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Rainfall variability and changes in market gardening systems: a case study in Réo (mid-west region of Burkina Faso)

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Abstract: Lowland market gardening is an economic activity in Burkina Faso. However, current climatic conditions are causing changes in this activity. The objective of this study is to analyze changes in market gardening systems in the light of rainfall variability. Both primary and secondary data were used. The study shows that the area is experiencing an increase in annual rainfall, with high variability (CV over 30%). The climatic aridity index shows alternating wet periods (1990-2002), dry periods (2002-2011) and a wet period (2011-2020). These different alternations of wet and dry periods are punctuated by high variability. In addition, the study reveals that market gardeners also perceive rainfall variability through the duration of the rainy season, the variability of annual rainfall and pockets of drought. This leads them to recompose their market gardening system. Thus, in the 2000s, the importance index (II) of vegetable cropping systems was high for systems such as: Onion + tomato + cabbage; Onion + tomato + chilli; Onion + tomato + African aubergine; Onion + tomato + African aubergine + chilli. The choice of these systems was motivated by urban demand. However, the current climatic context obliges market gardeners to produce vegetables while taking into account water problems. This has led market gardeners to recompose their vegetable growing system, with the domination of systems such as: Celery + parsley; Mint + parsley; Parsley + mint + celery; Parsley + onion + mint. However, the choice of these systems depends on socio-demographic characteristics. Thus, Spearman's rank correlation revealed that the experience of the vegetable farmers has a moderate correlation (p=0.559, p-value=0.000) with the choice of vegetable cropping systems and also the size of the farm, with p=0.657, p-value=0.000).

1. Introduction

Climate is a long-term average of the weather conditions of a place (Sidi, 2022). Today, the issue of climate variability is considered one of the most controversial issues in the world (Mozaffari, 2022). In West Africa, climate variability leads to crop yield losses of 11% (Roudier et al., 2011). In Burkina Faso, the droughts of the 1970s and 1980s led to environmental degradation, with population movements to wetter areas (lowlands) (Pale and Da, 2016). In addition, the Burkinabe state turned to irrigated agriculture. As a result, more than 1,400 small and large dams have been built (Cecchi, et al. 2009), compared to 200 dams before the 1970s (Gross, 2018). Then, several thousand-rural people invested in market gardening. Subsequently, the lowlands, which are seasonal wetlands, were taken over by farmers for market gardening, which is characterised by the production of a diverse range of crops (Tapsoba, 2016).

All the regions of the country are involved in vegetable production. However, the fluctuating rainfall in place in the country for several decades has led to a disruption of vegetable production in market gardening areas such as Sanguié in the Mid-West region of Burkina Faso. Many studies mention the decrease in productivity of the main vegetables such as onions, tomatoes and cabbages (Karambiri, 2020), the vulnerability of market gardeners to climate variability (Ouédraogo et al., 2022), as well as soil erosion and reduced moisture in lowlands (Yaméogo et al., 2022). However, few studies address changes in market gardening systems in the context of current rainfall variability.

This study fills this gap. The objective of this study is therefore to analyse changes in market gardening systems in the commune of Réo. More specifically, the aim is to characterise rainfall variability in the area, to analyse market gardeners' perceptions of rainfall variability and, finally, to analyse the changes in market gardening systems in the light of rainfall variability.

2. Materials and Methods

2.1. Presentation of the study area

The study area is a town in the department and the urban commune of Réo, the chief town, located in the province of Sanguié and the Mid-West region of Burkina Faso.

