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Standardized Precipitation Index (SPI)-Based Flood and Drought Hotspot Mapping in Niger, West Africa

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Abstract

Niger is a Sahelian territory in West Africa, with a surface area of 1,267,000 km². Most of it is desert, sparsely populated, or uninhabitable, with a low population density of around 18 inhabitants per km². The adverse effects of climate change and the frequency and intensity of natural disasters are increasing, while the country is evolving in a context characterised by a lack of and/or limited access to detailed, reliable, and up-to-date data, useful for better risk and disaster management. The methodological approach was based on the use of the agroecological map of Niger offering four main zones (Sudanian, agropastoral, pastoral and desert), the calculation and projection on this map of the Standardized Precipitation Index (SPI) of 3935 localities based on the rainfall proxy data series (1979-2035), and then the identification of zones impacted by extreme climatic events. The populations impacted in these identified areas are estimated by projecting onto these areas the updated population of more than 36,000 georeferenced localities in ReNaLoc. The result of this approach shows that it is possible to opportunely identify zones and collect key data for use in the disaster risk management process in the context of a country where data is difficult to acquire.

Keyword: *Floods, Droughts, SPI***,** *Extreme event, Risk Management Parameter, Characterisation, Impact, Niger.*

Introduction

Niger is a vast, landlocked country in the arid Sahel region of West Africa, covering an area of 1,267,000 km². Most of its territory is desert, sparsely populated, or uninhabitable, with a low population density of about 18 inhabitants per km² [1]. As a result of climate change, the frequency and intensity of natural disasters have increased [2-4].

Therefore, the country is faced with extreme events that often cause natural disasters, the impact of which is exacerbated by the vulnerability and exposure of the population. Drought, recurrent flooding since 2000, and locust invasion are the main hazards, factors, and causes of the catastrophic events observed in the country. So much so that during the same wet season, rare rainfall events can unexpectedly cause flooding, resulting in major damage in some localities, while in others, long dry spells can affect agricultural production, resulting in major food shortages [5, 6].

Between 1986 and 2020, some 56 disasters were reported in Niger. Most of these were droughts, floods, and epidemics, causing 10,384 deaths and affecting 28.2 million people [6-10]. Droughts accounted for 89% of the population affected by disasters, while epidemics were responsible for the majority (94%) of deaths in the country [1].

However, although they affect a small proportion of the population and are less deadly,

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floods have been a major threat to Niger in recent years. The human and economic consequences of flooding have been considerable and could be even greater in the future.

Although economic impact data are not readily available for all past floods, negative impacts on populations, housing, and the agricultural sector have increased significantly since 1998 and are exacerbated by practices such as unauthorized construction in flood-prone areas and near water points, and/or the dumping of solid waste in primary, secondary, and tertiary drainage infrastructure networks [8, 11-13].

The climatic shocks recorded in Niger also have exacerbating effects on poverty. According to surveys conducted in 2011 and 2014, households identified drought and floods as the main cause of widespread poverty (33%), while households experiencing income shocks due to drought or floods are 4 percentage points less likely to see their children attend school [8].

Thus, the country regularly faces disaster crises in a context characterized by (i) either a lack of detailed, reliable, and up-to-date data on food security, nutrition, vulnerability, and the standard mechanisms used to adapt to shocks or (ii) limited access to some of these data remains a challenge [10], [14].

This is a major constraint, leading to a lack of relevant data, which hampers proper analysis of the situation on the ground and makes it difficult to draw up risk and vulnerability maps. It also hampers the process of developing timely, identified, and effective responses and makes it difficult to anticipate the response, explains why, for a long time the national effort was essentially to react to disasters rather than prevent them [15, 16].

At the institutional level, an evaluation of performance of the institutional mechanisms and arrangements in place in relation to disaster risk reduction, conducted in 2018 [17], did highlight certain shortcomings, including: (1) the failure to adopt additional implementing legislation to make certain laws effective operational, (ii) the persistence of duplication between texts to the extent that several tools and institutions they have implemented overlap, (iii) the failure to take disaster risk reduction into account in environmental impact assessment and (iv) the failure to formalize the results of certain experiments that have proved their effectiveness in disaster risk management [17, 18].

It is obviously necessary to move away from an approach to disaster risk management that consists of reacting when disasters occur by focusing on emergency responses rather than promoting preventive interventions and minimizing the consequences. The country should focus on producing quality data and strengthening the institutional mechanism to put in place a reliable system with appropriate methods for collecting and making available data, strengthening the mechanism for processing this data and producing information to revitalize the early warning system and any other prevention mechanism.

A possible improvement to the current state of affairs is to develop a methodology that will help identify the impacts of droughts and floods a better spatial resolution than current governmental products.

The SPI-based identification of extremely wet and dry years approach will be based on easily accessible data (remote-sensed precipitation, population data) and generate estimates of affected populations. can be applied to past disasters and strengthen our understanding of these risks, identify hotspots that will be under increased surveillance when a flood or drought is imminent or ongoing.

The objective of this paper is to develop a simple methodology to identify extremely wet and extremely dry years using the Standard Precipitation Index (SPI) and then map the impacts for the driest and wettest year between 1979 and 2020.

The benefits of the generated information and avenues for generating even more useful risk products for disaster risk management in Niger are then discussed.

