Espaces Africains

Revue des Sciences Sociales

Numéro 2 | 2025

Numéro Varia | juin 2025

REA – Impact factor (SJIF) 2025 : 5.341 *Date de soumission : 14-04-2025 / Date de publication : 30-06-2025*

RAINFALL VARIABILITY AND FARMER'S BIO-ECOLOGICAL ADAPTATION STRATEGIES FOR MAIZE PRODUCTION IN WASSANDE, ADAMAWA, CAMEROON (1992–2022)

VARIABILITÉ PLUVIOMETRIQUE ET STRATÉGIES D'ADAPTATION BIO-ECOLOGIQUES POUR LA PRODUCTION DE MAÏS A WASSANDE, ADAMAOUA, CAMEROUN (1992–2022)

Reni Bibriven **LILA** – Yvette **KALWA**

ABSTRACT

This study evaluated the impact of rainfall variability on maize cultivation in the Wassande agricultural basin, Adamaoua, Cameroon, from 1992 to 2022. The aim was to elucidate its effects and highlight effective bio-ecological adaptation strategies for sustainable agriculture. Maize is vital for Wassande's economy, comprising 40% of Cameroon's agricultural GDP, yet it faces yield reductions of 20–50% due to rainfall variability. Erratic weather exacerbates socio-economic issues, including income loss and conflicts, necessitating urgent evidence-based strategies to enhance food security in the Sudano-Sahelian zone.

A mixed-methods approach, integrating qualitative and quantitative techniques, was employed to analyze rainfall variability and bio-ecological adaptation. Tools included QGIS for thematic mapping, Excel for data analysis, and KoboCollect for surveys. The Standardized Precipitation Index (SPI) evaluated precipitation variability, revealing significant inter-annual and seasonal fluctuations. For instance, extreme humidity was recorded in 2022 (SPI 3.47; 1,871 mm), while near-moderate dryness occurred in 2017 (SPI -0.04). A survey of 110 maize growers revealed a weak negative inter-annual yield correlation ($r \approx -0.35$, $p < 0.05$) and stronger seasonal inverse correlations ($r \approx -0.48$, $p < 0.01$), especially during erratic rainy seasons (2002–2012). Yields dropped to 2–6 bags/ha in 2022 from a typical 35–37 bags/ha due to waterlogging, seed loss, and pest proliferation (79% prevalence).

Farmers adapted to rainfall variability through spatially diversified cultivation, irrigation from Mayo Bogui, and drought-resistant IRAD maize varieties. To mitigate excess rainfall, they employed runoff channeling (73% adoption) and delayed April sowing. Soil fertility is maintained through organic manure (82% usage) and crop rotation, while pest management primarily relies on insecticides (79%), supplemented by resistant varieties for disease.

Keywords : Rainfall variability, bio-ecological adaptation, maize cultivation, sustainable agriculture, Wassande, Cameroon.

RÉSUMÉ

Cette étude a évalué l'impact de la variabilité pluviométrique sur la culture du maïs dans le bassin agricole de Wassande (Adamaoua, Cameroun) entre 1992 et 2022, visant à élucider les effets et à identifier des stratégies bioécologiques d'adaptation pour une agriculture durable. Le maïs, essentiel à l'économie locale, représente 40% du PIB agricole camerounais et subit des baisses de rendement de 20 à 50% dues aux aléas pluviométriques. Ces perturbations exacerbent les problèmes socio-économiques, entraînant pertes de revenus et conflits, nécessitant des stratégies fondées sur des preuves pour renforcer la sécurité alimentaire en zone soudano-sahélienne.

Une approche méthodologique mixte, combinant techniques qualitatives et quantitatives, a été employée pour analyser la variabilité pluviométrique et les adaptations bioécologiques, utilisant QGIS pour la cartographie, Excel pour l'analyse des données et KoboCollect pour les enquêtes. L'Indice Standardisé de Précipitation (SPI) a révélé des fluctuations interannuelles et saisonnières, avec une humidité extrême en 2022 (SPI 3,47 ; 1871 mm) et une sécheresse quasi modérée en 2017 (SPI -0,04). L'enquête auprès de 110 producteurs a montré une faible corrélation négative rendement-précipitations ($r \approx -0{,}35$; $p < 0{,}05$) et une corrélation inverse plus marquée en saison ($r \approx -0{,}48$; $p < 0{,}01$), particulièrement durant les saisons erratiques (2002-2012).

Les agriculteurs s'adaptent par : (1) diversification spatiale, (2) irrigation à partir du Mayo Bogui, et (3) utilisation de variétés tolérantes à la sécheresse. La gestion des excès pluviométriques combine drainage des eaux (adoption à 73%) et report des semis en avril, tandis que la fertilité des sols est préservée par amendements organiques (usage à 82%) et rotations culturales.

Mots-clés : Variabilité des précipitations, adaptation bio-écologique, culture du maïs, agriculture durable, Wassande, Cameroun.

INTRODUCTION

The challenges of improving livelihoods for vulnerable groups and addressing climate change are closely connected today (Olsson et *al.* 2014: 793). Climate change significantly impacts agrarian communities in sub-Saharan Africa, where rain-fed agriculture is crucial (Masson et al. 2018: 32). In Cameroon's Sudano-Sahelian zone, unpredictable rainfall, marked by droughts and floods, has destabilized agriculture, threatening food security (Gouataine 2018 : 326).

Maize, a vital staple in Wassande and Cameroon's second-largest agricultural contributor, generating 40% of national agricultural GDP (MINADER Report 2017: 69), faces significant challenges from rainfall variability. Following the decline of the wheat cooperative Société de Développement de Blé (SODEBLE), farmers shifted to maize, yet yields remain unstable due to erratic rainfall patterns, causing 20–50% yield reductions (PCD Report 2013 : 329; Teka Bekuma & Abdisa 2022 : 2057656). Unpredictable dry spells and heavy rainfall hinder optimal planting, exacerbating socio-economic challenges, including reduced incomes and increased conflicts. Limited access to climate-resilient methods highlights the need for evidence-based strategies to enhance food security in the Sudano-Sahelian zone.

This study assesses rainfall variability impacts on maize production in Wassande and proposes adaptive strategies for resilience. Integrating agroclimatology, socio-economic analysis, and farmer insights, we develop scalable solutions through geospatial rainfall trend analysis (1992-2022) and agro-ecological trials to inform Cameroon's climate adaptation policies.

Climate-agriculture interdependencies suggest sub-Saharan Africa could face a 56% yield decline by 2050 without adaptation (CCNUCC Report 2011 : 23). Rainfall deviations of ±200 mm impair maize kernel formation, with northern Cameroon experiencing a 16% rainfall decline since 1951. While drought-resistant crops show promise, localized studies in Wassande are scarce, underscoring the urgency of aligning global climate models with local Sudano-Sahelian agro-systems.

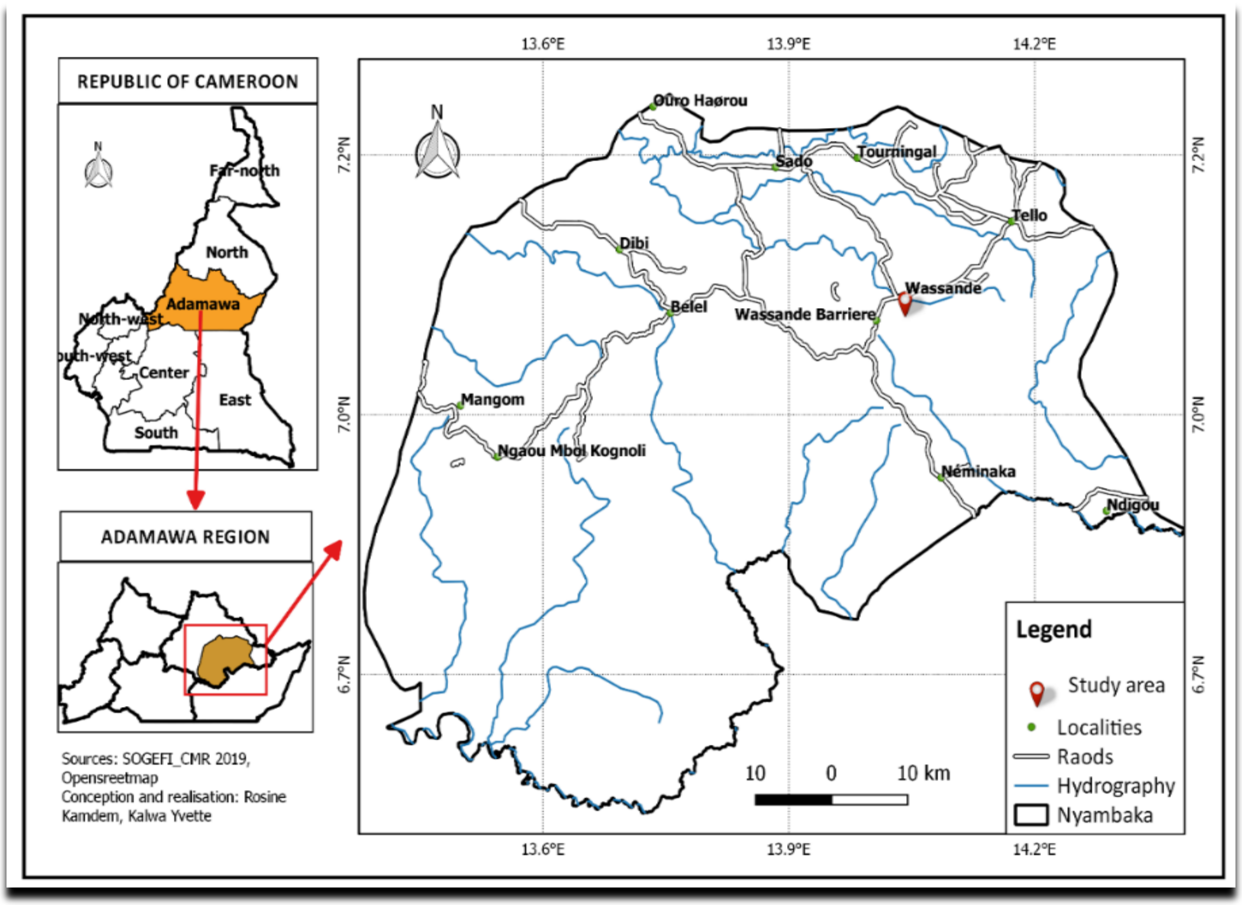
1. STUDY AREA: WASSANDE, NYAMBAKA DISTRICT, CAMEROON

This research centers on Wassande, a village in the Nyambaka district of Cameroon's Adamaoua region, which includes 58 villages over approximately 4,500 km². Wassande is located at latitude 7°07' North and longitude 14°11' East (**Fig. 1)**.

1.1. Geo-Biophysical Context and Spatial Delimitation

Wassande, located in the Sahelo-Sudanian agroecological zone of Nyambaka, a commune vital for regional agriculture, occupies a dynamic ecological and cultural landscape.

Fig. 1 : Location map of the study area (Wassande)



Its geographic location highlights a spatial context essential for analyzing environmental and anthropogenic influences on the study area. The biophysical environment of Wassande is shaped by its topography, climate, vegetation, and hydrography, collectively determining its agricultural potential and ecological resilience. Varied terrain governs water flow and soil distribution, while the semi-arid climate, with distinct wet and dry seasons, impacts crop cycles and water availability. Seasonal streams enhance the area's suitability for farming and resource management, underpinning Wassande's agricultural productivity and environmental sustainability. Wassande, located in Nyambaka on the Adamaoua plateau, lies within a stepped tabular relief divided into five orographic units. Its agricultural basin consists of four geomorphological units: 30% below 1,370 m with steep slopes; 60% between 1,370–1,440 m, centrally dominant; 15% from 1,440–1,460 m as a transitional zone; and 5% above 1,460 m with volcanic cones. The humid tropical Sudanian climate features a dry season (November–March) and a rainy season (April–September), receiving 1,400 mm of annual rainfall and temperatures of 24–28°C, influenced by harmattan and monsoon winds. The vegetation is Sudano-Guinean savannah, with fodder grasses like Hyparrhenia rufa supporting livestock.

