



Effects of Planting Dates in Farming Systems in Ghana: A Review

Nathaniel Kwawu¹, Chonchorkor Bitembi¹, Agyemang Robert¹,
Abdul-Mumin Hardi¹, Sadongo Sylvanus¹, Salifu Abdul- Jalil¹, Seidu Muzabiru¹

10.18805/ag.RF-425

ABSTRACT

In Ghana, planting-date decisions are increasingly constrained by delayed rainfall onset, frequent false starts, rising dry-spell intensity and shifting agroecological boundaries. Although individual studies have examined crop-specific responses, a consolidated synthesis linking climatic variability with planting window reliability across zones has been limited. This review addresses this gap by analysing evidence on rainfall onset behaviour, intra-season moisture patterns, crop physiological sensitivity and farming system interactions to determine how planting dates influence establishment and yield outcomes in Ghana's rain-fed systems. A narrative review approach was applied, drawing on empirical field studies, climatic analyses, intercropping trials and modelling assessments in the reviewed literature. The synthesis shows that compressed and increasingly unpredictable planting windows affect all agroecological zones, with the Guinea Savannah and Transition zones exhibiting the highest sensitivity owing to unstable onset and prolonged early season dry spells. Key crops, particularly maize, sorghum, cowpea and upland rice, experience substantial yield losses when planting is misaligned with early season moisture. Labour constraints, equipment limitations, weak advisory integration and the persistence of false rainfall start further restrict farmers' ability to plant within optimal windows. These interactions also influence nutrient uptake, pest dynamics and intercrop competition, demonstrating that planting dates operate as system-wide risk factors rather than a single management decision. Overall, this review underscores the need for high-resolution planting date datasets, calibrated crop models and advisory systems that combine rainfall onset probabilities, soil moisture thresholds and indigenous indicators to support more dependable planting recommendations across Ghana's changing agroecological landscape.

Key words: Agro-climatic zones, Crop emergence, Cropping calendar, Farming systems, Ghana, Rainfall breaks, Rainfall initiation.

Planting date determination has long been a central agronomic decision in rain-fed crop production systems, directly influencing germination success, early biomass accumulation and yield formation (Shrestha *et al.*, 2018). In a rain-fed country like Ghana, where crop production is highly dependent on seasonal rainfall, planting decisions are traditionally synchronized with the perceived onset of the rainy season. Unfortunately, the increasing variability in rainfall onset, the growing incidence of false starts and shortening of effective growing seasons have progressively undermined the reliability of these conventional calendars (Atiah *et al.*, 2019; Amekudzi *et al.*, 2015; Yorke and Omotosho, 2010). Consequently, planting-date uncertainty has emerged as a critical constraint to crop productivity across Ghana's agroecological zones. With empirical evidence from literature, the rainfall onset in Ghana is no longer temporally stable, with delayed commencement, intermittent early season rainfall and prolonged dry spells being widely reported (Gbangou *et al.*, 2020; Yengoh *et al.*, 2010; Ampofo *et al.*, 2024). These hydro-climatic shifts disproportionately affect the initial stages of crop establishment, when shallow root systems and high evaporative demand render seedlings particularly vulnerable to moisture stress (Asante *et al.*, 2022). Not excluding mistimed planting, which can negatively impact crop establishment with serious consequences, by leading to early crop failure, also shortening the growing period, compressing vegetative growth and lessening grain filling in cereals. Mistimed planting also affects leguminous

¹Department of Agrobiotechnology, Institute of Agriculture, RUDN University, 117198 Moscow, Russian Federation, Russia.

Corresponding Author: Nathaniel Kwawu, Department of Agrobiotechnology, Institute of Agriculture, RUDN University, 117198 Moscow, Russian Federation, Russia.
Email: nathanielkwawu@gmail.com

How to cite this article: Kwawu, N., Bitembi, C., Robert, A., Abdul-Mumin, H., Sylvanus, S., Abdul-Jalil, S. and Muzabiru, S. (2026). Effects of Planting Dates in Farming Systems in Ghana: A Review. *Agricultural Reviews*. **47(4)**: 600-608. doi: 10.18805/ag.RF-425.

Submitted: 05-01-2026 **Accepted:** 08-05-2026 **Online:** 09-06-2026

crops by disrupting both flowering and nodulation stage and in root and tuber crops, tuber development is constrained. (Boksoon *et al.*, 2016; Shrestha *et al.*, 2018; Atiah *et al.*, 2019; Naveena *et al.*, 2025).

Despite extensive agronomic and climatological studies addressing rainfall variability and crop performance in Ghana, planting dates are frequently treated as a static or secondary management variable. Many yield-response studies fail to explicitly account for planting-window dynamics, onset variability, or intra-season rainfall distribution (Fosu-Mensah *et al.*, 2019; Quagraine *et al.*, 2017). Existing planting recommendations often rely on generalized calendars that inadequately capture district-level rainfall heterogeneity, shifting agroecological boundaries and evolving constraints related to labour availability, mechanisation and access to climate information

(Yamba *et al.*, 2023). This disconnect reduces the operational relevance of current planting-date advisories under increasingly variable climatic conditions.

Recent evidence further demonstrates that planting-date decisions operate as system-level variables rather than crop-specific choices. Planting timing alters intercrop competition, soil-nutrient uptake efficiency, pest and disease synchrony and labour bottlenecks, thereby shaping overall farming-system performance (Ampofo *et al.*, 2024; Tanzubil, 2016; Shrestha *et al.*, 2018). Delayed planting can therefore amplify production risks even in seasons with adequate cumulative rainfall (Yengoh *et al.*, 2010). These interactions underscore the need for integrative analyses that explicitly link climatic signals, crop physiological responses and farming-system constraints.

