

(RESEARCH ARTICLE)



CONSTRAINTS AND ADAPTATION STRATEGIES REGARDING SOIL AND CLIMATIC CONSTRAINTS IN THE PLATEAU DEPARTMENT, BENIN

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ABSTRACT

Tomato production has increased steadily over the last decades in the Plateau department. However, it remains highly exposed to soil and climatic hazards that threaten its sustainability. This research aims to analyze the pedoclimatic constraints and the adaptation strategies developed by producers to cope with these constraints in the Plateau department of Benin.

The methodological approach used for this research focuses on the data used, data collection, data processing and results analysis. A total of 379 tomato producers were surveyed using the KoboCollect application for this research.

The results show that soil constraints (erosion, soil degradation, overuse of chemical products and soil infertility) and climatic constraints (changes in the rainfall regime, drought and yellowing of tomato leaves) threaten tomato production in the Plateau department. Thus, 22% of producers mention changes in rainy days, 18% prolonged drought, 14% erosion, 18% degradation and 17% soil infertility as the main pedoclimatic constraints. Faced with these constraints, producers develop endogenous adaptation strategies: the use of organic manure (57%), fallowing (95%), crop rotation (65%), mulching, crop association (78%), rescheduling of the agricultural calendar and irrigation (75%).

Keywords: Plateau Department, Tomato production, Pedoclimatic constraints, Adaptation strategies.

1 INTRODUCTION AND RATIONALE

Economic growth in developed countries is closely linked to the identification of priority sectors for socio-economic development (A. Adjatini et al., 2019, p. 2757). Agriculture is inherently risky, a fact that holds true worldwide (A. Hemaho, 2022, p. 24). In both developing and developed nations, family farming constitutes the primary form of agriculture within the food production sector (S. Moussa, 2016, p. 15). The agricultural sector the backbone of Benin's economy employs 80% of the workforce and contributes 40% to the Gross Domestic Product (L. Sare, 2012, p. 12).

Climate change, a major source of concern for farmers, negatively affects tomato crop yields by impacting plant growth, development, and varietal diversity (H. Yahaya, 2012, p. 5). Declining agricultural yields resulting from adverse soil and climatic conditions inevitably lead to rising food insecurity, increased vulnerability among farming communities, reduced household incomes, and higher poverty levels (K. Srivastava, 2012, p. 11).

The vegetable farming sector is a priority for improving nutritional balance and increasing producers' incomes (C. Adjiré, 2015, p. 7). Tomato cultivation, like all vegetable farming, is a highly water-intensive activity (W. Akpla, 2014, p. 5). Among vegetable crops, the tomato is the most widely consumed and is used as a condiment in daily diets based on cereals and tubers (W. Yehouessi, 2012, p. 9). However, agriculture which depends on climatic conditions and relies on practices incompatible with environmental sustainability (E. Ogouwalé, 2006, p. 21) is characterized by difficult access to specific inputs, resulting in low yields (D. Madegnan et al., 2022, p. 19).