Wassande has an estimated population of 3,466 inhabitants, with a notable gender disparity: 42% male (1,466) and 58% female (2,000), indicating a predominantly female community (PCD, 2013). The ethnic composition is diverse, including Peulh, Gbaya, Dii, Kole, and Tupuri, with Fulbe as the primary language. Economic activities focus on agriculture, livestock rearing, fishing, and trade, supported by fertile soils. Agriculture is practiced on 3,000 hectares previously managed by SODEBLE, primarily cultivating maize, which yields approximately 2 tonnes per hectare, with 90% sold. Notably, 98% of farmers are male, employing slash-and-burn techniques (PCD 2013).

Support from MINADER benefits 26% of 103 grassroots organizations (GICs), while livestock rearing is predominantly carried out by Peulh herders. Subsistence fishing in Mayo Salgo primarily targets catfish, and Wassande's market serves as a regional trade center for livestock and agricultural products.

1.1.1. Spatial Dynamics of Maize Cultivation in Wassande Agricultural Zone

Maize, a vital cereal crop in Cameroon, sustains two-thirds of the population and drives socio-economic progress in rural regions like Wassande, Nyambaka district. Here, we explore the spatial dynamics and maize production systems, varietal preferences, marketing channels, and farmers' socio-demographic profiles. Integrating historical, agronomic, and socio-economic insights, it reveals how spatial and environmental factors shape maize farming, supported by field surveys and authoritative literature

1.1.2. Historical and Botanical Context

Originating 9,000 years ago in Mexico from teosinte domestication, maize (Zea mays), a Poaceae species, became a staple for Amerindian societies. Introduced to Cameroon by Portuguese traders, it flourishes across agro-ecological zones, notably Adamaoua, bolstering food security. Botanically, maize exhibits seminal and adventitious roots, a 2–3 m stalk, and distinct male (panicle) and female (ear) inflorescences, yielding caryopsis grains.

Maize cultivation leverages fertile clay soils to support flowering in July–August. The crop's adaptability to mixed cropping and agroforestry enhances its spatial integration, optimizing land use and ecological balance.

1.1.3. Production Systems and Techniques

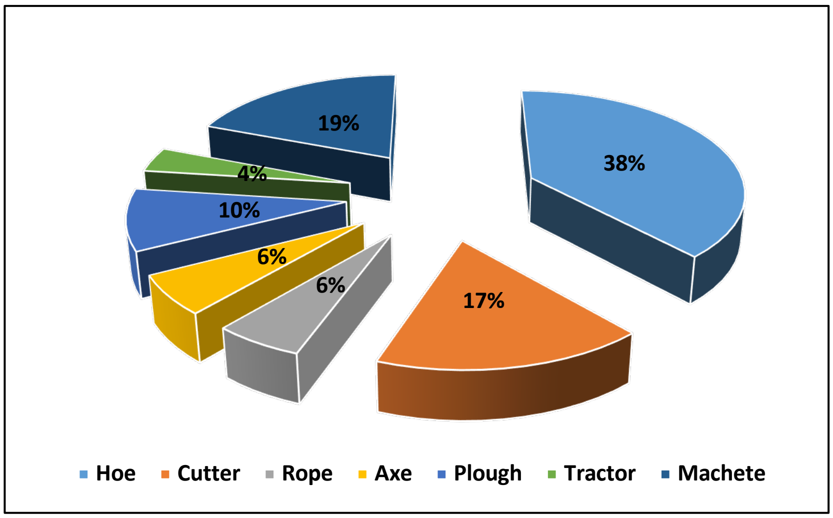
In Wassande, maize cultivation utilizes a mixed cropping system, combining maize with groundnuts, potatoes, cassava, and bananas to enhance soil fertility and adapt to rainfall variability. Soil preparation, occurring from March to April, entails manual clearing and ploughing to a 30 cm depth, primarily using hoes. Tractor-based ploughing is reserved for larger plots, though fuel costs limit its adoption, with 95 of 110 surveyed farmers (38%) relying on hoes, (**Tabl. I**) and (**Fig. 2**).

Tabl. I : Distribution of equipment used to grow maize at Wassande.

Maize growing Equipment	Work-force	Percentages(%)
Hoe	96	38%
Cutter	45	17%
Rope	15	6%
Axe	16	6%
Plough	25	10%
Tractor	10	4%
Machete	50	19%

Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Fig. 2: Diagram showing the distribution of equipment used to grow maize at Wassande.



Source: *Field Survey and Data Analysis KALWA/LILA, 2023*

Ridging and direct sowing techniques enhance root stability and reduce labor duration and intensity.
Weed control, essential for protecting yields, involves either manual hoeing or the application of herbicides. Mixed cropping and agroforestry with mango trees exemplify adaptive strategies to environmental constraints. The agricultural calendar, outlined in (**Table II**), schedules land clearing from February to April, weeding from May to July, and harvesting in August (for fresh produce) or from November to January (for dry produce), all in alignment with rainfall patterns.

Tabl. II : Agricultural calendar for maize production at Wassande.

Month / Activities	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan.
Site preparation	■	■										
Semi			■	■								
Maintenance (weeding)				■	■	■						
Plant health treatment						■	■					
Harvest							■			■	■	

Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

In Wassande, maize production follows a schedule from farmer surveys. Field preparation (clearing and plowing) spans February to early April, but late rains may delay plowing to late April, reducing yields. Weeding occurs from May to July, with occasional autumn sessions. Fresh maize is harvested in August when cobs are milky. The dry harvest, vital for storage, runs from late November to January.

1.1.4. Varietal Preferences and Marketing Dynamics

Local maize varieties in Wassande, characterized by sweet or hard endosperms, are selected for consumption or milling, with Shaba (50%), Pannar (36%), and CMS 8704 (14%), dominating due to yield resilience, as shown in (**Tabl. III**).

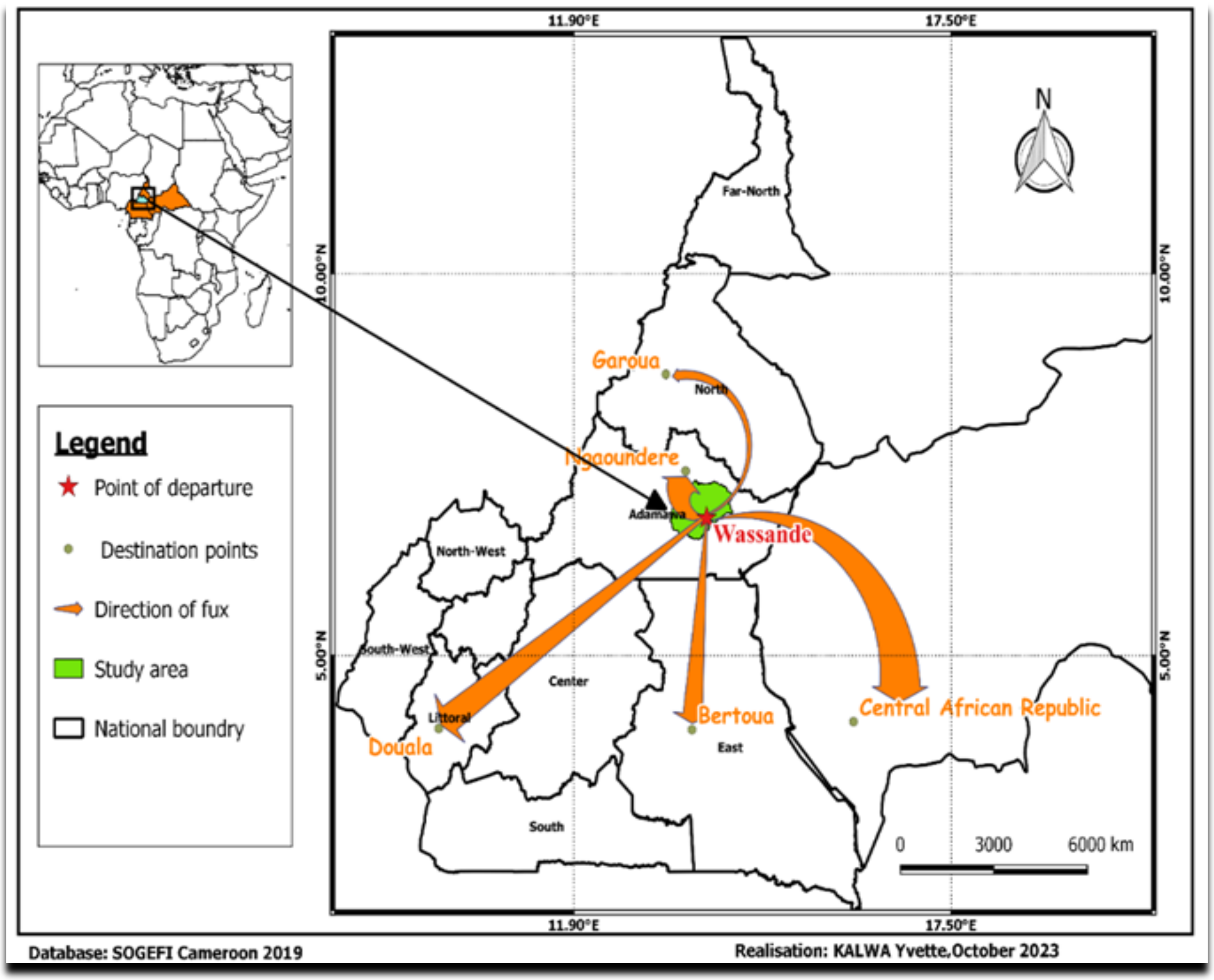
Tabl. III: Characteristics of some maize varieties and their differences

Varieties	Colours	Number of days until the maturation
Shaba	White	6 months-3 months
Pannar	White	75
Cms 130	White	/
CMS 8704	Orange-yellowich	110-120
CMS 2019	White	/

Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Marketing channels, pivotal to Wassande's economy, involve cultivators, wholesalers, semi-wholesalers, and retailers, with maize transported to the Central African Republic, Ngaoundéré, Bertoua, Douala, and Garoua, as mapped in (**Fig. 3**).

Fig. 3: Flux map of maize from our study area to other destinations



Traditional storage methods prevail due to the absence of cold storage, prompting early sales to mitigate pest-related losses. The socio-demographic profile of farmers in Wassande reveals a predominantly male population (91%), with 46% aged 40–50, 77% married, and 53% unschooled.

Men dominate maize cultivation, controlling 91% of the land, while women, constrained by local customs, manage only 9% and are limited to small plots for personal consumption. Farmers aged 40 to 50, often married and sometimes polygamous, form the primary workforce. Children begin learning land management at age 15 under family supervision, with some farmers allocating plots to their children as part of their inheritance.

Married individuals constitute 77% of farmers, driven by family responsibilities, while single farmers represent 18%. The educational levels of maize growers are generally low, hindering their understanding of optimal agricultural practices to cope with rainfall challenges. The spatial dynamics of maize cultivation reflect a complex interplay of historical, agronomic, and socio-economic factors, with traditional practices optimizing land use despite climatic challenges.

2. Methodology

2.1. Research Materials and Data

This study in Wassande, Nyambaka district, employs a comprehensive data collection strategy to analyze climatic variability's impact on maize cultivation. Documentary research, initiated in February 2023 at the University of Ngaoundéré, synthesized academic literature and climate reports (Dinet & Passerault 2004 : 126). Climatic data (1992–2022) from Ngaoundéré meteorological sources, IRAD Wakwa Agricultural Research Centre, Cameroon's National Directorate of Meteorology, and agronomic data from field surveys, and socio-demographic data from the PCD (2013) were integrated. Cataloged in (**Tabl. IV**), these datasets combine quantitative metrics (rainfall, yields) and qualitative insights (adaptive strategies), forming a comprehensive analytical foundation.