This review aims to use previous publications' empirical and modelling evidence which geared towards the inconsistencies in planting-date and their consequences on farming in the various agroecological zones of Ghana. Specifically, the review examines;

- (i) Patterns of rainfall-onset variability and intra-season dry spells.
- (ii) Crop-specific physiological responses to planting-date shifts.
- (iii) System-level interactions affecting productivity under rain-fed farming systems.

By integrating climatic, agronomic and farming-system evidence, the review provides a structured assessment of how changing rainfall patterns are reshaping planting-window reliability and identifies pathways for improving planting-date recommendations in Ghana's evolving agroecological landscape.

Review methodology

This study employed a structured narrative review approach to synthesise evidence on the relationships between rainfall variability, planting-date decisions, crop physiological responses and farming-system performance in Ghana. A narrative synthesis was selected because the reviewed studies differ considerably in research design, spatial scale and analytical methods, which limits the feasibility of quantitative meta-analysis.

Relevant literature was identified through systematic searches of major academic databases, including Web of Science, Scopus and Google Scholar. Search queries combined climatic and agronomic keywords such as rainfall onset, planting dates, dry spells, crop establishment, agroecological zones and Ghana, alongside crop-specific terms for cereals, legumes, root and tuber crops, vegetables and tree crops. Reference lists of key articles were also screened to identify additional relevant studies.

Studies were included if they (i) analysed rainfall onset, dry-spell behaviour, or growing-season characteristics relevant to Ghana; (ii) assessed crop responses explicitly linked to planting time or early-season moisture conditions;

or (iii) examined farming-system interactions influenced by planting timing, including intercropping dynamics, soil nutrient interactions, pest and disease pressure, labour constraints, or advisory systems. Excluded studies were those lacking a clear connection between climatic conditions and planting-date decisions, focusing solely on irrigation-based systems, or providing insufficient spatial or temporal context for Ghanaian agroecological conditions.

Following selection, studies were thematically grouped according to agroecological zone, crop group and system-level interaction. Evidence was then synthesised to identify consistent patterns, divergences and emerging trends related to planting-window reliability under increasing climatic variability. Particular emphasis was placed on cross-zone comparisons, crop-specific sensitivities and the convergence of climatic and management constraints shaping planting decisions. This synthesis framework enabled the integration of diverse evidence into a coherent assessment of how planting-date variability influences crop production and farming-system performance in Ghana.

Rainfall onset behaviour and intra-season variability in Ghana

Rainfall onset remains the principal climatic signal guiding planting decisions in Ghana; however, its reliability has deteriorated markedly over recent decades. Multiple studies document increasing delays in the commencement of the rainy season, heightened interannual variability and frequent early-season rainfall interruptions across all agroecological zones (Mensah-Brako *et al.*, 2026) (Fig 1). These changes have direct agronomic implications because the success of crop establishment depends less on total seasonal rainfall than on the timing, continuity and stability of early-season precipitation. Even though, in the Guinea and Sudan Savannah zones, rainfall onset is unimodal but increasingly characterised by long dry spells and reduced numbers of rainy days following initial precipitation events (Ampofo *et al.*, 2024; Yengoh *et al.*, 2010), recently the commonly reported rainfall pattern by various studies has been false rainfall starts, defined as early-season rainfall. This rainfall pattern is insufficient to sustain seedling establishment, leading to frequent crop establishment failure when planting occurs prematurely (Gbangou *et al.*, 2020). As a result, farmers delay planting until rainfall patterns stabilise, often shortening the effective growing season and exposing crops to terminal moisture stress later in the cycle.

Bimodal rainfall zones, including the Forest Savannah Transition and Coastal Savannah, exhibit distinct but equally problematic onset dynamics. While these zones historically supported two reliable planting seasons, recent evidence indicates increasing overlap, weakening separation between major and minor seasons and oscillation in onset dates between March and May (Atiah *et al.*, 2019; Quagrainie *et al.*, 2017; Gbangou *et al.*, 2020). Such variability complicates planting decisions for crops traditionally

aligned with specific seasonal windows, increasing the probability of mismatch between crop growth stages and rainfall availability.

Even though, across zones intra-season dry spells represent a dominant constraint even in years with near-normal cumulative rainfall, prolonged consecutive dry days

during the first three to four weeks after planting significantly increase seedling mortality and reduce early biomass accumulation, particularly for cereals and legumes with shallow root systems (Yengoh *et al.*, 2010; Ampofo *et al.*, 2024). These effects are compounded by rising temperatures and high evaporative demand, which intensify

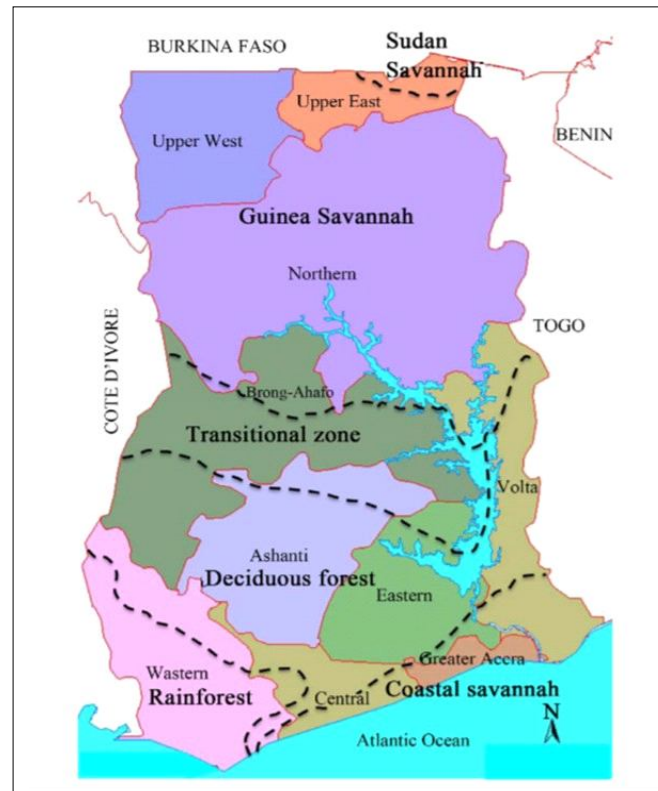


Fig 1: The six agroecological zones of Ghana. (Source: Kemausuor *et al.*, 2013).