Methods

The Standardized Precipitation Index (SPI) is used to identify extremely dry or extremely wet years. Based on year-by-year mapping of these events, the principle is to identify areas affected by extreme climate events and to use them as an area to extract the physical and socioeconomic parameters needed for disaster risk management.

Approach and Sites Selection

The approach adopted is an entry by agroecological zone of Niger [8] for the targeting of localities where secondary data on rainfall and runoff will be collected [19]. In each agroecological zone selected, the targeted localities were those for which the capitalized data cover a period of 44 years (1979-2022). The research was conducted by using the Standardized Precipitation Index (SPI) to spatialize climate risk profile of the selected area of the country by assessing floods risk and droughts recurrence at each of the 3935 geolocated villages of more than 1000 inhabitants in the country.

Rainfall Data

A long series of proxy rainfall data has been collected from NASA open data. This series covers 3935 localities geo-referenced by ReNaLoc and targeted based on their demographic weight (villages with more than 1000 inhabitants in 2022) [20]. Based on the extraction of satellite data provided by International Research Institute for climate and Society [19], annual rainfall amounts were calculated for each locality from 1979 to 2022.

Calculation of SPI and Characterization of Years with Extreme Events

The characterization of years of extreme climatic events is based on an analysis of the standardized precipitation index (SPI). Since it is standardized and can be used for both wetter and drier climates, it has been used to identify years of low precipitation (drought) as well as wet years. To make this assessment, proxy rainfall heights were collected from 1979 to 2022, covering 3,935 localities, including 88 localities in Sudanian zones, 3,271 in agropastoral zones, 554 localities in pastoral zones and 22 localities in desert zones. The SPI was calculated based on annual rainfall from 1979 to 2022, using the formula as follows:

$$SPI = \frac{(x - \mu)}{\sigma}$$

Where:

x *is the amount of precipitation recorded in a given period,*

μ *is the mean precipitation over the same period, and*

σ *is the standard deviation of the precipitation over the same period.*

This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the average SPI for the desired location and period is equal to zero [19, 20]. Positive values of the SPI indicate precipitation above the median and negative values indicate precipitation below the median. As the SPI index is standardized, wetter and drier climates have been represented in the same way in this characterization of extreme events [21].

The characterisation approach is in line with McKee et al [22], who used the classification system shown in the table of SPI values below (Table 1) to define the drought intensities resulting from the SPI. They also defined the criteria for a drought event for each time scale selected. Thus, a drought event occurs whenever the SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive again. Each drought episode therefore has a duration defined by its start and end, and an intensity for each month during which the episode continues. Depending on whether the value is negative (drought) or positive (humidity), its trend is used in accordance with the classification in Table 1 to determine dry and wet years.

Table 1. SPI Values and Class Events

Class	Event
2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-0.99 to 0.99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

Source: WMO, manual, 2012

The years with extreme events were identified by combining the average annual SPI calculated at global level and by agroecological zone. The list of years affected by these extreme events, based on climatic analysis using the SPI, was also compared with the list drawn up by the technical services based on disaster events history since the 1970s.

Identifying Zones of Impact of Climatic Events and Projection of Secondary Data

Impact zones were identified using maps based on the calculated average SPI [1, 9, 10, 18], and the maps obtained served as a basis for this identification. From these maps, the years to be considered are selected based on the extreme or close degree of the event, and the identified years are used to delimit the impact zones of extreme climatic events and to extract the data relating to the impact of the extreme events that have occurred.

Based on the projection of ReNaLoc data [20], georeferenced villages and their updated populations are projected into the selected zones, from which data extraction can also make it possible to specify their municipal affiliation. For areas marked by extreme humidity, geomorphological and hydrographic characterization data is also used, as a means of extracting data that provide information on flood risks. This identifying is carried out using the parameters below.

1. **Extreme aridity:** The value of negative SPI less than -1.5. These values are calculated according to the standard formula to determine SPI, which is = $(x - \mu) / \sigma$ (x is the amount of precipitation recorded in a given period, μ is the mean precipitation over the same period and σ is the standard deviation of the precipitation over the same period) (Table 2) [21-23].
2. **Extreme humidity**: Positive SPI value greater than +1.5. In contrast to aridity, all positive values greater than 1.5 are points of extreme humidity. They are also determined using the same SPI calculation formula as above.
3. **Extreme event impact zones**: All zones where projected SPI values are less than -1.5 for aridity zones and greater than +1.5 for humidity zones. The perimeters of these zones and their estimated surface areas.

Determining Key DRM Parameters and Extracting Relevant Data

The adopted principle is to determine disaster risk management parameters based on the impacted area. These parameters will encompass both information for the early warning system and data for preparing and anticipating the response to crises. To summaries, the above approach is applied to each of the parameters, depending on whether the primary data is calculated or extracted and the secondary data to be collected:

Primary Data Calculated and/or Extracted

1. **Extreme event impact zones**: All zones where projected SPI values are less than -1.5

for aridity zones and greater than +1.5 for humidity zones. The perimeters of these zones and their estimated surface areas.

2. **Geomorphological and hydrographical characteristics**: The topographic layers showing the relief and the hydrographic network will also be projected in the circumscribed impact zones to allow a more detailed analysis of the risk of flooding.
3. **Projected population**: For the selected year, the population is updated based on ReNaLoc data, 2012 [20] according to the formula below and projected onto the map of impact zones using the georeferencing of localities provided by ReNaLoc.
   $C_N = C_0 \times (1+X)^{N.}$
   X = rate of increase,
   N = number of years,
   C = population
4. **Population vulnerability**: This can be derived from the most recent proxy secondary data obtained from the survey of sentinel sites monitored by the Early Warning System Coordination Unit (CC/SAP) [7].

