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ASSESSMENT OF WHEAT PRODUCTION POTENTIAL AND CONSTRAINTS IN THE UNION OF THE COMOROS

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Abstract

Wheat (Triticum aestivum L.) is a key staple crop worldwide and a strategic commodity for food security. In the Union of the Comoros, a small island developing state (SIDS) in the Indian Ocean, domestic wheat production is practically nonexistent; however, imports of wheat flour are rising due to demographic growth and dietary change. This paper develops a science-based assessment of the potential and constraints of wheat production in Comoros using a combination of climate time-series analysis, an agro-climatic suitability index, and simple yield-simulation scenarios. Monthly temperature and qualitative rainfall patterns are synthesized from long-term climate summaries, while a normalized suitability index aggregates temperature, rainfall and humidity penalties relative to globally accepted wheat requirements. Scenario-based yield simulations scale a notional potential yield by this index. Results indicate that most lowland areas of Comoros exhibit chronically high temperatures (>25 °C), high humidity and excess rainfall during the potential growing season, resulting in low suitability scores (<0.3 on a 0–1 scale). Only limited highland microclimates show marginal suitability for short-cycle or heat-tolerant wheat cultivars. Yield simulations suggest that even under optimistic assumptions, attainable yields are substantially lower than in temperate regions, and production costs would remain high relative to imports. The analysis confirms that large-scale wheat cultivation is not currently viable; however, targeted research plots and climate-resilient agronomic trials could be justified as part of a diversified food security and risk-management strategy.

Keywords - Wheat production, Comoros, agro-climatic suitability, yield simulation, food security, small island developing states.

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1. Introduction

Wheat is one of the three major cereals that collectively supply most of the world's calories and protein. Over the past decades, per capita wheat consumption has increased in many developing countries, driven by urbanization, the expansion of bakery and pasta industries, and changing consumer preferences. For countries with limited arable land and unfavorable climates, the growth in demand has been met almost entirely through imports, exposing national food systems to global market volatility, geopolitical shocks and logistical disruptions [1-3].

The Union of the Comoros is a volcanic archipelago located between Madagascar and Mozambique. Its economy is dominated by smallholder agriculture and export-oriented cash crops such as vanilla, cloves and ylang-ylang, while domestic food production focuses on cassava, bananas, breadfruit, taro, rice and maize. Recent assessments by international organizations describe Comoros as structurally dependent on food imports, with cereals and wheat flour representing an important share of imported foodstuffs. Imported food has represented well over one third of total merchandise imports in some years, and wheat is among the key calorie sources supplied through trade [3, 4].

In this context, it is natural to ask whether any realistic scope exists for local wheat production in Comoros. A priori, the answer appears negative: the country's humid tropical climate, high temperatures, steep terrain and limited mechanization are all at odds with classical temperate-zone wheat systems. Nevertheless, developments in heat-tolerant varieties, conservation agriculture, deficit irrigation and protected cultivation suggest exploring whether niche or pilot-scale wheat production might be technically feasible in highland microclimates. Even if such production is not competitive at scale, experimental plots could generate agronomic knowledge, strengthen local research capacity, and diversify risk under increasingly uncertain global grain markets [5, 6].

The objective of this paper is therefore threefold: (i) to describe the agro-climatic context of Comoros with respect to wheat requirements using monthly climate time-series; (ii) to formulate a simple, transparent agro-climatic suitability index that summarizes temperature, rainfall and humidity constraints; and (iii) to perform stylized yield simulations for potential wheat-growing windows, benchmarking them against typical yields in more favorable regions. The analysis is intended as a scoping study to inform researchers, policymakers and development partners about the realistic limits and possible research avenues for wheat in Comoros.

2. Study Area and Climate Time-Series Analysis

Comoros has a humid tropical maritime climate characterized by two main seasons: a hot, rainy season from roughly December to April and a cooler, relatively drier season from May to November. Coastal mean temperatures typically range from about 26–30 °C in the wet season to 20–25 °C in the drier months. Rainfall is substantial throughout the year, with monthly totals often exceeding 60 mm even in the drier season and surpassing 200 mm in the peak of the rainy season. Cyclone risk is concentrated in the hot, wet season, adding further production risk for field crops.