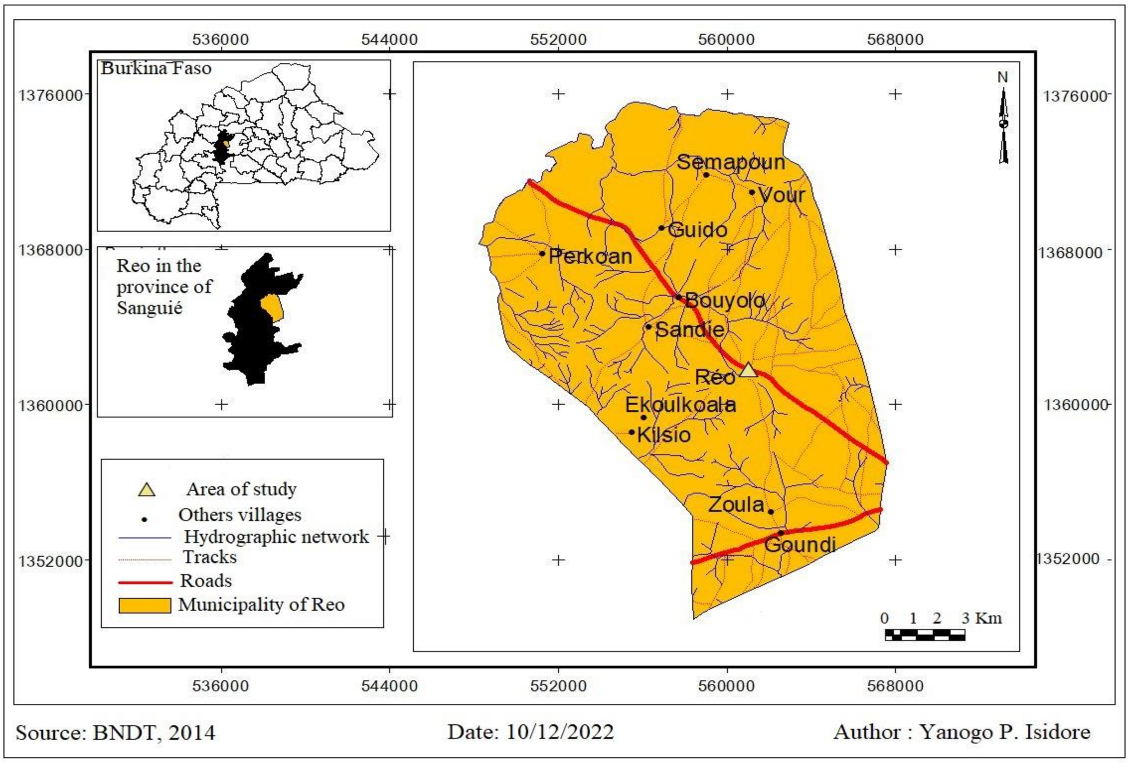

Figure 1. Geographical location of the study area

2.2. Data collection methods

2.2.1. Secondary data

Rainfall data were collected from the National Meteorological Agency of Burkina Faso (NMABF). The study focuses on the agricultural station of Réo in the province of Sanguié, Mid-West region of Burkina Faso. The period considered is from 1991 to 2020. Rainfall data were collected on a monthly basis.

2.2.2. Primary data

They come from the field surveys. Indeed, a preliminary survey was first carried out in the field to determine the total population engaged in market gardening in Réo. We were able to estimate it at 1,100 market gardeners. This allowed us to find the target population through the formula of Yamane, 1967 quoted by Israel (1992) as follows:

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

We therefore have 286 market gardeners who were surveyed during the two-month period from December 2022 to January 2023. The surveys focused on the characteristics of the actors and the market gardening systems promoted. These primary data were supplemented by secondary data from readings, scientific articles and books.

2.3. Data processing methods and analysis

2.3.1. Methods for analysing rainfall variability

- Detection of trends and breaks in stationarity of rainfall data

The methods used for this study are based on the detection of breaks in the time series. These are the Pettitt test and the Hubert segmentation. In the Hubert segmentation process, the time series is divided into consecutive segments m, with m>1 and satisfying the Scheffe test (Ndione et al., 2017). It also looks for multiple changes in the mean (Servat et al., 1999). The means of the different segments must be significantly different from the mean of the raw data. The tests in the Hubert segmentation procedure involve the use of the squared difference Dm between the online observations and the means of all retained segments (Ndione et al., 2017). For the authors, we can consider ik (k=1,2,...,m), the rank of the last observation of a kth validated segment in the raw time series Xt , the dispersion and the mean of the corresponding segment are respectively:

$$n_k = i_k - i_{k-1} \quad (2)$$

$$\bar{X}_k = \frac{1}{n_k} \sum_{i=i_{k-1}+1}^{i_k} x_1 \, , with\, i_0 = 0 \quad (3)$$

The Pettitt test is a non-parametric approach derived from the Mann and Withney test (Servat et al., 1999). It allows to identify a break point in a sequence of independent random variables Xi, i = 1, N (Zodekon et al., 2021). The test is particularly sensitive to a change in the mean. For this purpose, we define the variable (Zodekon et al., 2021):

$$U_{t,n} = \sum_{i=n}^{t} \sum_{j=t+1}^{n} sgn(x_i + x_j), \qquad with\, sgn(x) = 1\, if\, x > 0, \qquad 0\, if\, x = 0, \qquad and - 1\, if\, x < 0 \quad (4)$$

- Interannual variability index or Coefficient of Variance (CV)

The coefficient of variance (CV) is a statistical measure of the difference between the data points and the mean value of a series (Achite et al., 2021). In addition, it is used to detect the seasonal and annual variability of precipitation for the observation period (Belay et al., 2021). For this reason, it is also called the interannual variability index (Longobardi and Boulariah, 2022). Higher values of CV indicate higher variability and vice versa (Achite et al., 2017). Its formula is declined as follows (Oliver, 1980):

$$CV = 100 \times \frac{\sigma}{\mu} \quad (5)$$

Where, CV is the coefficient of variation, σ is the standard deviation and μ is the mean precipitation of the recording period.

The degree of variability of annual precipitation is, however, ranked on a scale (Table 1).

Table 1: Coefficient of variation (CV) scale

Coefficient of Variation (CV)	Scale of interpretation
CV > 30	High rainfall variability
20 < CV > 30	Moderate rainfall variability
CV < 20	Low rainfall variability

Source: Adapted from Belay et al., 2021

- Martonne Climate Aridity Index

Climatic aridity combines rainfall and temperature. Its characterisation is done through the calculation of the Martonne index, which makes it possible to characterise the absorbing and evaporating power of the air from the temperature (Ba et al., 2018). Seingue, 2018 also notes that this index helps to characterise the climate of a region and assess its impact on physical and biological processes. For the author, the index is defined as follows:

For the year:

$$I_{\alpha(annual)} = \frac{P}{T+10} \quad (6)$$

with, **P** = Total annual rainfall/mm and **T** = Average annual temperature in degrees Celsius (°C); In which, **P** = Total monthly rainfall, and **T** = Average monthly temperature.