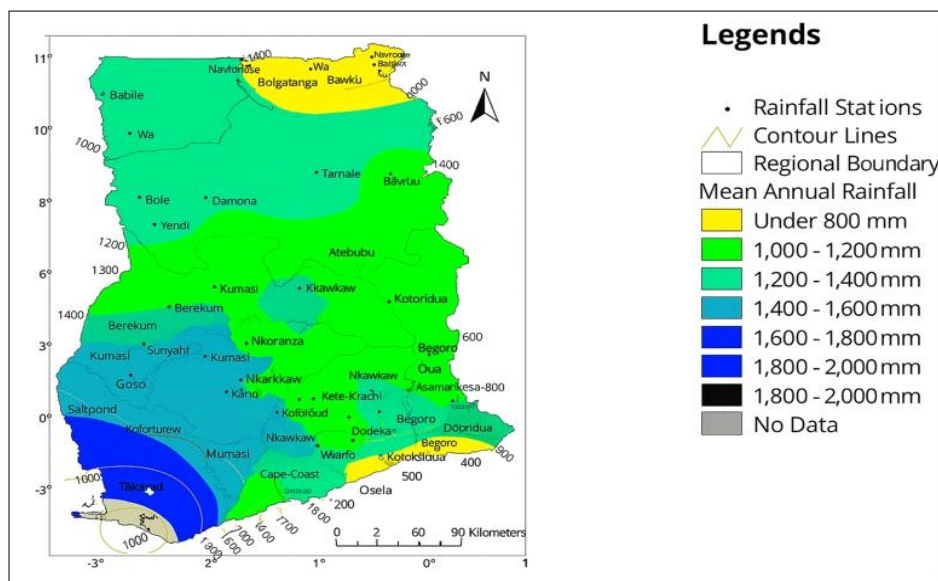


Fig 2: Rainfall onset and variability in the zones of Ghana (Source: Bosson-Amedenu *et al.*, 2025).

moisture stress during early growth stages (Ankrah *et al.*, 2023). Recent analyses further indicate that rainfall variability is not spatially static. Southward shifts of the Guinea and Sudan Savannah agroecological boundaries reflect broader climatic reorganisation, altering historical rainfall crop relationships and invalidating long-established planting calendars (Adaawen, 2021). Consequently, planting-window reliability is increasingly context-specific, dependent on local onset thresholds, soil moisture retention and the capacity of farmers to absorb early-season risk (Fig 2).

Collectively, these findings demonstrate that rainfall onset in Ghana can no longer be treated as a fixed temporal reference. Instead, it represents a probabilistic signal with significant uncertainty, necessitating planting strategies that

account for onset stability, dry-spell risk and zone-specific rainfall behaviour rather than adherence to static calendar dates.

Crop-specific sensitivity to planting dates

Crop responses to planting dates in Ghana are governed by interactions between rainfall availability during early growth stages and crop-specific physiological requirements. Evidence across agroecological zones consistently shows that mismatches between planting timing and early-season moisture conditions lead to significant yield penalties, though the magnitude and mechanisms vary by crop group.

To facilitate clearer comparison across crop groups, the major physiological responses and risks associated with early and late planting are summarised in (Table 1),

Table 1: Crop-group sensitivity to planting dates in Ghana's agroecological zones.

Crop group	Optimal planting-date conditions (Evidence)	Risks under early planting (Evidence)	Risks under late planting (Evidence)
Cereals (Maize, Sorghum, Millet)	Establish immediately after first effective rains in unimodal zones to ensure adequate moisture and early biomass accumulation (Ampofo <i>et al.</i> , 2024; Yengoh <i>et al.</i> , 2010). Early planting increases radiation interception and lengthens vegetative phase (Shrestha <i>et al.</i> , 2018; Boksoon <i>et al.</i> , 2016).	In bimodal/high-rainfall areas, early planting may expose cereals to water-logging and erratic early-season rainfall patterns (Atiahr <i>et al.</i> , 2019).	Reduced cumulative radiation, shorter grain-filling period, higher heat stress exposure, increased terminal drought risk (Boksoon <i>et al.</i> , 2016; Shrestha <i>et al.</i> , 2018; Ampofo <i>et al.</i> , 2024).
Legumes (Cowpea, Soybean, Groundnut)	Best when flowering coincides with stable moisture periods; moderate early-season rainfall improves nodulation (Shrestha <i>et al.</i> , 2018; Atiah <i>et al.</i> , 2019).	High early-season rainfall in forest/transition zones increases water logging and flower abortion risk; early wet conditions may increase disease pressure (Atiah <i>et al.</i> , 2019).	Late planting exposes legumes to increased dry spells, reduced nodulation, poor pod set and terminal drought (Ampofo <i>et al.</i> , 2024; Gbangou <i>et al.</i> , 2020). Late cycles also coincide with higher pest pressure (Atiah <i>et al.</i> , 2019).
Roots and Tubers (Cassava, Yam, Cocoyam)	Early planting in forest and transition zones promotes long canopy development and strong vegetative growth needed for tuber initiation (Issaka <i>et al.</i> , 2012; Afele <i>et al.</i> , 2021).	In high rainfall or fluctuating wet dry cycles, early planting can expose cassava and yam to waterlogging or disease-prone conditions (Atiah <i>et al.</i> , 2019).	Shortened vegetative phase, restricted canopy formation, moisture decline during tuber initiation, resulting in smaller tubers and reduced biomass (Atiah <i>et al.</i> , 2019; Ampofo <i>et al.</i> , 2024).
Vegetables (Tomato, Pepper, Onion, Cabbage)	Optimal when planted after rainfall has stabilized or during dry-season irrigation periods in northern Ghana (Issaka <i>et al.</i> , 2012; Ampofo <i>et al.</i> , 2024).	Early planting in forest/transition zones coinciding with heavy rains increases waterlogging, disease pressure and leaf-wetness (Atiah <i>et al.</i> , 2019).	Late planting increases heat stress, reduces fruit set, shortens growth period; in the periods north, late dry-season planting risks high temperature before harvest (Ampofo <i>et al.</i> , 2024).
Tree Crops (Cocoa, Cashew, Mango)	Best when planted early in the rainy season to allow seedlings time for root establishment before dry spells set in (Issaka <i>et al.</i> , 2012; Afele <i>et al.</i> , 2021).	Excess moisture and early heavy rains may reduce field access and hinder seedling survival in high-rainfall zones (Atiah <i>et al.</i> , 2019).	Late planting exposes young seedlings to long consecutive dry days, increasing mortality and reducing early vigor (Yengoh <i>et al.</i> , 2010; Atiah <i>et al.</i> , 2019).