Tabl. IV : Types of data collected, sources, and nature

Data type	Source	Data collected	Qualitative or quantitative
Climatic	-Regional delegation of agriculture, Ngaoundere airport, National direction of Meteorology	-Pluviometric -Temperature	Quantitative
agronomic	-Field survey	-Agricultural practices -Agricultural yield	Qualitative and quantitative
Socio-demographic	-Field survey -PCD	-Gender -Level of education -Matrimonial status	Qualitative and quantitative

Source: *Field Survey and Data Analysis KALWA/LILA, 2023*

Cartographic data from the SOGEFI 2019 database and Landsat imagery facilitated the production of spatial maps, enhancing geospatial analysis. This multi-faceted data framework enabled a nuanced evaluation of bio-ecological adaptations to climatic stressors in Wassande's agricultural landscape.

2.2. Method

This study employed a mixed-methods framework, blending quantitative and qualitative analyses to examine rainfall variability and bio-ecological adaptation in Wassande's maize farming, consistent with other agro-climatic research standards, which employs systematic methods to assess the interplay between agriculture and climate. They emphasize rigorous data collection through mixed-methods that combine quantitative measurements with qualitative insights. In this research, the framework enabled a comprehensive analysis of climatic variability's impact, guiding sustainable agricultural strategies and enhancing resilience to climate change. An exploratory mission utilized GPS and cartographic tools to refine survey instruments and engage local authorities. Primary data collection, conducted from 25 July to 20 August 2023, systematically selected and surveyed 110 maize farmers, yielding 100 valid responses, as reported in (**Tabl. V**).

Tabl. V : Classification of producers surveyed and site selection criteria by neighborhood.

Localities	Longitude	latitude	Altitude	Corn producer	Choice of Site
Mogmo	14.081	7.09991	1438	60	Zone of corn cultivation very solicited by the rural populations.
Mbamti	14.0548	7.09504	1393	15	Presence of large number of maize farm over vast surfaces and installation of COOPA Mbamti corporation.
Wassande camps	14.0548	7.09504	1393	25	Were the population have farms near their house

Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Questionnaires were administered using Kobocollect in both "Fulbe" and "French" languages, exploring cultivation techniques, perceptions of rainfall, and adaptation strategies. The questionnaires included variables such as age, gender, education, and agricultural output. Additionally, supplementary interviews with key informants and local administrators in the study area were conducted.

For data processing, QGIS was used for cartographic visualization, while Excel was utilized for climatic analysis. The Nicholson index was applied to quantify and classify rainfall variability, as detailed in (**Table VI**), using metrics such as mean, standard deviation, and the standardized precipitation index, expressed mathematically :

(**SPI** = (**Pi – Pm**)/**σ**), per OMM (2012) standards,

Where;

Pi= rainfall for the year

Pm= inter-annual mean

α = the standard deviation of the rainfall series.

Tabl. VI : Classification standard for calibration of degree of drought in rainfall series.

SPI Classification	Qualification of the degree of drought
SPI<2(2 and more)	Extreme humidity
SPI<2	High humidity
0<SPI<0	Moderate humidity
De -0.99 to 0.99	Close to normal
-1<SPI<1	Moderately dry
-2<SPI<-1	Very dry
SPI<-2	Extremely dry

Source : OMM 2012

This index's application over a 30-year dataset illuminated precipitation anomalies, directly correlating with maize yield fluctuations and in some seasons inversely. By iteratively synthesizing field data with statistical rigor, this methodology incisively captured local adaptive responses to climatic variability, offering a replicable model for agro-ecological research in similar contexts.

3. RESULTS AND ANALYSIS

The spatial dynamics of maize cultivation in Wassande are closely tied to climatic variability, especially rainfall patterns. These factors influence productivity and socio-economic outcomes. This analysis synthesizes quantitative and qualitative data to explore climate variability, its impact on maize farming, and local adaptation strategies for addressing rainfall-driven challenges.

3.1. Climate Variability Dynamics

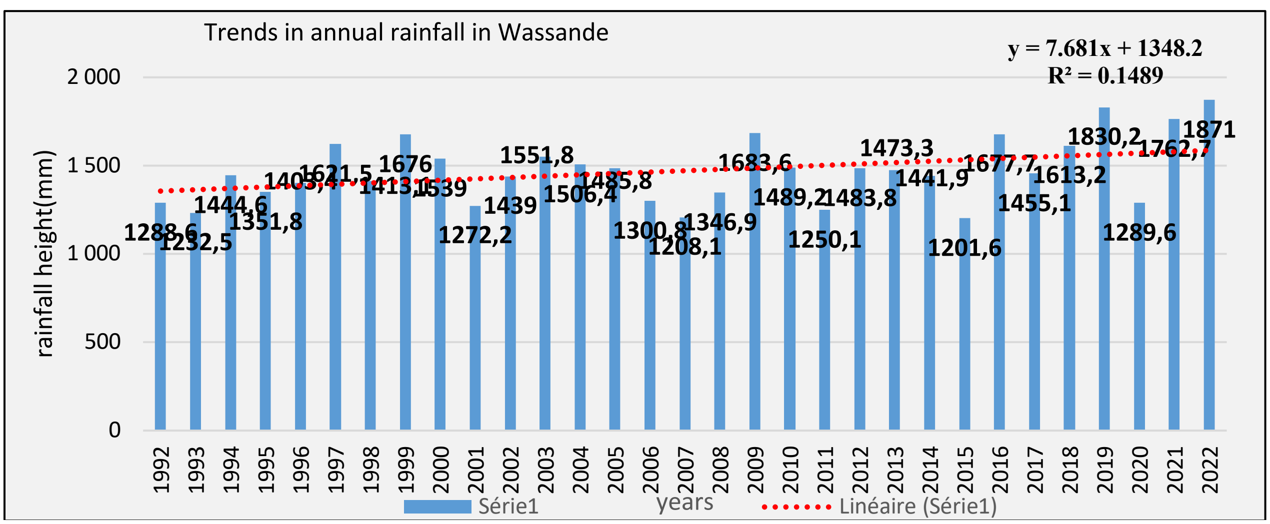
3.1.1. Spatial and Temporal Analysis of Rainfall Distribution in Wassande, 1992–2022

Rainfall, with significant spatial and temporal variability, shapes maize yields in sub-Saharan Africa's rain-fed systems. This research, using data from Ngaoundéré's meteorological station and employing the Standardized Precipitation Index (SPI), analyzes precipitation trends and seasonal patterns illustrated in figures (fig. 4, 7, 8, 9), highlighting bio-ecological adaptations.

3.1.2. Rainfall Characteristics and Trends

Successful rain-fed agriculture in Wassande depends on understanding rainfall variability, crucial for maize cultivation. The Adamaoua region receives 900 to 1,500 mm of annual rainfall, but irregular patterns pose challenges. Precipitation types—convective, orographic, and frontal—are measured at the Ngaoundéré meteorological station, with trends illustrated in (Fig. 4).

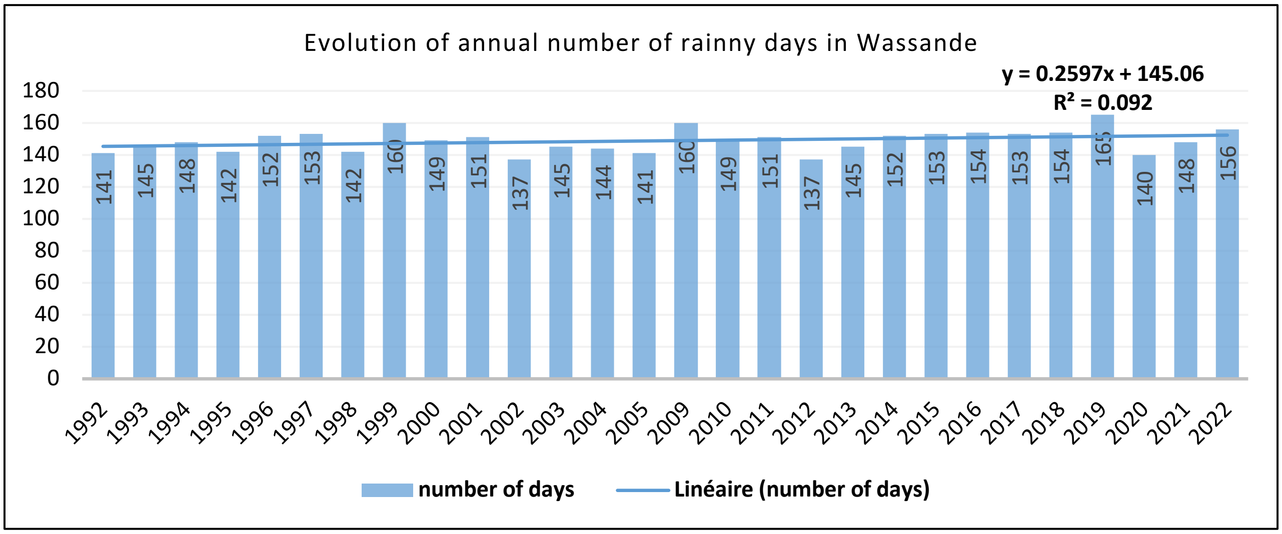
Fig. 4 : Trends in annual rainfall in Ngaoundéré (Wassande) from 1992 to 2022



Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Conversely, the **number of rainy days**, (**Fig. 5**) remains relatively stable, indicating concentrated rainfall.

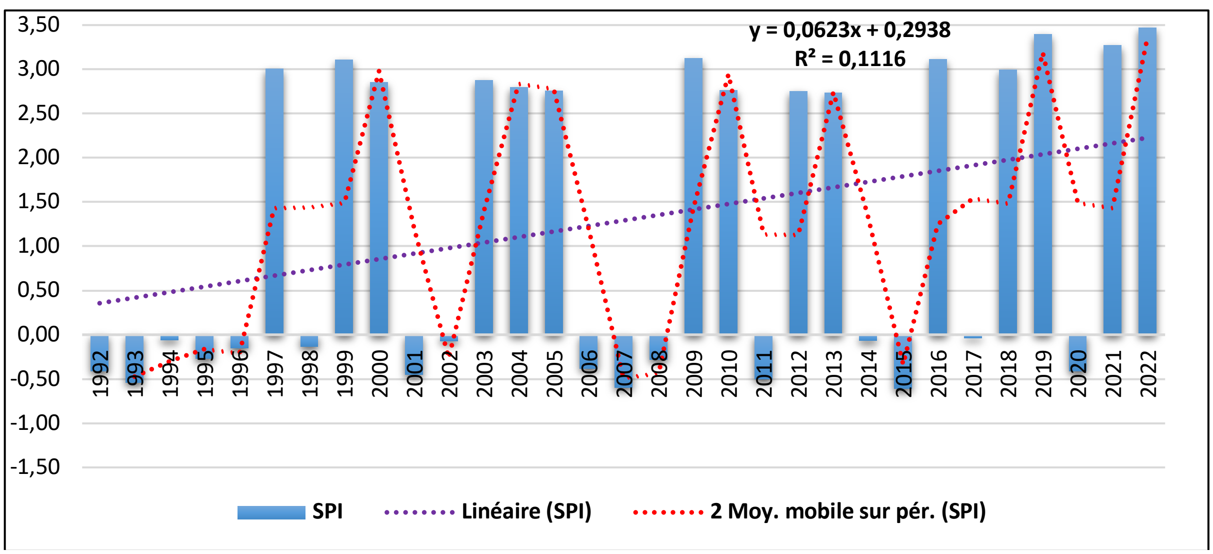
Fig. 5: Evolution of the annual number of rainy days in Ngaoundéré (Wassande) over 30 years



Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

This trend, supported by a high coefficient of determination (R^2), correlates with yield reductions due to kernel rot, soil nutrient leaching, and disrupted flowering, as confirmed by field surveys. The SPI, calculated as SPI = (Pi – Pm)/σ, quantifies anomalies, with 2022 recording peak humidity (SPI 3.47; 1,871 mm) and 2017 the lowest (SPI -0.04), (**Fig. 6**) and (**Tabl. VII**)

Fig. 6: Standardized rainfall index for the rainfall series from 1992 to 2022



SPI analysis reveals predominantly normal to extremely humid conditions, with 2022 recording peak humidity (SPI: 3.46 mm) and 2017 the driest year (SPI: -0.04 mm). Normal humidity years (SPI: -0.99 to 0.99 mm) include 1992–1996, 1998, 2001–2002, 2006–2008, 2011, 2014–2015, 2017, and 2020.

