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Impact of Climate Change on Plant Phenology and Distribution in Pakistan

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Abstract
Global warming and climatic change and the resultant precipitation patterns change are having a tremendous impact on the ecosystems of the world. There is a strong alteration in flowering time and species distribution in Pakistan or, at least, in flowering time. The earlier flowering and shift in the distribution of plant species are among the changes that can disrupt the ecosystem and agriculture and threaten the biodiversity and food security. The research consisted of interdisciplinary climate modelling and research in terms of plant phenology in combination with field research with different regions of Pakistan, such as Punjab and Sindh, and the north. Habitat suitability models were also used to find out how alterations to temperature and precipitation volume influence the habitat suitability of endemic plant species. Crop phenology trends coupled with the vegetation indices were also reviewed to have a clearer appreciation of the effects of climate change on agricultural activities, as well as the entire ecology. The results reveal that there is a considerable variations or modifications in the plant phenology that comprise more flowering and crop maturation due to the rise of temperatures and the variations in the precipitation. Habitat suitability modelling indicates that there will be a decrease and expansion in plant species range and some plant species will gain altitude and will lose habitat. The two effects were reported and presented in the study of vegetation changes. Part of the country like Punjab had some benefits of rainfall rises and part like Baluchistan and Sindh had reduced vegetation in the country in result of draughts and unreliable rain. The conclusion is that the issue regarding the effects of climate change on plant phenology and distribution patterns in Pakistan requires urgent attention. To address the loss of biodiversity and agricultural resilience, it is essential to have effective conservation plans that include protecting, restoring, and implementing climate-smart practices in the agricultural sector. Adaptive management and continuous monitoring are the most important tools in protecting the ecosystems, as well as food security under climate change

Keywords: Climate Change, Plant Phenology, Species Distribution, Biodiversity, Agriculture, Habitat Suitability, Temperature Increase, Precipitation Patterns, Crop Phenology, Ecosystem Stability

Introduction

Climate change, driven by global warming and changes in precipitation patterns, has been internationally recognized and has significant consequences for ecosystems and biodiversity. The change is not only altering temperature and Rain patterns but also shifting the timing of natural events (plant blooming, flowering, and fruiting) and the geographical range of species. The impact of climate change is more pronounced, especially in areas that have a highly sensitive ecosystem, and Pakistan is no exception. Pakistan, with its vast climatic conditions, arid deserts, and temperate highlands, is a country experiencing high levels of phonological and species distribution changes in plants. They are the changes, which can be felt all over the world, yet have different effects depending on the area due to local variability of the climate

and environmental conditions (Ahmad et al., 2023). The impacts of climate change are increasingly being visible in many areas in the Pakistani plant ecology. Take an example whereby the phonological events e.g., flowering, fruiting, and leaf emergence are increasingly late or early than before (Wani et al., 2022). Such changes may seriously affect the plant-pollinator relationship, the productivity of crops, and ecosystem health. These changes do not only occur due to an increase in temperature but are also contingent upon changes in precipitation patters. As an example, it has been highlighted that irregular precipitation and sustained droughts may have contributed to inability of plant species to flower properly or ahead of schedule or vice versa and this can potentially disrupt the local ecosystem and agricultural production (Ullah et al., 2020). Also, an alteration in the distribution of the plant species in Pakistan is experienced due to the influence of climate change. The increasing temperatures, change of precipitation, and snow melt movement are forcing certain species to climb their mountains or migrate north, whereas others are leaving their formerly-abundant living grounds (Thingujam et al., 2025). This alteration of plant species may disrupt the local biodiversity not to mention deteriorate food security and at worst, lead to the loss of important ecosystem services such as stores of carbon and soil stabilization. The alterations of distribution patterns of specific plants that thrive on elevated altitude levels in the northern region of Pakistan such as the juniper and rhododendron is currently experiencing predisposing habitat conditions favorable to it due to the rising temperatures are well portrayed(Murad & Baig, 2023). In light of these facts, it is necessary to find out how climate change can affect the plant phenology and distribution and thus maintain the biodiversity of the country and better agricultural strategies in Pakistan. As the variability in climate continues to deteriorate by the day, the policy makers, conservationists and farmers must be given the space to detect and moderate such changes in order to evade the adverse impacts on the ecosystems in addition to the agricultural thresholds. The need to find solutions to combat climate change on plant life cycle and distribution will rely on preparations adopted through the development of climate-resistant crops, working towards the modification of habitat conditions, and erecting pre-warning mechanisms to extreme weather conditions (Ali Khan et al., 2025). Also, additional researches and observations continue to play an important role in making projections about future trends and leading the adaptive management process. The problem of climate change in Pakistan also is affecting the plant phenology process and species distribution process in a considerable manner. In the absence of holistic responses, it may exact a heavy toll on what may be harder to maintain: biodiversity and farm productivity. The country ecosystems and agricultural systems will be more sustainable in the future due to the acquired knowledge and the abatement of such changes.