which synthesises evidence from agronomic field studies conducted across Ghana's agroecological zones.

Cereals, particularly maize, sorghum and millet, exhibit strong sensitivity to delayed planting. Early planting immediately after stable rainfall onset enhances radiation interception, prolongs vegetative growth and supports adequate grain-filling duration (Boksoon *et al.*, 2016; Shrestha *et al.*, 2018). In contrast, delayed planting shortens thermal accumulation and exposes crops to terminal moisture stress and high temperatures, resulting in reduced kernel number and grain weight, especially in the Guinea and Transition zones (Ampofo *et al.*, 2024; Fosu-Mensah *et al.*, 2019). In bimodal rainfall zones, premature planting during unstable early rains can also increase establishment failure due to waterlogging and rainfall discontinuity (Atiah *et al.*, 2019).

Legumes, including cowpea, soybean and groundnut, are particularly vulnerable to planting-date mismatches during flowering and pod-filling stages. Optimal planting ensures alignment between reproductive development and periods of relatively stable moisture, facilitating nodulation and nitrogen fixation (Abdul-Aziz *et al.*, 2025; Fakhr *et al.*, 2020). Early planting in high-rainfall environments increases disease incidence and flower abortion, while delayed planting in unimodal zones exposes legumes to dry spells during flowering, leading to poor pod set and reduced yields (Atiah *et al.*, 2019; Ampofo *et al.*, 2024).

Root and tuber crops, such as cassava, yam and cocoyam, require extended periods of soil moisture availability to support canopy development and tuber initiation. Early planting in forest and transition zones promotes root establishment and vegetative growth; however, excessive early-season rainfall can increase rot and disease incidence (Issaka *et al.*, 2012; Afele *et al.*, 2021). Delayed planting shortens the vegetative phase, restricts canopy expansion and limits assimilate partitioning to storage organs, resulting in reduced tuber size and biomass (Kim *et al.*, 2012) (Atiah *et al.*, 2019).

Vegetable crops, including tomato, pepper, onion and cabbage, display narrow optimal planting windows due to their sensitivity to both excess and deficit moisture. Early planting during periods of high rainfall increases waterlogging, leaf diseases and fruit drop, particularly in forest and transition zones (Barickman *et al.*, 2019; Atiah *et al.*, 2019). Late planting, especially in the northern savannahs, exposes crops to extreme temperatures and moisture stress during reproductive stages, reducing marketable yield (Ampofo *et al.*, 2024).

Tree crops, notably cocoa and cashew, depend on timely planting early in the rainy season to ensure seedling establishment before the onset of dry spells. Delayed planting exposes seedlings to prolonged moisture deficits and increases mortality rates, while excessive early-season rainfall can restrict field operations and reduce survival in poorly drained soils (Issaka *et al.*, 2012; Afele *et al.*, 2021).

Overall, the reviewed evidence demonstrates that planting-date sensitivity is crop-specific but consistently

mediated by early-season moisture stability. Across crop groups, delayed planting increases exposure to terminal drought, shortens effective growth periods and amplifies production risk, reinforcing the need for planting recommendations that account for both crop physiology and rainfall onset behaviour.

Farming-system interactions influenced by planting dates

Planting-date decisions in Ghana operate beyond individual crop performance and exert system-wide effects on resource use, crop interactions and risk exposure within smallholder farming systems (Fig 3). Evidence across agroecological zones demonstrates that poorly synchronized planting amplifies inefficiencies in intercropping arrangements, nutrient use, pest and disease dynamics and labour allocation (Aduhene-Chnbuah *et al.*, 2025; Shrestha *et al.*, 2018; Ampofo *et al.*, 2024). However, intercropping systems which are widely practiced to manage risk and enhance resource-use efficiency, on the other hand are highly sensitive to planting-time coordination among component crops. Simultaneous or appropriately staggered planting improves canopy complementarity, soil cover and light interception, thereby reducing weed pressure and moisture loss (Tanzubil, 2016). In contrast, delayed or staggered planting driven by uncertain rainfall onset increases interspecific competition for moisture and nutrients, often favouring early-emerging crops and reducing overall system productivity (Shrestha *et al.*, 2018).

Soil fertility management and nutrient uptake efficiency are also tightly linked to planting timing. Early planting following stable rainfall onset enhances nutrient dissolution and root soil contact, particularly for nitrogen and phosphorus in rain-fed systems (Issaka *et al.*, 2012). Delayed planting, especially in degraded or low-organic-matter soils, reduces nutrient-use efficiency as shortened growth periods limit root expansion and nutrient assimilation, resulting in lower biomass accumulation and yield (Fosu-Mensah *et al.*, 2019). These effects are more pronounced in northern savannah zones where soil moisture retention is inherently limited.