Table 2. Martonne Index (MI) and its four (04) levels of interpretation

Index	**Climatic condition**
MI >20	Sufficient humidity
MI < 10	Aridity
10 <MI< 20	Tendency to drought
MI< 5	Hyper aridity

Source: Adapted from Seingue, 2018

2.3.2. Methods of analysis of survey data

Descriptive statistics such as mean, sum and citation frequencies were used. The citation frequency (Fc) was obtained according to the formula Fc is equal to f divided by N, where f is the number of respondents involved in the cropping system; N is the total number of respondents practicing the cropping systems.

Furthermore, the calculation of the degree of importance (DI) of the vegetable cropping systems before and after the climatic disturbance was done according to the following formula (Assaf et al., 1995):

$$DI = \sum_{t=1}^{4} \frac{a_1 \times x_1}{3} \quad (7)$$

where, DI= importance index; a_i=weight of the *i*th response; x_i=frequency of the *i*th response; i=response category index. The weight of the answer is given in the following table 3.

Table 3. Response categories and their weight

Response	**Weight**
Very important (VI)	3
Important (I)	2
Somewhat important (SI)	1
Not important (NI)	0

Source: Adapted from Abd El-Razek et al., 2008

To analyze the correlation between sociodemographic characteristics and vegetable cropping systems adopted in the context of rainfall variability, Spearman rank correlation was performed using the following formula (Lobo and Guntur, 2018):

$$p = \frac{1-6\sum D^2}{N(N^2-1)} \quad (8)$$

where: *p*=Spearman rank correlation value; d = margin of each pair value; n = Sperman rank pair values

The Spearman rank correlation is a non-parametric test, which has the obvious advantage of not requiring the assumption of normality or homogeneity of variance (Assaf and Al-Hejji, 2006). Again, according to the authors, it compares medians rather than means and therefore, if the data contain one or two outliers, their influence will be cancelled out. In order to interpret the correlations in the context of the relationship under discussion, we can use some indicative values in Table 4 below.

Table 4. Spearman rank correlation value et interpretation

Spearman rank correlation	Intervals	Interpretation
p	0.3 to 0.5	Low positive correlation
p	−0.3 to −0.5	Low negative intensity correlation
p	0.5 to 0.8	Positive medium-intensity correlation
p	−0.5 to −0.8	Negative medium intensity correlation
p	0.8	High intensity correlation

Source: Held, 2010

SPSS 25 software was used to calculate the Spearman rank correlation.

3. Results

3.1. Trend and break in stationarity in the rainfall series between 1991 and 2020

The pettitt test shows that the rainfall data had a break in 2011 (Figure 2).

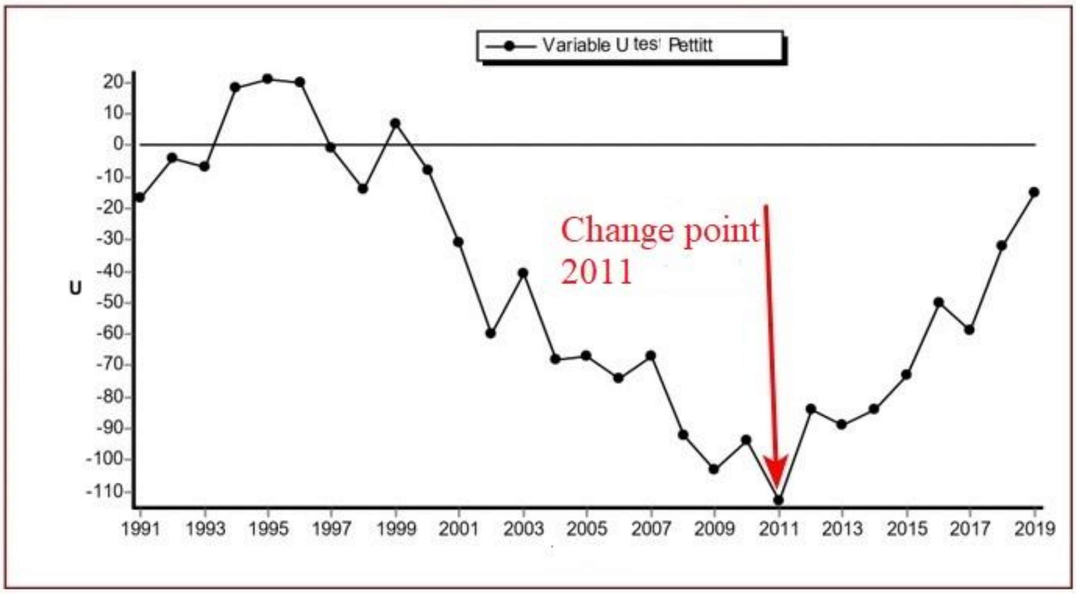

Figure 2. Pettitt test applied to rainfall data from the Reo station

This figure shows an ascending phase of annual rainfall totals after the 2011 break. Hubert's segmentation procedure clearly shows the beginning and end of the breaks as well as the average rainfall totals (Table 5).

