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RESEARCH ARTICLE

LAND SUITABILITY AND SUSTAINABLE MANAGEMENT OPTIONS FOR COTTON PRODUCTION IN BAFIME AND LARAZOUROU, KORHOGO DEPARTMENT, CÔTE D'IVOIRE

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Abstract

Cotton yields in the Northern Basin of Côte d'Ivoire have declined under the combined effects of pests, diseases, soil degradation, water stress and poor crop management, a situation made worse by the scarcity of detailed site-level pedological data. This study characterized soil fertility constraints and evaluated land suitability for cotton in two representative villages of Korhogo Department, Bafime and Larazouro u. Six composite topsoil samples (four from Bafime, two from Larazourou) and two complete soil profiles (0–100 cm, one per village) were collected in 2021 and analysed using standard laboratory methods. Climatic suitability was assessed from 1980–2020 ERA5 reanalysis data, and both components were evaluated with the FAO/Sys et al. (1993) crop-requirement framework. The soils were slightly acidic to near-neutral (mean pH 6.52) with moderate base saturation (55.6%), but their overall fertility was low. Total nitrogen (0.070%), organic carbon, cation exchange capacity (7.21 $cmol^+/kg$) and sum of exchangeable bases (SEB, 4.21 $cmol^+/kg$) were all low, and SEB was the main fertility-related limiting factor. Based on soil characteristics alone, Larazourou was moderately suitable (S2) and Bafime was marginally suitable (S3), the latter because of five moderate limitations: drainage, texture, coarse fragments, effective soil depth and sum of basic cations.

When climate was included, however, both villages were classified as currently not suitable (N1). This result was driven mainly by high mean relative humidity during the June–October growing season (79%), which was the principal limiting factor under the Sys et al. (1993) criteria. The assessment covers only two villages and is resource-

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based, since no cotton yield, biomass or disease-incidence data were collected. Its findings therefore reflect local conditions and should not be generalized to the wider Korhogo cotton basin. Site-specific soil fertility management, combined with agronomic practices that reduce humidity-related disease and pest pressure, is recommended to support more sustainable cotton production in these villages, pending validation through field trials.

Introduction:-

Soil and water, as vital natural resources, face escalating pressure from increasing anthropogenic activities, reducing agricultural land availability per capita and challenging efforts to meet growing demands for food, fodder, fibre, and fuel (Surya et al., 2020). Cotton is a major global commodity, with Gossypium hirsutum (upland cotton) accounting for around 90% of global production (Shahbandeh, 2022). In Côte d'Ivoire, cotton cultivation ranks as the 4th largest agricultural export after cocoa, rubber, and cashew nuts, contributing 1.7% to the gross domestic product (GDP) (Didi et al., 2018), and directly supports 180,000 producers, or about 2.5 million inhabitants (Oudin, 2020). However, the cotton industry faces significant challenges, particularly in the Northern Guinea Savannah region, which encompasses northern Côte d'Ivoire, northern Ghana, and south-western Burkina Faso. This region has been a focal point for numerous studies on soil constraints to cotton production, soil fertility, and taxonomy. Surprisingly, despite the wealth of research in this area, a gap remains in synthesizing and applying this knowledge at the scale relevant to individual cotton-growing villages.

Recent studies by Zhang et al. (2023), Li et al. (2022), and Zagbaï et al. (2006) have shed light on multifaceted challenges related to cotton production in this region. Similarly, Ramasundaram and Hemchandra (2001) in India have identified unique constraints. These findings underscore the complexity of cotton farming, emphasizing the need for region-specific solutions to promote sustainable and resilient practices. Several studies have also been conducted on the soil fertility and taxonomy of northern Côte d'Ivoire, northern Ghana, and southwestern Burkina Faso (Zhang et al., 2023; Li et al., 2022). However, these studies have not focused on the specific needs of cotton production. A study by Kouakou et al. (2023) used a multi-criteria decision analysis (MCDA) approach to assess the suitability of land for cotton cultivation across the entire cotton basin of Côte d'Ivoire, at a regional scale, and found that 42% of the basin is highly suitable for cotton cultivation, 35% is moderately suitable, and 23% is marginally suitable, with soil acidity, low organic matter content, and poor drainage identified as the main regional constraints. That basin-wide analysis, by design, does not resolve village-level variability in soil morphology or fertility, nor does it combine detailed soil-profile description with a village-scale climatic suitability assessment.

The present study extends this regional picture along three lines that have not, to our knowledge, previously been combined for this basin. First, it characterises soil fertility and morphology at the scale of individual cotton-growing plots and villages, through composite topsoil sampling combined with full 0-100 cm soil-profile description, rather than through the coarser spatial units typical of regional MCDA assessments. Second, it couples this site-level soil evaluation with a village-scale climatic suitability analysis built on a 41-year (1980-2020) climatology, which allows the relative contribution of soil and climate to the overall suitability class to be distinguished explicitly rather than inferred. Third, its management recommendations are derived directly from the limiting factors measured at each site, rather than drawn from generic regional guidance. Because only two villages were surveyed, the study is best read as a site-level complement to the basin-wide analysis of Kouakou et al. (2023) rather than a substitute for it, and its conclusions are not intended to characterise the Korhogo cotton basin, or Korhogo Department, as a whole. Three objectives follow from this framing: characterising the pedological constraints, physical and chemical, of the topsoils and soil profiles in Bafime and Larazourou; classifying the climatic and edaphic suitability of the two villages for cotton cultivation under the FAO/Sys framework; and proposing site-adapted soil and land management options, still to be validated, based on the constraints identified.

Soil forms the foundation of land resources and is pivotal for agricultural development and ecological sustainability (FAO, 2014). It represents a reservoir of biodiversity critical to our planet (INRA, 2018). Maintaining or enhancing soil fertility is a paramount challenge (Sanchez, 2002), particularly in West Africa, where improving soil fertility and agricultural productivity are top priorities (CORAF, 2008). Land suitability, the fitness of a given piece of land for a specified use, is a fundamental aspect of land management (Driessen & Konijn, 1992). It should be distinguished from the related but distinct concept of land capability, which describes the land's general potential across a broad range of uses rather than its fitness for one specific crop and management system (FAO, 1976). Assessing land suitability provides valuable insight into land-use constraints and opportunities, essential for informed land-use planning (AbdelRahman et al., 2016).

Soil parameters, influenced by climate and topography, have a significant impact on crop performance (Sehgal, 1991), and land suitability classification aims to predict the agricultural potential of land development units based on land resources (Sys et al., 1991). Under the FAO Framework for Land Evaluation (FAO, 1976), each land unit is ranked against the requirements of a specific use, cotton cultivation in the case of this study, guiding decisions on the most suitable use for a given location and ranking the factors that limit it. This study evaluates the suitability of land specifically for cotton cultivation in Bafime and Larazourou, Korhogo Department, Côte d'Ivoire; it does not evaluate land capability in the broader, multi-use sense.

Materials and Methods:-

Sites Characterization:-

The study was conducted at two villages, Bafime and Larazourou, within Korhogo Department, located in northern Côte d'Ivoire, within the Poro Region. The Department belongs to the Savanes Autonomous District and constitutes one of the country's major cotton-producing zones, covering an area of approximately 12,500 km² and characterized by a Sudanian climate, marked by an alternation between a four- to five-month wet season and a long dry season. Throughout this manuscript, "study area" refers specifically to the six sampled plots and the two study villages; broader units, namely Korhogo Department, the Poro Region, and the wider Ivorian cotton basin, are named explicitly wherever they are discussed, and findings are not extrapolated beyond the sampled villages unless stated otherwise (Section 4.3).

The vegetation is predominantly composed of wooded savannas and open woodlands, while the soils of the wider Department are generally susceptible to water erosion. These environmental characteristics make Korhogo particularly relevant for analysing agricultural practices and their agro-environmental implications within local cotton-based farming systems. Within this study area, three primary classes of soils hold prominence in the French (ORSTOM/CPCS) pedological classification traditionally used in the region: tropical ferruginous soils, hydromorphic soils, and soils on basic rocks. In the international Soil Taxonomy (USDA) system, these soils are broadly classified as Alfisols. Bafime and Larazourou were selected as study sites because they are active cotton-producing villages representative of the two dominant local soil-texture conditions found within Korhogo Department's cotton-growing plots (a coarser, deep sandy profile in Bafime and a finer, sandy-loam profile in Larazourou), allowing the study to capture contrasting fertility and management conditions within a single department.

The vegetative cover within the wider Department exhibits three distinct zones: the Forest Zone in the central western part, the Guinean Savanna Zone in the eastern sector, and the Sudanian Savanna Zone in the northern expanse, which together shape land use and ecological dynamics across the region. Notably, three of Côte d'Ivoire's primary rivers, namely Sassandra, Bandama, and Comoé, course through the Ivorian cotton basin, traversing the landscape from North to South (Dekoula, 2018). Korhogo Department was selected as the regional setting for this study owing to its susceptibility to pronounced climatic variations, which makes it one of the most vulnerable agro-ecological zones in the country (MINESUDD, 2013). Given this vulnerability, the study aims to provide stakeholders with practical, site-level decision-making tools that can be extended, in future work, to other villages within this dynamic cotton-producing region.