Secondary Data to be Collected

1. **Farm characteristics**: this will involve collecting data from the country's agricultural statistics services on the size of agricultural/pastoral farms according to the location of the impact zone in the country's agroecological zoning, the physical agricultural area per household, average crop/feed yields, cropping systems, etc.

Statistical Methods Used

Descriptive statistics were used to complete the analyses of the calculated SPI values or other parameters [24].

Results

The SPI was used to characterize the years and areas affected by extreme weather events. The use of the values of this index, calculated on the basis of average annual rainfall over the series from 1979 to 2022, is based on the verification of the hypothesis that, its average values for all 3935 geo-referenced sites and its disaggregation to the scale of the agroecological zones selected make it possible (i) to characterize the years and screen those affected by extreme events and (ii) to identify and analyze, according to the years targeted, the zones of impact of extreme events and identify the rational procedures for effective and objective evaluation of the impacts of these elements.

Characterisation of Extremely Wet and Extremely Dry Years

Based on the overall averages of the SPI calculated for all the sites and those of the sites divided by agroecological zone [5] previously selected, the years were first classified according to whether they were extremely wet or extremely dry according to the event class of the World Meteorological Organization [21]. The occurrence of extreme weather events is calculated for each year, which makes it possible to determine the number of times the same year occurs in different agroecological zones. The years marked by extreme humidity events (extremely wet to very wet) and those marked by dry events (extremely dry to severely dry) were selected. The table below gives a list of *eleven* years in the series from 1979 to 2022, two of which are particularly dry (1984 and 1987) and *nine (9)* of which are wet. Of these, seven are extremely wet (1994, 2014, 2015, 2017, 2019, 2020 and 2022) and two are very wet (1999 and 2012).

Table 2. Years with Occurrence of Extreme Events

Years	Occurrences' extreme events				
	Extremely wet	Very wet	Severely dry	Extremely dry	Occurrences
1984	-	-	3	1	4
1987	-	-	1	-	1
1994	1	2		-	3
1999	-	4	-	-	4
2012	-	3	-	-	3
2014	1	-	-	-	1
2015	1	-	-	-	1
2017	1	-	-	-	1
2019	1	-	-	-	1
2020	1	-	-	-	1
2022	1	-	-	-	1

