	
5. Le nombre d'utilisateurs différents	
6. Le manque de coopération régionale	
7. Autre, spécifiez:	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

Imaginez que vous maintenant avez la possibilité d'être raccordé au réseau d'eau. Cela signifie un accès 24h/24h à une eau de bonne qualité pour votre foyer. Ce raccordement est coûteux. Si vous décidez d'être raccordé au réseau, vous devrez alors payer chaque mois une facture pour ce service d'eau.

36. Dans ce cadre, seriez-vous d'accord pour être raccordé au réseau et ainsi, payer chaque mois une facture pour le service d'eau

1. Oui		2. Non	

37. Si vous avez répondu NON à **la question 36**, pouvez-vous indiquer la raison principale ? (une seule réponse possible)

1. Je n'ai pas les ressources financières suffisantes pour régler une facture d'eau	
2. Je pense que c'est au gouvernement de financer la fourniture en eau	
3. Je n'ai pas confiance dans les la qualité de l'eau distribue par le réseau	
4. Seulement les foyers aisés devraient s'acquitter d'une facture d'eau	
5. Autre raison (spécifier):_____	

38. Si vous avez répondu OUI à la **question 36**, pourriez-vous indiquer le montant maximum par mois que vous seriez prêt à payer ?

1. 50 FCFA	
2. 100 FCFA	
3. 200 FCFA	
4. 300 FCFA	
5. 500 FCFA	
6. 750 FCFA	
7. 1 000 FCFA	
8. 1 500 FCFA	
9. 2 000 FCFA	
10. 3 000 FCFA	
11. 4 000 FCFA	
12. 5 000 FCFA	
13. 10 000 FCFA	
14. Plus de 10 000 FCFA	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

IV-USAGE DE L'EAU PAR L'AGRICULTURE

39. Est-ce que vous ou un des membres de votre foyer a cultivé de la terre durant l'année écoulée? (Si OUI allez a la **question 40**, si NON allez directement à la **question 47**)

1. Oui		2. Non	

40. Liste de toutes les récoltes produites par votre foyer durant l'année écoulée

1. Récolte (code)	2. Superficie de terre cultivable (ha)	3. Production annuelle (kg)	4. Quelle quantité de cette production avez-vous vendu? (kg)	5. Quel a été le montant de la vente de cette production ? (in FCFA)	6. A qui l'avez-vous vendu principalement? 1=Etat 2=Restaurants, hôtels, supermarché 3=Coopératives 4=Operateur privé, ou de marché 5=autres foyers 6= Autre	7. Ou avez-vous vendue cette production? 1=auto consommation 2=marché local 3=autres marchés 4=contrat de vente 5=Autre

CODES Récolte	Nom	CODES Récolte	Nom	CODES Récolte	Nom	CODES Récolte	Nom
01	Millet	13	Sésame	25	Melon	37	Haricot vert
02	Sorgho	14	Manioc	26	Pastèque	38	Calebasse
03	Riz	15	Patate Douce	27	Laitue	39	Radis
04	Maïs	16	Pomme de terre	28	Chou	40	Navet
05	Souchet	17	Poivron	29	Tomate	41	Poireaux
06	Blé	18	Ginger	30	Carotte	42	Amarante (Tchapata)
07	Fonio	19	Clous de girofle	31	Jaxatu	43	Coton
08	Doliques à œil noir	20	Menthe	32	Aubergine	44	Betterave
09	Voandzou-pois de bambara	21	Epinard	33	Oignon	45	Pois
10	Cacahouète	22	Cèleri	34	Concombre	46	Taro
11	Gombo	23	Persil	35	Courge	47	Yams
12	Oseille	24	Epices(Poivre)	36	Ail	48	Autre (spécifier)

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

41. Quelle source d'eau avez-vous utilisé durant l'année écoulée pour irriguer vos cultures?

Source d'Irrigation	1= OUI, 2= OUI, mais Je ne sais pas quelle quantité 3=NON	**Si QUI (1)** M3/année dernière (estimation)
L'eau de la rivière Mekrou		
Puit privé		
Autre source d'eau de surface		
Autre, specifier:		

42. Avez-vous utilisé des engrais chimiques durant l'année écoulée?

1. Oui		2. Non	

43. Si OUI, lister les engrais chimiques que vous avez utilisés:

Engrais chimiques	*Quantité (kg)*	*Prix (FCFA/kg)*
1. Urine		
2. DAP		
3. NPK (15/15)		
4. Autre		

44. Avez-vous utilisé des pesticides durant l'année écoulée?

1. Oui		2. Non	

45. Si OUI, lister les pesticides que vous avez utilisés:

Insecticides/Fongicides/Herbicides	*Quantité (Litre)*	*Prix (FCFA/Litre)*
1. Insecticides		
2. Fongicides		
3. Herbicides		
4. Autres types de produit		

46. Accepteriez-vous d'utiliser de l'eau issue de stations d'épuration/eau traitée pour irriguer et fertiliser vos cultures?