Soil Sampling:-

The soil sampling methodology adopted for this study was designed to systematically collect representative soil samples from each cotton-growing plot at a depth of 0–0.2 m, using a soil auger. Sampling was conducted in the villages of Bafime and Larazourou, Korhogo Department, as part of the 2021 sampling campaign, across six distinct cotton-growing plots in total: four plots in Bafime and two in Larazourou. Within each plot, between one and five sampling points were established, the number being adjusted to the plot's size (larger plots received up to five points). At each sampling point, 17 elementary (elemental) increments were collected within a small radius around the point and combined on the spot into a single, homogenised sub-sample for that point. All of the point-level sub-samples obtained within a given plot, one from each of its one to five sampling points, were then pooled and thoroughly homogenised to form a single composite topsoil sample representing that plot. Each of the six composite samples (four from Bafime, four plots; two from Larazourou, two plots) therefore corresponds to one plot and integrates between 17 and 85 elementary increments (17 increments × 1–5 sampling points), consistent with reconnaissance-level soil survey practice for characterizing the dominant cultivated soils of a village (FAO, 2006).

The six composite samples are treated as independent sampling units, each representing a distinct cotton-growing plot; they are not sub-samples of one another. Figure 1 provides a schematic diagram of this sampling design to aid reproducibility. In addition to these six topsoil composites, one full soil profile (0–100 cm) was described in each village (two profiles in total; Figure 2), independently of the composite sampling, to characterize subsurface morphology and effective soil depth. Because only one profile was described per village, each profile should be interpreted as representative of the dominant soil condition encountered at that village's profile pit, and not as a full characterization of within-village variability in effective depth, gravel content, drainage, or horizon development; replicating profile description across multiple pits or soil-mapping units per village is recommended as a priority for follow-up work (Section 4.3).

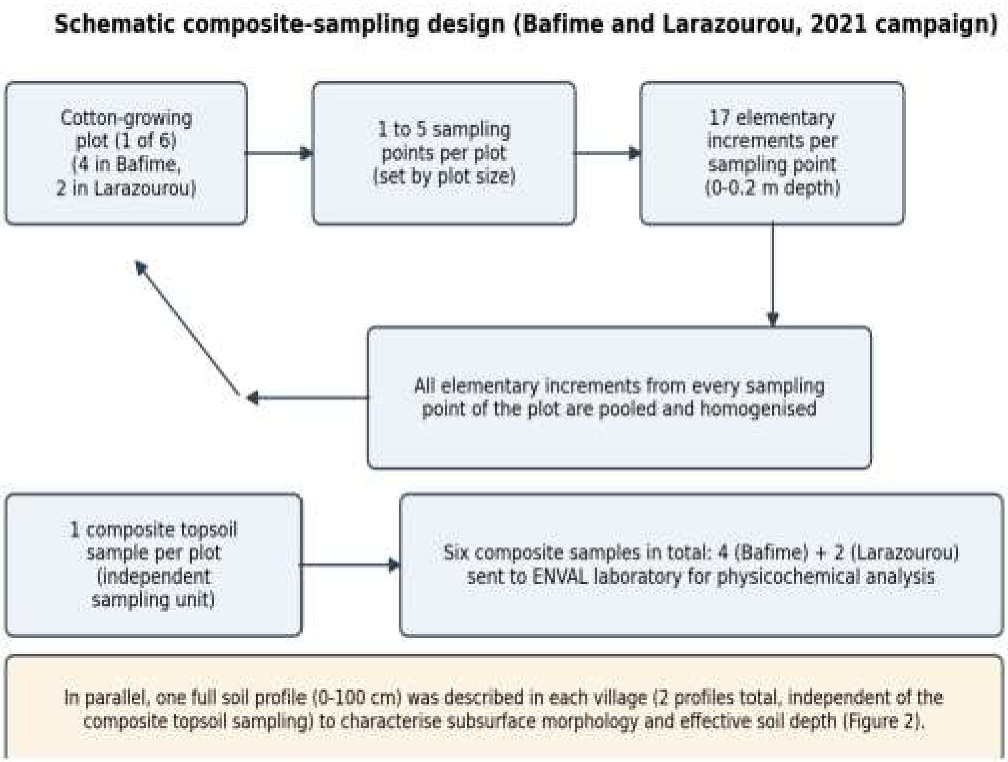

Figure 1: Schematic diagram of the composite-sampling design applied at Bafime and Larazourou (2021 campaign): plot → 1–5 sampling points per plot → 17 elementary increments per sampling point → pooling into one composite sample per plot → six composite samples in total, analysed independently of the two soil profiles. In the subsequent stages of analysis, the average values of physicochemical soil characteristics were calculated for the topsoil layer of each village, from its corresponding composite samples (n = 4 for Bafime, n = 2 for Larazourou). This approach enabled an evaluation of soil properties and suitability for cotton cultivation under the conditions found in these two villages, at the reconnaissance level of detail appropriate to a six-sample, two-village dataset (Section 4.3).

Laboratory Analysis:-

The six soil samples were delivered to ENVAL (Laboratoire de l'Environnement et de l'Alimentation de Côte d'Ivoire). The field samples were air-dried at room temperature, crushed, and sieved through a 2 mm sieve. The soil fraction < 2 mm was analyzed for physical and chemical properties. Particle size analysis was performed using the densimetric method, which involved using Robinson's pipette after dispersing 50 g of soil in a solution of sodium hexametaphosphate ($NaPO_3$) (Bouyoucos, 1962). The organic carbon content of the soil was determined using the Walkley-Black wet combustion method, which involves oxidation with potassium dichromate and subsequent titration with iron sulfate (Walkley & Black, 1934; as adapted by Crétenet & Gourlot, 2015). Soil pH was measured at a soil:solution ratio of 1:2.5 in distilled water (pH-H_2O) (Dabin, 1970). Total N was determined by the Kjeldahl wet digestion method. The assimilable phosphorus (P_{ass}) was determined by the Bray 1 method, and the Cation Exchange Capacity (CEC) was measured according to the NFX 31-130 standard (AFNOR, 1999), which displaces the cations adsorbed on the exchange sites and saturates them with a single cation, ammonium (NH_4^+). At the same time, the exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+) were determined by Atomic Absorption Spectrophotometry (Optima 2100 DV).Particle-size fractions (clay, silt, sand) were expressed as percentages of the <2 mm fine-earth fraction and were used to characterize soil texture in Bafime and Larazourou.

Land-suitability evaluation framework:-

The suitability of land for cotton cultivation depends on terrain, soil, and climate characteristics. Terrain and soil factors, such as topography and drainage, impact soil quality. Terrain-soil suitability was assessed using the FAO method, which categorizes land into five suitability classes. The evaluation involves collecting land characteristics, matching them with land-use requirements, and identifying limitations; here it was applied at the six sampling points across the two villages of Bafime and Larazourou. In the FAO Framework for Land Evaluation (FAO, 1976), each land unit is assigned a suitability class from the five-member set S ∈ {S1, S2, S3, N1, N2} = {highly suited, moderately suited, marginally suited, currently not suitable, permanently not suitable}, as shown in Table 1. Throughout this evaluation, the degree of limitation of each land characteristic is scored on a 0–4 scale (0 = no limitation, 1 = slight, 2 = moderate, 3 = severe, 4 = very severe), which maps directly onto the five suitability classes (0→S1, 1→S2, 2→S3, 3→N1, 4→N2); the overall suitability class of a land unit is then determined by applying the criteria in Table 1 to the full set of characteristics assessed: for soil, several moderate (degree-2) limitations are needed before the class is downgraded, whereas a single severe or very severe characteristic is sufficient on its own to set the class, following the Simple Limitation Method (SLM), whose full application procedure is detailed step-by-step in Section 2.6.

Table 1: Criteria for determination of land suitability classes (Sys et al., 1993)

Land classes	**Criteria**
S1 : Very suitable	Land units with no or only 4 slight limitations
S2 : Moderately suitable	Land units with more than 4 slight limitations, and/or no more than 3 moderate limitations
S3 : Marginally suitable	Land units with more than 3 moderate limitations, and/or one or more severe limitations.
N1: Currently not suitable	Land units with limitations severe enough to preclude successful use under current management, but that could be corrected by improved management or additional inputs.
N2 : Permanently not suitable	Land units with limitations so severe that they preclude any successful use for cotton cultivation and cannot be corrected.

Assessment of climatic suitability:-

Cultivation practices in the Côte d'Ivoire cotton basin have been defined by the Centre National de Recherche Agronomique of Ivory Coast (CNRA), and this division of the cultivation calendar is a function of the climatic conditions present in each agroecological zone (MINESUDD, 2013). The assessment of climatic suitability for cotton production is based on several climate variables, including total rainfall during the growing season, total rainfall received between June and October, mean temperature during the growing season, and mean maximum temperature between June and October. These climate variables were selected because they are known to have a significant impact on the agronomic performance of cotton production (Sys et al., 1993).

In the agro-ecological zone, cotton is mainly sown in the first decade (D1: 21–31 May) and harvested from November to December. The main growing period was defined as the period between June and October. To avoid the ambiguity raised during review, Table 2 below specifies, for each meteorological variable, the exact data source, spatial resolution, temporal resolution, and period used in this study.