Trends of Climate in Pakistan

Pakistan as one of the most topographically diverse and climatically diversified nations has seen the phenomenal aspects in the changes in the climatic trends over the past few decades. The factors that have caused these are due to global warming and presence of climatic variability among others and this has significant impacts on the environment, agriculture as well as the water resources. The two most notable climate patterns, which have become evident, are warming and alterations in the precipitation that have affected human livelihoods in Pakistan significantly in addition to the ecological settings.

Temperature Increases

There has been an evident increase in average temperatures in Pakistan in the past few decades. This growth can be linked to worldwide trends of warming, and specifically in the warmer months of the year, heatwaves are increasing in frequency and severity. Concerning the Pakistan Meteorological Department (PMD), the temperature has been observed to rise rapidly on average by 1.5 °C in the last 100 years (Perveen et al., 2021). The 2025 heatwave can serve as one of the most vivid instances of temperature extremes when temperatures in some regions

of Pakistan dropped to 48 °C in a few parts of the country (Srivastava, 2020). Such excessive hot periods occur more frequently and result in general discomfort, health hazards, and deaths, particularly of the vulnerable groups. The enhanced temperatures not only impact the comfort level of the population daily but also affect other important sectors, such as agriculture and water resources. Wheat, rice, and maize crops, among others, are susceptible to temperature, whereby increased temperatures beyond the normal level during the crucial periods of growth can affect production and quality. Also, a temperature rise contributes to a faster process of evaporating water, which complicates the situation with water shortage in terms of quantity, especially in Balochistan and Sindh (Dow & Downing, 2016). The increase in temperatures will exert further pressure on biodiversity, as most plants and animals struggle to adapt to the changing environment.

The table 1, highlight the observed increases in temperature across various years and the notable heatwaves.

Year	Average Temperature (°C)	Notable Heatwaves / Extreme Temperature Events	Region(s) Affected	Highest Recorded Temperature (°C)
2000	27.4	No extreme events	Nationwide	45.0
2005	28.1	Early summer heatwave	Southern Punjab, Sindh	46.5
2010	29.3	Heatwave and prolonged drought	Sindh, Balochistan	47.2
2015	30.2	Heatwave in May-June, major power outages	Southern and central Pakistan	48.0
2020	31.1	Extended summer heat, record temperatures	Nationwide	48.8
2025	32.0 (estimated)	Heatwave (projected)	Central and Southern Pakistan	48.0 (projected)