1. Oui		2. Non	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

47. Est-ce que vous ou un membre de votre foyer possède un(des) animal(aux) d'élevage? (Si OUI allez a la **question 48**, si NON allez directement à la **question 50**)

1. Oui		2. Non	

48. Si OUI, lister ces animaux

1. Animal	2. Quantité	3. Production annuelle de viande (kg)	4. Quelle quantité de cette production avez-vous vendu? (kg)	5. Quel a été le montant de la vente de cette production ? (in FCFA)	6. A qui l'avez-vous vendu principalement? 1=Etat 2=Restaurants, hôtels, supermarché 3=Coopératives 4=Operateur privé, ou de marché 5=autres foyers 6= Autre	7. Où avez-vous vendue cette production? 1=auto consommation 2=marché local 3=autres marchés 4=contrat de vente 5=Autre

CODES animaux	Nom	CODES animaux	Nom	CODES animaux	Nom	CODES animaux	Nom
01	Poules	02	Bovins	03	Porcs	04	Pintades/Dindes
05	Moutons	06	Chèvre	07	Chevaux	08	Anes
09	Lapins	10	Oies	11	Chameaux		

49. Quelle source d'eau avez-vous utilisé durant l'année écoulée pour l'abreuvage de votre troupeau?

Source d'Irrigation	1= OUI, 2= OUI, mais je ne sais pas en quelle quantité 3=NON	**Si QUI (1)** M3/année dernière (estimation)
1. L'eau de la rivière Mekrou		
2. Puit privé/forage		
3. Autre source d'eau de surface		
4. Autre, specifier:		

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

50. Pratiquez-vous la pêche ?

1. Oui		2. Non	

51. Si OUI, quel type de pêche ?

1. industrielle	
2. traditionnelle	

52. Si NON, à quel type de désagrément faites-vous face ?

1. Insuffisance d'eau	
2. Conflit d'usage de l'eau entre les éleveurs et les maraichers	
3. On se retrouve en même temps au niveau du fleuve	

53. Avez-vous connaissance d'associations de chasseurs et/ou de pêcheurs qui s'activent autour du bassin de la Mekrou ?

1. Oui		2. Non	

54. Existe t-il à votre connaissance une des associations suivantes dans votre village?

1. Association des usagers de l'eau	
2. Association agricole/d'agriculteurs	
3. Une coopérative agricole de femmes	

55. **(Répondre seulement dans le cas où le répondant est une femme)**. Si vous avez indiqué au moins qu'une association est présente dans votre village, précisez votre niveau d'implication dans les actions/interventions de cette (ces) association (s)

	1=Pas impliqué	2=Un peu impliqué	3=Fortement impliqué
Association des usagers de l'eau			
Association agricole/d'agriculteurs			
Une coopérative agricole de femmes			

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

V-SERVICES FOURNIS PAR LES ECOSYSTEMES

56. Quel niveau d'importance attribuez-vous aux services fournis par les écosystèmes aquatiques de la Mekrou sur une échelle de 1(pas important) à 5 (très important) : !!! Un service écosystémique ou fourni par les écosystèmes est defini comme l'eau mise à disposition par la Rivière Mékrou afin de satisfaire les besoins d'eau de boisson, de l'agriculture et l'élevage, pour la préservation des animaux, des poissons, et de la végétation/foret vivant sur le bassin versant.

	1	2	3	4	5
1. Eau de consommation pour les espèces et les animaux					
2. Provision d'un habitat/abri pour les espèces					
3. Eau de consommation pour les humains					
4. Source d'eau à usage agricole					
5. Cadre nécessaire à la biodiversité					
6. Protection contre les inondations et sècheresse					
7. Autre, spécifier:					

57. Est-ce important pour vous de bien gérer et protéger le bassin versant de la Mekrou? La zone correspondant au bassin versant de la Mekrou est disponible en page 2

1. Important (**aller à la question 58**)	
2. Pas important (**aller à la question 59**)	
3. Sans opinion (**aller à la question 60**)	

58. Si vous avez répondu à la **question 57** IMPORTANT, spécifiez en pourquoi l'écosystème de la rivière Mékrou est important? (sélectionnez 1 seule réponse)

1. il existe de bas-fonds qui absorbent l'eau et la restituent plus tard.	
2. il permet l'agriculture et la production de nourriture	
3. Il minimise les inondations et les sècheresses	
4. Ils améliorent la qualité de l'eau	
5. Il permet un approvisionnement en eau durable/pérenne	
6 .Il préserve la destruction des forets et de la nature	
7. Autre, spécifier:	