Sources: SPI from data by agroecological zone, in Niger

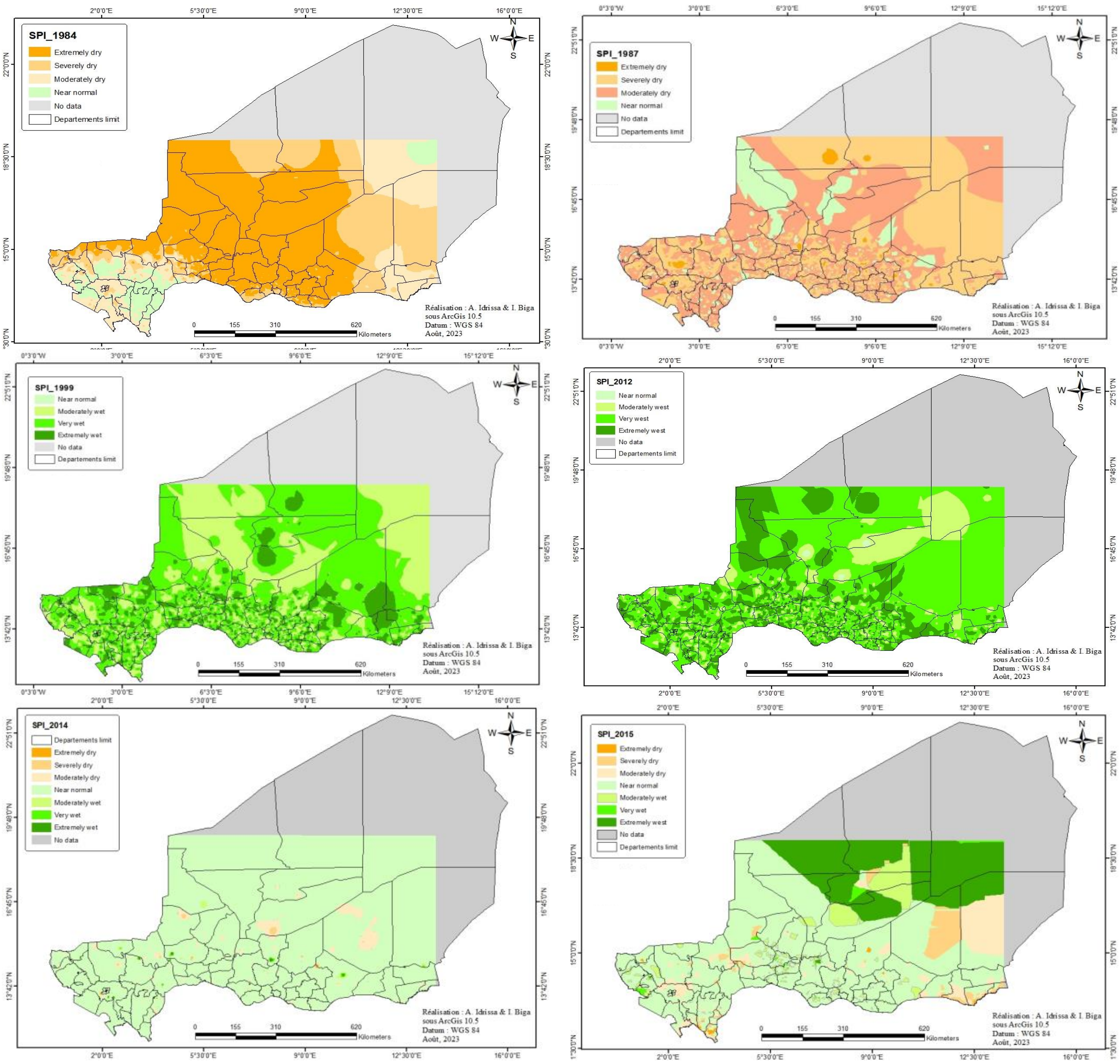

Figure 1. Geolocation of Areas Affected by Extreme Events in Niger in 1984, 1987, 1999, 2012, 2014 and 2015

Identification of Impact Zones According to the Years Characterized

The characterization of the years carried out based on the calculated SPI values made it possible to target eleven years affected by extreme events as illustrated in table 2 above. For each of these years, an in-depth analysis is carried out based on the graphical representation of the SPI calculated for all the sites selected as part of this study. As these sites were georeferenced, annual spatialization maps were drawn up with the calculated SPIs. On each of the maps drawn up, the areas affected by extreme drought and/or flood risk events were marked as shown in figure 2. Then surface areas, administrative location at municipal scale and populations affected were estimated.

Another level of characterization involved estimating the areas impacted by extreme events in each of the years targeted. This estimate covered 648,212 km^2, i.e., more than half of Niger's land area, but covering *at least* 98% of the country's agricultural and pastoral land.

Table 3. Area by Year and by Event Class as a Percentage of the Total Area Covered by the Study

Year	Area extremely dry (km^2)	Area very dry (km^2)	Area very wet (km^2)	Area extremely wet (km^2)
1984	-	15.09%	2.44%	0.98%
1987	21.35%	29.11%	1.77%	1.62%
1994	5.99%	36.10%	3.45%	0.90%
1999	31.08%	19.93%	1.94%	1.14%
2012	42.04%	14.24%	2.04%	1.34%
2014	36.01%	23.28%	2.20%	1.14%
2015	29.84%	27.41%	2.24%	1.34%
2017	33.61%	21.17%	1.68%	1.50%
2019	36.06%	23.13%	1.64%	1.63%
2020	34.12%	26.40%	2.28%	1.21%
2022	31.67%	24.32%	1.88%	1.68%

Identifying Representative Years According to the Impact of Extreme Events

Although, a priori, any year can be used to carry out this approach, the most representative years to be used as a basis for the present analysis were identified on the basis of the characterization of the years carried out [16] using the standardized precipitation index and the updated population projection from ReNaLoc [20], which allowed us to estimate the populations affected in each locality according to the class of extreme climatic event. The option is to carry out this process over two identified years from among the eleven years screened [16] in the series from 1979 to 2022. For this purpose, the years marked by the most extreme impacts of aridity and humidity are chosen to ensure that the two most frequent hazards in Niger, namely drought and floods, are addressed. The combined use of the rainfall index and the projection of the updated number of inhabitants to extract the impacted populations made it possible to identify the years 1984 and 2012, which have been two typical years for extreme events in Niger since 1979. 1984 was a particularly arid year, with 70% of the country's population affected by aridity, while 2012 was a particularly wet year, with 86% of the population affected and exposed to the risk of flooding, as shown in Table 4 and Figure 2 below.

Table 4. Populations Affected by the Extreme Event Class

Year	Event	Number of localities	Population affected (x1000)	Number of households (x1000)	% of households affected
1984	Extremely dry	16,286	3,700	529	55
	Severely dry	4,619	973	139	15
	Moderately dry	5,348	1,141	163	17
	Near normal	5,418	886	127	13
	Total	31,671	6,700	957	100
2012	Near normal	162	75	11	0
	Moderately wet	4,529	2,272	325	13
	Very wet	16,931	8,987	1,284	53
	Extremely wet	10,040	5,580	797	33
	Total	31,662	16,914	2,416	100%