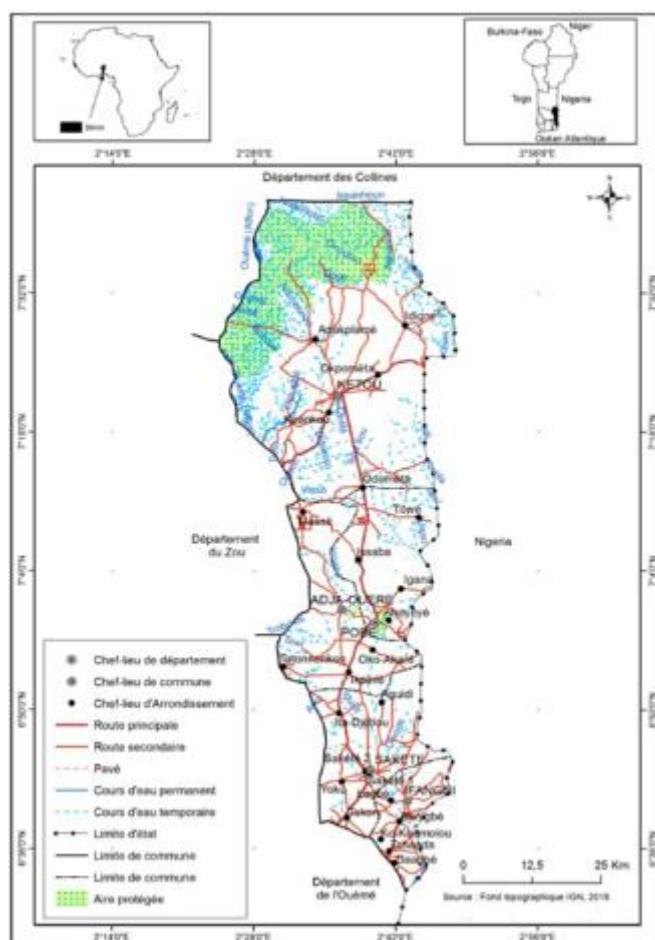


Figure 1: Geographical and administrative location of the Plateau department

In Benin, tomatoes are grown throughout the country (Y. P. Adegbola et al., 2013, p. 22) and rank first among fruit vegetables in terms of cultivated area and total production (K. Assogba et al., 2013, p. 22). Despite its significant contribution to the economy, the sector faces numerous constraints, including climate change characterized by fluctuating rainfall duration, variations in annual precipitation, rising temperatures, drought, soil degradation, unexpected floods, strong winds, and the proliferation of diseases and pests (J. A. Yabi, 2012, p. 2). Water and soil vital production resources are currently experiencing a decline in both quantity and quality (B. Bonou, 2023, p. 8).

In the Plateau Department, soil types and the climate are generally favorable for tomato production. However, rainfall variability, along with soil degradation and progressive infertility, expose this crop to recurring soil and climate-related constraints. Key adaptation strategies implemented by producers include the use of soil and water conservation techniques, adjustments to sowing dates, irrigation systems, the adoption of improved varieties, agroforestry, the use of fertilizers, and investment in improved land management practices (M. Ouedraogo et al., 2010, p. 91).

The Plateau Department is located in southeastern Benin, between 6° 20' and 7° 40' North latitude and between 2° 20' and 2° 46' East longitude. It comprises five (5) communes (Kétou, Pobè, Adja-Ouèrè, Sakété, and Ifangni) and two hundred and eighteen (218) villages grouped into twenty-nine (29) arrondissements. It covers an area of 3,264 km², representing approximately 3% of the national territory (INSAE, 2016, p. 3). It is bordered to the north by the Collines

Department, to the east by the Federal Republic of Nigeria, to the west by the Zou Department, and to the south by the Ouémé Department (Figure 1).

This diversity of soil and climate conditions, combined with growing demographic and land-use pressures, exposes tomato production in the department to multiple constraints; identifying these is essential to better understand the adaptation strategies developed by producers. This article therefore aims to analyze the soil and climate constraints and the adaptation strategies adopted in response to them in the Plateau department.

2 DATA AND METHODS

The climatological data (rainfall and temperatures) used were obtained from the National Meteorological Directorate (Météo-Bénin). Data from the Pobè synoptic station the reference station for the Plateau department were collected for the 1991–2021 period (monthly and annual data) due to their reliability and continuity. Demographic data were derived from the results of the General Population and Housing Censuses (RGPH 1979, 1992, 2002, and 2013) conducted by the National Institute of Statistics and Demography (INStaD).

The overall sample size was determined using D. Schwartz's formula (1995): $\beta = Z\alpha^2 \times pq/i^2$, where β = sample size, $Z\alpha$ = 1.96 (standard normal deviate corresponding to an α risk of 5%), i = desired precision (5%), p = proportion of agricultural households in the Plateau department, and $q = 1 - p$. Based on the department's agricultural households (49,456 households in the localities visited out of a total of 110,532 households), $p = 49,456/110,532 = 0.44$ (or 44%); thus, $\beta = (1.96)^2 \times 0.44 (1 - 0.44) / 0.05^2 \approx 379$ households.

Given time and resource constraints, the in-depth survey was conducted across the six communes of the Plateau department, chosen due to the significant tomato production observed there. Two villages were selected within each *arrondissement*. The sample size for this area was determined using the formula by J. P. Beau and B. Marien (2003): $n = (N \times 400) / (N + 400)$, where $N = 1,621$ agricultural households across the selected villages; this resulted in a sample of $n \approx 379$ households, surveyed using the KoboCollect application.