Sixteen years showed negative SPI values, indicating drier conditions. Table VII quantifies SPI data by humidity intensity, clearly classifying SPI ranges for enhanced clarity.

Tabl. VII : Rainfall standardized index of pluviometric sequences from 1992–2022 (Wassande)

SPI Classification	Qualification of the degree of drought	Chosen years
SPI>2(2 and more)	Extreme humidity	1997,1999,2000,2003,2004,2005,20092010,2012,2013,2016,2018,2019,20212022
SPI<2	High humidity	------------
De -0.99 to 0.99	Close to normal	1992,1993,1994,1995,1996,1998,20012002,2006,2007,2008,2011,2014,2015,2017,2020
-1<SPI<1	Moderately dry	------------
-2<SPI<-1	Very dry	------------
SPI<-2	Extremely dry	-------------

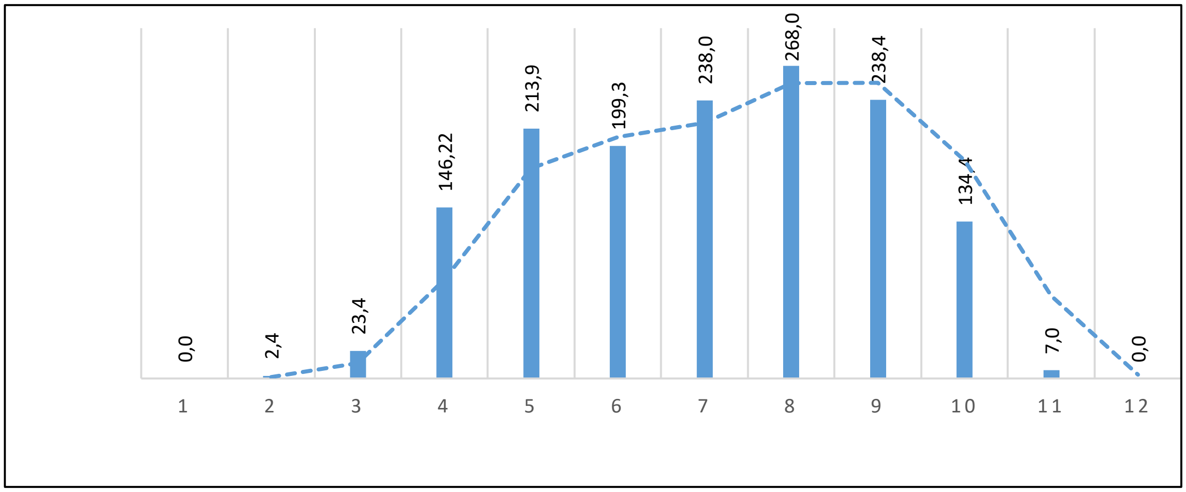
Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Interpretation of Table 8 reveals 2022 as the most humid year, with 1871 mm of rainfall and an SPI of 3.47. The study area consistently experienced either extremely humid or normal conditions, with 2017 approaching moderately dry (SPI -0.04). Extremely humid years encompassed 1997, 1999–2000, 2003–2005, 2009–2010, 2012–2013, 2016, 2019, and 2021–2022, while normal years (SPI: -0.99 to 0.99) included 1992–1996, 1998, 2001–2002, 2006–2008, 2011, 2014–2015, 2017, and 2020. These findings underscore the need for further analysis of humidity trends and seasonal patterns to enhance maize cultivation strategies.

3.1.3. Seasonal and Decadal Dynamics

Wassande's mono-modal rainfall regime comprises a seven-month rainy season (April–October) and a five-month dry season (November–March), with occasional March precipitation (**Fig. 7**).

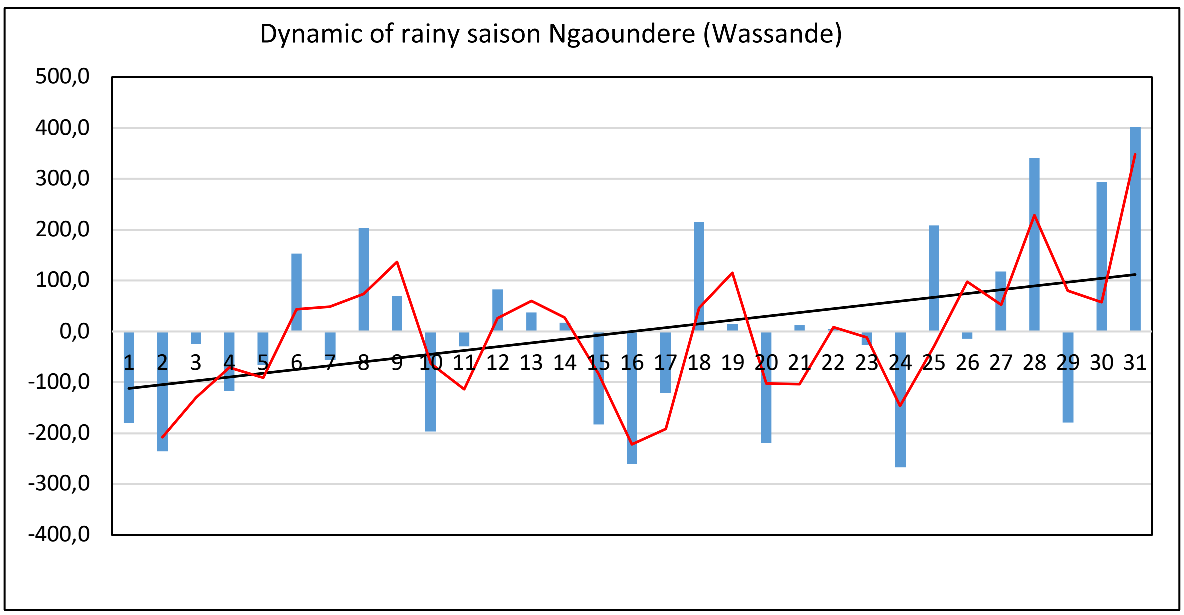
Fig. 7: Dynamic of rainy season Ngaoundéré (Wassande)



Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Rainy season analysis, shown in (**Fig. 8**), reveals increasing wetness, with 2022 peaking at 1,871 mm and 2015 at 1,201.6 mm.

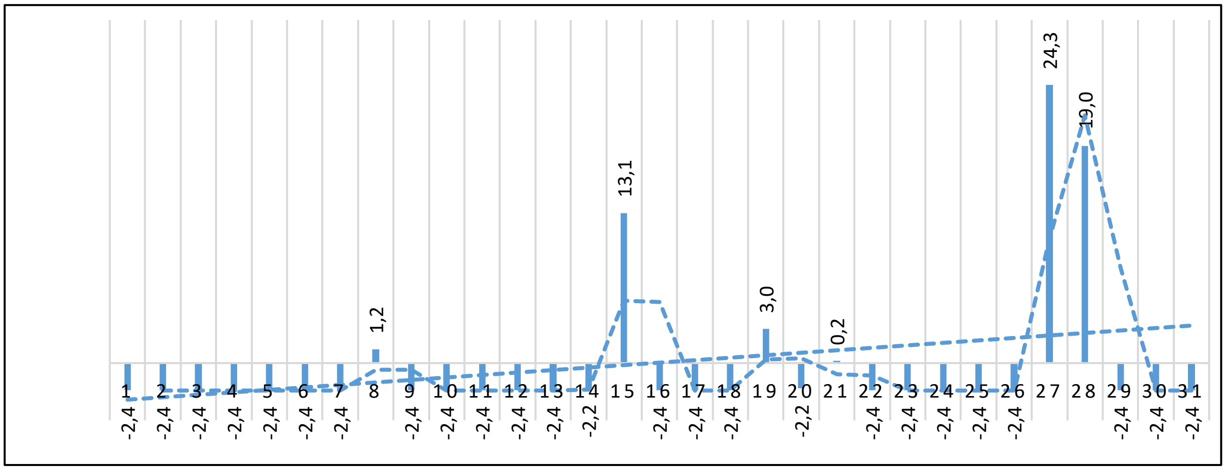
Fig. 8 : Dynamic of rainy season in Ngaoundéré (Wassande)



Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Dry season rainfall, averaging 2.4 mm, peaked in 2019 at 21.4 mm, (**Fig. 9**).

Fig. 9 : Evolution of dry season 1992–2022 of Ngaoundéré (Wassande)



Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Decadal analysis of the months of March and April detailed in (**Tabl. VIII**) and (**Tabl. IX**), indicates minimal rainfall (40.5 mm in the first decade), rendering it unsuitable for sowing.

Tabl. VIII : Decadal analysis of March rainfall in Wassande between 1992 and 2014

Years	Months	Decade1 (1-10) mm	Decade 2 (11_20) mm	Decade3 (21-31) mm
1992	March	0.0	41.0	8.0
1993	March	31.9	5.4	4.1
1994	March	0.0	1.5	0.0
1995	March	0.0	8.0	1.9
1996	March	7.4	32.6	14.6
1997	March	0.0	0.0	32.3
1998	March	0.0	0.0	0.0
1999	March	0.6	9.6	1.2
2000	March	0.0	22.7	0.2
2001	March	0.0	0.0	4.5
2002	March	0.0	0.0	1.0
2003	March	0.0	1.2	0.0
2004	March	0.0	0.0	0.0
2005	March	0.0	0.4	0.3
2009	March	0.6	9.6	106.1
2010	March	0.0	22.7	0.2
2011	March	0.0	0.0	4.5
2012	March	0.0	0.0	1.0
2013	March	0.0	1.2	0.0
2014	March	0.0	0.0	0.0
total	20	40.5	155.9	179.9
Decade average		2.03	7.80	9.00

Source : Cameroon National Meteorological Directorate, KALWA, August 2023

Rainfall data for March (1992–2014) reveal a progressive increase in precipitation across the month's three decades. The first decade (1–10 March) totaled 40.5 mm, averaging 2.03 mm, with a peak of 31.9 mm in 1993, yet over 80% of periods recorded no rainfall (0.0 mm), reflecting persistent dry season effects. The second decade (11–20 March) recorded 155.4 mm, averaging 7.80 mm, with a maximum of 32.6 mm in 1992. The third decade (21–31 March) had the highest total, 179.9 mm, averaging 9.00 mm, peaking at 106.1 mm in 2009. Despite this trend, March's variable and low rainfall, particularly early in the month, suggests it is suboptimal for sowing.