Planting dates further influence pest and disease dynamics through crop climate synchrony. Early planting can enable crops to escape peak pest populations and disease-favourable conditions, whereas delayed planting often aligns vulnerable growth stages with heightened pest pressure and humidity (Atiah *et al.*, 2019; Afele *et al.*, 2021). In vegetable production systems, mistimed planting increases disease incidence and pesticide reliance, raising production costs and environmental risk. Also, availability of labour and mechanisation access impose additional constraints on planting-date flexibility, this is because in smallholder systems, rainfall uncertainty frequently leads to labour bottlenecks as farmers delay planting until rainfall stabilises, resulting in simultaneous demand for land preparation and sowing (Yamba *et al.*, 2023). Limited mechanisation exacerbates these delays,

particularly in northern Ghana, where timely land preparation is critical due to shorter growing seasons (Ampofo *et al.*, 2024). Consequently, climatic uncertainty interacts with socio-economic constraints to compound planting delays and yield losses.

Collectively, the evidence indicates that planting dates function as a structural driver of farming-system performance rather than an isolated management choice. Improving planting-date recommendations therefore requires integration of climatic signals with system-level realities, including cropping patterns, soil constraints, pest dynamics and labour organisation.

The evidence synthesised in this review demonstrates that planting-date reliability in Ghana is increasingly undermined by the combined effects of rainfall-onset variability, intra-season dry spells and shifting agroecological boundaries (Fig 4). Across all zones,

planting decisions based on historical calendars no longer consistently align crop establishment with stable moisture availability, exposing crops to early-season failure or terminal stress despite near-normal seasonal rainfall totals (Atiah *et al.*, 2021; Kumar *et al.*, 2024).

However, looking from a climatic perspective, rainfall onset has transitioned from a relatively predictable seasonal marker to a probabilistic signal characterised by false starts and spatial heterogeneity (Gbangou *et al.*, 2020; Agoungbome *et al.*, 2025). This uncertainty disproportionately affects early crop growth stages, where moisture stress irreversibly constrains canopy development and yield potential (Kelly *et al.*, 2025). The southward shift of savannah agroecological conditions further disrupts long-established rainfall crop relationships, rendering zone-based planting calendars increasingly obsolete (Yamba *et al.*, 2023).

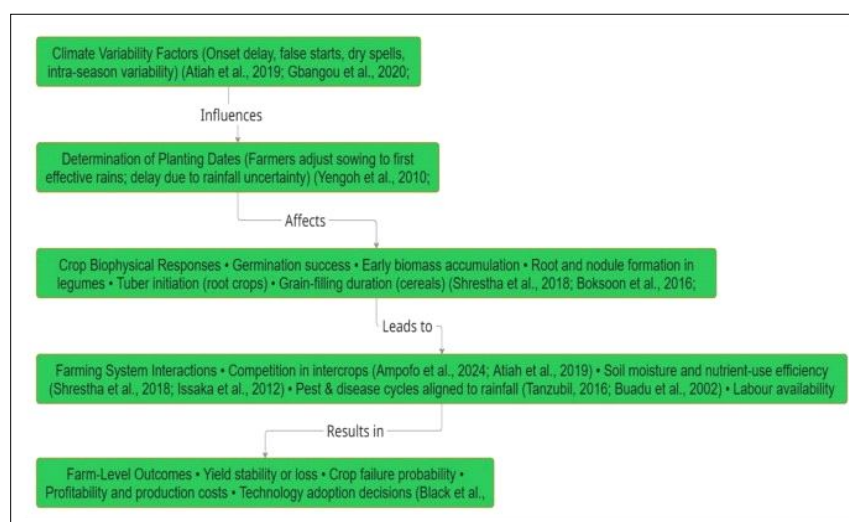


Fig 3: Conceptual diagram: How planting dates interact with farming system constraints.

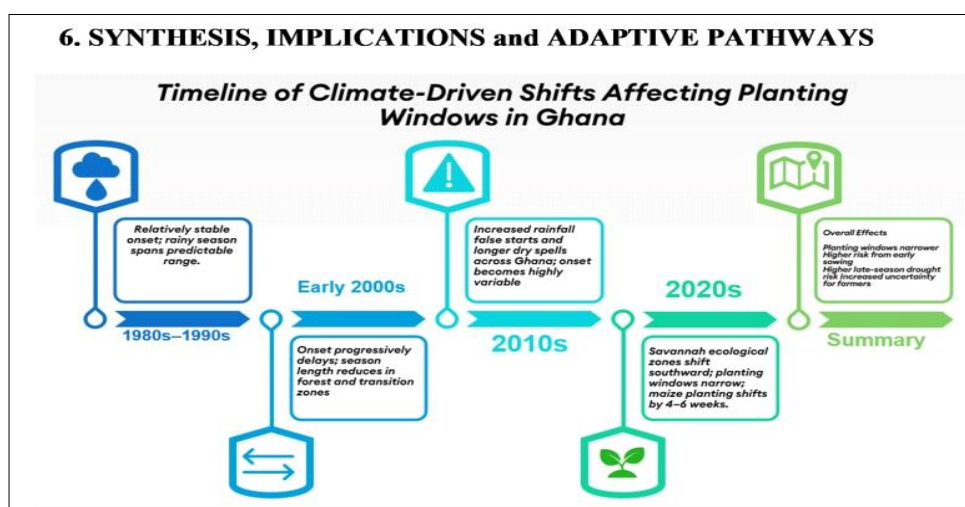


Fig 4: Timeline of planting-window shifts under climate change.

Nonetheless, crop-specific analyses reveal that while sensitivity to planting dates varies by crop group, delayed or poorly timed planting consistently shortens effective growth periods, reduces assimilate accumulation and increases exposure to reproductive-stage stress across cereals, legumes, root and tuber crops, vegetables and tree crops (Shrestha *et al.*, 2018; Boksoon *et al.*, 2016; Afele *et al.*, 2021). Consequently, these responses confirm that planting dates act as a primary yield determinant under rain-fed conditions, mediating how crops interact with rainfall variability rather than merely responding to total precipitation.