The questionnaires, interview guides, and observation checklists administered in the field were subsequently processed. Data analysis was performed using Excel, enabling the calculation of average rainfall ($X = \sum xi/N$) and standardized rainfall indices (Land's index); these indices were used to identify years with excess rainfall (index > +0.5) and rainfall deficits (index < -0.5) over the 1991–2021 period.

Analysis of the results made it possible to identify pressures linked to soil and climatic constraints, assess the state of soil and water resources, measure impacts on tomato production, and determine the responses namely, the adaptation strategies developed by producers in the Plateau department. The methodological approach adopted yielded the results presented below.

3 RESULTS

3.1 Soil and climatic constraints on tomato production in the Plateau Department

This section addresses the soil and climatic constraints affecting tomato production in the Plateau Department.

3.1.1 Soil-related constraints on tomato production

The soil-related constraints identified in the Plateau Department are linked to erosion, soil degradation, the excessive use of chemicals, and soil infertility.

3.1.1.1 Erosion

In the Plateau Department, erosion is particularly severe in tomato fields located in depressions, notably the Lama Depression. The fields are overrun by runoff water that transports soil particles to low-lying areas. Tomatoes grown on ridges are also affected by the displacement of particles from the ridges, which leads to the exposure of the plants' root systems.

Process that reduces soil quality and productivity. The adoption of certain farming practices such as tilling, vegetation burning, and the use of agricultural inputs whose impact on the soil is unknown to farmers is a key factor in soil degradation. This results in low tomato yields and poor maintenance of soil fertility.

3.1.1.2 Use of chemical products

In the Plateau department, 67% of the tomato growers surveyed use chemical fertilizers (such as NPK nitrogen, phosphorus, and potassium), insecticides, and herbicides to boost soil fertility and control insects. However, the excessive use of these chemicals has consequences for crops, the soil, and human health. This misuse negatively affects the quality of arable land.



Figure 2: Chemicals and treatment equipment used by growers

Picture: L. Falola, August 2024

The first image in Figure 2 shows a chemical called Sniper, used to prevent insect pests from destroying the crop, while the second image in displays a product named Andrime contained in a small bottle alongside the equipment growers use to spray the tomato plantations.

3.1.1.3 Soil infertility

Soil infertility is the primary soil-related constraint facing tomato fields in the department. A significant portion of the soil in the study area is of poor fertility for tomato production, leading farmers to frequently purchase and use excessive use of chemical fertilizers. Furthermore, this infertility has negative effects on yield, as the harvested tomatoes do not keep well after harvesting.



Figure 3: Field of ripening tomatoes on infertile soil in Houédamè

Picture: L. Falola, August 2024

Figure 3 shows a tomato field on infertile soil where the plants, despite reaching the ripening stage, exhibit insufficient vegetative development.

3.1.2 Climatic constraints on tomato production

The climatic constraints influencing tomato production in the Plateau department include changes in rainfall patterns, drought, and the resulting yellowing of tomato leaves.

3.1.2.1 Changes in rainfall patterns

Changes in rainfall patterns in the department manifest as delayed onset of rains, low rainfall volume, prolonged drought, and early cessation of rains. According to 72% of the producers surveyed, rain is a "necessary evil," with both

excessive and insufficient amounts posing constraints for tomato production. When nurseries are established during the major rainy season (May) or the minor rainy season (September) and a water deficit occurs, pests (aphids and bacteria) destroy the seedlings; conversely, heavy rainfall promotes the proliferation of insects, locusts, and mites that destroy the tomato plants. Delayed rainfall also forces the plants to remain in the nursery beds for a longer period before flowering.

Analysis of monthly rainfall levels recorded at the Pobè station between 1991 and 2021 reveals that April, May, June, July, September, and October are the department's wet months, with heavy rainfall in June (190.18 mm) and a marked drop in rainfall during August–September (77.16 mm). The major rainy season extends from April to July, and the minor season from September to October (approximately 150 mm), whereas the long dry season (November to March) is characterized by rainfall of less than 40 mm. This monthly variation reflects significant rainfall variability within the department.