Tabl. IX : Decadal analysis of April rainfall.

years	Months	Decade1 (1-10) mm	Decade 2 (11_20) mm	Decade3 (21-31) mm
1992	April	67.9	90.5	1.5
1993	April	19.4	61.1	70.6
1994	April	54.0	27.2	47.1
1995	April	23.1	46.5	53.6
1996	April	25.3	95.7	89.6
1997	April	7.8	135.5	153.3
1998	April	9.0	3.8	136.6
1999	April	4.6	37.8	53.8
2000	April	53.7	88.6	88.8
2001	April	10.5	61.5	42.7
2002	April	9.3	33.2	14.6
2003	April	47.0	118.4	45.2
2004	April	28.0	35.1	65.1
2005	April	0.0	44.8	81.4
2009	April	4.6	37.8	53.8
2010	April	53.7	84.6	88.8
2011	April	10.5	61.5	42.7
2012	April	93	33.2	14.6
2013	April	47.0	118.4	45.2
2014	April	28.0	35.1	65.1
TOTAL	20	596.4	1250.3	1254.1
Decade average		29.82	62.52	62.71

Source : *Cameroon National Meteorological Directorate, KALWA, August 2023*

From 1992 to 2014, April rainfall data across three decades reveal distinct patterns. The first decade recorded 596.4 mm (average 29.82 mm), peaking at 93 mm in 2012 and dropping to 0.0 mm in 2015. The second decade totaled 1250.3 mm (average 62.52 mm), with a high of 118.4 mm in 2003 and 2013 and a low of 3.8 mm in 1998. The third decade had 1254.1 mm (average 62.71 mm), reaching 153.3 mm in 1997 and 1.5 mm in 1992. These patterns support seed production, with sowing typically beginning late in April's first decade, as earlier rains are insufficient except in river valleys and lake banks.

October's decreasing rainfall, (**Tabl. X**), marks the end of the rainy season by the third decade, informing harvest timing. These results highlight the importance of precise agronomic scheduling to maximize maize yields under variable rainfall conditions.

Tabl. X : Decadal analysis of October rainfall in Wassande between 1992 and 2014

Years	Months	Decade1 (1-10) mm	Decade 2 (11_20) mm	Decade3 (21-31) mm
1992	October	31.2	37.9	15.4
1993	October	16.0	1.8	36.4
1994	October	62.9	64.8	24.8
1995	October	33.1	4.1	57.0
1996	October	78.7	39.3	89.0
1997	October	39.2	53.1	35.1
1998	October	30.9	23.6	4.2
1999	October	109.3	99.4	31.8
2000	October	66.4	26.9	0.0
2001	October	54.5	42.2	0.0
2002	October	68.9	57.1	23.4
2003	October	32.2	79.4	2.0
2004	October	35.9	11.6	17.8
2005	October	84.4	36.0	8.6
2009	October	109.3	99.4	31.8
2010	October	66.4	26.9	0.0
2011	October	54.5	42.2	0.0
2012	October	68.9	57.1	23.4
2013	October	32	79.4	2.0
2014	October	35.9	11.6	17.8
TOTAL	20	1110.6	893.8	420.5
Decades average		55.53	44.69	21.03

Source : *Cameroon National Meteorological Directorate, KALWA, August 2023*

From 1992 to 2014, October rainfall data in the studied region show a declining trend, marking the shift from rainy to dry season. The first decade (1–10 October) recorded 1110.6 mm, averaging 55.53 mm, peaking at 109.3 mm in 2009 and dropping to 31 mm in 1992. The second decade (11–21 October) totaled 893.8 mm, averaging 44.6 mm, indicating further decline. The third decade (22–31 October) fell to 420.5 mm, averaging 21.03 mm, signaling the rainy season's end by late October, with the dry season likely beginning in the third decade.

3.1.4. Farmer Perceptions and Pluviometric Impacts

In Wassande, maize farmers' experiential knowledge of rainfall onset, documented in (**Tabl. XI**), shapes adaptive responses to climatic variability but varies widely and often deviates from empirically optimal sowing periods.

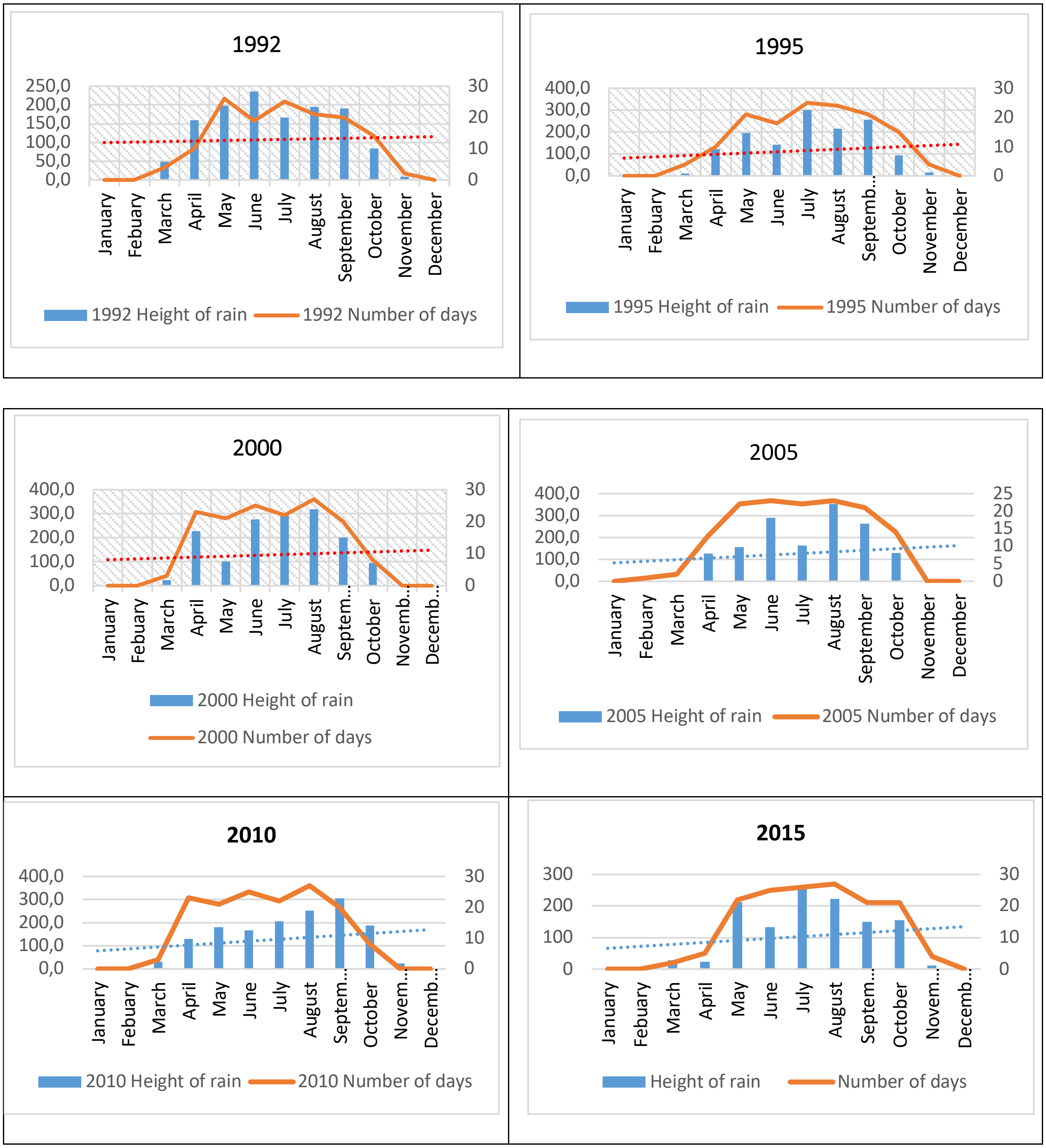
Tabl. XI : Maize farmers' experiential knowledge of rainfall onset

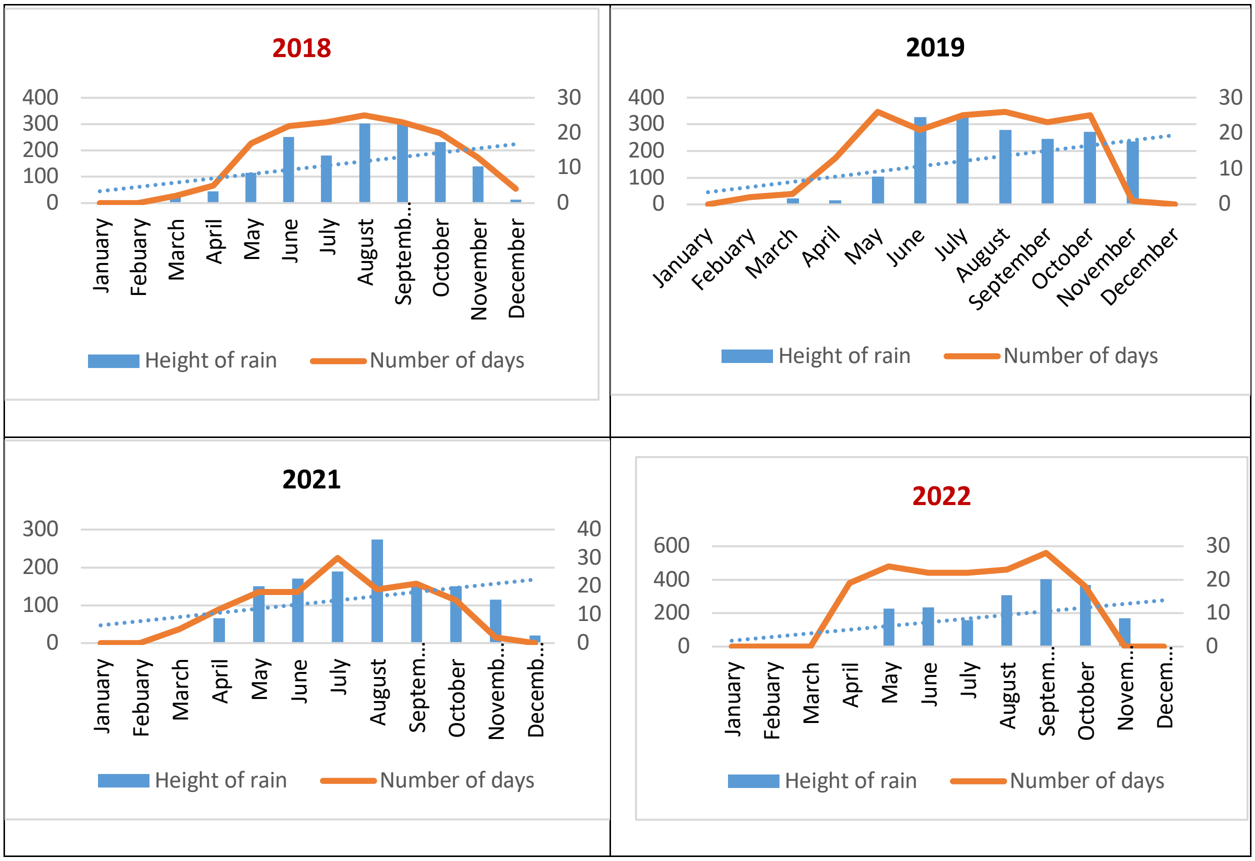
Perceptions	Effectives	Percentages (%)
Early	20	22%
Normal	14	15%
Late	57	63%
Total	110	100%

Source : *Field Survey KALWA/LILA 2023*

This misalignment, from traditional indicators like phenological cues or early showers, increases yield variability due to early or late planting. Pluviometric analysis (**Fig 10a-j**) shows key years of agronomic disruption, especially 2022 with delayed onset and high rainfall (1,871 mm), and 2018 where extended rains in December harmed harvest quality.

Fig. 10a-j : Pluviometric spatial variability analysis of Wassande area from 1992–2022.





Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

In Wassande, maize yields are influenced by when and how much it rains. In 2022 and 2019, late rainy seasons with heavy rain caused big yield drops. In 2018, a long rainy season disrupted harvesting, leading to losses. However, in 2011, an early rainy season with fewer rainy days improved yields. Late starts and too much or long rain consistently harm maize production. Anomalies, confirmed by field surveys, caused major yield losses due to waterlogging, germination on cobs, and pests. Heavy rainfall and a stable number of rainy days show a trend toward intense rain events, increasing risks for maize. These findings highlight the need to use scientific climate data with local knowledge to improve sowing schedules and crop resilience against rainfall changes in Wassande's maize sector.