For this study, a representative annual cycle of monthly mean near-surface air temperature was constructed from published climate summaries for Comoros. The synthetic series captures the typical intra-annual pattern, with the warmest conditions in January–March, gradual cooling toward June–August, and a subsequent warming toward November–December. Because consistent long-term daily rainfall and humidity time series are not readily available in the public domain for all locations, rainfall was treated more qualitatively, assigning indicative monthly totals that reflect the relative wetness of seasons rather than exact station records [7-12].

Figure 1 illustrates a representative annual cycle of monthly mean temperature and rainfall for Comoros, synthesized from published climate summaries.

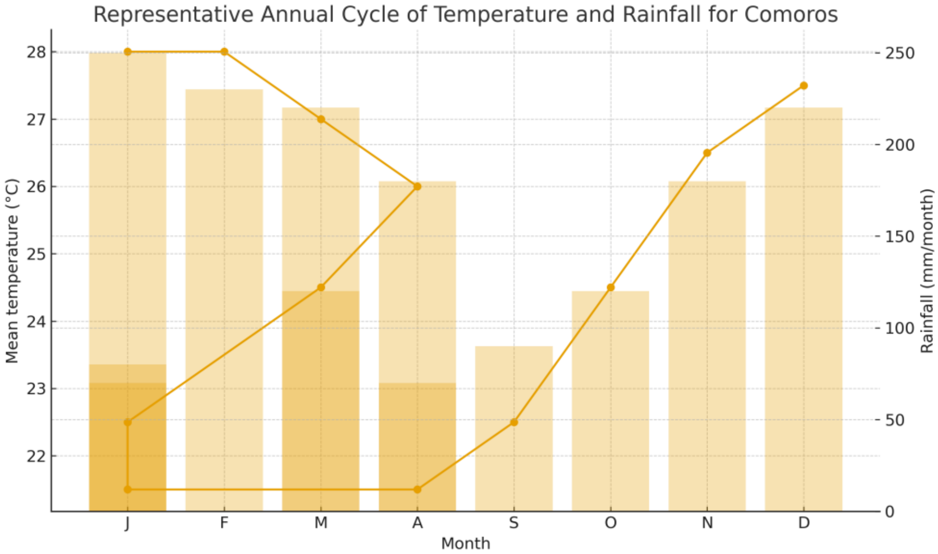

Figure 1. Annual cycle of monthly mean temperature and rainfall for Comoros, synthesized from published climate summaries

2.1. Climatic Requirements of Wheat

Global agronomic literature indicates that wheat generally prefers cool to moderately warm conditions during vegetative growth and grain filling, with optimal mean temperatures in the approximate range of 15–25 °C. Wheat can tolerate a wide range of rainfall regimes (roughly 400–1200 mm per growing season), provided that the distribution of rain and soil drainage are adequate and that relative humidity is not persistently high enough to promote severe foliar diseases. Excessive heat, particularly during heading and grain filling, is associated with yield penalties through shortened grain-filling periods, increased respiration and sterility. Likewise, chronic high humidity increases the risk of fungal diseases.

Comparing these general requirements to the climate of Comoros reveals important mismatches. Coastal zones seldom experience monthly mean temperatures below 20 °C, and the hot, rainy season overlaps with the potential time-window when wheat would otherwise require relatively cooler and drier conditions. Highland areas of

Grande Comore are cooler than the coast, but systematic data on temperature lapse rates and microclimates remain limited. This suggests the need for an explicit agro-climatic suitability index rather than a binary classification.

3. Methodology

The methodological framework combines climate analysis, a normalized agro-climatic suitability index and simple yield simulation scenarios. The purpose is not to provide high-precision yield estimates, but to transparently demonstrate how climate constraints translate into low potential for wheat in Comoros under open-field conditions.