Table 2: Climate data sources used in this study

Variable *	*Dataset / source** *	Spatial resolution**	Temporal resolution**	*Period**
Rainfall (RGS, RRP)	SODEXAM meteorological stations, supplemented by the CNRA/LCSEP climate database	Station-level (point) observations	Monthly totals, aggregated to growing-/ ripening-seaso	1980–2020
Mean and maximum temperature (TGS, TGSmax, TRS)	ERA5 reanalysis (Copernicus Climate Change Service, ECMWF), accessed via Google Earth Engine	0.25° grid (~31 km), nearest grid cell to each village	Monthly means derived from hourly/daily fields	1980–2020
Relative humidity (RH)	ERA5 reanalysis (Copernicus Climate Change Service, ECMWF), accessed	0.25° grid (~31 km), nearest grid cell to each village	Monthly means, averaged over June–October for each year,	1980–2020

Variable *	*Dataset / source** *	Spatial resolution**	Temporal resolution**	*Period**
	via Google Earth Engine		then averaged across 1980–2020	

Rainfall data therefore come exclusively from ground-based station records (SODEXAM and CNRA/LCSEP), which also supply the long, station-specific series used to describe intra-seasonal rainfall characteristics of the region (Dekoula et al., 2018); these intra-seasonal descriptors (onset and cessation dates, dry-spell frequency) are referenced qualitatively from that regional dataset to characterize typical rainfall behaviour in the wider Korhogo climatic zone, but were not independently recomputed or statistically tested for Bafime and Larazourou specifically, a limitation discussed further in Section 4.3. Temperature and relative humidity, by contrast, come exclusively from the ERA5 reanalysis product.

The native grid of the ERA5 reanalysis distributed by ECMWF/Copernicus is 0.25° (approximately 31 km). The higher-resolution ERA5-Land product (0.1°, roughly 9 km) was not used in this study. Given this 0.25° grid, the ERA5 pixel nearest to each village centroid was extracted; because Bafime and Larazourou lie only about 5 km apart, the two villages likely fall within the same, or immediately adjacent, ERA5 grid cell(s), so the resulting temperature and relative-humidity values should be interpreted as representative of the shared local climate of the two villages rather than as capturing fine-scale, village-specific differences in these two variables. This resolution constraint, discussed further in Section 4.3, is important context for interpreting the climatic, as opposed to the soil, component of the suitability classification. No resampling or downscaling beyond the standard Google Earth Engine monthly aggregation was applied.

Regarding the relative-humidity value used to drive the climatic classification (Section 3.3), the reported figure of 79% is the arithmetic mean of the ERA5 monthly-mean relative-humidity values for the June–October growing season, averaged over 1980–2020; it does not distinguish daytime from night-time humidity, nor does it capture the diurnal cycle, since ERA5 monthly means are themselves averages over each month's hourly values. The threshold applied (70–80% = degree-3, severe limitation; Table 3) follows Sys et al. (1993), whose crop-requirement tables for cotton were originally developed from station-based climatological means of the same general type (monthly or seasonal mean relative humidity), rather than from reanalysis products; the authors are not aware of a documented sensitivity analysis showing that ERA5-derived seasonal-mean relative humidity is numerically equivalent to the station-based means underlying the original Sys et al. (1993) thresholds for this specific cotton production system, and this equivalence is treated in the present study as a working assumption rather than as an established fact. This caveat is revisited in Section 4.1.

The climatic suitability was analyzed based on the recommendations of Sys et al. (1993). Consistent with this being a long-term climatology rather than a trend study (Section 2.6 and 4.3), the term "climate averages" is used in preference to "climate trends" throughout this manuscript wherever only the 1980–2020 mean values, rather than a statistically tested change over time, are being described.

Assessment of terrain and soil suitability, and application of the Simple Limitation Method:-

The lands were classified using the Simple Limitation Method (SLM), a land-evaluation approach commonly applied to specific crops such as maize, potato, onion, and cotton (Jafarzadeh et al., 2008), in which crop-specific requirement tables define, for each land characteristic, the value ranges corresponding to each class-level (Table 3).

The SLM was applied here in the following explicit sequence:-

1. Each raw measured or observed value for a given land characteristic (e.g., mean growing-season relative humidity, texture class, coarse fragment content, effective depth, sum of basic cations) was compared against the corresponding value ranges in Table 3 and assigned a degree of limitation on the 0–4 scale (0 = no limitation, …, 4 = very severe), separately for each village.
2. For climate, the overall climatic class was set by the single most limiting (i.e., numerically lowest-ranked) class among the individual climatic characteristics assessed (rainfall during the growing season, rainfall during the ripening stage, mean temperature, mean maximum temperature, and relative humidity); no averaging or weighting across climatic variables was applied.
3. For soil (terrain, physical, and fertility characteristics), the overall soil class was set by applying the number-of-limitations criteria of Sys et al. (1993) (Table 1) to the complete set of assessed soil characteristics for each village: a single severe (degree-3) or very severe (degree-4) characteristic is sufficient, on its own, to set the

class, whereas several (more than three) moderate (degree-2) limitations are required, together, to downgrade the class from S2 to S3; no numerical weighting was applied among the individual soil characteristics.

4. The overall land-suitability class for each village was then set by comparing the climatic class from step 2 with the soil class from step 3 and retaining the more limiting (numerically lower-ranked) of the two; this final integration step uses the same "most-limiting-factor" logic as steps 2 and 3, applied once at the climate-soil level, and no additional weighting was applied between the climate and soil components.

This sequence follows the same underlying decision rule at each level, so it is stated here in full in the Methods, rather than being reconstructed only from the Results (Section 3.4). In the land evaluation process, the morphological characterization of the soil profiles (0–100 cm depth) (Figure 2) and the physicochemical parameters of the topsoil (0–0.2 m) were matched with the requirements of the cotton plant (Table 3). The limitations of the soils at each site for cotton cultivation were assessed according to the criteria of Sys et al. (1993) and expressed in terms of their degree of limitation (0, 1, 2, 3, and 4) (Table 1 and Table 3).

Table 3. Crop requirement for cotton according to Sys et al (1993)

Land characteristics	Class, degree of limitation, and rating scale					
	S1	S2	S3	N1	N1–N2	N2
	Degree 0	Degree 1	Degree 2	Degree 3	Degree 4	Degree 4
Rating (index)	100	95	85	60	40-25	0
Climatic characteristics (c)						
Rainfall, growing season (mm)	1000-850	850-750	750-600	600-500	-	<500
Rainfall during the ripening stage (mm)	<25	25-50	50-75	75-100	-	>100
Mean temp., growing stage (°C)	28-26	26-24	24-22	22-20	-	<24
Mean max. temp., growing stage (°C)	35-32	32-28	28-26	26-24	-	<24
Mean temp. of ripening stage (°C)	<25	25-50	50-75	75-100	-	<100
Mean R.H. in the growing season (%)	<50	50-60	60-70	70-80	>80	-
Topography (t), slope (%)						
(1) Irrigated	0-1	1-2	2-4	4-8	-	>6
(2) Full mechanization	0-2	2-4	4-8	8-16	-	>16
(3) Animal traction / manual	0-4	4-8	8-16	16-30	30-50	>50
Wetness (w)						
Flooding (4)	F0	-	-	F1	-	F2+
Drainage (5)	good	-	Moderate	Imperfect	Poor, but drained	Poor, Not drained
Physical soil characteristics (s)						
Texture / structure	C<60s, SiC, Co, SiCL, Si, SiL, CL	C<60v, SC, C>60s, L	C>60v, SL, SCL	FS, S, LS, Lcs	-	Cm, SiCmcS
Coarse fragment (g 100 g^{-1})	0-3	3-15	15-35	35-55	-	>55
Soil depth (m)	>1	1-0.75	0.75-0.50	0.50-0.25	-	<0.25
Soil fertility characteristics (f)						
Apparent CEC ($cmol^+$/kg)	>24	24-16	<16 (-1)	<16 (+1)	-	-
Base saturation, BS (%)	>80	80-50	50-35	>35	-	-
Sum of basic cations, SBC ($cmol^+$/kg)	>6.5	6.5-4.6	4-2.8	2.8-1.6	<1.6	-
pH H_2O *	6.7-7.0	7.0-7.6	6-5.6 / 7.6-8	5.6-5.2 / 8-8.5	<5.2	<8.2
Organic carbon (g 100 g^{-1})						

(6) Fine-textured soils	>2.0	2-1.2	1.2-0.8	<0.8	-	-
(7) Medium-textured soils	>1.8	1.2-0.8	<0.8	-	-	-
(8) Coarse-textured soils **	>0.8	0.8-0.4	<0.4	-	-	-
EC_e (dS m⁻¹)	<2	2-4	4-8	8-15	>15	-

Source: Sys et al. (1993). Notes on textural classes (USDA system): C, clay; SiC, silty clay; SC, sandy clay; CL, clay loam; SiCL, silty clay loam; SCL, sandy clay loam; Si, silt; SiL, silt loam; L, loam; FS, fine sand; S, sand; LS, loamy sand; Co, coarse-textured soils; Lcs, loamy coarse sand. Structure qualifiers: C<60v / C>60v, clay content below/above 60% with vertic (shrink-swell) structure; C<60s / C>60s, clay content below/above 60% with blocky structure; Cm, massive clay; SiCm, massive silty clay; SiCmcS, massive silty clay over coarse sand. Wetness/flooding: F0, no flooding limitation; F1, slight flooding limitation; F2+, moderate to severe flooding. Rating scale (0–4): 0 = no limitation, 1 = slight, 2 = moderate, 3 = severe, 4 = very severe, mapping to classes S1, S2, S3, N1 and N2 respectively, as defined in Table 1. (1) Irrigated; (2) Full mechanization; (3) Animal traction/Manual; (4) Medium- and fine-textured soils; (5) Coarse-textured soils; (6) Fine-textured soils (organic-carbon threshold set); (7) Medium-textured soils (organic-carbon threshold set); (8) Coarse-textured soils (organic-carbon threshold set, applicable to Bafime and Larazourou in this study). In Table 3, the single asterisk (*) on the pH H_2O row marks that its cells combine two threshold sub-ranges (acid side / alkaline side) exactly as reported in the source table; readers should consult Sys et al. (1993) for the precise agronomic basis of each sub-range. The double asterisk (**) marks organic-carbon row (8), the coarse-textured-soil threshold set applicable to Bafime and Larazourou in this study.