Source: Calculated data

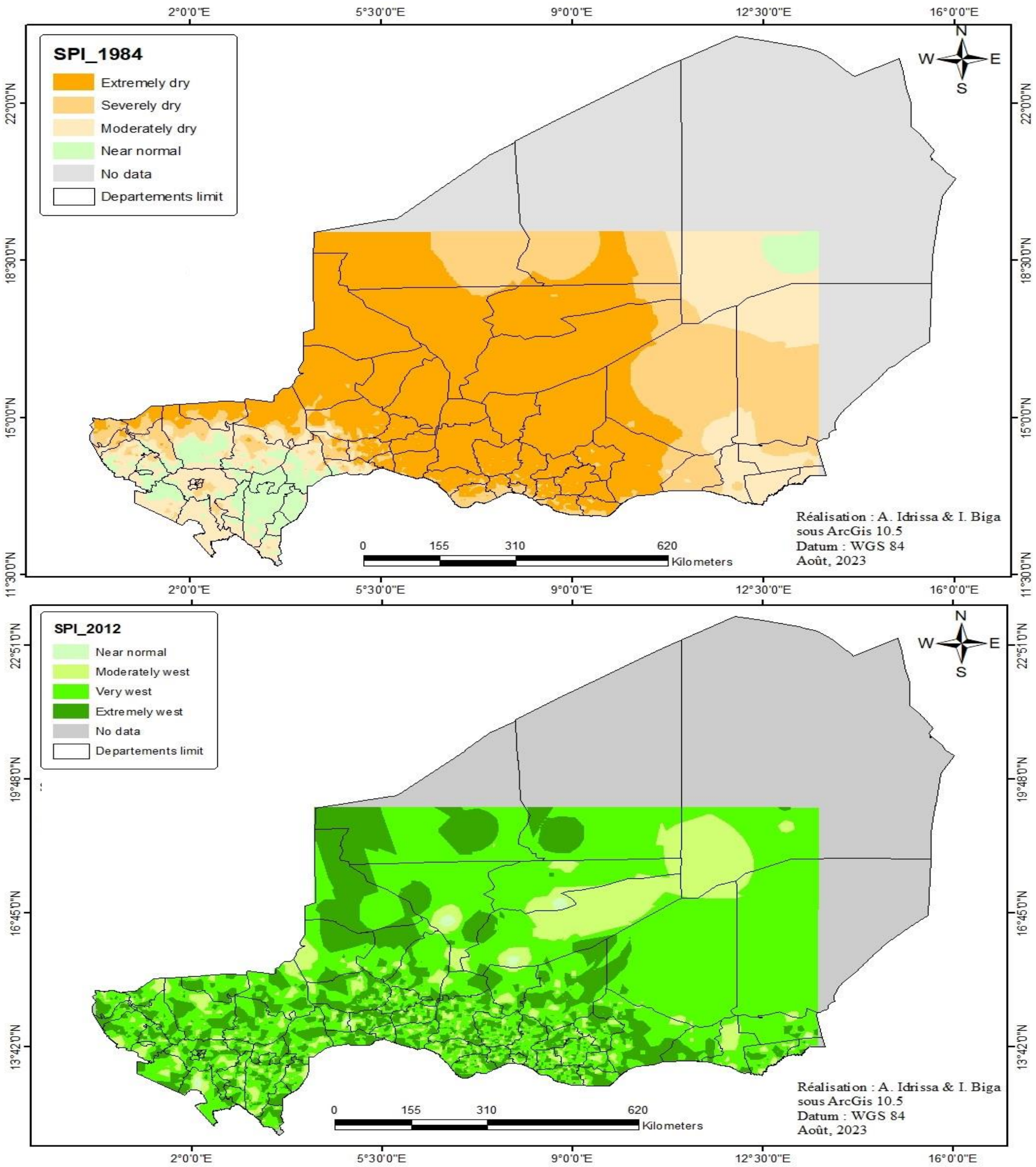

Figure 2. Years Selected (1984, 2012) for Application of the Data Analysis Approach

Impact Zones for Climatic Events and Projection of Secondary Data

The identification of impact zones for extreme climatic events was based on the two years 1984 and 2012. Thus, based on the mapping carried out with the SPI calculated from annual rainfall data over the long series from 1979 to 2022 collected from nearly 4,000 georeferenced villages in Niger. These maps were used to delimit the zones impacted by extreme events according to the class established [21]. They also served as a projection medium for other types of georeferenced information, namely the population updated from ReNaLoc 2012 [20], the administrative boundaries of the regions, departments, and communes, the surface area of georeferenced localities, and the mapping of the hydrographic network. Thus, based on the maps for the two reference years (1984 and 2012), the areas of the territory impacted by extreme and severe aridity events on the one hand and extreme and intense humidity events on the other are identified (Figure 2).