Table 5. Hubert's segmentation of rainfall data

Start	Start	End	Standard deviation
1991	2011	747.724	118.223
2012	2020	880.933	110.888

Source: NMABF, 1991-2020; Significance level of the Scheffé test: 1%.

Table 5 shows two (02) breaks in the rainfall data, but with an increase in cumulative rainfall from an average of 747.724mm (1991-2011) to an average of 880.933mm (2012-2020). This indicates an increase in annual cumulative rainfall over the period 1991-2020.

3.2. Annual and monthly rainfall variability between 1991 and 2020

Figure 3 below shows that over the period 1991-2020, annual rainfall totals vary strongly, which is due to coefficients of variation (CV) of over 30% between 1991 and 2020. However, in the years 2007 and 2008, annual rainfall varies less, while in the years 2010-2011 and 2018-2019, it varies very strongly.

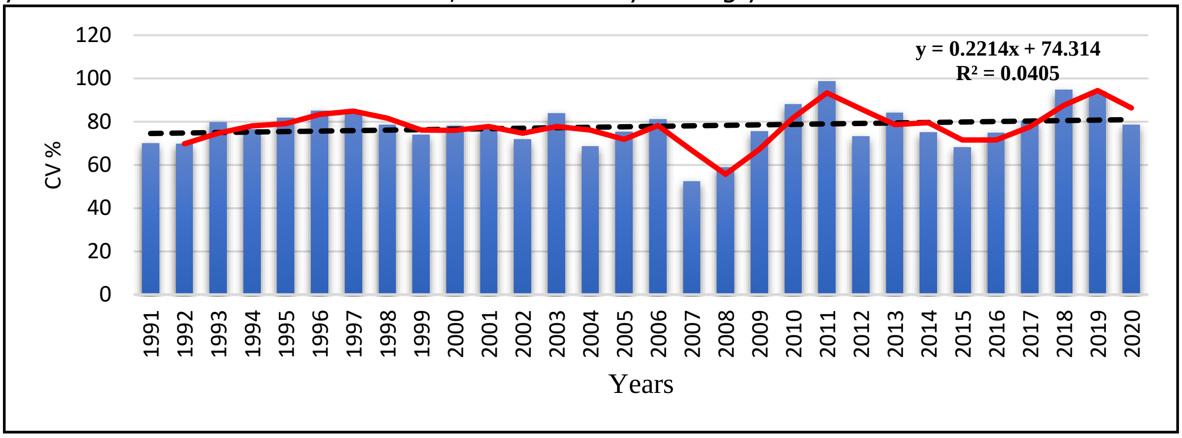

Figure 3. High variability of annual precipitation between 1991 and 2020

Monthly rainfall also varies. However, the beginning and end of the rainy seasons are more subject to fluctuation. Only the rainy months (July, August and September) are stable over the periods 1991-2020.

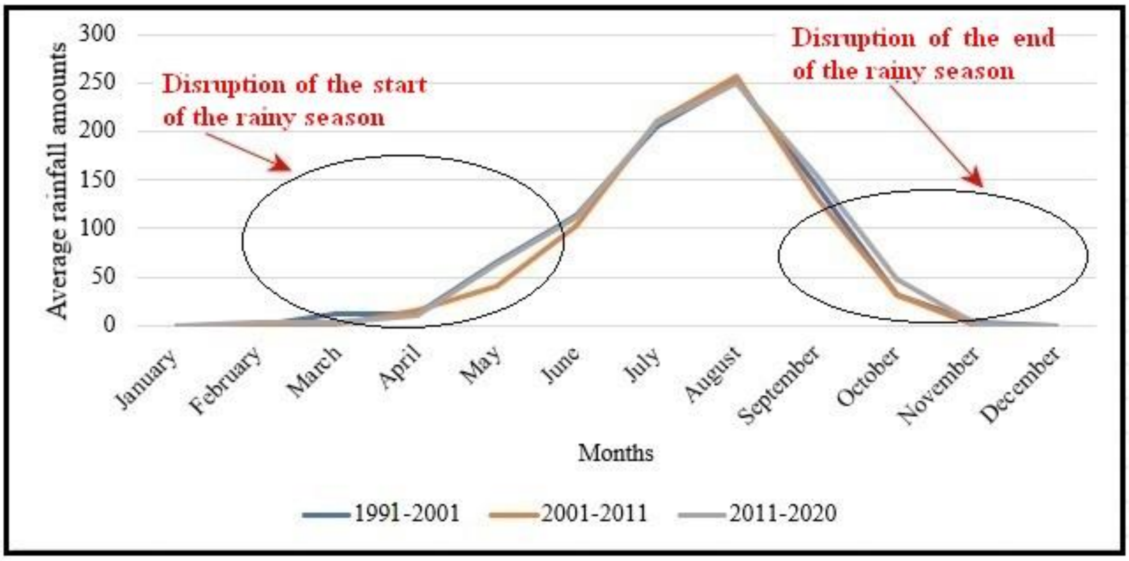

Figure 4. Disruptions in the beginning and end of the rainy seasons from 1991 to 2020

3.3. Climate aridity trend between 1991 and 2020

The Martonne index was used to assess the climatic status of the area. It shows that in the Reo station, three (03) periods, namely a wet trend between 1991 and 2002, then a dry trend from 2002 to 2011, and finally a wet trend from 2012 to 2020 were observed (Figure 5).