3.2. Rainfall Variability Impact on Maize Cultivation

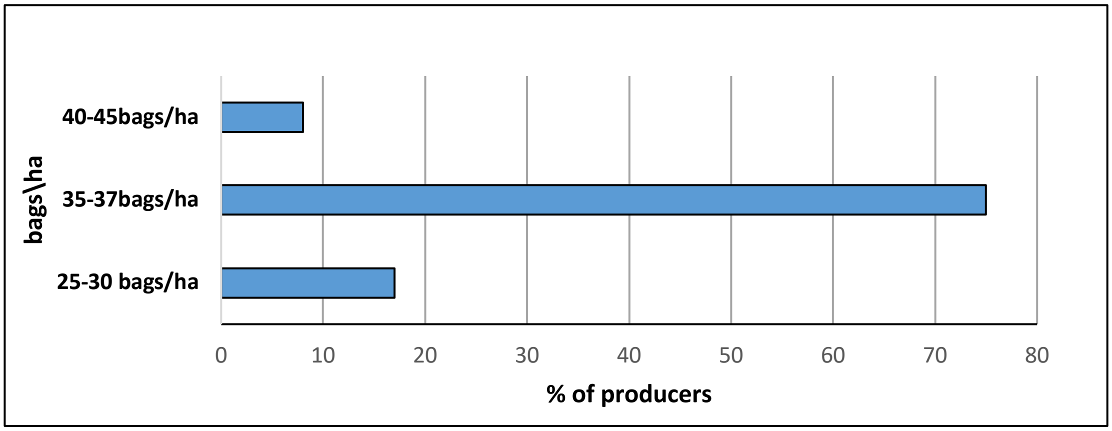
3.2.1. Evaluation and Results of Rainfall Variability Effects on Maize Production in Wassande

Rainfall variability significantly influences rain-fed agriculture. This study assessed its effects on maize farming in Wassande, Nyambaka district over the past thirty years. It utilized field survey data, precipitation indices, and farmer perceptions to identify challenges faced by maize farmers and to encourage resilience strategies that balance productivity with sustainability.

3.2.2. Agricultural Parameters and Yield Trends

Maize is a key crop in Wassande, with its farmland numbers growing after the closure of SODEBLE. However, yields are declining due to climate issues and pests. Field surveys show that 75% of farmers harvest 35–37 bags per hectare, 17% get 30–35 bags, and 8% yield 40–45 bags, as shown in (**Fig. 11**).

Fig. 11: Farmer yields per harvest over last thirty years.



Source: *Field Survey and Data Analysis KALWA/LILA, 2023*

However, losses are severe in adverse years, with 77% of farmers reporting fewer than 5 bags per hectare, 14% between 5–10 bags, and 9% between 10–15 bags.

The year 2022, marked by excessive rainfall (1,871 mm) and delayed sowing, recorded unprecedented losses, with yields plummeting to 2–6 bags per hectare. Yield trends indicate a perceived decline by 57% of farmers, stagnation by 34%, and an increase by 9%, reflecting rainfall-driven disruptions.

Land use patterns, detailed in (**Tabl. XII**), show 54% of farmers cultivating 2–3 hectares, 15% on 1–2 hectares, and 14% on 5–6 hectares, with cooperatives managing over 250 hectares.

Tabl. XII : Distribution of surface area according to the 2023 field surveys.

Superficies (ha)	Effective	Percentage (%)
-1]	3	3%
[1-2]	16	15%
[2-3]	56	54%
[3-4]	4	4%
[4-5]	10	10%
[5-6[+	15	14%
Total	110	100%

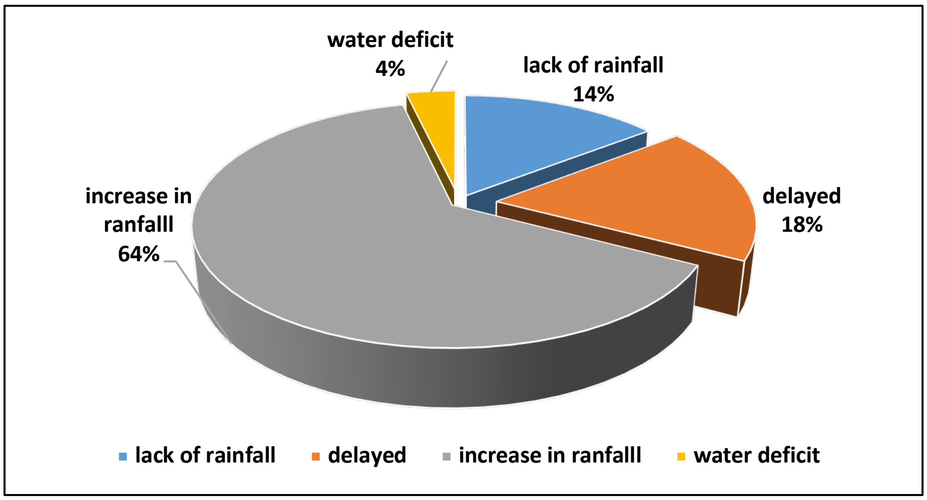
Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

These patterns underscore the interplay between land allocation and yield variability, exacerbated by rainfall instability and secondary factors like pests and soil degradation.

3.2.3. Rainfall Variability Impacts

Rainfall variability, including irregular start, too much rain, and dry spells, harms maize production in Wassande. Water stress from late rains or mid-season droughts leads to stunted growth and ear failure. Excess rainfall, like in 2022, causes runoff and seed rot. Farmers' views on rainfall trends (**Fig. 12**), show 64% see increased rain, 18% report delays, 14% note early cessation, and 4% observe deficits, with early excesses being especially harmful during sowing and blooming .

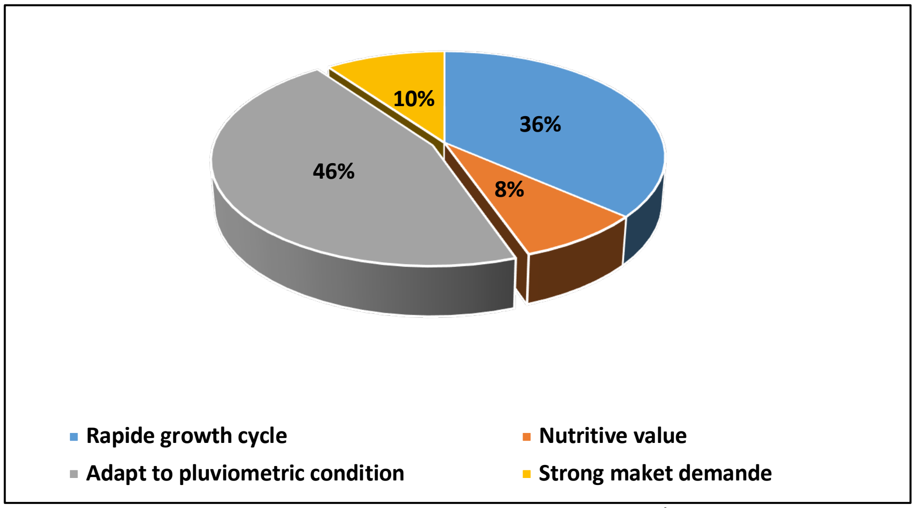
Fig. 12: Farmers' perceptions of rainfall trend characteristics



Source: *Field Survey and Data Analysis KALWA/LILA, 2023*

To counter these challenges, farmers adopt resilient varieties like CMS 2019, Pana, and Shaba, selected for climatic adaptability (46%), rapid vegetative cycles (36%), market demand, and nutritional value, as shown in (**Fig. 13**).

Fig. 13 : Farmers' perceptions on the reasons for choosing maize species.



Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

These adaptations reflect strategic responses to environmental stressors, aligning with global trends in climate-resilient agriculture.

Beyond rainfall, biotic and abiotic factors further constrain maize yields in Wassande. Diseases such as Maize Streak Virus, rust (*Puccinia polysora*), helminthosporiosis (*Helminthosporium turcicum*), sheath rot, and corn smut, detailed in (**Tabl. XIII**), cause significant losses, with early infections reducing yields by up to 50%.

Tabl. XIII : Factors linked to destructive maize diseases at Wassande and their symptoms

Deseases /parasites	Damage/events
Corn charcoal or smut *(ustilago maydis)*	Appearance of tumours in the epi
Yellow leaves	disturbance to the plant cycle
Corn Rust (*Puccinia polysora*)	This rust attacks the oldest leaves first and develops mainly at the end of the crop, which limits its impact on yields.
Band disease	As these striae develop, they merge to form irregularly interrupted lines running parallel to the veins.
Helminthosporiose	Helminthosporiosis is characterised by scorch marks that appear on the leaves as large brownish spots running parallel to the veins.

Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Pests, including stalk borers and leaf pests, affect 79% of fields, according to maize farmers opinion and (**Tabl. XIV**), with damage usually caused to plants by these pest.

Maize crops are subject to pest attacks throughout their growing cycle. Among these pests, the most damaging to the maize crop at Wassandé are soil pests such as the stalk and cob borers and leaf pests. These soil pests' infections on maize plants and leafs, outlined in table 14, provide information on some of the pests encountered in the study area, and their manifestation.

Tabl XIV : Pests encountered in the study area, and their manifestation.

Pests	Manifestation.
-insects	The young larvae bore holes in the leaves of shoots. Older larvae dig galleries at the base of the shoot.
- Weevils	- Dig egg-laying holes or adult exit orifices in envelopes, -the larvae feed on the contents of the grain, which reduced the weight and quality of stored foodstuffs
- Birds	With its beak, the bird tears the protective spathes from the ears and the grains are swallowed whole. .
- Rodents (rats, hedgehogs)	At the time of heading, animals cut the stems a few centimeters from the ground and eat the ears on the spot or carry them to their burrows).

Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Soil infertility, driven by leaching and overgrazing, impacts 82% of farmers, with 62 of 110 surveyed citing reduced fertility, (**Fig. 14**) and (**Fig. 15**).

Fig. 14: Wassande maize growers' perception of soil infertility

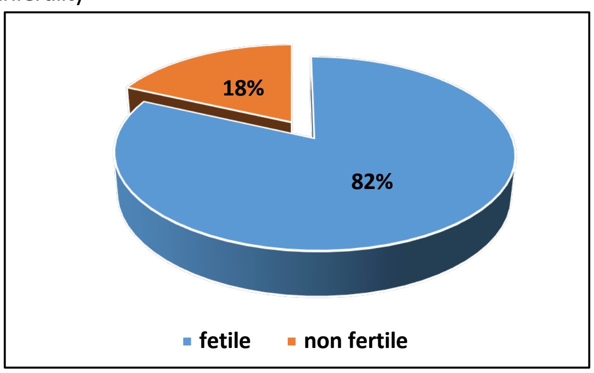
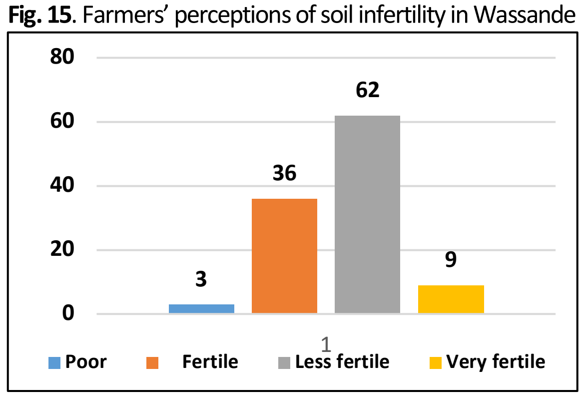


Fig. 15. Farmers' perceptions of soil infertility in Wassande



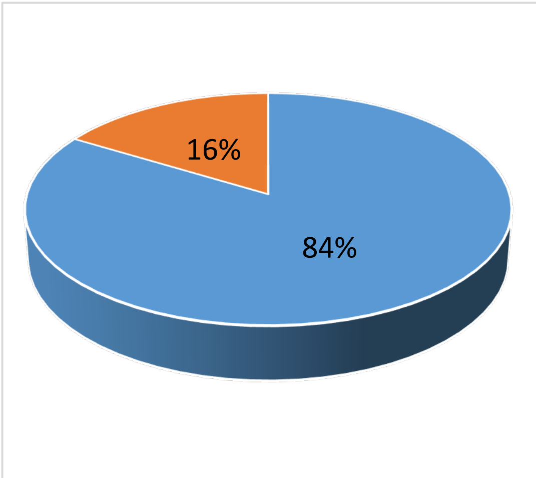
Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Farmers in the surveyed areas have technical views on soil infertility. Many maize growers shared their experiences regarding soil quality. One anonymous farmer noted, ***"The soil you see here has changed a lot. It's cold so we have to put in limestone (carbonate) before planting. We're also facing the problem of too much rain at the start of the season. It was a disaster here, with yields falling by more than 56%. "*** Another farmer explained that to determine soil infertility, they check for weed growth and other soil elements. They mentioned that cold soils and a lack of weeds suggest degradation, leading to the need for limestone (which further degrades the soil) and crop rotation.