Results:-

Texture of different soils:-

The soils of the six sampled plots in Bafime and Larazourou are predominantly sandy, with sand content averaging 88.0% in Bafime and 66.0% in Larazourou (Table 4). Clay content is very low at both sites (2.3% in Bafime; 6.4% in Larazourou), while Larazourou also carries a markedly higher silt fraction (25.7% versus 8.3% in Bafime). This high sand content, combined with the low clay proportion, indicates a low water- and nutrient-retention capacity in the sampled plots, particularly in Bafime. These textural characteristics can increase the vulnerability of these soils to rapid drainage, nutrient leaching, and water stress, and are interpreted here as potential constraints on cotton productivity, especially during prolonged dry periods; no yield data were collected to confirm this relationship directly (Section 4.2).

Table 4: Texture of the sampled soils (mean of composite topsoil samples per village)

Village	Clay (%)	Silt (%)	Sand (%)
Bafime (n = 4)	2.30	8.35	**88.03**
Larazourou (n = 2)	6.40	25.70	**65.95**

Note: These percentages of texture represent averages from the composite topsoil samples collected in each village (four in Bafime, two in Larazourou). Fractions do not sum to exactly 100% because coarse fragments (gravel, >2 mm) were excluded from the fine-earth particle-size analysis and are reported separately as part of the soil profile descriptions (Figure 2). Given the small number of composite samples per village, individual sample values and a measure of spread (range or standard deviation) are reported in Table 5 rather than here, and no inferential statistical comparison (e.g., t-test) between villages was attempted, consistent with the sample sizes available (Section 4.3).

Soil morphological description and physicochemical properties:-

The soils of the sampled cotton production plots, in the great majority, exhibit the descriptive characteristics illustrated in Figure 2 (pictures a, b, and c) for the representative profile described in each village. In the Korhogo department, the soils that support cotton cultivation in the villages of Bafime and Larazourou have superficial horizons. The soil profile described in the village of **Bafime** is red in colour (5 YR 4/6), dry, humus-bearing, with a lumpy structure induced by coarse elements and roots, Sand (S) texture, very porous, numerous roots with a preferential subhorizontal orientation, moderate internal drainage, diffuse transition by colour, and a more or less regular boundary; this profile terminates at approximately 65 cm owing to an underlying layer of rocks and concretions, which sets its effective soil depth. The profile described in the village of **Larazourou** has a brown colour (7.5 YR 5/3), is dry, humic, with a lumpy structure induced by coarse elements and roots, Sandy Loam (SL) texture, very porous, numerous roots with a preferential subhorizontal orientation, moderate internal drainage, diffuse transition by colour, and a more or less regular limit; this profile extends to at least 100 cm without reaching a rock or concretion layer. As only one profile was described per village, these observations should be read as representative of the dominant profile at each site rather than as an exhaustive characterization of within-village variability (Section

2.2). Textural classes were assigned using the USDA soil texture triangle applied to the laboratory particle-size data (Table 4).

(A) Department KORHOGO /village: Bafime (Latitude:9° 28'8.59'' N, Longitude: 5° 33' 22.13 W)

Depth (cm)	Image	Morphological characteristics
0-2		Dry, humus-rich, red (5 YR 4/6), lumpy structure induced by coarse elements and roots, loamy sand texture (5-10 % clay)
2-11		Fresh, humus, yellowish red (5 YR 4/6), gritty structure induced by coarse elements and roots, loamy sand texture (10-15% clay), porous, coherent, many roots (mm) with preferential subhorizontal orientation, good internal drainage, 26 % of gravel content,
11-29		Fresh, humus-bearing, yellowish-red (5 YR 4/6), gritty structure induced by coarse elements and roots, loamy sand texture (10-15 % clay), porous, coherent, many roots (mm) with preferential subhorizontal orientation, good internal drainage, 28 % of gravel content, clear gradual transition through.
29-65		Fresh, not very humic, yellowish red (5 YR 5/6), general polyhedral subangular structure, sandy clay loam texture with medium sand (25-35 % clay), not very porous, coherent, a few rare roots (mm) with preferential subhorizontal orientation, 26 % of gravel content, medium internal drainage.
>65		Rocks and Concretions

(B) Department KORHOGO /village: Larazourou (Latitude:9° 29'59.3'' N, Longitude: 5° 55' 7.17 W)

Depth (cm)	Image	Morphological characteristics
0-2		Dry, humic, brown (7.5 YR 5/3), loamy sand texture and , good internal drainage, 13 % of gravel content
2-12		Fresh, non-humic, brown (7.5 YR 5/6), alteration spot, dark red (2.5YR 3/6) polyhedral structure with subangular grumbling, sandy clay loam texture (20-35% clay) not very porous, coherent, some roots (mm) with preferential subhorizontal orientation, 23 % of gravel content, medium internal drainage, progressive transition.
12-36		Fresh, not very humic, brown (7.5 YR 5/8), gritty structure induced by coarse elements and roots, loamy sand texture (15-25 % clay), porous, coherent, some acini (mm) with preferential subhorizontal orientation, 47 % of gravel content, good internal drainage, progressive transition.
36-55		Fresh, non-humic, brown (7.5 YR 5/6), alteration spot, dark red (2.5YR 3/6) polyhedral structure with subangular grumbling, sandy clay loam texture (20-35% clay), not very porous, coherent, some roots (mm) with preferential subhorizontal orientation, 23 % of gravel content, medium internal drainage, progressive transition.
55-100		Fresh, not humic, brown (7.5 YR 5/6), alteration spot (3.5YR 3/6), polyhedral structure with sub-angular grumbling, sandy-clay texture (45% clay), not very porous, coherent, some roots (mm) with preferential sub-horizontal orientation, 10 % of gravel content, average internal drainage.

Figure 2: Characteristics of the representative soil profile described in each study village (Bafime and Larazourou).

The results indicate that all six composite samples have moderately acidic to near-neutral pH values, ranging from 6.25 to 6.85 (mean 6.52), which suggests that the topsoils are slightly acid to near-neutral. Soil acidity is therefore not judged to be a significant constraint to cotton growth at either village. Although the pH values are relatively uniform, there is a difference of up to 0.6 units between the two villages; changes of this magnitude in pH can be accompanied by shifts in cation exchange capacity and in physical properties (Pernes-Debuyser & Tessier, 2005). The base saturation rate of the sampled soils varies from 38.8% to 66.6% (mean 55.6%), which falls within the range of published values of 40–60% reported for comparable West African cotton soils (Amonmide et al., 2019). Soil organic carbon has low values (0.24–0.42%), and total nitrogen is likewise low (0.050–0.090%) across all six composite samples (Table 5). This general fertility threshold of 2% organic carbon (Dabin, 1970) is a broad reference value for overall soil fertility, distinct from the lower, texture-specific organic-carbon thresholds defined for coarse-textured soils under the Sys et al. (1993) crop-suitability framework (Table 3, footnote 8); consequently, organic carbon values that are low relative to the 2% general fertility benchmark do not automatically translate into a severe limitation under the crop-specific suitability classification, and indeed Larazourou is rated degree 0 (no limitation) for organic carbon under the Sys criteria despite being below the 2% general threshold (Table 8). The CEC shows low values ranging from 4.90 to 8.99 cmol$^+$/kg. Because the apparent-CEC thresholds in the Sys et al. (1993) system are specifically adjusted downward for coarse-textured (sandy) soils, these CEC values were rated as posing no additional limitation (degree 0; Table 8) in the crop-specific land-suitability evaluation, even though they remain low in absolute terms relative to typical fertile-soil benchmarks; "low absolute CEC" and "no CEC limitation under this classification system" are therefore two distinct, and both correct, statements that should not be read as contradictory.