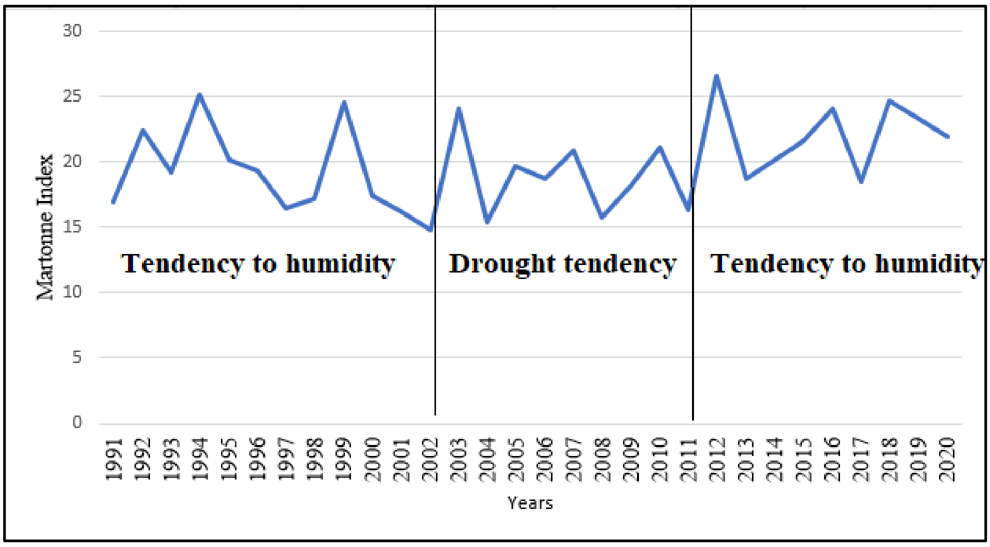

Figure 5. Martonne index calculated on an annual scale between 1991 and 2020

3.4. Market gardeners' perceptions of rainfall variability between 1991 and 2020

3.4.1. Socio-demographic characteristics of market gardeners

They relate to gender, age, level of education, experience and farm size. The male gender dominates with 83.2% of the market gardeners of which 75.2% are educated (Table 6).

Table 6. Gender and educational level of market gardeners

Sex	Frequency	Percentage	Educational level	Frequency	Percentage
Man	238	83.2	Instructed	215	75.2
Woman	48	16.8	No Instructed	71	24.8
Total	286	100.0	Total	286	100

Source: Field surveys, December 2022-January 2023

In terms of age groups, the 25- and 30-year-olds dominate, with 54.2% of market gardeners (table 7).

Table 7. Age range of market gardeners

Age range	Frequency	Percentage
[20 to 25 years]	45	15.7
[25 to 30 years]	156	54.5
[30 to 35 years]	21	7.3
[35 to 40 years]	17	5.9
40 years and +	47	16.4
Total	286	100.0

Source: Field surveys, December 2022-January 2023

The experience of the market gardeners varies between [1 to 2 years], and [8 years and +] (table 8). The [8 years and more] bracket represents 64.3%, followed by [1 to 2 years], with 22% and finally [6 to 8 years], with 12.9%. 0.5ha constitutes the majority of the market gardeners' farm sizes.

Table 8. Experience and farm size of market gardeners

Experience	Frequency	Percentage	Size of the farm	Frequency	Percentage
[1 to 2 years]	63	22.0	0,25 Ha	69	24.1
[4 to 6 years]	2	0.7	0,5Ha	169	59.1
[6 to 8 years]	37	12.9	0,75Ha	47	16.4
[8 ans and +	184	64.3	1 Ha	1	0.3
Total	286	100	Total	286	100

Source: Field surveys, December 2022-January 2023

3.4.2. Market gardeners' perceptions of rainfall variability

Market gardeners perceive rainfall variability through a number of local variables such as the frequency of pockets of drought, the duration of the rainy season, and the variability of annual rainfall (table 9).

Table 9. Market gardeners' perceptions of rainfall variability between 1991 and 2020

Study area	Rainy season			Rainfall variability Annual			Frequency of pocket of drought		
Réo	Short	Long	Total	Increase	Decrease	Total	High	Low	Total
No.	280	6	286	270	16	286	250	36	286
%	97.9	2.01	100	94.4	5.6	100	87.4	12.6	100
Total	280	6	286	270	16	286	250	36	286

Source: Field surveys, December 2022-January 2023

The table shows that 97.90% of market gardeners noted that the rainy season has become short. In addition, 94.40% pointed out that the variability of annual rainfall has increased. On the other hand, 87.40% of the respondents found that the frequency of droughts has increased between 1991 and 2020.

3.5. Changes in market gardening systems in the face of rainfall variability

3.5.1. Market gardening systems promoted in the 2000s

The practice of market gardening was initially a climatic constraint since the drought years of the 1970s and 1980s in Burkina Faso. Over the years, market gardeners have gradually oriented their production to the market. As a result, vegetables such as onions, tomatoes, African aubergines and cabbage have become popular, due to the relentless demand from urban centres such as Koudougou. Vegetable cropping systems will be developed to suit the market (Figure 6).