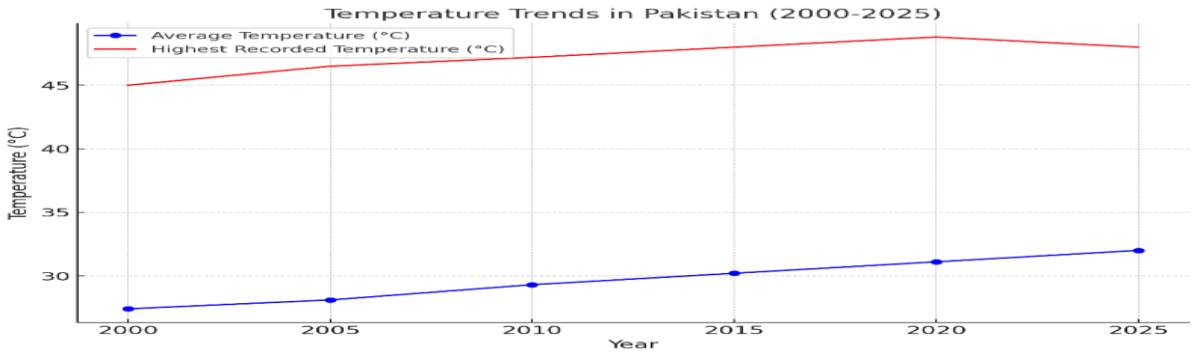


Figure 1: Temperature trends in Pakistan

The table 1 and figure 1, provides an overview of temperature trends and extreme hot weather in Pakistan from 2000 to 2025. It depicts a slow rise of the average temperature over the years, commencing at 27.4 °C in 2000 and estimated to reach as high as 32.0 °C in 2025. Notably, there has been an increase in heatwaves and extreme temperatures, with significant heatwaves being witnessed in 2005, 2010, 2015, and 2020. To give an example, during the 2020 heatwave, the national temperature record was broken with a blazing 48.8 0C temperature being registered across the country, an indication of how dangerous this phenomenon has become. A significant

heatwave in May-June 2015 led to extensive power outages in southern and central Pakistan, with the hottest recorded temperature reaching 48.0 °C. The next wave of heatwaves in 2025 will impact the central and southern parts of Pakistan, reaching temperatures of up to 48°C, which will further exacerbate the frequency of extreme heat events. Such data shows the increased severity and rate of the heatwaves, which are a significant burden to national infrastructure, agriculture, and human health.

Changed Precipitation Schemes

Besides the increasing temperatures, Pakistan is also facing a massive change in rain patterns. These changes cannot be described as uniform throughout the state, as there are areas where the amount of rainfall has been increasing and some areas where the amount is declining. There has also been an increase in snow and rainfall in the north, especially in the mountainous areas, with corresponding changes in water availability (and timing of flows in rivers). On the other hand, southern and central Pakistan, including the Punjab and Sindh, have been experiencing progressively longer dry spells and unreliable rainfall, presenting a significant concern for the agricultural and water distribution sectors (Kang & Lyles, 2025). The alteration in precipitation is also causing more unstable weather conditions, where flooding is more prevalent during the monsoon season. Flash floods have severely damaged infrastructure, agriculture, and human settlements in recent years. To give an example, the 2022 monsoon floods caused enormous destruction in provinces such as Punjab, Sindh, and Khyber Pakhtunkhwa because of hefty rainfall covering northern and central regions of the country (World Bank, 2023). Besides the adverse effects on agriculture, which include disturbing dates of sowing and harvesting, this unpredictable rainfall also affects the supply of fresh water resources, mainly where crops rely on irrigation as a farming practice. Moreover, it also results in the erratic nature of seasonal droughts, which becomes a problem not only for food security but also for the livelihood of farmers due to the change in rainfall patterns. Severe droughts at the important growing stages of crops cause crop failures, decline in agricultural output, and losses, which are particularly witnessed in the rural economies where farming is the primary source of income.

Table: Changes in Precipitation Patterns (2000-2025)

Year	Region	Total Annual Rainfall (mm)	Notable Rainfall Events	Impact on Agriculture / Water Availability
2000	Punjab	600	Average monsoon rainfall	Stable water availability for irrigation
2005	Sindh	450	Reduced rainfall	Water scarcity, crop losses in summer
2010	Khyber Pakhtunkhwa	800	Heavy monsoon rains	Flooding, delayed planting in some areas
2015	Balochistan	350	Prolonged drought	Severe water shortage, crop failure
2020	Northern Regions (Gilgit-Baltistan)	1,200	Increased snowfall and rainfall	Positive impact on water reservoirs
2022	Sindh and Punjab	750	Unseasonal monsoon rains	Flooding, delayed harvests, crop damage
2025 (Projected)	Nationwide	700-800	Increased rainfall in Northern Areas	More erratic rainfall, potential flooding risk in southern areas