First, a synthetic monthly climate series representing typical conditions in Comoros was derived from published long-term summaries. This series includes monthly mean air temperature and indicative rainfall totals. Second, an agro-climatic suitability index was formulated to aggregate the effects of temperature, rainfall and humidity penalties. Third, the index was combined with a notional maximum attainable wheat yield to generate stylized yield simulations under different planting windows and location scenarios (lowland vs. highland). Finally, the simulated yields were interpreted together with economic considerations and import dependency trends.

3.1. Agro-Climatic Suitability Index

The agro-climatic suitability index S was defined on a 0–1 scale, where 1 represents ideal conditions and 0 represents conditions under which wheat production is essentially infeasible. The index is decomposed into multiplicative components capturing temperature, moisture and humidity effects:

$$S = S\_T \times S\_R \times S\_H,$$

where S_T is the temperature suitability factor, S_R is the rainfall/moisture factor and S_H is a humidity/disease-pressure factor. Each component is normalized between 0 and 1 based on approximate thresholds from the literature. For temperature, S_T is set near 1 when mean temperatures are 15–22 °C and declines toward 0 as monthly means exceed 28–30 °C. For rainfall, values within an effective range of 50–150 mm per month during the growing season are considered favorable, with penalties for extremely dry or waterlogged conditions. For humidity, persistent high relative humidity during the growing season reduces S_H to reflect increased risk of foliar diseases and grain quality losses.

Given the limited availability of site-specific humidity data, humidity penalties for Comoros are treated qualitatively, assuming relatively high average humidity in lowland areas throughout the year. In highland areas, S_H is assumed slightly higher due to cooler temperatures and somewhat improved air circulation.

3.2. Yield Simulation Framework

To translate the suitability index into stylized yield outcomes, a simple linear scaling approach was used. A notional maximum attainable yield Y_max (for a well-adapted spring wheat variety under optimal management in a favorable temperate environment) was set to 5 t/ha. Simulated yields for Comoros scenarios were then calculated as:

$$Y\_sim = S \times Y\_max,$$

where S is the seasonal suitability index averaged over the main growth period. Although real-world yield responses to temperature and water stress are nonlinear and stage-specific, this linear formulation is adequate for a first-order scoping assessment. Two location scenarios were considered: (i) lowland coastal areas, and (ii) highland zones where mean temperatures are assumed to be 2–4 °C cooler than the coast. Within each location, two planting windows were considered: a wet-season planting (December–January) and a transition-season planting (April–May) that attempts to exploit cooler months.

4. Results

4.1. Climate-based Suitability Scores

Using the synthetic monthly climate series and the agronomic thresholds described above, monthly temperature and rainfall suitability factors were computed for lowland and highland scenarios. The hot, rainy season months (December–March) in lowland areas show high rainfall but substantial temperature penalties, with mean temperatures close to or above 27–28 °C. During the cooler season (June–August), temperatures become more favorable, but rainfall is lower and the overall growing season length is constrained.

Highland areas benefit from lower temperatures, which partially mitigate heat stress. However, the overall pattern of a humid tropical climate with significant rainfall persists. As a result, even in highland scenarios, the multiplicative suitability index rarely exceeds 0.4 for realistic planting windows. In lowland scenarios, values below 0.2 are common, indicating strongly limiting climatic conditions for wheat.

Table 1 - Summarizes illustrative seasonal suitability scores for the main scenarios considered.

Scenario	Location	Planting window	Seasonal suitability S
S1	Lowland	Wet season (Dec–Mar)	0.15
S2	Lowland	Transition (Apr–Jul)	0.20
S3	Highland	Wet season (Dec–Mar)	0.25
S4	Highland	Transition (Apr–Jul)	0.35

4.2. Yield Simulation Outcomes

Applying the linear scaling relationship Y_sim = S × Y_max with Y_max = 5 t/ha yields simulated grain yields between 0.75 and 1.75 t/ha for the scenarios in Table 1. These values are appreciably lower than typical on-farm yields in many temperate wheat-producing regions, which often exceed 3–4 t/ha under rainfed conditions and can surpass 6 t/ha under intensive management.