The sum of exchangeable bases (Ca^{2+}, Mg^{2+}, Na^+, and K^+) averages 4.21 cmol$^+$/kg and contributes to just over half of the cation exchange capacity of these soils (Reddy et al., 2012); this insufficient quantity of exchangeable bases is interpreted as unfavourable for cotton nutrient supply, though this interpretation, like the other fertility findings in this section, is not validated against measured cotton yields (Section 4.2). Ca^{2+} is the dominant cation in all six composite samples, varying between 1.25 and 4.48 cmol$^+$/kg, followed by Mg^{2+}, Na^+, and K^+. The electrical conductivity, ranging from 0.04 to 0.06 dS m^{-1}, indicates very low salinity levels, suggesting that the sampled soils are non-saline and pose no salinity risk to cotton cultivation (Santos & Castro, 2020). Overall, Larazourou consistently shows a finer texture (higher clay and silt content), a higher CEC, and a larger reserve of exchangeable bases than Bafime (Table 5), suggesting a comparatively greater nutrient-holding capacity, consistent with Larazourou's more favourable soil suitability class (S2) relative to Bafime (S3; Section 3.4).

Table 5: Physicochemical properties of the topsoil (0–0.2 m) in Bafime and Larazourou: individual composite samples, village means, and overall dataset. Individual values were extracted from the authors' 2021 ENVAL laboratory dataset.

Sample	pH (H2O)	OC (%)	N tot. (%)	CEC	SEB	BS (%)	Ca2+	Mg2+	K+	Na+
	-	-	-	cmol+/kg	cmol+/kg	-	cmol+/kg	cmol+/kg	cmol+/kg	cmol+/kg
Bafime, individual composite samples (n = 4)										
Bafime 1	6.85	0.420	0.08	8.37	5.37	64.2	3.86	1.07	0.394	0.050
Bafime 2	6.64	0.378	0.08	8.99	5.99	66.6	4.48	1.05	0.402	0.062
Bafime 3	6.29	0.344	0.07	4.90	1.90	38.8	1.25	0.40	0.204	0.048
Bafime 4	6.34	0.241	0.05	5.02	2.02	40.2	1.41	0.35	0.197	0.054
Bafime, mean	**6.53**	**0.346**	**0.07**	**6.82**	**3.82**	**52.5**	**2.75**	**0.72**	**0.299**	**0.054**
Bafime, SD	0.26	0.077	0.01	2.16	2.16	15.0	1.66	0.39	0.114	0.006
Bafime, CV (%)	4.0	22.2	20.2	31.7	56.6	28.6	60.4	54.6	38.2	11.6
Larazourou, individual composite samples (n = 2)										
Larazourou 1	6.25	0.412	0.09	7.04	4.04	57.4	2.89	0.75	0.326	0.066
Larazourou 2	6.73	0.237	0.05	8.91	5.91	66.3	4.33	1.06	0.432	0.095
Larazourou, mean	**6.49**	**0.325**	**0.07**	**7.98**	**4.98**	**61.9**	**3.61**	**0.91**	**0.379**	**0.080**
Larazourou, SD	0.34	0.124	0.03	1.32	1.32	6.3	1.01	0.21	0.075	0.020

Larazourou, CV (%)	5.2	38.3	40.4	16.6	26.6	10.2	28.1	23.5	19.8	25.0
Overall dataset (n = 6, unweighted by village)										
Overall, mean	**6.52**	**0.339**	**0.07**	**7.21**	**4.21**	**55.6**	**3.04**	**0.78**	**0.326**	**0.063**
Overall, SD	0.26	0.082	0.02	1.87	1.87	12.9	1.43	0.33	0.103	0.017
Overall, CV (%)	3.9	24.2	23.9	26.0	44.6	23.2	47.2	42.6	31.7	27.4
Overall, min	6.25	0.237	0.05	4.90	1.90	38.8	1.25	0.35	0.197	0.048
Overall, max	6.85	0.420	0.09	8.99	5.99	66.6	4.48	1.07	0.432	0.095

Note: OC, organic carbon; N tot., total nitrogen; CEC and SEB (sum of exchangeable bases: Ca^{2+}+Mg^{2+}+K^{+}+Na^{+}) in cmol^{+}/kg; BS, base saturation (%) = SEB/CEC × 100. Individual values, means, standard deviations (SD), and coefficients of variation (CV) are reported directly from the six composite topsoil samples (four from Bafime, two from Larazourou) to characterise sample-level variability rather than village means alone. Given the small number of samples per village (n = 4 and n = 2), SD and CV are reported as descriptive measures of spread only; no inferential statistical test (e.g., a t-test comparing villages) was performed or should be inferred from this table. Electrical conductivity (EC), measured separately, ranged from 0.04 to 0.06 dS/m across both villages, confirming non-saline conditions at all sites.

Climate requirements for cotton production:-

Table 6 presents climatic averages for the six study parameters over the 1980–2020 period (Table 2, Section 2.5, specifies data sources and resolution for each variable). The suitability of a location for cotton is primarily determined by rainfall, temperature, and relative humidity (Figure 3). In the northern savannah zone, where cotton is grown, the growing season begins in June and continues through October. The ripening season starts in November and lasts until December, when cotton is also harvested. The 1980–2020 average rainfall and temperature during the growing and ripening season are suitable for cotton production. However, the 1980–2020 average relative humidity in the study area exceeds the requirements for cotton-growing under the Sys et al. (1993) criteria (Section 2.5).

Table 6: Climatic averages (1980–2020) for Korhogo Department, applied to both study villages given their proximity and the 0.25° resolution of the underlying ERA5 grid (Section 2.5)

Area	RGS (mm)	RRP	TGS (°C)	TGSmax (˚C)	TRS (˚C)	RH (%)
Korhogo	909	23	25.3	32.8	25.5	79

RGS: Rainfall during the growing season (mm); RRP: Rainfall during the ripening season; TGS: Mean temperature, growing season; TGS_{max}: Mean maximum temperature, growing stage; TRS: Mean temperature, ripening stage; RH: Mean relative humidity, growing season (see Section 2.5 for how RH was computed and its limitations).

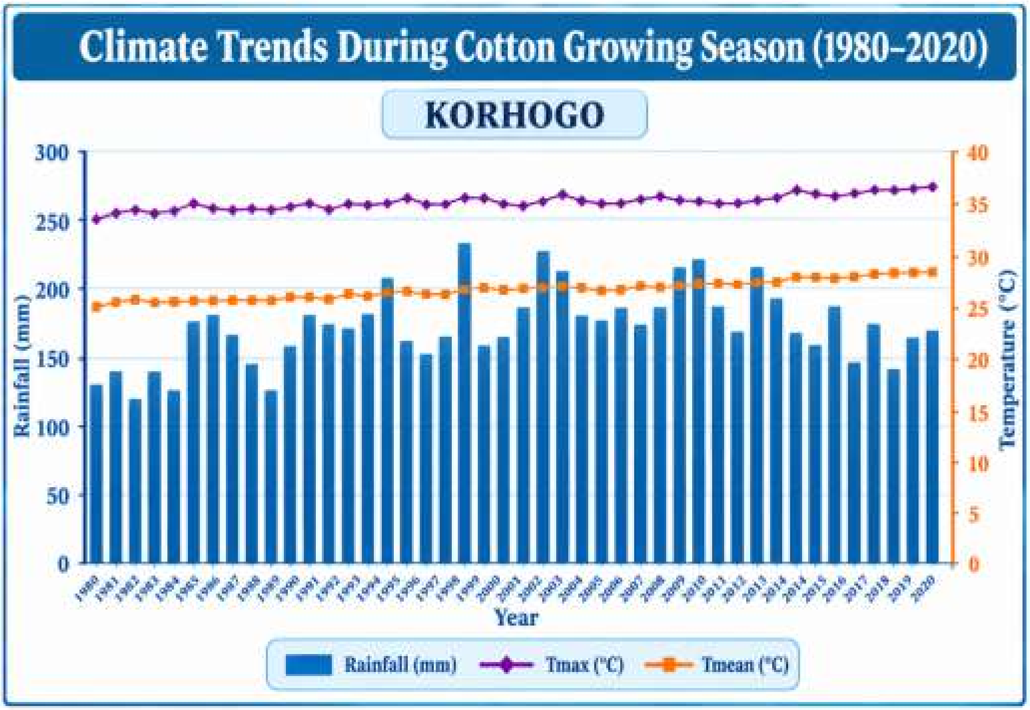

Figure 3: Monthly rainfall (mm, bars), from SODEXAM and CNRA/LCSEP station records, and monthly mean/maximum air temperature (°C, lines), from the ERA5 reanalysis (Copernicus/ECMWF, 0.25° resolution), for Korhogo Department, 1980–2020; see Table 6 for the suitability thresholds applied and Table 2 for full source details. These panels display the long-term monthly climatology (average by calendar month across the 41-year period); they are not intended to show, and no formal statistical test was applied to identify, a temporal trend over 1980–2020 (Section 4.3).

Suitability evaluation for cotton production:-

The agro-climatic requirements for the considered land utilization type were temperature (°C), relative humidity, and total growing period rainfall (mm) (Figure 3). Rainfall and temperature parameters (RGS, RRP, TGS, TGSmax, TRS) showed no more than slight limitations (degree 0–1; Table 7). Relative humidity, however, averaged 79% during the growing season, which falls within the 70–80% bracket that Sys et al. (1993) classify as a severe limitation (degree 3) for cotton (subject to the interpretive caveats on this metric discussed in Section 2.5 and revisited in Section 4.1). Following the Simple Limitation Method (Section 2.6), under which the overall climatic class is set by the single most limiting characteristic, the agro-climatic situation of the study area is therefore currently not suitable (N1) for the considered varieties of cotton (Table 7), driven entirely by relative humidity; all other climatic parameters remain favourable.