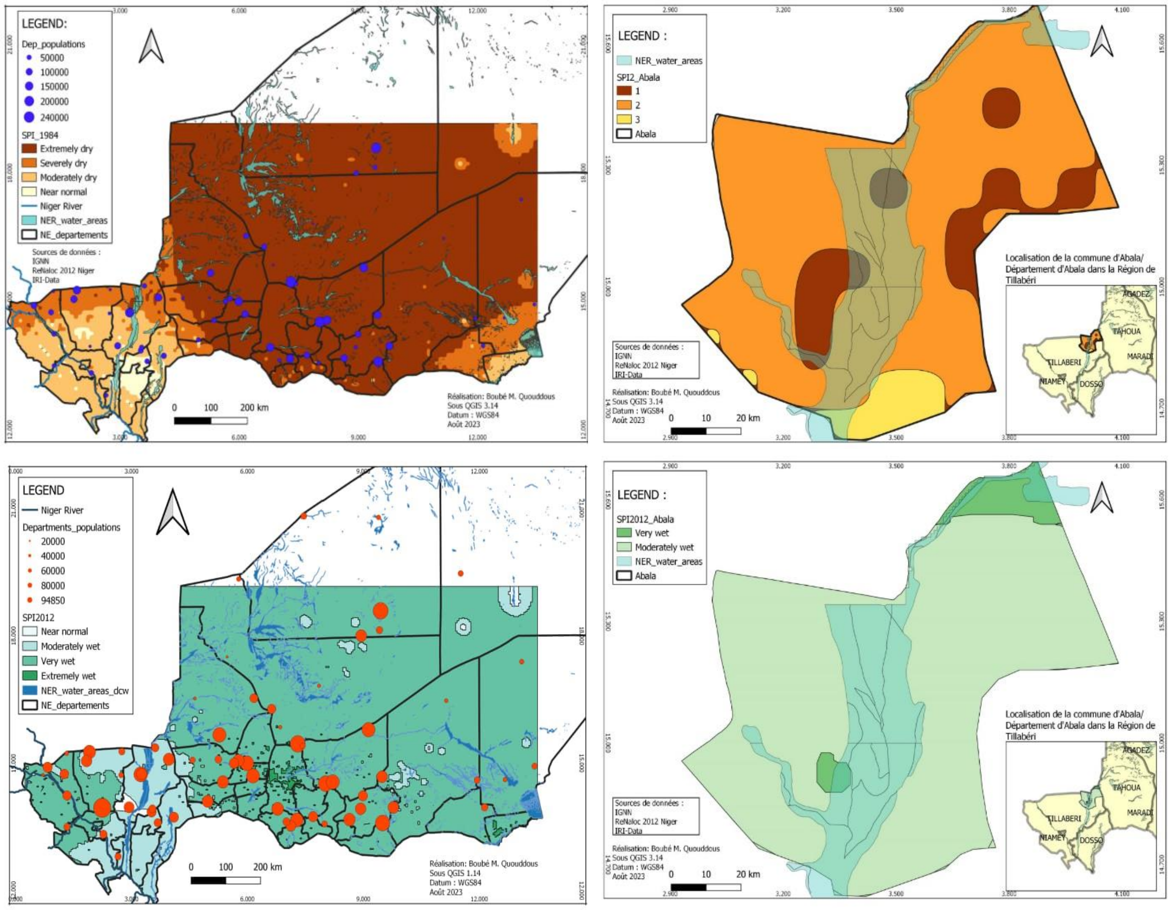

Figure 3. Mapping and Delimitation of Zones of Extreme Events and Populations Affected for 1984 and 2012

Extreme Event Impact Zones

The delimitation of extreme event impact zones is the key phase in this process. To do this, it is necessary to collect rainfall data collected and a map of the administrative boundaries. These data may be observation data, where a dense rainfall network is available, and/or estimated data, as in the case used in this analysis, where it was possible to extract estimated rainfall data from georeferenced data in nearly 4,000 localities in Niger [20]. These localities are also classified according to the agroecological zones [8] defined in the country to add a dimension of spatial analysis. The rainfall data collected, whether from the national observation network and/or extracted proxies, will have to be organised in appropriate time steps to meet the need to produce information for rapid and/or early warning. For the purposes of this analysis, the annual time step has been considered, but the decadal or monthly time steps would be more relevant and would make it possible, at the end of each time step, to calculate standardized rainfall indices and to circumscribe the zones of impact of climatic events according to whether the zone is extremely arid, normal, or extremely humid. This mapping allows one to assess the extent and location of events as a basis for analysis and data collection, as illustrated in Table 4. It should be noted here that disaggregation is possible down to locality level using secondary data from the country's geographic information system. However, to have a more precise level of analysis, it is important, as mentioned above, to have as short a time step as possible. In the case of Niger, this time step could be a decade, which would make it possible to cross-reference the analyses with those of other products already in place.

At the scale of the zones identified with extreme climatic events with impact, it is essential to have data on the geomorphological and hydrographical characteristics to superimpose them to enable another level of analysis linked to exposure, particularly about zones of extreme humidity and, therefore, at risk of flooding. As part of this analysis, the hydrographic network of Niger was used to complete the mapping carried out based on the standardized rainfall index, and the Niger localities were used to extract localities located in extremely wet areas.

Table 5. Area by Year and by Event Class Affected

Year	Event	Number of localities	Area (km^2)
1984	1-Extremely dry	16,286	385,233
	2-Severely dry	4,619	194,381
	3-Moderately dry	5,348	138,569
	4-Near normal	5,418	47,454
2012	4-Near normal	162	3,488
	5-Moderately wet	4,529	115,917
	6-Very wet	16,931	463,143
	7-Extremely wet	10,040	183,180

Source: Calculated data.

Population affected: The population affected under this approach can be determined by updating data from ReNaLoc, 2012 [11] using the formula:

$C_N = C_0 \, x \, (1+X)^{N.}$

X = rate of increase,

N = number of years,

C = population.

This formula was used to update the number of inhabitants to be considered for each of the two years selected, 1984 and 2012. The estimate is made for all 32,000 georeferenced localities in ReNaLoc. The updated data are projected onto a map based on the standardized precipitation index calculated on an annual time scale but could also be calculated on a decadal or monthly time scale depending on the quality and sensitivity of the information required. The information extracted from the affected population can be used as a basis for preparing the emergency response if it is analysed immediately at the end of the campaign. This SPI-based identification of extremely wet and dry years approach makes it possible to identify the localities affected, the populations affected, and their administrative affiliation.