Also approaching from a farming-system level, planting-date uncertainty propagates through intercropping

performance, nutrient-use efficiency, pest and disease dynamics and labour organisation (Tanzubil, 2016; Fosu-Mensah *et al.*, 2019; Ampofo *et al.*, 2024). Delayed planting triggered by rainfall instability often leads to synchronised labour demand, increased pest pressure and reduced system resilience, particularly in smallholder contexts with limited mechanisation and advisory support (Amankwaa-Yeboah *et al.*, 2024).

Collectively, these findings suggest that effective adaptation cannot rely solely on fixed planting recommendations. Instead, adaptive pathways must integrate rainfall-onset monitoring, crop-specific sensitivity thresholds and system-level constraints. Approaches that combine seasonal

Table 2: Climate-change impacts on planting windows in Ghana.

Climate-change impact	Description of observed change (Evidence)	Implications for planting windows	Supporting citations
Delayed rainfall onset	Onset dates increasingly shifting later, especially in Transition and Coastal zones; shift from March → April documented (Atiah <i>et al.</i> , 2019; Quagraine <i>et al.</i> , 2017; Amekudzi <i>et al.</i> , 2015).	Shortens effective planting season; compresses sowing windows; increases risk for crops requiring long growing seasons.	Atiah <i>et al.</i> , 2019; Quagraine <i>et al.</i> , 2017; Amekudzi <i>et al.</i> , 2015
Increased false starts of rains	Frequent oscillation of onset dates and increased early-season rainfall interruptions lead to failed early planting attempts (Gbangou <i>et al.</i> , 2020; Yengoh <i>et al.</i> , 2010).	Early planting becomes riskier; farmers delay planting until rains stabilize; increases vulnerability to late-season drought.	Gbangou <i>et al.</i> , 2020; Yengoh <i>et al.</i> , 2010
Shortened rainy seasons	Evidence of decreasing length of the growing season across several zones (Yorke and Omotosho, 2010; Adjei and Kyerematen, 2018).	Reduces flexibility in sowing; affects crops like maize and sorghum that rely on extended moisture periods.	Yorke and Omotosho, 2010; Adjei and Kyerematen, 2018
More frequent and longer dry spells	Rising consecutive dry days and seasonal dryness across savannah zones (Ampofo <i>et al.</i> , 2024; Yengoh <i>et al.</i> , 2010; Kranjac-Berisavljevic <i>et al.</i> , 2014).	High risk of post-planting moisture stress, especially when planting late; increases seedling mortality.	Ampofo <i>et al.</i> , 2024; Yengoh <i>et al.</i> , 2010; Kranjac-Berisavljevic <i>et al.</i> , 2014
Shifting agroecological boundaries	Notable southward shift of the Guinea and Sudan Savannah belts (Yamba <i>et al.</i> , 2023).	Alters traditional planting calendars; certain crops become unsuitable in their historical planting windows.	Yamba <i>et al.</i> , 2023
Increased rainfall variability (within-season)	Alternating wet and dry sequences, high rainfall intermittency (Atiah <i>et al.</i> , 2019; Quaye-Ballard <i>et al.</i> , 2020).	Makes planting-date determination more uncertain; increases risk of both waterlogging (early) and moisture stress (late).	Atiah <i>et al.</i> , 2019; Quaye-Ballard <i>et al.</i> , 2020
Crop-specific planting window shifts	Example: maize planting shifted by up to six weeks in various Ghanaian districts due to rainfall unreliability (Fosu-Mensah <i>et al.</i> , 2019).	Farmers increasingly rely on adaptive, flexible planting strategies rather than fixed dates.	Fosu-Mensah <i>et al.</i> , 2019
ENSO-related seasonal anomalies	El Niño years linked to shorter and more erratic rainy seasons (Owusu <i>et al.</i> , 2019).	Early planting during ENSO years becomes highly vulnerable; late planting shortens grain-fill period.	Owusu <i>et al.</i> , 2019

climate information, flexible planting windows and locally contextualised decision support are better suited to managing planting risk under Ghana's evolving climatic conditions (Atiah *et al.*, 2019; Ampofo *et al.*, 2024). Such integration represents a critical step toward enhancing climate resilience and stabilising crop productivity across agroecological zones.

Broader climatic drivers influencing planting-window variability are synthesised in (Table 2) highlighting the major mechanisms through which climate change is altering planting decisions in Ghana.

CONCLUSION

Planting-date reliability in Ghana is increasingly threatened by rainfall variability, false onset events and shifting agroecological conditions. This review demonstrates that delayed or poorly synchronized planting negatively affects crop establishment, growth duration, and yield formation across cereals, legumes, root and tuber crops, vegetables, and tree crops. The effects extend beyond individual crops to influence nutrient-use efficiency, pest dynamics, intercropping performance and labour organization within smallholder farming systems. Evidence further shows that traditional planting calendars are becoming less dependable under changing climatic conditions. Improving planting-date decisions therefore requires flexible, climate-informed approaches that integrate rainfall monitoring, crop-specific sensitivity, and local farming constraints. Strengthening climate information services and adaptive advisory systems will be essential for enhancing resilience and sustaining rain-fed agricultural productivity across Ghana's agroecological zones.