To evaluate the suitability of the land for cotton cultivation, the results obtained for climate and soil parameters in the study area are summarized in Tables 4, 5 and 6. The class and degree of limitation assigned to each input parameter are shown in Tables 7 and 8. Considered on their own, soils in Larazourou are "moderately suitable" (S2) for cotton production, whereas soils in Bafime are "marginally suitable" (S3), owing to a combination of **five** moderate limitations (drainage, texture, coarse fragments, effective depth, and sum of basic cations, SBC) that together exceed the three-limitation threshold defining S2 under the Sys et al. (1993) criteria (Table 1); Larazourou, with three moderate limitations (drainage, texture, coarse fragments), remains within this threshold. Low soil fertility (SEB) is a shared constraint in both villages, compounded in Bafime by shallower effective depth and coarser texture; addressing these limitations through management, as described in Section 5, is proposed as a set of options for future evaluation rather than as a validated solution. However, because the climatic class (N1, driven by relative humidity) is more restrictive than either soil class (S2 in Larazourou, S3 in Bafime), and the overall land suitability class is determined by retaining the single most limiting component (climate or soil; Section 2.6), the combined land suitability of Bafime and Larazourou for cotton cultivation is currently not suitable (N1), primarily on climatic grounds rather than on soil-fertility grounds.

Table 7: Climatic Suitability Classification and Limitation Levels

Area	RGS	RRP	TGS (°C)	TGSmax (˚C)	TRS (˚C)	RH Max	Limitation / Suitability class
Korhogo	0	0	1	1	1	3	L3 / N1

Note: Values in the RGS to RH Max columns are the degree of limitation (0–4 scale defined in Section 2.4/Table 1) assigned to each individual climatic characteristic, following Table 3. "Limitation / Suitability class" (L3 / N1) reports the single most limiting of these six degrees (here, RH at degree 3) and the corresponding overall climatic suitability class (Section 2.6, step 2).

Table 8: Soil Limitation and Suitability Classes by Profile

Land characteristics	Bafime	Larazourou
Topography		
Slope (%) (Manual tillage Operation)	0	0
Drainage	2	2
Flooding	0	0
Soil characteristics		
Texture class	2	2
Coarse fragments (vol %)	2	2
Depth (cm)	2	1
Soil fertility		
CEC (soil) ($cmol^+/kg$)	0	0
SBC ($cmol^+/kg$)	2	1
BS (%)	1	1
O.C. (%)	1	0
ECe (dS m-1)	0	0
pHH2O	0	0
Suitability class for dominant soil	S3	S2

Note: All values in this table are degrees of limitation on the 0–4 scale defined in Table 1 (0 = no limitation, 1 = slight, 2 = moderate, 3 = severe, 4 = very severe). The suitability class shown in the last row reflects soil characteristics only: S3 for Bafime, driven by a combination of five moderate (degree-2) limitations (drainage, texture, coarse fragments, depth, and SBC) that exceeds the threshold of three moderate limitations defining S2 under the Sys et al. (1993) criteria (Table 1); and S2 for Larazourou, whose three moderate limitations (drainage, texture, coarse fragments) remain within that threshold. Regardless of this difference, the overall land suitability class, combining both climate (Table 7) and soil components (Section 2.6, step 4), is currently not suitable (N1) for both villages, since the climatic limitation (relative humidity, degree 3) is more severe than any individual soil-related limitation (maximum degree 2) in either village.

Discussion:-

Climatic suitability for cotton production:-

Climatic conditions play a pivotal role in cotton cultivation, as in any form of agriculture. This study, in conjunction with existing research, identifies key climatic factors affecting the suitability of cotton production (Shi et al., 2021). Our findings indicate that Korhogo Department enjoys favourable long-term average rainfall and temperature conditions for cotton production. Cotton, being a thermophilic crop, thrives in regions with relatively high temperatures, which strongly influence its yield and fibre quality (Luo et al., 2014), typically requiring 25–35°C for around 150 days (Hébert et al., 2006). Profitable cotton production generally occurs where rainfall during the growth phase is between 850 and 1100 mm; yields tend to be uneconomical below 500 mm, underscoring the importance of well-distributed rainfall, especially during the growing season. Excessive rainfall lasting more than two weeks during harvest negatively affects fruit opening and fibre quality through the loss of essential waxes (Zhang et al., 2021), and cotton has limited tolerance for waterlogging stress, which reduces photosynthetic rates and can cause significant yield losses (Zhang et al., 2021). While early growth stages require sufficient rainfall, sunny and dry weather is important after flowering.

However, despite favourable long-term average rainfall and temperature, the 1980–2020 mean growing-season relative humidity in the study area (79%) places its climatic suitability, under the Sys et al. (1993) criteria, in the currently not suitable (N1) class. As detailed in Section 2.5, this conclusion rests on three linked assumptions that merit explicit discussion here rather than being left implicit: first, that a single 41-year arithmetic mean of monthly-mean relative humidity is an adequate summary of the humidity regime relevant to cotton, even though relative humidity varies considerably within each day and across the season; second, that ERA5 monthly-mean relative humidity, extracted at 0.25° resolution, is comparable in kind and magnitude to the station-based relative-humidity metric that originally underpinned the Sys et al. (1993) thresholds; and third, that a threshold developed from a broader set of cotton production systems applies without adjustment to the Bafime–Larazourou context. None of these assumptions is unreasonable, and the 79% value is well within, rather than marginal to, the 70–80% severe-limitation bracket (Table 3), which limits the sensitivity of the overall N1 classification to any single one of these assumptions; nonetheless, the classification should be read as the outcome of applying an established, published threshold to a regionally consistent dataset, rather than as direct proof that the measured atmospheric humidity, as distinct from its Sys-classification consequence, actually constrains cotton physiology at these two sites. This distinction is discussed further below in relation to disease and pest risk.

Excessive humidity throughout the vegetative cycle can affect cotton yields directly, by impeding plant growth, or indirectly, by promoting parasitism and disease (Stern et al., 2006). Additional research conducted by the Centre National de Recherche Agronomique (CNRA) in Côte d'Ivoire has quantified the impact of parasitism on cotton production, with severity increasing from the Northwest toward the South. Humidity and temperature are documented in the literature more broadly as indicators of disease and pest risk. It should be emphasized that the present study did not directly measure disease incidence, pest pressure, or yield losses at Bafime or Larazourou; the elevated relative humidity recorded for Korhogo Department is therefore interpreted here as a potential agronomic risk factor supported by prior research elsewhere, rather than as a directly observed outcome of the present study, and no claim is made that high humidity has caused disease or yield loss in the sampled cotton fields.

Land suitability for cotton production:-

The assessment of potential soil fertility, based on organic carbon (OC) and the Sum of Exchangeable Bases (SEB, equivalent to SBC in Tables 3 and 8), indicates that all six sampled plots show a limitation in at least one of these properties. Soil pH does not pose a significant limitation at either village. Soils with clay content exceeding 60% and a massive structure, as well as coarse loamy/sandy soils, are generally considered less suitable for cotton cultivation (Sehgal, 1990); sand content strongly exceeds clay and silt content in Bafime (88.0%) and, to a lesser extent, in Larazourou (66.0%). This is potentially unfavourable for cotton nutrient supply, since clay minerals are the main carriers of exchangeable cations such as Ca^{2+}, Mg^{2+}, and K^{+}, whose scarcity in sandy soils limits nutrient retention. FAO guidance associates a soil depth of 100-200 cm with favourable conditions for cotton growth, while depths below 100 cm are considered less favourable (Sehgal, 1991).

The two observed profiles are consistent with this pattern: in Larazourou, the profile extends to at least 100 cm without reaching a rock or concretion layer, whereas in Bafime effective soil depth is limited to approximately 65 cm by an underlying layer of rocks and concretions (Section 3.2, Figure 2). These are potential limitations inferred from measured soil properties and published crop requirements, not yield outcomes: the present study did not measure cotton yield, biomass, or fibre quality at either village, and is therefore best characterized as a resource-based suitability assessment rather than a yield-based validation of the S2/S3/N1 classes (Section 4.3). A future study pairing the suitability classification presented here with field-measured yield, boll number, or fibre-quality data at Bafime and Larazourou would allow this resource-based assessment to be validated directly against productivity outcomes.

Considered on soil characteristics alone, Larazourou is classified as moderately suitable (S2), while Bafime is marginally suitable (S3) on account of five moderate limitations (drainage, texture, coarse fragments, effective depth, and sum of basic cations, SBC) that together exceed the threshold used to define S2 in the Sys et al. (1993) system (Table 1), in addition to low soil fertility (SEB) shared by both villages. Because the climatic component of the evaluation is more limiting (N1, driven by relative humidity; Section 4.1) than either soil class, the overall combined land suitability of both villages is currently not suitable (N1). Addressing the fertility- and depth-related soil limitations through appropriate amendments and conservation measures could improve the soil suitability class in both villages, but would not by itself resolve the climatic limitation, which remains the primary constraint on the overall classification.