Table 6. Population Affected by Year and Event Class

Year	Event	Number of localities	Population
1984	1-Extremely dry	16,286	3,699,807
	2-Severely dry	4,619	973,323
	3-Moderately dry	5,348	1,141,173
	4-Near normal	5,418	886,006
2012	4-Near normal	162	75,205
	5-Moderately wet	4,529	2,271,869
	6-Very wet	16,931	8,986,492
	7-Extremely wet	10,040	5,579,887

Source: Calculated data

Also, based on the data collected on the affected population, a demographic analysis can be carried out (age, sex, marital status, income or poverty level, level of education and employment status), for which the type of property and the area can provide a useful approximation for the identified community based on the impact of extreme climatic events. It can also be used to conduct in-depth analyses of the identify population in terms of vulnerability and resilience capacity [27]. This, combined with other impact parameters, particularly agropastoral production, can be used to develop a detailed impact assessment for each commune and locality. For this, the secondary data analysed by the early warning system coordination unit [16] and the agricultural statistics services can help provide proxies for all the identified localities, but, if necessary, new surveys can be used to refine the situation.

The SPI-based identification of extremely wet and dry years approach used to characterize and target years based on the extreme climatic events experienced and determined by using the calculated average value of the global SPI and at the agroecological area level, gives results demonstrating the similarity between the years characterized according to this approach and those documented according to the history of disasters in Niger [12]. Of the eleven years characterized according to the calculated SPI, there is a concordance with those listed in the history of natural disasters recorded in Niger since 1904 [17]. This concordance [Table 7] therefore proves the relevance of the approach used to target the eleven years selected for this study and confirms the coherence of the characterization work of the zones and impacts of extreme climatic events to be carried out according to the approach.

Discussions

Table 7. History of Disaster and Extreme Events in Niger

Climatic hazards recorded	Year	Extreme event characterized
Drought	1984	Severely dry
-	1987	Severely dry
Flood	1994	Extremely wet
Flood	1999	Very wet
Flood	2012	Very wet
-	2014	Extremely wet
-	2015	Extremely wet
Flood	2017	Extremely wet
Flood	2019	Extremely wet

Flood	2020	Extremely wet
Flood	2022	Extremely wet

Source: history of disasters in Niger and characterization of extreme events

This approach also makes it possible to carry out a more detailed analysis for each targeted year and provides relevant data that can be used to feed into risk and disaster management mechanisms. In this case, the use of georeferenced data from ReNaLoc, 2012, combined with the mapping of SPI values calculated from the average rainfall estimated for almost 4,000 localities taken from ReNaLoc, enabled us to target the areas affected depending on whether it was an extreme drought and/or wet event (Figure 2). The in-depth analysis of the zones resulting from this characterization demonstrates the opportunity offered by this approach to have access to the relevant parameters involved in the issue of risk and disaster management, and this could well help to improve the early warning and preparedness aspect of risk management in Niger.

In a context characterised by inadequate availability of data or even an absence of quality data, any approach that makes it possible to remedy this shortcoming can only help to improve the effectiveness of the process for better disaster risk management. The SPI-based identification of extremely wet and dry years approach, used in the present study, carried out in Niger, is based on three fundamental inputs, namely (i) the mastery of physical parameters through the delimitation of zones impacted by extreme climatic events and the description of risk exposure factors, (ii) the determination of affected populations and the possibility of performing a demographic analysis based on the collected data, and (iii) the characterization of agricultural farms based on secondary data available from agricultural statistics services. The results of the study show that the use of geographic information can be used to collect relevant and useful data for risk and disaster management in a country where data collection systems are somewhat inadequate.

Initially, using rainfall data and the standardized precipitation index, the approach allows one to characterize the years [6] and identify the zones impacted by extreme climatic events. Then, to support the analysis at the scale of these identified zones of impact from extreme events, data on geomorphological and hydrographical characteristics are used and superimposed to conduct another level of analysis linked to exposure to risks, particularly about zones of extreme humidity and therefore presumed to be at risk of flooding. For the purposes of this analysis, the series of extracted data used is the average annual rainfall to calculate the Standardized Precipitation Index, which is a long enough time step to enable an analysis that would lead to information that could be used for warning purposes. Relatively short time steps, i.e., decadal, or monthly, would be more relevant and would enable standardized precipitation indices to be calculated at the end of each time step, making it possible to circumscribe the impact zones of climatic events quickly and predict their consequences. It should also be noted that this approach makes it possible to disaggregate information down to municipal level, as illustrated in the table below, and even to the level of the circumscribed zone if it does not coincide with the administrative boundary, which constitutes a major advance in the disaggregation of information that has hitherto been limited to department level in Niger. The acquisition of information down to the locality level (Table 6) using secondary data from the country's geographic information system will improve this approach.

Table 8. Disaggregated Data for Areas Affected at the Municipal Level, 2012

Municipality	**Event**	**Localities**	**Area (km²)**
Bader Goula	Extremely wet	162	1,677
	Very wet	55	406
Bouza	Extremely wet	3	31
	Moderately wet	1	26
	Very wet	100	456
Kornaka	Extremely wet	47	260
	Very wet	252	1,449
Maiyara	Extremely wet	6	22
	Very wet	116	464
Grand Total			

Source: Calculated data

Second, the affected populations of the circumscribed impacted areas are extracted using the ReNaLoc data, which are updated and projected by year / current period. This extraction of affected populations provides data disaggregated by commune or by circumscribed area, which is also a step forward from the current data collection system, which is limited to the Department level. Data collected on the affected population can be used to perform a demographic analysis of the objectively identified community based on the impact of extreme weather events and to conduct in-depth analyses of the identified population in terms of vulnerability and resilience [25-27]. This, combined with other impact parameters, such as production, makes it possible to draw up a detailed impact assessment for each commune and locality.