On an annual basis, rainfall totals recorded in Pobè between 1991 and 2021 ranged from 640.7 mm to 1,359.15 mm. The 1991–2000 period was marked by a downward trend, with only one year of above-average rainfall (1999: 1,114.44 mm) and a low of 640.7 mm recorded in 1998. Conversely, the 2001–2010 period saw an upward trend, featuring years of rainfall deficit (2001 and 2004, with 864 mm and 744.9 mm respectively) and years of surplus (2007 and 2010). This inter-annual rainfall instability directly affects the agricultural operations nursery work, planting, growth, and maturation that drive tomato production in the department.

3.1.2.2 Drought

The impact of drought on tomato production stems from a lack of rainfall. Increased drought conditions not only reduce yields but also make soil cultivation more difficult due to the soil hardening. For 40% of the farmers surveyed, drought is caused by insufficient or delayed rainfall, which hinders the cultivation and development of tomato plants, as their root systems are particularly delicate. Furthermore, intense heat causes the tomato plants to wilt.



Figure 4: Tomato plants affected by drought

Picture: L. Falola, August 2024

The figure shows a tomato crop with leaves withered due to drought. According to 71% of growers, this phenomenon occurs following a prolonged dry season particularly when the rains arrive late negatively impacting tomato cultivation.

3.1.2.3 Yellowing of tomato leaves

The yellowing of tomato leaves is caused by intense solar radiation beating down on the plants in the field; the affected plants exhibit wilted stems. According to 68% of producers, a lack of rainfall or its early cessation during the rainy season results in intense solar radiation and soil water deficits, leading to leaf yellowing and, consequently, a loss in both yield quality and quantity.



Figure 5: Yellowing of tomato leaves in fields in the Plateau Department

Picture: L. Falola, August 2024

Observation of the figure reveals that tomato leaves are gradually turning yellow due to the sun. The lack of rainfall, combined with intense sunlight, slows plant development and results in low yields.

3.2 Adaptation strategies developed by producers to address soil and climate constraints

To minimize the impact of the identified soil and climate constraints, producers in the Plateau Department have developed several adaptation strategies.

3.2.1 Strategies addressing soil constraints

3.2.1.1 Use of organic fertilizers

To combat soil degradation linked to the use of chemical products, tomato producers are adopting the strategy of using organic fertilizers. To boost soil fertility, they apply animal manure to their fields. This strategy is primarily employed by livestock farmers and producers with limited land. Furthermore, 57% of the surveyed producers stated that those with fields near their homes, or with sufficient family labor, collect household waste to enrich their tomato fields.

3.2.1.2 Fallowing

Fallowing involves temporarily halting cultivation on a field for a period of months or years to allow soil fertility to recover. 95% of tomato producers have stated that after prolonged cultivation, when a poor soil response is observed, they leave the field fallow for a few seasons to allow for regeneration. This strategy is primarily adopted by producers who own multiple agricultural plots.

3.2.1.3 Crop rotation

Crop rotation involves varying the crops grown from one season to the next. It increases available soil nutrients and limits the accumulation of chemicals or substances secreted by plants. 65% of the surveyed producers practice crop rotation: after harvesting tomatoes, they grow cassava intercropped with maize the following season. According to the producers, cassava leaves help fertilize the soil, and this rotation aids in eliminating certain pests, thereby enabling successful tomato cultivation while reducing reliance on fertilizers and herbicides.

3.2.1.4 Mulching

Mulching is the primary strategy used by tomato producers in the Plateau department to combat erosion. It involves protecting the soil or planting ridges after sowing—using couch grass, weeds cleared from the land, or oil palm fronds—to retain soil moisture and mitigate the impact of solar radiation on crops and nursery beds. This strategy is particularly employed during the dry season.



Figure 6: Mulched nursery bed in the Plateau department

Picture: L. Falola, August 2024

The figure shows oil palm fronds arranged on a nursery bed. This practice, known as mulching, is used to protect tomato nursery beds, particularly when disruptions to the agricultural calendar cause the nursery phase to coincide with the end of the dry season.

3.2.2 Strategies for coping with climatic constraints

Faced with climatic constraints affecting tomato production, 57% of the surveyed growers have developed strategies to adapt to various phenomena, such as changes in the rainfall pattern rainfall patterns, drought, and leaf yellowing. Key measures include intercropping, rescheduling the agricultural calendar, and irrigation.