59. Si vous avez répondu à la **question 57** PAS IMPORTANT, spécifiez en pourquoi cela n'est pas important? (sélectionnez 1 seule réponse)

1. Cela n'affecte pas mon foyer directement	
2. Je ne crois pas à leurs rôles dans l'amélioration de l'approvisionnement en eau	
3. Je ne vois pas le lien entre la protection des écosystèmes et l'approvisionnement en eau.	
4. Autre, spécifier:	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

60. Selon votre opinion, quelle est la qualité de l'eau de la riviere Mekrou (hors eau de boisson) ?

1.Mauvaise		2. Moyenne		3. Bonne		4. Excellente		5. Je ne sais pas	

61. Selon vous, la qualité de l'eau de la Mekrou s'est améliorée ou dégradée ces 10 dernières années?

1. Améliorée		2. Pas de changement		3. Dégradée		4. Je ne sais pas	

62. Quelle est la principale menace à laquelle la rivière Mekrou fait le plus face? **1 réponse seulement**

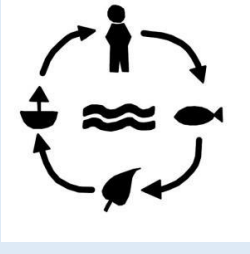
1. Ensablement (action des hommes)	
2. Envasement/sédimentation.	
3. Pollution	
4. Assèchement	
5. Autre (spécifier):	
6. Je ne sais pas	

63. Connaissez-vous le Parc W et son importance écologique?

1. Oui		2. Non	

64. Combien de fois avez-vous visité le Parc W?

1. Plus de 12 fois par an	
2. Entre 6 et 12 fois par an	
3. Entre 1 et 5 fois par an	
4. Je l'ai visité moins d'une fois par an	
5. Je ne l'ai jamais visité	



Scénario d'évaluation: Dans un scénario hypothétique, les gouvernements des trois pays (Benin, Burkina Faso, et Niger) dans lesquels se situe le bassin versant de la MEKROU décident de mettre en œuvre un Programme pour la Gestion des ressources en EAU (PGEAU). Celui-ci sécurisera la ressource en eau dans le bassin de la Mekrou pour les 20 prochaines années. Si ce programme est mis en œuvre, il y aura assez d'eau pour subvenir aux besoins :
- des animaux,
- des milieux (forêt, flore, végétation)
- des populations qui dépendent de l'eau de la rivière Mekrou.

Afin de pouvoir financer le PGEAU, il serait nécessaire que, vous, comme **chaque foyer dans** ces 3 pays (Burkina Faso, Benin et Niger) **paye une redevance forfaitaire annuelle** qui serait collectée par les 3 ministères de l'eau respectifs. L'argent sera utilisé exclusivement pour la gestion durable des ressources en eau du bassin de la Mekrou à travers du Fond PGEAU dédié.

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

65. Seriez-vous d'accord pour que **chaque foyer dans ces 3 pays paye une redevance forfaitaire annuelle** afin de financer le PGEAU ?

1. Oui		2. Non	

66. Si vous avez répondu NON, pouvez-vous en indiquer la raison principale? **(une seule réponse possible)**

1. Je ne pense pas que la protection de la Mekrou le nécessite	
2. Je ne peux pas me permettre de payer une redevance additionnelle à ce que je paye actuellement	
3. Je pense que c'est au gouvernement de financer le PGEAU	
4. Je ne fais pas confiance aux institutions en charge de gérer les fonds du PGEAU	
5. Je ne pense pas que la fiabilité de l'approvisionnement en eau soit importante	
6. Je ne crois pas que payer cette redevance va améliorer la gestion de la rivière	
7. Je ne crois pas le PGEAU permettra un approvisionnement plus fiable et donc un meilleur usage de l'eau	
8. Seulement les ménages les plus aisés devraient payer	
9. Autre raison, spécifié:	

67. Si vous avez répondu OUI, pouvez-vous indiquer le montant maximum que vous seriez prêt à payer par an ?

1. 50 FCFA	
2. 100 FCFA	
3. 200 FCFA	
4. 300 FCFA	
5. 500 FCFA	
6. 750 FCFA	
7. 1,000 FCFA	
8. 1,500 FCFA	
9. 2,000 FCFA	
10. 3,000 FCFA	
11. 4,000 FCFA	
12. 5,000 FCFA	
13. 10,000 FCFA	
14. Plus de 10,000 FCFA	

68. Distribuez le MONTANT INDIQUE à la **question 67** aux sous catégories suivantes:

	%
1. Protection des services fournis par les écosystèmes	
2 .Approvisionnement en eau à usage domestique	
3. Approvisionnement en eau pour l'irrigation des cultures	
4. Autre, spécifié:	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