3.2.3. Socio-Economic Conflicts

Agro-pastoral conflicts, fueled by livestock encroachment in maize fields, exacerbate production challenges, as livestock farming rivals agriculture in economic importance Such conflicts, reported by 84% of farmers, (**Fig. 16**), arise from herders' proximity to fields, negligence, and unpaid penalties, with mitigation strategies like ditches shown in (**Fig. 17**) being implemented locally to prevent animals from entering farmland

Fig. 16: Maize farmer-breeder conflicts.



Source: *Field Survey and Data Analysis KALWA/LILA, 2023*

Fig 17 : Techniques to keep animals from farms.

Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

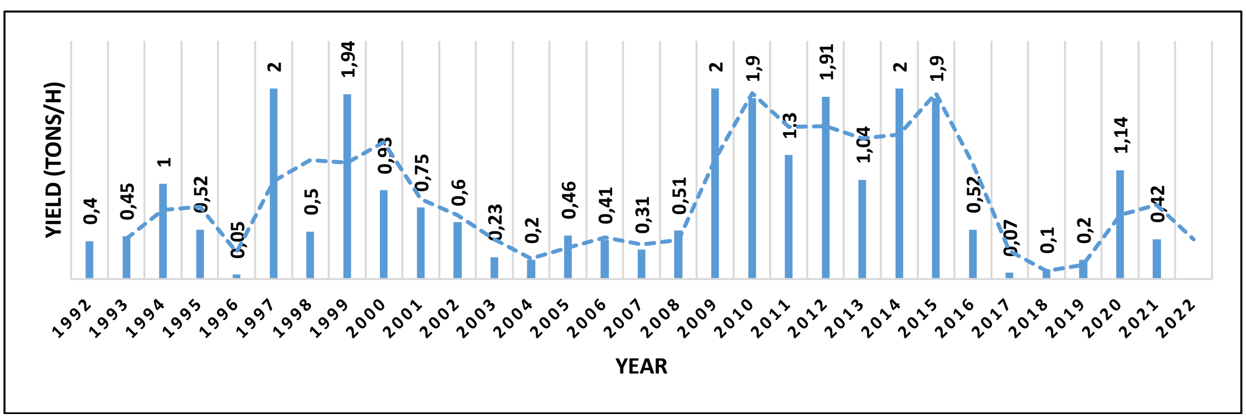
These tensions underscore the need for integrated land-use policies to harmonize agricultural and pastoral activities.

4. Correlations Patterns of Rainfall Variability and Maize Production in Wassande, 1992–2022

4.1. Evolution of maize production yield in Wassande between 1992-2022

Maize production in the Wassande agricultural basin demonstrates considerable variability across the 1992–2022 period, driven by environmental and agronomic factors. Analysis of yield data over these three decades reveals distinct inter-annual fluctuations, offering critical insights into the determinants of maize productivity. A key finding is the strong correlation between yield variations and rainfall patterns, underscoring precipitation as a pivotal driver of agricultural outcomes. These findings inform strategies to bolster resilience and optimize maize production amid evolving climatic conditions (**Fig. 18**).

Fig. 18 : Temporal Trends in Maize Production Yield in Wassande (1992–2022).



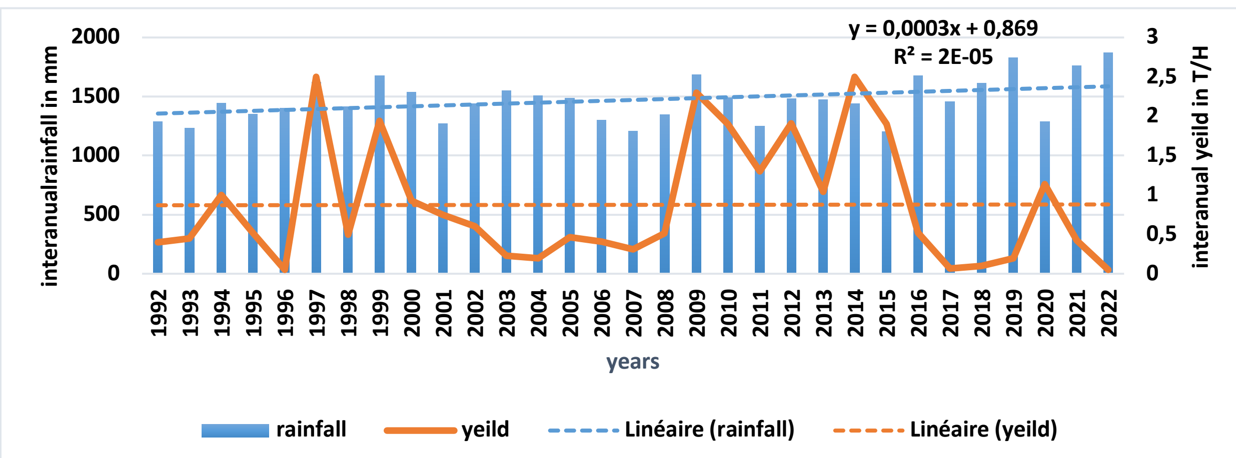
Source: *Field Survey and Data Analysis KALWA/LILA, 2023*

Total annual rainfall does not always improve yields, especially when it exceeds 1,200 mm. Extreme years like 2022 (1,871 mm), 2018, 2017, and 2019 had yield declines due to issues like waterlogging and pests, with yields dropping to 2–6 bags/ha in 2022 from a usual 35–37 bags/ha. Moderate rainfall (~1,200 mm) and its timing often lead to better yields.

4.1.1. Inter-Annual Rainfall and Maize Yield Correlation (1992–2022)

Rainfall is a critical determinant of crop performance, especially for maize, a staple in Wassande. A correlation analysis of annual rainfall and maize yield data from 1992 to 2022 reveals a mean yield of 0.95 tonnes per hectare. The results indicate a declining trend in yields when rainfall exceeds optimal levels, typically over 1,200 mm annually. The linear trend in (**Fig. 19**) shows that excessive rainfall negatively impacts yields through waterlogging, nutrient leaching, and increased pest prevalence. Notably, years with high rainfall, such as 2017, 2018, 2019, and 2022, correspond to reduced yields. This suggests that additional factors, including rainfall distribution, soil quality, and agricultural practices, also significantly influence productivity.

Fig. 19 : Correlation Between Inter-Annual Rainfall and Maize Yield (1992–2022).

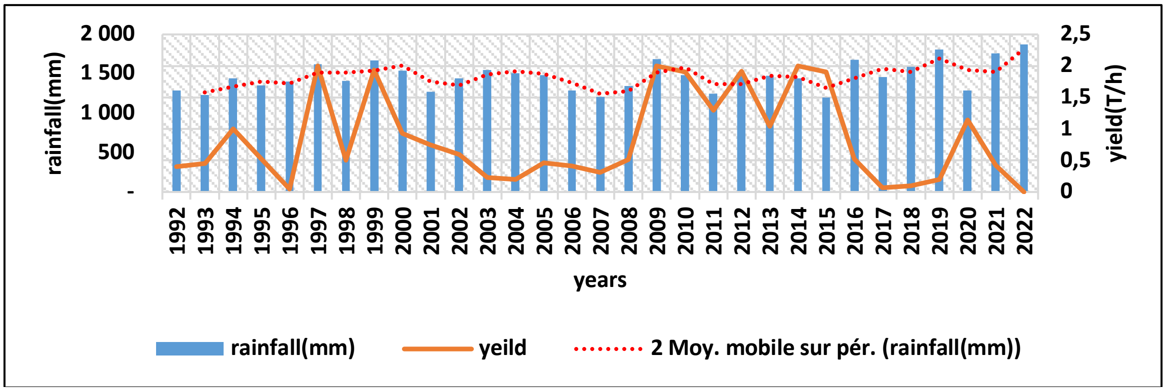


Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

4.1.2. Inter-Seasonal Rainfall and Maize Yield Dynamics (1992–2022)

Maize cultivation in Wassande primarily occurs during the rainy season, making rainfall variability crucial for yield outcomes. Analysis of inter-seasonal rainfall and maize yield data from 1992 to 2022 reveals significant fluctuations, especially during the second decade, with an inverse correlation noted in several years (**Fig. 20**). These findings underscore the complex relationship between climatic variability and agricultural productivity, impacting regional food security. By clarifying how seasonal rainfall affects maize yields, this analysis aids in developing adaptive strategies to enhance resilience against climate change.

Fig. 20 : Correlation Between Inter-Seasonal Rainfall and Maize Yield (1992–2022).



Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

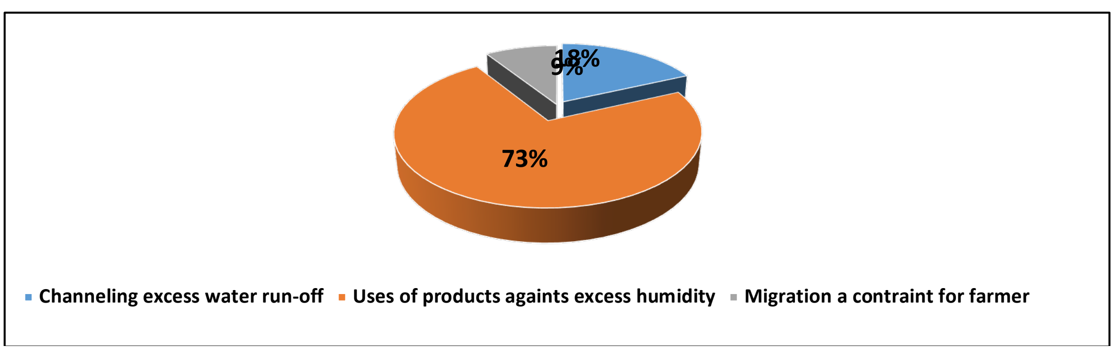
The analysis of maize yield trends in Wassande from 1992 to 2022 underscores the profound influence of rainfall both annual and seasonal on agricultural productivity. Excessive rainfall, poor distribution, and other agronomic factors contribute to yield variability, necessitating targeted interventions to mitigate risks such as waterlogging and nutrient loss. These insights are vital for informing sustainable agricultural practices and ensuring food security in Wassande under changing climatic conditions. By aligning cultivation with predictive climate models and adopting resilient varieties, farmers can optimize yields, bolster food security, and sustainably navigate the challenges of climate variability in Wassande's agricultural landscape.

4.2. Local Adaptation Strategies

4.2.1. Strategies Addressing Water Stress and Rainfall Deficits

Rainfall variability significantly threatens maize cultivation in Wassande, requiring strong adaptation strategies for agricultural resilience and food security. To address water stress from irregular rainfall, Wassande farmers implement adaptive measures based on ecological resilience, defined as a system's ability to recover from disturbances. Cultivating near watercourses like Mayo Bogui and using motor pumps or manual irrigation with 25-liter cans ensures water availability during dry spells, as field surveys indicate. Many farmers practice combined cropping, pairing maize with groundnuts or bananas to enhance water-use efficiency (**Fig. 21**).