Limitations rooted in largely permanent characteristics, such as soil depth, slope, and stoniness, are not easily correctable, whereas the soil-fertility limitations affecting both villages, and the additional physical limitations placing Bafime in class S3 (drainage, texture, coarse fragments), can potentially be improved through management. The climatic limitation driving the overall N1 classification (relative humidity) is not correctable through farm-level intervention, but its agronomic impact can potentially be mitigated through crop-management practices. A strategic approach combining the judicious use of organic manures with inorganic fertilizers, together with cultural practices intended to reduce humidity-related disease and pest pressure, is therefore proposed as a set of management options for future field trials that could help sustain cotton yields and soil fertility over time, even though the site's inherent climatic constraint cannot itself be removed.

This assessment has focused on rainfall totals, temperature, relative humidity, soil texture, depth, and drainage; it did not evaluate groundwater availability, irrigation access, soil available water capacity, or the frequency of seasonal droughts or dry spells. Given the pronounced dry season that characterizes this Sudanian climatic zone (Section 2.1), these water-availability dimensions could be relevant to a fuller assessment of agricultural water stress at Bafime and Larazourou, and are recommended as a priority for future work (Section 4.3) in addition to, not instead of, the rainfall and drainage indicators already assessed here. To make the practical, site-specific contribution of this study more explicit, Table 9 summarizes the main constraint profile and corresponding management emphasis identified for each village.

Table 9: Site-specific constraint profile and management emphasis, by village.

Village	Main measured constraints	Primary management emphasis (to be evaluated in future trials)
Bafime	Shallow effective depth (approximately 65 cm, rock/concretion layer); coarse (sandy) texture (88.0% sand); coarse fragments; imperfect drainage; low sum of basic cations (SBC); low organic carbon	Soil and water conservation (mulching, contour tillage, vegetative strips); targeted fertility amendments guided by site-specific soil analysis
Larazourou	Low sum of basic cations (SBC), though less severe than Bafime; imperfect drainage; coarser-than-ideal texture, though finer than Bafime; deeper, more favourable profile (100 cm or more)	Fertility management (organic amendments, mineral fertilizers based on soil analysis); maintaining and protecting the favourable deeper soil profile
Both villages	Climatic limitation: mean growing-season relative humidity (79%), classified as degree-3 (severe) under Sys et al. (1993)	Agronomic practices to reduce humidity-related disease and pest pressure (wider spacing and row orientation, pruning, weed control, disease-tolerant varieties, integrated pest/disease monitoring)

Study scope and limitations:-

This study characterizes cotton-growing soils at two representative villages (Bafime and Larazourou) within Korhogo Department, based on six composite topsoil samples, each integrating between 17 and 85 elementary increments collected across one to five sampling points per plot (Section 2.2, Figure 1). This composite-sampling design follows established reconnaissance soil-survey practice, in which a small number of spatially aggregated composite samples are used to characterize the dominant soil conditions of a mapping unit or village (FAO, 2006; Sys et al., 1991), rather than a large statistical sample intended for inferential testing. The present dataset is therefore well suited to describing the typical fertility status and land-suitability class of the two villages, but the values reported for individual physicochemical parameters (Table 5) should be interpreted as the spread observed among sampling points rather than as population-level variability, and no inferential statistical test (e.g., a t-test comparing Bafime and Larazourou) was attempted or should be inferred from Table 5, given the small numbers of composite samples available per village (n = 4 and n = 2, respectively).

Because the assessment is limited to two villages, the soil-related findings should be extrapolated to the wider Korhogo cotton basin only with caution, and are not intended to characterize Korhogo Department, the Poro Region, or the Ivorian cotton basin as a whole (Section 1, Section 2.1). Similarly, only one soil profile was described per village (Section 2.2), so the reported effective-depth and drainage characteristics should be read as representative of the profile pit examined, rather than as an exhaustive characterization of within-village variability in these properties. On the climatic side, the 0.25° native resolution of the ERA5 product used for temperature and relative humidity (Section 2.5) means that these two variables were extracted from a grid cell (or cells) shared by, or immediately adjacent to, both villages, and should be interpreted at that coarser spatial scale rather than as village-specific measurements; rainfall, by contrast, draws on ground-station records (SODEXAM, CNRA/LCSEP). The climatological summary presented (Table 6, Figure 3) reflects 1980-2020 long-term averages rather than a tested temporal trend; no formal statistical trend analysis (e.g., a Mann-Kendall test with Sen's slope and associated confidence intervals) was performed, and this manuscript therefore refers throughout to "climate averages" rather than "climate trends." Likewise, although intra-seasonal rainfall descriptors (onset, cessation, dry-spell frequency) are available in the regional CNRA/LCSEP dataset and are referenced qualitatively in Section 2.5, they were not independently computed or tested for Bafime and Larazourou in the present study.

A fuller characterization of intra-seasonal and inter-annual climatic variability, together with a village-specific assessment of groundwater availability, irrigation access, soil available water capacity, and drought frequency (Section 4.2), is recommended as a priority for follow-up work, alongside expanding the sampling network to additional villages and cropping seasons and complementing composite sampling with replicated plot-level soil measurements and replicated soil-profile description per village. As emphasized throughout Section 4.2, this study provides a resource-based (soil- and climate-based) suitability assessment; it is not a substitute for a field-validated assessment based on measured cotton yield, biomass, fibre quality, or disease incidence, and the management recommendations proposed in Section 5 are options for future field-trial evaluation rather than demonstrated interventions.

Conclusion:-

This study shows that, combining soil and climate characteristics, cotton cultivation in Bafime and Larazourou (Korhogo Department) is currently not suitable (N1), a classification driven primarily by relative humidity (79% during the growing season, based on the 1980-2020 ERA5 climatology; Sections 2.5 and 4.1) rather than by soil fertility. Considered on soil characteristics alone, Larazourou is moderately suitable (S2) while Bafime is marginally suitable (S3), the latter reflecting a combination of five moderate limitations (drainage, texture, coarse fragments, effective depth, and sum of basic cations, SBC), in addition to low organic carbon (OC) common to both villages. Based on six composite topsoil samples and two soil profiles from two villages, these findings characterize local soil and climatic conditions at Bafime and Larazourou specifically; they are not sufficient, and are not intended, to generalize to the wider Korhogo cotton basin, Korhogo Department, or the Poro Region as a whole (Section 4.3). This is a resource-based suitability assessment: no cotton yield, biomass, fibre-quality, or disease-incidence data were collected, so the correspondence between the S2/S3/N1 classes reported here and actual field productivity remains to be tested (Section 4.2).

While the climatic limitation is not correctable at farm level, the individual soil-related limitations in both villages remain at a moderate rather than a severe degree of severity, indicating that targeted management could potentially improve the soil suitability class, particularly in Bafime, where limitations are more numerous. Based on the constraints measured in this study, three management priorities are proposed for Bafime and Larazourou (summarized in Table 9); none of these interventions were tested within the present study, and their effectiveness should be verified through follow-up field trials before being adopted as standard practice. Firstly, given the low sum of exchangeable bases (SEB averaging 3.82 $cmol^{+}/kg$ in Bafime and 4.98 $cmol^{+}/kg$ in Larazourou) and the low absolute CEC values (4.90–8.99 $cmol^{+}/kg$) identified in Section 3.2, targeted soil fertility management is proposed, combining organic amendments (including retention of crop residues) with mineral fertilizers applied on the basis of soil analyses, guided by site-specific soil and leaf sampling rather than blanket recommendations, given the marked textural contrast measured between the two villages (88.0% sand in Bafime versus 66.0% in Larazourou; Table 4).

Secondly, the shallow effective soil depth measured in Bafime (approximately 65 cm, limited by an underlying rock and concretion layer; Figure 2) constrains root development and water storage; soil and water conservation practices that control erosion, improve infiltration, and reduce runoff (e.g., mulching, contour tillage, vegetative strips) are proposed specifically for this village, whereas Larazourou's greater soil depth (≥100 cm) makes it comparatively more resilient to this particular constraint. Thirdly, since the overall N1 classification is driven by relative humidity rather than soil fertility, practices intended to reduce humidity-related disease and pest pressure around the crop canopy are proposed as a priority alongside soil management: wider plant spacing and row orientation to improve airflow, timely pruning and weed control to reduce canopy density, use of disease-tolerant cotton varieties where available, and integrated pest/disease monitoring during the most humid months. Realigning current land-use and input practices with the site-specific suitability classes identified in this study, rather than applying uniform recommendations across both villages, would be a reasonable basis for future, field-tested efforts toward more productive and sustainable cotton farming in Bafime and Larazourou; validating these proposed classes and recommendations against measured yield and field trial data is recommended as the logical next step of this research programme.