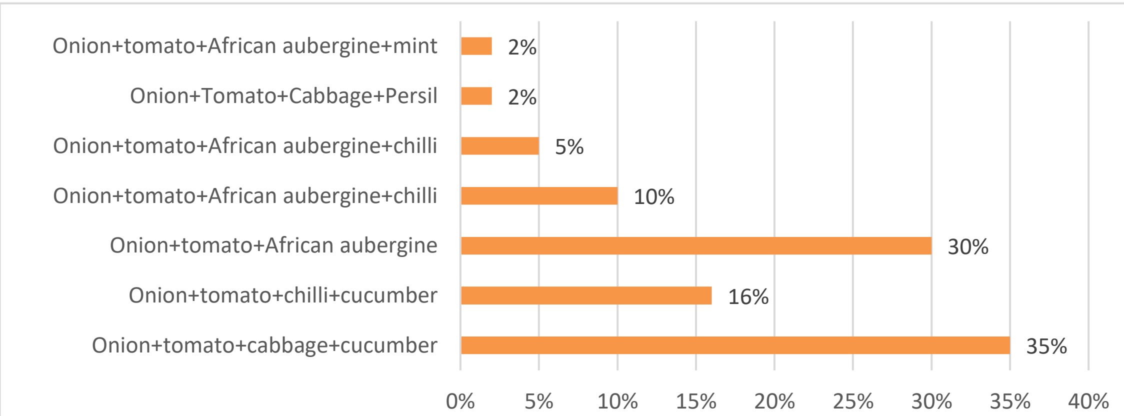

Figure 6. Different market gardening systems deployed in the 2000s

From this figure, seven (07) vegetable cropping systems can be identified, of which onion + tomato + cucumber and onion + tomato + African aubergine are the most used during this period. The degree of importance of the vegetable cropping systems below confirms the importance of systems such as onion + tomato + cucumber and onion + tomato + African aubergine as well as onion + tomato + cucumber (table 10).

Table 10. The importance index of market gardening systems in the 2000s

Vegetable cropping systems	VI (3)	I (2)	SI (1)	NI (0)	$a_1 * x_1$	DI	Rank
Onion + tomato + cabbage	480	26	70	0	576	192	2nd
Onion + tomato + chilli	120	300	50	0	470	156.66	3rd
Onion + tomato + African aubergine	420	140	50	0	610	203.33	1st
Onion + tomato + African aubergine + chilli	135	150	120	0	405	135	4th
Onion + tomato + African aubergine + chilli	9	80	25	0	114	38	5th
Onion + tomato + cabbage + parsley	3	20	5	0	28	9.33	6th
Onion + tomato + African aubergine + mint	3	6	5	0	14	4.66	7th

Source: Field surveys, December 2022-January 2023

Table 10 shows that onion, tomato and African aubergine are the vegetables that make up the market gardening systems. These market gardening systems, which were once promoted on the basis of urban demand, have begun to change in the light of rainfall variability.

3.5.2. Recomposition of market gardening systems in the context of climate variability

Profitability is the leitmotif for producers, both in vegetable and cash crop production. This drives the producer to optimize production options in order to increase profits. However, the advent of climatic variability has changed the situation. In addition to ensuring the economic profitability of his cropping system, the vegetable farmer also takes into account the variability of rainfall that affects the recharge of surface and deep-water tables. This has led to a modification of the market gardening systems in the area. The recomposition of cropping systems that takes into account both economic profitability and rainfall variability is highlighted (Figure 7).

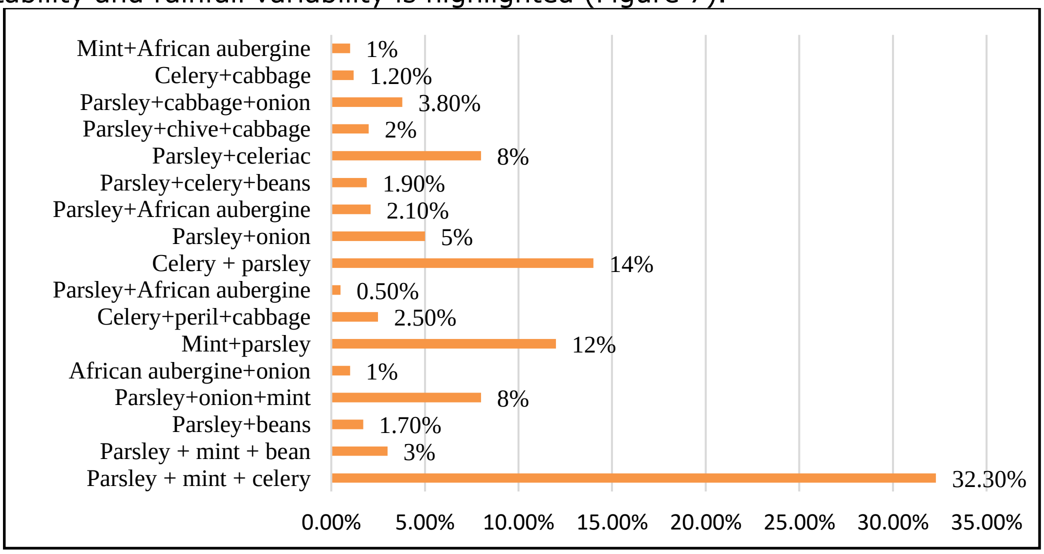

Figure 7. Market gardening systems today

According to Figure 7, Parsley + mint + celery, Mint + peril, and Celery + parsley, are highly cited by vegetable farmers. The importance index also corroborates these results, since these systems (Parsley + mint + celery; Mint + peril, Celery + parsley) are systems considered very important by the market gardeners, and are therefore highly ranked (table 11).