VI- EVENEMENTS EXTREMES ET STRATEGIES DE REPONSE

69. Durant les 10 dernières années, avez-vous noté des changements en termes de:

1. Quantité de pluie? 1=pas de changement 2=moins de pluie 3=plus de pluie	
2. Distribution des pluies sur l'année? 1=pas de changement 2=meilleure distribution 3= distribution moins adéquate	
3. Fréquence plus élevée de sécheresses? 1=OUI 2=NON	
4. Fréquence plus élevée d'inondations? 1=OUI 2=NON	
5. Retard de l'arrivée de la saison des pluies? 1=OUI 2=NON	
6. La saison des pluies se termine plus tôt? 1=OUI 2=NON	
7. Périodes de forte chaleur? 1=pas de changement 2=Plus courte 3=plus longue	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

70. A cause du changement climatique (température, pluie), votre foyer ou un membre de celui-ci, a t'il adopté une des stratégies suivantes depuis les 10 dernières années?

Stratégie	**a. Température (OUI=1/NON=2)**	**b. PLUIE (OUI=1/NON=2)**
1. Changer de variétés de semences		
2. Terrasser le sol ou utiliser une autre technique pour limiter l'érosion		
3. Opter pour des cultures contre-saison		
4. Planter des arbres		
5. Irriguer de manière plus intensive		
6. Elever moins de bétail afin d'augmenter les surfaces cultivées		
7. Elever moins de petits ruminants pour passer à l'élevage de bovins		
8. Elever moins de bovins pour passer à l'élevage de chameaux		
9. Adopter des techniques spécifiques pour régénérer la couverture végétale nécessaire au bétail		
10. Elever moins de moutons pour passer à l'élevage de chèvres		
11. Migration de certains membres du foyer		
12. Pratiquer des activités non agricoles plus fréquemment (diversification des revenus)		
13. Location ou hypothèque		

71. Changements récents durant l'année écoulée (Jan 2015 – Déc. 2015)

1. Selon vous, comment qualifieriez-vous le début la saison des pluies **cette année**?	1=En avance 2=Normal 3=Tardive		
2. Durant quel mois la saison des pluies a-t-elle démarrée **cette année**?	01=Janvier 02=Février 03=Mars 04=Avril 05=Mai 06=Juin 07=Juillet 08=Aout 09=Septembre 10=Octobre 11=Novembre 12=Décembre		
3. Quelle est votre sentiment par rapport à la quantité de pluies de **cette année**?	1 = Plus faible que la moyenne 2 = juste un peu plus faible que la moyenne 3 = dans la moyenne 4 = juste un peu plus élevé que la moyenne 5 = Plus élevé que la moyenne 6 = Je ne sais pas		
4. Durant quel mois avez-vous eu le plus de pluie **cette année** ?	01=Janvier 02=Février 03=Mars 04=Avril 05=Mai 06=Juin 07=Juillet 08=Aout 09=Septembre 10=Octobre 11=Novembre 12=Décembre		

72. Combien d'inondations et de sècheresses avez-vous affronté ces 10 dernières années?

Nombre d'inondations:	
Nombre de sècheresses:	

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-195
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 20 June 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

73. Avez-vous subi une inondation majeure liée à la Mékrou ces 2 dernières années?

1. Oui		2. Non	

74. SI oui, quelles ont été les conséquences pour votre foyer (**plusieurs réponses possibles**):

1. Dégâts sur la maison	
2. Dégâts sur les appareils électriques et le mobilier	
3. Perte de production agricole	
4. Blessure ou décès d'un des membres du foyer	
5. Perte de bétail	
6. Autre, spécifier:	

75. Quelle est votre estimation des dégâts de cette inondation en termes de coûts?

_____ (FCFA)		2. Je ne sais pas	

76. Dans quelles proportions pensez-vous avoir retrouvé votre situation d'avant cette inondation?

1. 0-20%		2. 20-40%		3. 40-60%		4. 60-80%		5. 80-100%	

77. Avez-vous subi une sécheresse majeure liée à la Mékrou ces 2 dernières années?

1. Oui		2. Non	

78. SI OUI, quelles ont été les conséquences pour votre foyer (**plusieurs réponses possibles**):

1. Perte de production agricole	
2. Malnutrition d'au moins une personne de votre foyer	
3. Perte de bétail	
4. Autre, spécifier:	

79. Quelle est votre estimation des dégâts de cette sécheresse en termes de coûts?

_____ (FCFA)		2. Je ne sais pas	

80. Dans quelles proportions pensez-vous avoir retrouvé votre situation d'avant cette sècheresse?

1. 0-20%		2. 20-40%		3. 40-60%		4. 60-80%		5. 80-100%	