3.2.2.1 Intercropping

To address the issue of tomato leaf yellowing, growers in the Plateau department prioritize intercropping as a strategy. This involves cultivating two crops in the same field during the same season: tomatoes are grown alongside maize or cassava sown with wide spacing with the faster-growing tomatoes planted between the rows of maize or cassava. This practice contributes to soil fertility and ensures that at least one of the two crops can be harvested before the rains cease.



Figure 7: Intercropping in the Plateau Department

Picture: L. Falola, août 2024

Farmers grow tomatoes alongside other vegetables or cassava in the same field simultaneously. 78% of farmers practice intercropping, either to harvest one crop before the rains cease (as with the tomato-vegetable combination) or to harvest a crop that is more resilient to rainfall variability (such as cassava, which remains in the ground for at least two seasons).

3.2.2.2 Adjusting the agricultural calendar

To cope with changing rainfall patterns, farmers are revising their agricultural calendars; consequently, tomatoes are now grown year-round. Table I outlines the adjusted agricultural calendar for tomato cultivation in the Plateau department.

Table I: Reorganization of the Tomato Cultivation Calendar in the Plateau Department

Season / Operation	March	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Jan.	Fev.
Nursery (MS)		N	N									
Planting (MS)			N	N								
Harvest (MS)					H	H						
Nursery (SS)							N	N				
Planting (SS)								N	N			
Harvest (SS)										H	H	

Source: Field Surveys, 2024 (MS = main season, SS = short season; N = nursery, R = harvest)

An analysis of this table shows that tomatoes are produced during both rainy seasons. During the main rainy season, nursery operations begin towards the end of March and conclude around early May; planting starts in late April and continues until the end of June; and harvesting begins in early July and ends in August. During the short rainy season, nursery operations start in late August and finish in early October; planting takes place in October and November; and harvesting extends from December to mid-January.

3.2.2.3 Watering

Irrigating nurseries is the primary strategy tomato growers use to cope with drought conditions in the Plateau department. According to 75% of the growers surveyed, nurseries are given priority for watering when rains are delayed, in order to ensure the production of viable young seedlings.



Figure 8: Watering a tomato nursery in the Plateau Department

Picture: L. Falola, August 2024

The figure shows a grower watering his tomato nursery following a significant delay in the rains. According to the growers, this practice allows the crop to develop under favorable conditions.

4 DISCUSSION

This research, focusing on soil-climate constraints and tomato production in the Plateau department, contributes to a better understanding of the factors limiting the development of this crop.

The results reveal that two categories of constraints threaten tomato production in the department: soil-related constraints (erosion, soil degradation and infertility, excessive use of chemicals) and climatic constraints (changes in rainfall patterns, drought, leaf yellowing). These findings corroborate those of J. B. Hounkanrin (2015), who noted that the biophysical constraints affecting the agricultural development of valleys are diverse and varied, relating primarily to climate and water, soil characteristics, and biotic factors.

In response to these constraints, farmers in the Plateau department have developed endogenous adaptation strategies, namely intercropping, mulching, the use of organic fertilizers, fallowing, crop rotation, the rescheduling of agricultural calendars, and watering. These results confirm the work of G. S. Gbedjemedji (2023) on agricultural risks, which demonstrated that farmers develop endogenous risk management strategies to cope with the adverse effects of agricultural risks. They also align with the conclusions of M. Ouedraogo et al. (2010), who found that diversifying farming practices, adjusting agricultural calendars, and using irrigation are common responses by farmers to climate variability in West Africa. While effective at the farm level, these strategies remain largely empirical and would benefit

from technical support measures such as training, access to organic inputs, and irrigation assistance to enhance their reach and sustainability across the Plateau department.

5 CONCLUSION

Soil and climate constraints negatively impact tomato production in the Plateau department. This research analyzed these constraints as well as the adaptation strategies developed by producers to address them.

The methodological approach focused on the data used, data collection and processing, and the analysis of results. The findings indicate that soil-related constraints (erosion, soil degradation and infertility, and the excessive use of chemicals) and climatic constraints (changes in rainfall patterns, drought, and leaf yellowing) threaten tomato production in the department.

To cope with these constraints, tomato producers have developed local strategies to minimize their effects, such as the use of organic fertilizers, fallowing, crop rotation, mulching, intercropping, adjustments to the agricultural calendar, and irrigation. Strengthening these practices through appropriate technical and institutional support offers a promising path toward ensuring the long-term sustainability of tomato production in the Plateau department.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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