Table 11. Importance of market gardening systems in relation to rainfall variability

Vegetable growing system	VI (3)	I (2)	SI (1)	NI (0)	$a_1 * x_1$	DI	Rank
Parsley + mint + celery	300	100	50	0	450	150	3rd
Parsley + mint + bean	9	94	18	0	121	40.3	8th
Parsley + beans	3	2	16	0	21	7	14th
Parsley + onion + mint	126	140	150	0	416	138.7	4th
African aubergine + onion	3	4	15	0	22	7.3	15th
Mint + parsley	225	250	11	0	486	162	2nd
Celery+ parsley + cabbage	45	20	5	0	70	23.3	9th
Parsley + African aubergine	3	2	1	0	6	2.0	18th
Celery + parsley	300	200	30	0	530	176.7	1st
Parsley + onion	180	84	27	0	291	97	5th
Parsley + African aubergine	30	10	5	0	45	15	11th
Parsley + celery + beans	45	8	1	0	54	18	10th
Parsley + celery	120	40	8	0	168	56	6th
Parsley + chive + cabbage	24	6	1	0	31	10.3	12th
Parsley + cabbage + onion	60	40	28	0	128	42.7	7th
African aubergine + cabbage	6	2	2	0	10	3.3	16th
Mint + African aubergine	3	2	1	0	6	2	17th

Source: Field surveys, December 2022-January 2023

The table shows that celery, parsley and mint systems are very important and rank first. Indeed, the first five (05) systems promoted are composed of systems such as: Celery + parsley (1st); Mint + parsley (2nd); Parsley + mint + celery (3rd); Parsley + onion + mint (4th); Parsley + onion (5th). Parsley, mint and celery require little water for their production (80% of respondents). Moreover, these crops can be grown throughout the year depending on the capacity of the water table to recharge. This allows producers to generate financial resources on a continuous basis. Thus, 30% of respondents receive 850,000 FCFA/year from buyers in the town of Koudougou, which is 14km from the town of Réo.

Despite their economic importance, crops such as onions, tomatoes and cabbage have been reduced in favour of parsley, mint and celery. This change in vegetable cropping systems is aimed at coping with the decline in the surface water table (depth: 0-15m) and the deep-water table (depth: +15m). The introduction of a seed called 'kokologo onion', which has a short production cycle (more than one month), confirms the concern of producers about the lack of water resources in the lowlands.

3.5.3. Relationships between socio-demographic characteristics and adoption of vegetable cropping systems in the context of rainfall variability

The adoption of vegetable cropping systems in response to climate variability also depends on the socio-demographic characteristics of the vegetable farmers surveyed. A Spearman rank correlation was used to examine the relationship between socio-demographic characteristics and the vegetable cropping systems adopted in response to climate change. Indeed, a very weak negative correlation was found between the level of education and the vegetable cropping system adopted (Table 12). The same is true for gender (table 13). This means that these two socio-demographic characteristics do not have a strong influence on the choice of market gardening systems in the context of rainfall variability.

Table 12. Very weak negative correlation between the level of education and the market gardening system adopted

			Educational level	Vegetable growing system
Spearman's Rho	Educational level	Correlation coefficient	1.000	-.123*
		Sig (two-tailed)	0.0	.039
		N	286	284
	Vegetable growing system	Correlation coefficient	-.123*	1.000
		Sig (two-tailed)	.039	0.0
		N	284	284

*. The correlation is significant at the 0.05 level (two-tailed).

Table 13. Very weak negative correlation between gender and the market gardening system adopted

			Vegetable growing system	Sex
Spearman's Rho	Vegetable growing system	Correlation coefficient	1,000	-.249**
		Sig (two-tailed)	0.0	.000
		N	284	284
	Sex	Correlation coefficient	-.249**	1.000
		Sig (two-tailed)	.000	0.0
		N	284	286

**. The correlation is significant at the 0.05 level (two-tailed).

On the other hand, the age group is very weakly correlated with the vegetable growing system, with p=0.019 (Table 14), which is almost zero. Therefore, it is not significant. This indicates that the choice of cropping systems is not related to being young, adult or old.

Table 14. Very weak positive correlation between age group and market gardening system adopted

			Vegetable growing system	Age range
Spearman's Rho	Vegetable growing system	Correlation coefficient	1,000	.019
		Sig (two-tailed)	0.0	.752
		N	284	284
	Age range	Correlation coefficient	.019	1.000
		Sig (two-tailed)	.752	0.0
		N	284	286

However, experience and farm size influence the choice of vegetable cropping systems in the context of climate variability. Thus, the level of correlation is medium positive for experience (Table 15) and farm size of vegetable growers (Table 13).