Table 9. Disaggregated Data on Populations Affected by Events in Municipalities, 2012

Municipality	**Event**	**Localities**	**Population**
Bader Goula	Extremely wet	162	67,089
	Very wet	55	16,224
Bouza	Extremely wet	3	6,724
	Moderately wet	1	5,575
	Very wet	100	98,099
Kornaka	Extremely wet	47	19,508
	Very wet	252	108,697
Maiyara	Extremely wet	6	2,569
	Very wet	116	53,329
Grand Total		**742**	**377,814**

Source: Calculated data

Third, the analysis of proxy data on the characteristics of agricultural farms in areas affected by extreme climatic events provides parameters for a rapid assessment of impact of the events on agricultural production. This type of data can be used to deeper analyze the situation, particularly in the case of areas and populations affected by extreme aridity events with a high risk of drought, but it can also be used to analyze the situation in areas at risk of flooding.

The data to be collected from the country's agricultural statistics services, depending on the level of disaggregation of the affected population, will be the average size of agricultural/pastoral holdings according to the location of the impacted area in the country's agroecological classification, the average physical agricultural area per household, average crop/forage yields, etc.

Determination of Certain Key of DRM Parameters and Extraction of Their Data

A monitoring system designed to provide early warning and collect basic data to anticipate crisis must be able to quickly identify vulnerable areas and have up-to-date data to enable it to perform essential primary analyses. To achieve this objective, it is essential to determine the parameters to be monitored and to define and clearly describe the approach to be followed. This study is a contribution in this direction and is based essentially on updated secondary data and certain primary data, such as rainfall, which is the key parameter used, and the standardized precipitation index, which allows a classification of areas and extraction of those that are extremely arid or humid. The first step in the approach is to use rainfall data and the standardized index calculated to define the zones impacted by extreme events and to extract information on the updated key parameters from these zones.

Conclusion

The results of this study clearly demonstrate that the geographic information approach makes it possible to determine the parameters and data that are relevant, useful, and usable in disaster risk management in a context where the institutional arrangements in place are not able to produce the right data in a timely manner.

The use of SPI calculated based on average annual rainfall over several geolocated sites may provide an approach for characterizing the impact zones of extreme climatic events in Niger and may help to improve the effectiveness of the campaign monitoring system used in Niger. This approach proves that SPI mapping can be used to geolocate areas according to whether they are affected by drought or extreme humidity as a key factor in the risk of flooding.

The delimitation of the impact zones of these extreme climatic events and the projection of population data onto these mapped zones can provide a solid basis for determining the parameters for assessing the impacts of disasters when they occur as a result, of extreme climatic events in the context of Niger, where the data collected is limited.

The SPI-based identification of extremely wet and dry years approach has shown that the use of standardized rainfall index data calculated from proxy rainfall data estimated for a large number of spatially representative sites spread over a given territory makes it possible to circumscribe and delimit the zones of impact of extreme climatic events (extreme and severe aridity and extreme and intense humidity), and thus constitutes a good way of monitoring and collecting appropriate data for the production of information for warning and vigilance messages if the time steps are close enough to allow this. Furthermore, within each circumscribed impact zone, the use of complementary available geographical information (geomorphology, hydrography, etc.) collected from the national GIS can help refine the characterization of the identified impact zone and determine the risk factors linked to exposure, particularly in the case of zones characterized by extreme humidity.

The results of this study demonstrated the possibility of extracting other key parameters, in particular the population explosion in each extreme event impact zone perimeter. The use of geo-referenced data from the national network of localities and the updating of population data from the reference year of the RGPH, 2012, makes it possible to project population data and extract those in the zones circumscribed based on the index of identified extreme events.

The data extracted from the affected populations makes it possible to construct an objective survey of the affected population and to conduct, on the one hand, a demographic analysis of the community circumscribed in the zones impacted by the extreme climatic events and, on the other hand, an analysis of the state of their vulnerability and their capacity for resilience.

As a result, the application of this approach makes it possible to: (i) delimit, down to locality level, the zones impacted by extreme climatic events and identify the localities affected by each type of extreme event produced. The delimitation of the impact zone can also be done using various rainfall data time steps, which can be decadal, monthly, or annual, which makes it possible to have more detailed information that can be used as a basis for warnings depending on the impact of the extreme event that has occurred. (ii) identify areas at risk of flooding according to their exposure to the hydrographic network and extract localities with their populations located within the rights-of-way of watercourses in areas of extreme humidity and therefore exposed to the risk of flooding, (iii) extract demographic data and identify localities with their impacted populations, which makes it possible to conduct a demographic analysis and household typology on this basis.

Limitations

Although the approach used has been shown to collect data relevant to disaster risk management, the annual time step used for the rainfall data collected was a limitation, to the extent that it made it impossible to assess the plausible variability during the season and obtain data that could be used as parameters in the early warning mechanism. The other limitation of this approach is its dependence on analyses of primary data collected to provide better information on the exposure and vulnerability of populations for which a rapid survey can provide reliable data to prepare a better response. These two limitations constitute avenues for future research.

Conflict of Interest Statement

All authors declare that they have no conflicts of interest.

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