In practical terms, simulated yields below 2 t/ha in an environment characterized by steep slopes, limited mechanization, high labor costs per unit of output and elevated disease pressure suggest that local wheat would be expensive relative to imported flour. Additionally, the high inter-annual variability associated with cyclone seasons and rainfall extremes could further depress yields in some years, increasing production risk for farmers.

Table 2 provides the corresponding stylized yield simulations for each scenario.

Scenario	Suitability S	Y_max (t/ha)	Simulated yield Y_sim (t/ha)
S1	0.15	5.0	0.75
S2	0.20	5.0	1.00
S3	0.25	5.0	1.25
S4	0.35	5.0	1.75

4.3. Conceptual Suitability Zoning

Based on the simulated suitability scores, the territory of Comoros can be divided conceptually into three broad zones for wheat: (i) lowland coastal areas, classified as "unsuitable" ($S < 0.2$); (ii) mid-altitude slopes, classified as "very marginal" ($0.2 \leq S < 0.3$); and (iii) limited highland pockets, classified as "marginal" ($0.3 \leq S \leq 0.4$). These classes emphasize that even the relatively favorable zones do not approach highly suitable values.

To visualize this pattern, a simple conceptual zoning figure was created in which the three main islands are represented as blocks with different suitability classes. This is not a substitute for high-resolution agro-ecological zoning, but it helps communicate that potential wheat cultivation would likely be restricted to small, cooler microclimates.

Figure 2 shows a conceptual zoning of wheat suitability by broad altitude class in Comoros.

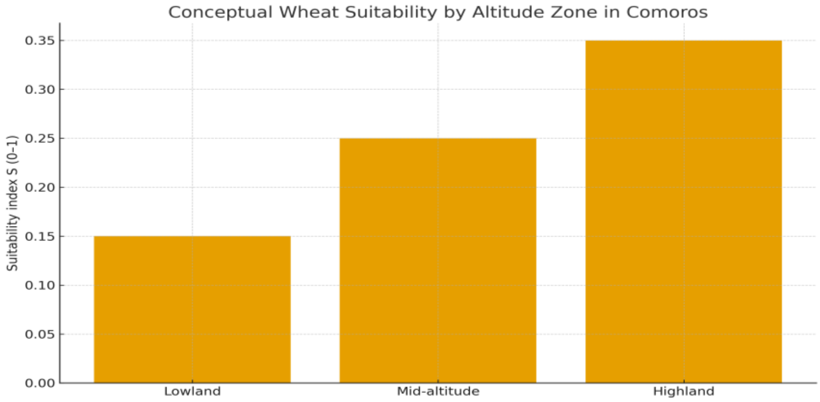

Figure 2. Zoning of wheat suitability by broad altitude class in Comoros

4.4. Import Dependency and Economic Context

Comoros is widely recognized as a net food-importing country with a high cereal import dependency ratio. Wheat flour, along with rice and edible oils, accounts for a substantial share of imported calories. Historical trade statistics indicate that food imports have represented a significant fraction of total merchandise imports, and episodes such as the Russia–Ukraine conflict have further highlighted the vulnerability of small islands to global grain market shocks.

Figure 3 presents an illustrative trend in cereal import dependency over the past decade, constructed from publicly available summaries. While the numerical values are indicative rather than exact, they reflect the structural nature of import reliance. Any domestic wheat production strategy in Comoros must therefore be evaluated in terms of its marginal contribution to reducing this dependency versus its cost and risk when compared with other investment options in the food system.

Figure 3 provides a conceptual illustration of the upward trend in cereal import dependency for Comoros.