ACKNOWLEDGEMENT

The present study was supported by my friends and thank to all who made any significant input to the success of this study. Thank you all.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

- Abdul-Aziz, A.L., Haruna, B., Ulzen, J. *et al.* (2025). Determining the optimal inoculant rate to maximize soybean productivity in the Guinea Savanna agro-ecological zone of Ghana. *Sci Rep.* **15**: 39503. <https://doi.org/10.1038/s41598-025-23244-z>.
- Adaawen, S. (2021). Understanding climate change and drought perceptions, impact and responses in the rural savannah, West Africa. *Atmosphere.* **12**(5): 594. <https://doi.org/10.3390/atmos12050594>.
- Adjei, V. and Kyerematen, R. (2018). Impacts of changing climate on maize production in the transitional zone of Ghana: A case study of Nkoranza south municipality. *International Journal of Agriculture Environment and Food Sciences.* **2**(4): 164-170. <https://doi.org/10.31015/JAEFS.18028>.
- Aduhene-Chinbuah, J., Peprah, C.O., Agyeman, K., Frimpong, F. and Danquah, E.O. (2025). Agroecosystem and plant nutrient management in a changing climate. *Organic Fertilizers-Their Role Sustainable Agriculture: Their Role Sustainable Agriculture.* **21**: 129.
- Afele, J.T., Dawoe, E., Abunyewa, A.A., Afari-Sefa, V. and Asare, R. (2021). Carbon storage in cocoa growing systems across different agroecological zones in Ghana. *Pelita Perkebunan: A Coffee and Cocoa Research Journal.* **37**(1). doi: 10.22302/iccj.jur.pelitaperkebunan.v37i1.395.
- Agoungbome, S.M.D., van de Giesen, N., ten Veldhuis, M.C., Su, Z. and De Fraiture, C. (2025). Analysis of the dynamics of the onset of the rainy season in relation to crop productivity in West Africa [Doctoral dissertation, Delft University of Technology]. TU Delft Institutional Repository.
- Amankwaa-Yeboah, P., Ofosu-ampong, K., Masoud, J., Akpatsu, I.B., Yeboah, S., Jizorkuie, A.B., Kyerematen, A. and Abera, W. (2024). Scaling climate resilience in Ghana's savannah maize belt: Leveraging smart production, soil technologies and capacity strengthening. *Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) Technical Report.* pp. 21.
- Amekudzi, L.K., Yamba, E.I., Preko, K., Asare, E.O., Aryee, J.N.A., Baidu, M. and Codjoe, S.N.A. (2015). Variabilities in rainfall onset, cessation and length of rainy season for the various agro-ecological zones of Ghana. *Climate.* **3**(2): 416-434. <https://doi.org/10.3390/CLI3020416>.
- Ampofo, S., Annor, T., Aryee, J.N.A. and Amekudzi, L.K. (2024). A half century dataset on ETCCDI annual precipitation indices for the Northern savanna agro-ecological zone (Ghana) and the entire country. **3**(1). <https://doi.org/10.21203/rs.3.rs-5510707/v1>.
- Ankrah, J., Monteiro, A. and Madureira, H. (2023). Extreme temperature and rainfall events and future climate change projections in the coastal savannah agroecological zone of Ghana. *Atmosphere.* **14**(2): 386. <https://doi.org/10.3390/atmos14020386>.
- Asante, M., Hoffmann, M., Naab, J.B., Traore, K., Augustin, J. and Frimpong, K.A. (2022). Effect of Soil Management Practices on Soil Carbon Dynamics under Maize Cultivation. Tropentag, Prague, Germany. pp. 14-16.
- Atiah, W.A., Amekudzi, L.K., Quansah, E. and Preko, K. (2019). The spatio-temporal variability of rainfall over the agro-ecological zones of Ghana. *Applied Geographical Structures.* **09**(03): 527-544 <https://doi.org/10.4236/ACS.2019.93034>.
- Atiah, W.A., Muthoni, F.K., Kotu, B., Kizito, F. and Amekudzi, L.K. (2020). Trends of rainfall onset, cessation and length of growing season in Northern Ghana: Comparing the rain gauge. *Satellite and Farmer's Perceptions.* **12**(12): 1674. <https://doi.org/10.3390/atmos12121674>.