Fig. 21: Strategies used by farmers in Wassande to combat excess rainfall.



Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

This strategy aligns with agroecological principles that promote biodiversity for improved resilience. Farmers also select drought-resistant, short-cycle varieties introduced by IRAD, prioritizing early-maturing hybrids to adapt to erratic rainfall. The double-field strategy, involving planting in two locations to mitigate localized rainfall failure, further optimizes yields through adaptive spatial diversification.

4.2.2. Strategies for Excess Rainfall and Secondary Stressors

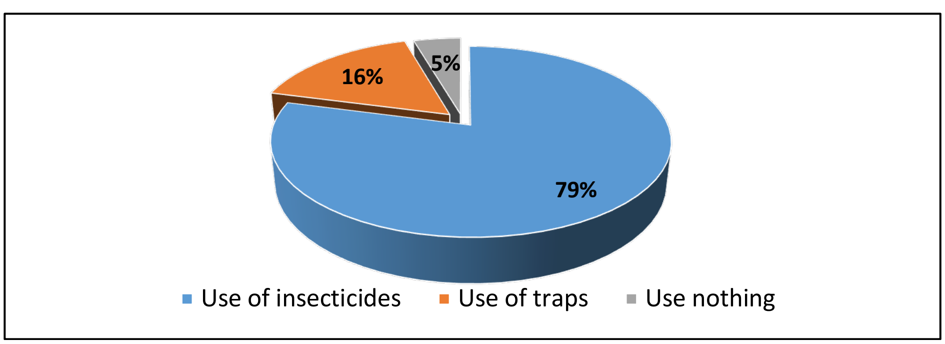
Excess rainfall in 2022 caused runoff and soil saturation, prompting targeted interventions. Farmers manage runoff in low-lying areas and use products like Bastion to reduce soil moisture; 73% employ these treatments, 18% channel water, and 9% abandon plots. Adjusting the agricultural calendar to delay sowing until late April helps mitigate risks from early rains, despite potential seed loss from dry sowing. Crop rotation with potatoes or cassava restores soil nutrients, while organic manure (chicken, goat, cow waste) enhances fertility, addressing infertility concerns reported by 82% of farmers. Analysis of pest control strategies (**Tabl. 15**) shows 79% use insecticides, 16% employ traps, and 5% take no action (**Fig. 22**).

Tabl. XV : Pest control methods used by Wassande farmers.

Diseases / parasites	Control techniques
Stem borers	Destroy stubble after harvest by burial or incineration Sow at the appropriate time
Corn charcoal (*Ustilago maydis*)	Use of seeds appropriate.
Yellow leaves	Setting up a system Irrigation.
Corn Rust (*Puccinia polysora*)	The use of insecticides
Band disease	To combat this disease, resistant or tolerant varieties should be used. Infected maize plants should not be uprooted, as disturbing the leafhoppers causes them to fly and spread the disease to other plants.
Helminthosporiosis	Control of this disease is essentially based on the use of less susceptible varieties.

Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

Fig. 22 : Distribution of farmers on the use of pest control methods on maize crops in Wassande.



Source : *Field Survey and Data Analysis KALWA/LILA, 2023*

These strategies, while resource-dependent, demonstrate farmers' ingenuity in navigating climatic and biotic challenges, informing sustainable practices for Wassande's maize sector.

5. DISCUSSION

This study analyzes the impact of rainfall variability on maize production in Wassande, Nyambaka district, from 1992 to 2022, validating climatological and agronomic theories while providing insights for sustainable agriculture. Inter-annual rainfall fluctuations, assessed through the Standardized Precipitation Index (SPI), confirm the average climate theory, with extreme humidity in 2022 (SPI 3.47, 1,871 mm) and near-moderate dryness in 2017 (SPI -0.04) contributing to yield declines (Nicholson, 2001). A weak negative correlation ($r \approx -0.35$, $p < 0.05$) between rainfall (>1,200 mm) and yields (mean 0.95 tonnes/ha) underscores maize's sensitivity to excess precipitation, reducing harvests to 2–6 bags/ha in 2022 from a typical 35–37 bags/ha due to waterlogging and nutrient leaching. Seasonal analysis reveals stronger inverse correlations ($r \approx -0.48$, $p < 0.01$) during erratic rainy seasons (2002–2012), exacerbating pest and disease incidence, such as Maize Streak Virus (Nkurunziza et al. 2012: 153). These findings are consistent with Lobell et al. (2011: 616), which highlight maize's vulnerability to extreme temperatures and precipitation. However, they contrast with Thornton et al. (2011:117), whose temperature-focused study found that rising temperatures primarily resulted in shorter growing seasons and more frequent crop failures. This underscores Wassande's unique reliance on rainfall and its distinct agricultural approach.

Wassande farmers' bio-ecological adaptations support adaptation theory, characterized by systemic adjustments to environmental stressors. Combined cropping (maize with groundnuts), cultivation near watercourses, and short-cycle varieties (e.g., CMS 2019) mitigate water stress, with 73% of farmers using moisture-regulating products. Crop rotation and organic manure address soil infertility (82% prevalence), while 79% apply insecticides against pests. These strategies reflect Lin, BB (2011:183) findings on crop diversification and resilience but differ from Thornton et al.'s (2011: 117) technological focus, highlighting Wassande's ecological unique approach. This study provides localized insights that differ from the agro-climatic resilience framework proposed by Shemshad et al. (2025: 3452), which primarily emphasizes improving agricultural practices in response to climate challenges but pays little attention to community engagement. In contrast, this research offers a model for community-driven resilience, enabling farmers to use precise sowing schedules and resilient crop varieties to enhance yields and strengthen food security amid climate variability.

CONCLUSION

In conclusion, this study provides a comprehensive examination of the effects of rainfall variability on maize cultivation in Wassande, Vina, Adamaoua, over a 30-year period. The findings highlight significant climatic and agronomic dynamics that are crucial for promoting sustainable agriculture in rain-fed systems. The analysis indicates notable fluctuations in rainfall patterns, with extreme humidity and moderate dryness profoundly impacting maize yields, which were further exacerbated by secondary stressors such as soil infertility, pests, and diseases. In response to these challenges, local farmers, predominantly women, have implemented innovative bio-ecological adaptations, including combined cropping, the use of short-cycle varieties, and organic practices, demonstrating resilience and a proactive approach to managing erratic rainfall. This localized focus underscores the importance of context-specific strategies in enhancing food security and aligns with broader calls for adaptive agricultural practices. However, the study acknowledges certain limitations, such as reliance on extrapolated data and the need for further exploration of maize genetics. Future research should prioritize the establishment of on-site meteorological stations and genomic profiling, alongside socio-economic assessments to address gender-specific barriers faced by farmers. Ultimately, by integrating empirical rainfall trends with adaptive strategies, this study offers a valuable model for empowering Wassande's agricultural community to effectively navigate the complexities of climate variability and improve productivity in an evolving climate landscape.

BIBLIOGRAPHIC REFERENCES

BEKUMA Abdisa, TEKA Girma Mamo Diga, ALEMAYEHU Regassa Tolessa, 2022. « Impact of climate variability on rain-fed maize and sorghum yield among small references older farmers »*Cogent Food & Agriculture*, vol. 8, n° 1, p. 2057656.

CCNUCC, 2011. *Document de politique générale sur l'agriculture et les changements climatiques*. Meridian Institute, p.25.

DINET Jérôme, PASSERAULT Jean-Michel, 2004. « La recherche documentaire informatisée à l'école », *Hermès, La Revue*, vol. 2, n° 39, vol. 2, p. 126-132.

GOUATAINE Seingué Romain, 2018. *Effets des variabilités pluviométriques sur les systèmes de culture et adaptations des agriculteurs dans la plaine du Mayo-Kebbi (sud-ouest du Tchad)*. Thèse de doctorat, université, ville non précisée, p.326.

Lin, Brenda, 2011. «Resilience in agriculture through crop diversification: adaptive management for environmental change. » *BioScience*, Vol. 61, n°.3, p. 183-193.

LOBELL David, SCHLENKER Wolfram, COSTA-ROBERTS Justin, 2011. « Climate trends and global crop production since 1980 », *Science*, vol. 333, n° 6042, p. 616-620.

MASSON-DELMOTTE Valérie, ZHAI Panmao., PÖRTNER Hans-Otto, ROBERTS Debra., SKEA Jim, SHUKLA Priyadarshi, PIRANI Anna 2018. *Résumé à l'intention des décideurs*, Réchauffement planétaire de 1,5° C, p. 32.

MINADER. 2021. *Analyse des effets du changement climatique sur l'agriculture : cas de la région de l'Adamaoua*, p.68

NKURUNZIZA Gélase, NDAYISENGA Modeste, NDAYIHANZAMASO Privat, NDAYIRAGIJE Pascal, NIYONGABO Damien, 2012. *Techniques de culture, de protection et de conservation du maïs – Cas des variétés à pollinisation libre (Manuel ISABU)*, Bujumbura.

OLIVRY, 1986. «Fleuves et rivières du Cameroun, Paris, Collections Monographiques hydrologiques». *ORSTOM*, n° 9, p.733.

OLSSON Lennart, OPONDO Maggie, TSCHAKERT Petra, AGRAWAL Arun, ERIKSEN Siri, MA Shiming, PERCH Leisa, ZAKIELDEEN Sumaya, 2014. « Livelihoods and poverty », dans FIELD Christopher B. (dir.), Climate Change 2014 Impacts, Adaptation and Vulnerability : Part A: Global and Sectoral Aspects, Cambridge, Cambridge University Press, p. 793-832.

PCD, 2013. *Plan communal de développement de Nyambaka, Nyambaka*, p329.

SHEMSHAD Masoomeh, SYNOWIEC Agnieszka, KOPYRA Marcin, BENEDEK Zsófia, 2025. « The Community-Driven Ecosystem Resilience and Equity Framework: A Novel Approach for Social Resilience in Ecosystem Services », *Sustainability*, vol. 17, n° 8, p. 3452.

THORNTON Philip, JONES Peter, ERICKSEN Polly, CHALLINOR Andrew, 2011. « Agriculture and food systems in sub-Saharan Africa in a 4 C+ world », Philosophical Transactions of the Royal Society A: *Mathematical, Physical and Engineering Sciences*, vol. 369, n° 1934, p. 117-136.

AUTEUR(ES)

Reni Bibriven **LILA**
Lecturer-Researcher, Environmental Geomorphologist
University of Ngaoundere, Cameroon
Courriel : bibriven1lila@gmail.com

Yvette **KALWA**
Master Level Graduate, Geography
University of Ngaoundere

AUTEUR CORRESPONDANT

Reni Bibriven **LILA**
Courriel : bibriven1lila@gmail.com

© Edition électronique

URL – Revue Espaces Africains : https://espacesafricains.org/

Courriel – Revue Espaces Africains : revue@espacesafricains.org

ISSN : 2957-9279

Courriel – Groupe de recherche PoSTer : poster_ujlog@espacesafricians.org

URL – Groupe PoSTer : https://espacesafricains.org/poster

© Éditeur

- Groupe de recherche Populations, Sociétés et Territoires (PoSTer) de l'UJLoG

- Université Jean Lorougnon Guédé (UJLoG) - Daloa (Côte d'Ivoire)

© Référence électronique

Reni Bibriven LILA, Yvette KALWA, *« Rainfall variability and farmer's bio-ecological adaptation Strategies for Maize Production in Wassande, Adamawa, Cameroon (1992–2022) »,* Numéro Varia (Numéro 2 | 2025), ISSN : 2957- 9279, p. 199-228, mis en ligne, le 30 juin 2025, Indexations : Road, Mirabel, Sudoc et Impact factor (SJIF) 2025 : 5. 341.