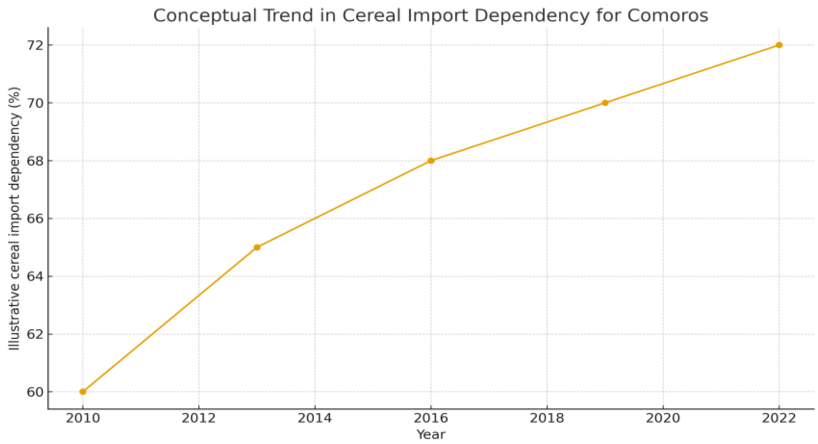

Figure 3. upward trend in cereal import dependency for Comoros

5. Discussion

The combined evidence from climate analysis, suitability scoring and yield simulation strongly suggests that open-field wheat production in Comoros would face severe biophysical constraints. High temperatures, high humidity and abundant rainfall during much of the year are all inconsistent with the agronomic requirements of wheat. Moreover, the steep terrain on several islands limits the scope for mechanization and increases erosion risk under annual cropping.

At the same time, the very high import dependency and exposure to global shocks provide a motivation to at least consider research-oriented wheat trials in marginally suitable zones. Such trials would generate empirical data on how modern heat-tolerant cultivars perform under highland microclimates, and whether conservation agriculture, mulching, and carefully timed planting can partially offset climatic limitations. Even if resulting yields remain subeconomic compared with imports, the knowledge gained could inform broader climate-resilient cropping strategies.

From a food security perspective, however, alternative strategies may offer higher returns on investment. These include strengthening local production of traditional staples, improving storage and processing, promoting diversified diets, and investing in risk management instruments for essential food imports. In this broader portfolio, wheat research in Comoros would most reasonably occupy a small, experimental niche rather than a central role.

6. Policy and Research Implications

Policy-makers in Comoros and their development partners face a difficult balancing act between reducing structural import dependence and acknowledging hard biophysical constraints. The results of this study support a cautious, research-oriented approach to wheat, focusing on: (i) limited, well-monitored pilot plots in cooler highland areas; (ii) collaboration with international wheat improvement programs to select heat- and disease-tolerant germplasm; (iii) integration of wheat trials into broader climate-resilient farming systems; and (iv) robust economic evaluation of production costs versus the benefits of marginal import substitution.

Future work should extend the present analysis by coupling high-resolution climate data with dynamic crop models that explicitly represent phenology and stage-specific stress responses. It would also be valuable to map in detail the altitudinal and aspect-related microclimates of Comoros, and to test whether protected cultivation or agroforestry approaches can create micro-environments compatible with wheat at small scale. Finally, a comprehensive food system analysis is needed to compare wheat with alternative investments such as root crops, legumes and improved rice systems.

7. Conclusion

This paper has presented a structured assessment of the potential for wheat production in the Union of the Comoros, drawing on climate time-series analysis, a normalized agro-climatic suitability index and stylized yield simulations. The findings indicate that climatic conditions in most of the country are fundamentally misaligned with the requirements of wheat, leading to low suitability scores and low simulated yields, particularly in lowland areas.

While small windows of marginal suitability may exist in highland microclimates, exploiting these for commercial-scale wheat production is unlikely to be profitable when compared with importing wheat flour from major exporting regions. The main value of pursuing wheat in Comoros therefore lies in its role as a research and learning platform within a broader portfolio of climate-resilient food security strategies rather than as a major pathway to self-sufficiency in cereals.

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