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Declaration of Competing Interest:-
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References:-
1. AbdelRahman, M. A. E., Natarajan, A., & Hegde, R. (2016). Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in Chamarajanagar district, Karnataka, India. The Egyptian Journal of Remote Sensing and Space Science, 19(1), 125–141. https://doi.org/10.1016/j.ejrs.2016.02.001
2. AFNOR. (1999). NF X31-130. Qualité des sols. Détermination de la capacité d'échange cationique (CEC) et des cations extractibles. Méthode à la cobaltihexammine. Association Française de Normalisation, Paris.
3. Amonmide, I., Dagbenonbakin, G., Agbangba, C. E., & Akponikpe, P. (2019). Contribution à l'évaluation du niveau de fertilité des sols dans les systèmes de culture à base du coton au Bénin. International Journal of Biological and Chemical Sciences, 13(3), 1846–1860. https://doi.org/10.4314/ijbcs.v13i3
4. Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analyses of soils. Agronomy Journal, 54(5), 464–465. https://doi.org/10.2134/agronj1962.00021962005400050028x
5. CORAF/WECARD. (2008). Déployer des systèmes agricoles innovants en Afrique de l'Ouest et du Centre. Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles (CORAF/WECARD), Dakar, Sénégal.
6. Crétenet, M., & Gourlot, J.-P. (2015). Le cotonnier. Éditions Quae. https://www.numilog.com/661621/Le-cotonnier.ebook
7. Dabin, B. (1970). Chapitre X: Les facteurs chimiques de la fertilité des sols (matière organique, phosphore, bases échangeables, sels, utilisation des échelles de fertilité). ORSTOM, Paris. https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers15-04/16384.pdf
8. Dekoula, C. S., Kouamé, B., N'goran, K. E., Ehounou, J.-N., Yao, G. F., Kassin, K. E., Kouakou, J. B., N'guessan, A. E. B., & Soro, N. (2018). Variabilité des descripteurs pluviométriques intrasaisonniers à impact agricole dans le bassin cotonnier de Côte d'Ivoire: cas des zones de Boundiali, Korhogo et Ouangolodougou. Journal of Applied Biosciences, 130, 13199-13212.
9. Didi, G. J. R., Kone, P. W. E., Ochou, G. E. C., Dekoula, S. C., Kouakou, M., Bini, K. K. N., Yao, M. D. S., Mamadou, D., & Ochou, O. G. (2018). Évolution spatio-temporelle des infestations de la mouche blanche Bemisia tabaci (Gennadius, 1889) associées à la culture cotonnière en Côte d'Ivoire. Journal of Applied Biosciences, 121, 12202–12210. https://doi.org/10.4314/jab.v121i1.10
10. Driessen, P. M., & Konijn, N. T. (1992). Land-use systems analysis. Wageningen Agricultural University, Department of Soil Science & Geology, Wageningen, 230 pp. ISBN 90-6754-228-8.
11. FAO. (1976). A framework for land evaluation. FAO Soils Bulletin 32. Food and Agriculture Organization of the United Nations, Rome.
12. FAO. (1993). Guidelines for land-use planning. FAO Development Series 1. Food and Agriculture Organization of the United Nations, Rome.
13. FAO. (2006). Guidelines for soil description (4th ed.). Food and Agriculture Organization of the United Nations, Rome.
14. FAO. (2014). Rapports thématiques: Les terres et les sols. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/fileadmin/user_upload/post2015/14_themes_Issue_Papers/FR/14_themes_december_2014/Landandsoils_fr-1.pdf
15. Hébert, A. (Ed.), Fovet-Rabot, C., Bachelier, B., Crétenet, M., Déat, M., Dessauw, D., Dugué, P., Fok, M., Frydrych, R., Gawrysiak, G., Hau, B., Lacape, J.-M., Lecomte, J., Pannetier, C., Rebuffel, P., Vaissayre, M., & Ducoeur, C. (2006). Le coton: fil des temps, des marchés et des cultures (dossier prepared for the Salon International de l'Agriculture, Paris, 25 February–7 March 2006). CIRAD, Montpellier, 15 pp.
16. INRA. (2018). De la connaissance de la biologie des sols et de ses fonctions, à son pilotage. Institut National de la Recherche Agronomique, Dijon, France.

https://www6.inrae.fr/ciag/content/download/6552/48226/version/1/file/ACTES%20COLLOQUE%20SOL-DIJON.pdf
17. Jafarzadeh, A., Alamdari, P., Neyshabouri, M., & Saedi, S. (2008). Land suitability evaluation of Bilverdy research station for wheat, barley, alfalfa, maize and safflower. Soil and Water Research, 3, S81–S88.
18. Kouakou, B., Coulibaly, S., Soro, G., & Kone, Y. (2023). Assessment of land suitability for cotton cultivation in the cotton basin of Côte d'Ivoire using a multi-criteria decision analysis (MCDA) approach. Agricultural Systems, 225, 103732.
19. Li, Y., Zhang, H., Du, S., & Zou, Y. (2022). Soil fertility and nutrient management in West Africa: Challenges and opportunities. Agronomy, 12(10), 2356.
20. Luo, Q., Bange, M., & Clancy, L. (2014). Cotton crop phenology in a new temperature regime. Ecological Modelling, 285, 22–29. https://doi.org/10.1016/j.ecolmodel.2014.04.018
21. MINESUDD. (2013). L'agriculture intelligente face au climat en Côte d'Ivoire: état des lieux et besoins d'appui pour mieux intégrer l'Agriculture Intelligente face au Climat (AIC) dans le Programme National d'Investissement Agricole (PNIA). Ministère de l'Environnement, de la Salubrité Urbaine et du Développement Durable, Abidjan. http://www.environnement.gouv.ci/pollutec/CTS3%20LD/CTS%203.2.pdf
22. Oudin, B. (2020). Étude sur les segments amont et aval du marché agricole de la Côte d'Ivoire. FranceAgriMer / CERESCO (ex. Blezat Consulting), 61 pp.
23. Pernes-Debuyser, A., & Tessier, D. (2005). Influence du pH sur les propriétés des sols: l'essai de longue durée des 42 parcelles à Versailles. Revue des Sciences de l'Eau, 15, 27–39. https://doi.org/10.7202/705484ar
24. Ramasundaram, P., Hemchandra, & Gajbhiye, H. (2001). Constraints to cotton production in India (CICR Technical Bulletin No. 19). Central Institute for Cotton Research, Nagpur.
25. Reddy, G. P. O., et al. (2012). GIS-based multicriteria overlay analysis in soil-suitability evaluation for cotton (Gossypium spp.): A case study in the black soil region of Central India. Computers & Geosciences. https://doi.org/10.1016/j.cageo.2011.08.020
26. Sanchez, P. A. (2002). Soil fertility and hunger in Africa. Science, 295(5562), 2019–2020. https://doi.org/10.1126/science.1065256
27. Santos, A., & Castro, F. (2020). Salinity of the soil and the risk of desertification in the semiarid region. Mercator, 19, 1–13. https://doi.org/10.4215/rm2020.e19002
28. Sehgal, J. L. (1990). Soil resource mapping of India and its applications for land use planning (NBSS Publication 25). NBSS&LUP (ICAR), Nagpur, Maharashtra, pp. 7–9.
29. Sehgal, J. L. (1991). Soil-site suitability evaluation for cotton. Agropedology, 1, 49–55.
30. Shahbandeh, M. (2022). Cotton: statistics and facts. Statista. https://www.statista.com/topics/1542/cotton/#topicHeader__wrapper
31. Shi, X., Wang, C., Zhao, J., Wang, K., Chen, F., & Chu, Q. (2021). Increasing inconsistency between climate suitability and production of cotton (Gossypium hirsutum L.) in China. Industrial Crops and Products, 171, 113959. https://doi.org/10.1016/j.indcrop.2021.113959
32. Stern, R., Rijks, D., Dale, I., & Knock, J. (2006). INSTAT climatic guide. Statistical Services Centre, University of Reading.
33. Surya, J. N., Walia, C. S., Singh, H., Yadav, R. P., & Singh, S. K. (2020). Soil suitability evaluation using remotely sensed data and GIS: A case study from Kumaon Himalayas. Journal of the Indian Society of Remote Sensing, 48(10), 1355–1371. https://doi.org/10.1007/s12524-020-01143-2
34. Sys, C., Van Ranst, E., & Debaveye, J. (1991). Land evaluation. Part I: Principles in land evaluation and crop production calculations (Agricultural Publications No. 7). General Administration for Development Cooperation, Brussels, pp. 40–80.
35. Sys, C., Van Ranst, E., & Debaveye, J. (1993). Land evaluation. Part III: Crop requirements (Agricultural Publications No. 7). General Administration for Development Cooperation, Brussels.
36. Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science, 37(1), 29–38.
37. Zagbaï, H. S., Berti, F., & Lebailly, P. (2006). Impact de la dynamique cotonnière sur le développement rural: étude de cas de la région de Korhogo, au Nord et au Centre de la Côte d'Ivoire. Biotechnologie, Agronomie, Société et Environnement, 10(4), 325–334.
38. Zhang, H., Zou, Y., Li, Y., & Du, S. (2023). Integrated soil fertility management for sustainable crop production in West Africa: A review. Frontiers in Plant Science, 14.
39. Zhang, Y. J., Liu, G. Y., Dong, H. Z., & Li, C. D. (2021). Waterlogging stress in cotton: damage, adaptability, alleviation strategies, and mechanisms. The Crop Journal, 9, 257–270. https://doi.org/10.1016/j.cj.2020.08.005.