- Atiah, W.A., Muthoni, F.K., Kotu, B., Kizito, F. and Amekudzi, L.K. (2021). Trends of rainfall onset, cessation and length of growing season in Northern Ghana: Comparing the rain gauge, satellite and farmer's perceptions. *Atmosphere*. **12(12)**: 1674. <https://doi.org/10.3390/atmos12121674>.
- Atiah, W.A., Tsidu, G.M., Amekudzi, L.K. and Yorke, C. (2020). Trends and interannual variability of extreme rainfall indices over Ghana, West Africa. *Theoretical and Applied Climatology*. **140**: 1393-1407. <https://doi.org/10.1007/S00704-020-0311140>.
- Barickman, T.C., Simpson, C.R. and Sams, C.E. (2019). Waterlogging causes early modification in the physiological performance, carotenoids, chlorophylls, proline and soluble sugars of cucumber. *Plants*. <https://doi.org/10.3390/PLANTS8060160>.
- Boksoon, M., Hee, K.S., Jinwon, K. and Menas, C.K. (2016). Regional variations of optimal sowing dates of maize for the Southwestern U.S. *Transactions of the ASABE*. <https://doi.org/10.13031/TRANS.59.11583>.
- Bosson-Amedenu, S., Baah, E.M., Ayiah-Mensah, F. and Addor, J.A. (2025). Advanced time series modelling to address seasonal variability and extreme rainfall in Ghana. *BMC Environ Sci*. **2**: 8. <https://doi.org/10.1186/s44329-025-00024-8>.
- Braimah, M.M., Asante, V.A., Ahiataku, M.A., Ansah, S.O., Otu-Larbi, F., Yahaya, B., Ayabilah, J. B. and Nkrumah, F. (2022). Variability of the minor season rainfall over southern Ghana (1981-2018). *Advances in Meteorology*. **2**: 1-14. <https://doi.org/10.1155/2022/1861130>.
- Fakhr, S.K.M., Fotouhi, F., Khaniani, B.H., Sadeghi, M. and Zadeh, S.A.F. (2020). Effect of planting date and density on yield and yield components of bean genotypes (*Vicia faba* L.). *Legume Research*. **43(5)**: 672-677. doi: 10.18805/D-207.
- Fosu-Mensah, B.Y., Manchadi, A. and Vlek, P.L.G. (2019). Impacts of climate change and climate variability on maize yield under rainfed conditions in the sub-humid zone of Ghana: A scenario analysis using APSIM. *West African Journal of Applied Ecology*. <https://doi.org/10.4314/WAJAE.V27I1>.
- Gbangou, T., Ludwig, F., Slobbe, E. van, Greuell, W. and Kranjac-Berisavljevic, G. (2020). Rainfall and dry spell occurrence in Ghana: Trends and seasonal predictions with a dynamical and a statistical model. *Theoretical and Applied Climatology*. **141**: 371-387. <https://doi.org/10.1007/S00704-020-03212-5>.
- Issaka, R.N., Buri, M.M., Tobita, S., Nakamura, S. and Owusu-Adjei, E. (2012). Indigenous Fertilizing Materials to Enhance Soil Productivity in Ghana. <https://doi.org/10.5772/27601>.
- Kelly, C.I., Boateng, E.F., Zibrila, A. and Akorful, S.A., Quaye-Ballard, J.A., Laari, P.B. and Damoah-Afari, P. (2025). Understanding hydrometeorological conditions and their relationship with crop production in the upper east region, Ghana. *Agricultural Water Management*. **309**: 109434. <https://doi.org/10.1016/j.agwat.2025.109434>.
- Kim, C.G., Ok, H.C., Jeong, J.C., Hur, O.S., Seo, J.H., Jeong, K.H. and Kim, S.J. (2012). Effects of altitude and planting time on tuber bulking of potato. *The Korean Journal of Crop Science*. **57(4)**: 418-423. <https://doi.org/10.7740/KJC.S.2012.57.4.418>.
- Kranjac-Berisavljevic, G., Abdul-Ghanyu, S., Gandaa, B. and Abagale, F.K. (2014). Dry spells occurrence in tamale, northern Ghana review of available information. *Journal of Disaster Research*. **9(4)**: 468-474. <https://doi.org/10.20965/JDR.2014.P0468>.
- Kumar, R., Sharma, B.C., Sharma, N., Nanadan, B., Verma, A., Banotra, M., Mahajan, A. (2024). Effect of different pulse and oilseed based cropping systems on yield and nutrient budgeting under rainfed conditions of Jammu. *Legume Research*. **47(6)**: 965-971. doi: 10.18805/LR-4603.
- Mensah-Brako, B., Buami, E.K. and Totimeh, J.A.A. (2026). Rainfall and temperature variability in Western North Ghana: Implications for sustainable food crop production. *Environ Dev Sustain*. pp. 1-52. <https://doi.org/10.1007/s10668-026-07433-y>.
- Naveena, E., Janavi, G.J., Rameshkumar, D., Fathima, F.A. and Nivedha, C.K. (2025). Effect of different spacing level and growth stages of chekkurmanis (*Sauropus androgynus* L.) on plant growth. *Indian Journal of Agricultural Research*. **59(6)**: 962-967. doi: 10.18805/IJARE.A-6111.
- Nyadzi, E., Werners, S.E., Biesbroek, R. and Ludwig, F. (2022). Towards weather and climate services that integrate indigenous and scientific forecasts to improve forecast reliability and acceptability in Ghana. *Environmental Development*. **42(6)**: 100698. <https://doi.org/10.1016/j.envdev.2021.100698>.
- Owusu, K., Darkey, S.K. and Boadi, S.A. (2019). El Niño southern oscillation, rainfall variability and sustainable agricultural development in the ho municipality, Ghana. *Natural Resources Forum*. **43(1)**: 31-40. <https://doi.org/10.1111/1477-8947.12161>.
- Quagraine, K.A., Klutse, N.A.B., Nkrumah, F., Adukpo, D.C. and Owusu, K. (2017). Changes in rainfall characteristics in wench and saltpond farming areas of Ghana. *International Journal of Geosciences*. **08(03)**: 305-317. <https://doi.org/10.4236/IJG.2017.83015>.
- Quaye-Ballard, J.A., Okrah, T.M. and Akorful, S.A., Awotwi, A., Antwi, T., Osei-wusu, W., Tang, X. and Quaye-Ballard, N.L. (2020). Spatiotemporal dynamics of rainfall in Upper East Region of Ghana, West Africa. 1981-2016. *SN Applied Sciences*. **2(10)**. <https://doi.org/10.1007/S42452-020-03463-X>.
- Shrestha, J., Kandel, M. and Chaudhary, A. (2018). Effects of planting time on growth, development and productivity of maize (*Zea mays* L.). *Journal of Agriculture and Natural Resources*. **1(1)**: 43-50. <https://doi.org/10.3126/JANR.V1I1.22221>.
- Tanzubil, P.B. (2016). Incidence of arthropod pests and diseases of groundnut *Arachis hypogaea* L in northern Ghana. *Journal of Entomology and Zoology Studies*. **4(4)**: 29-32.
- Yamba, E.I., Aryee, J.N.A., Quansah, E., Davies, P., Wemegah, C.S., Osei, M.A., Ahiataku, M.A. and Amekudzi, L.K. (2023). Revisiting the agro-climatic zones of Ghana: A re-classification in conformity with climate change and variability. *PLOS Climate*. **2(1)**: e0000023. <https://doi.org/10.1371/journal.pclm.0000023>.
- Yengoh, G.T., Armah, F.A., Onumah, E.E. and Odoi, J.O. (2010). Trends in agriculturally-relevant rainfall characteristics for small-scale agriculture in Northern Ghana. *The Journal of Agricultural Science*. **2**: 3-16. <https://doi.org/10.5539/JAS.V2N3P3>.
- Yorke, C.K.A. and Omotosho, J.B. (2010). Rainfall Variability In Ghana During 1961-2005. *Journal of the Ghana Science Association*. **12(1)**: 125-134. <https://doi.org/10.4314/JGSA.V12I1.56813>.