Table 15. Mean intensity correlation between experience and the market gardening system adopted

			Vegetable growing system	Experience
Spearman's Rho	Vegetable growing system	Correlation coefficient	1.000	0.559**
		Sig (two-tailed)	0.0	.000
		N	284	284
	Experience	Correlation coefficient	.259**	1.000
		Sig (two-tailed)	.000	0.0
		N	284	286

** The correlation is significant at the 0.05 level (two-tailed).

Table 15 shows that the level of significance of the link between the experience of the market gardeners and the market gardening system is very high. Farmers with more than 8 years of experience easily notice rainfall fluctuations and are more aware of the water problem. This will force him to recompose his system in order to cope with the situation.

Table 16 also shows that the significance level of the link between the size of the market gardeners' holdings and the market gardening system is very high. Indeed, most of the market gardeners (59.1%) have plot sizes that are on average 0.5 ha. This means that the market gardener must optimise his production in order to make a high profit, and he will be very attentive to factors such as water problems that can affect his production, hence the recomposition of market gardening systems.

Table 16. Positive average intensity correlation between farm size and the vegetable growing system adopted

			Vegetable growing system	Size of farm
Spearman's Rho	Vegetable growing system	Correlation coefficient	1,000	.657**
		Sig (two-tailed)	0.0	.000
		N	284	284
	Size of farm	Correlation coefficient	.357**	1.000
		Sig (two-tailed)	.000	0.0
		N	284	286

**. The correlation is significant at the 0.05 level (two-tailed).

4. Discussion

4.1 Rainfall variability

It is characterized in the study area by an increase in annual rainfall totals, high rainfall variability (CV greater than 30%), and alternating wet and dry periods between 1990 and 2020. This trend is also noted by Kaboré et al., 2017 in the north-central region of Burkina Faso. Indeed, between 1961 and 2015, the area experienced alternating wet and dry periods. This reflects a high variability in annual rainfall totals during the period. In Senegal, in the districts of Barkédji, Sagatta Djoloff and Yang-Yang, Sarr et al., 2021 note that rainfall has also experienced high variability, especially during the period 2009-2017, with CV=31%. This period (2009-2017) also corresponds to an increase in annual rainfall totals.

In northern Nigeria, most states have annual rainfall totals that vary between 1971 and 2012. Kano, Katsina and Maiduguri states have CVs above 25% (Mamman et al., 2018). According to Bose et al. (2015), cumulative rainfall in the northern parts of Nigeria was increasing from 1970 to 2012. In the central states of Nigeria, rainfall variability is also observed, with CVs ranging from 22.79% (in Kaduna) to 33.63% (in Zaria) (Animashaun et al., 2020). The same trend is also observed across Africa between 1983 and 2020 (Alahacoon et al., 2022).

4.2 Farmers' response to rainfall variability

Rainfall variability is evident in the study area, as rainfall data show increasing trends in annual rainfall, but also high variability, with alternating wet and dry phases. Market gardeners also perceive this variability. This has prompted many of them to respond to this new situation, resulting in the reorganization of market gardening systems, favoring crops such as celery, mint, parsley and kokologo onions with short production cycles. For example, almost all the top 10 vegetable cropping systems important to market gardeners are composed of celery, mint, parsley and kokologo onions (Table 9 above). Vegetable production in the lowlands is indeed difficult in Burkina Faso. Because of rainfall variability, the lowlands gradually lose their seasonal moisture, which leads to the retreat of the water table (Bambara et al., 2013).

In the commune of Réo, in the village of Nialdialpoun, in the Mid-West region of Burkina Faso, market gardeners, due to the variability of rainfall, rather opt for the multiplication of traditional wells and the intensification of the use of pesticides and organic fertiliser in order to allow the crops (onion, tomato, cabbage) to develop properly (Yaméogo et al., 2022). These results are not similar to those in the study area. In southern Mali, notably in Try and N'Goukan, farmers favour changing the sowing date, using seed varieties with a short production cycle, diversifying crops and using fertiliser (Traoré et al., 2015). These results partly corroborate the findings from the study area, particularly the use of short-cycle varieties to cope with rainfall variability. The work of Kpekpassi et al. (2020) confirms the results of the study area in that climatic constraints have pushed market gardeners in Benin, particularly in the communes of Kandi, Malanville and Banikoara, to recompose their market gardening system by rotating market garden crops. In Cameroon, on the other hand, market gardeners adopt sprinkler irrigation (46%), manual irrigation (32.5%), strip irrigation (15.5%) and drip irrigation (6%) to cope with water problems caused by rainfall variability (Awazi, 2022).

5. Conclusions

The variability of rainfall is an obvious fact in the study area. Market gardeners are aware of it. This forces them to reorganise their vegetable growing system to take this new situation into account. Thus, crops such as celery, parsley and mint make up the current market gardening systems. This is because of their ability to produce with little water. The choice of these crops is to the detriment of traditional vegetables such as onions, tomatoes, and cabbage, which according to the market gardeners require a lot of water to produce well. It is useful for communal authorities to monitor the economic viability of these new cropping systems to prevent market gardeners from falling into vulnerability.

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