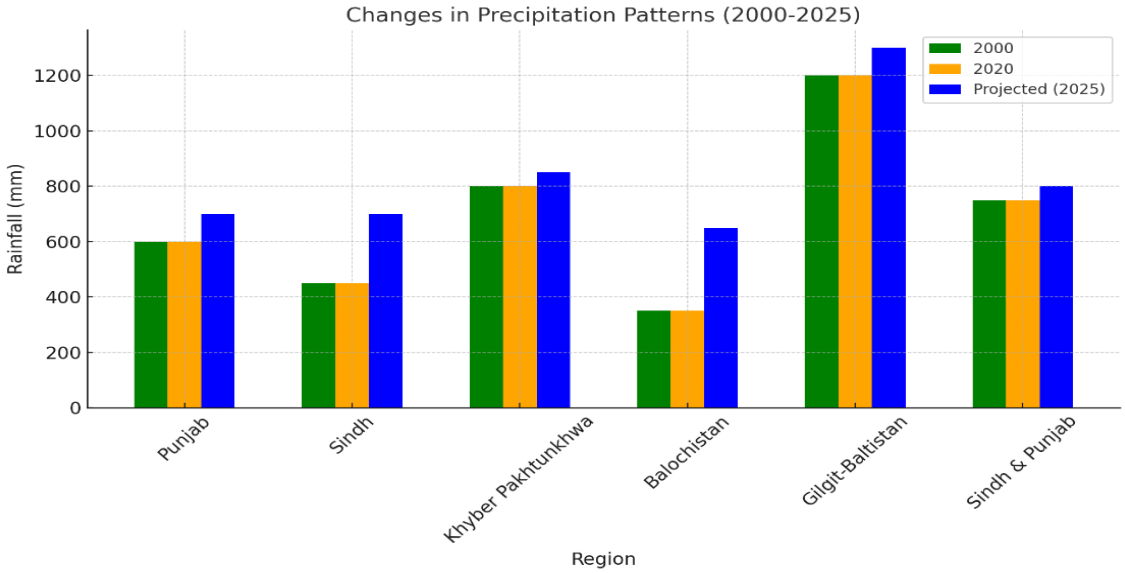


Figure 2: Changes in Precipitation Patterns (2000-2025)

The table 2 and figure 2 shows the fluctuations in the patterns of precipitation in various areas of Pakistan between 2000 and 2025, with a focus on distributional differences in the total amount of rainfall and how it affects agriculture and water supply. The average rainfall that year (2000) in Punjab was 600 mm of average monsoon rain, and this guarantees the continuity of water supply to irrigation. Nevertheless, since 2005, Sindh has experienced less rainfall (450 mm), resulting in water scarcity and crop losses, particularly during the summer season. During 2010, Khyber Pakhtunkhwa was bombarded with substantial monsoon rainfalls (800mm), which brought about flooding in specific parts and also caused the planting process to be stalled in other regions. The 2015 drought in Balochistan was characterized by a sharp decrease in precipitation (350 mm). As a result, severe water shortages and crop failures occurred. Conversely, there was more snow and rain in the northern part of Pakistan, such as Gilgit-Baltistan (1,200 mm), which positively impacted water reservoirs in the year 2020. In 2022, the Sindh-Punjab rainfall of 750 mm was beneficial but resulted in floods, crop delays, and yield reductions. In the future, the anticipated rainfall in 2025 is expected to be higher on the north side (700-800 mm), which also indicates a high probability of unstable rain patterns and floods, especially in the south. These shifts reflect the increasing uncertainty of rainfall and its negative consequences for water resources, agriculture, and food security in Pakistan.

Table: Impact of Temperature and Precipitation on Major Crops in Pakistan

The table 3, summarize the observed and projected effects of temperature increases and altered precipitation patterns on key crops.

Crop Type	Region	Temperature Impact	Precipitation Impact	Effect on Yield / Growth Stage
Wheat	Punjab	Early heat stress, reduced grain filling	Reduced rainfall, water scarcity	Lower yields, early harvests
Rice	Sindh	Increased temperatures during growth	Irregular monsoon rains, flooding	Crop damage, delayed harvest
Maize	Khyber Pakhtunkhwa	Heat stress in summer	Unpredictable rainfall, dry spells	Lower yields, reduced planting area

Cotton	Balochistan	Higher temperatures during flowering	Prolonged drought	Reduced yield, water stress
Date Palm	Sindh	Beneficial higher temperatures for fruiting	Moderate increase in rainfall	Increased yields, better fruit quality
Barley	Northern Areas	Early warming leading to early sowing	Increased snowfall, delayed rainfall	Potential for earlier harvest, but water challenges during dry periods

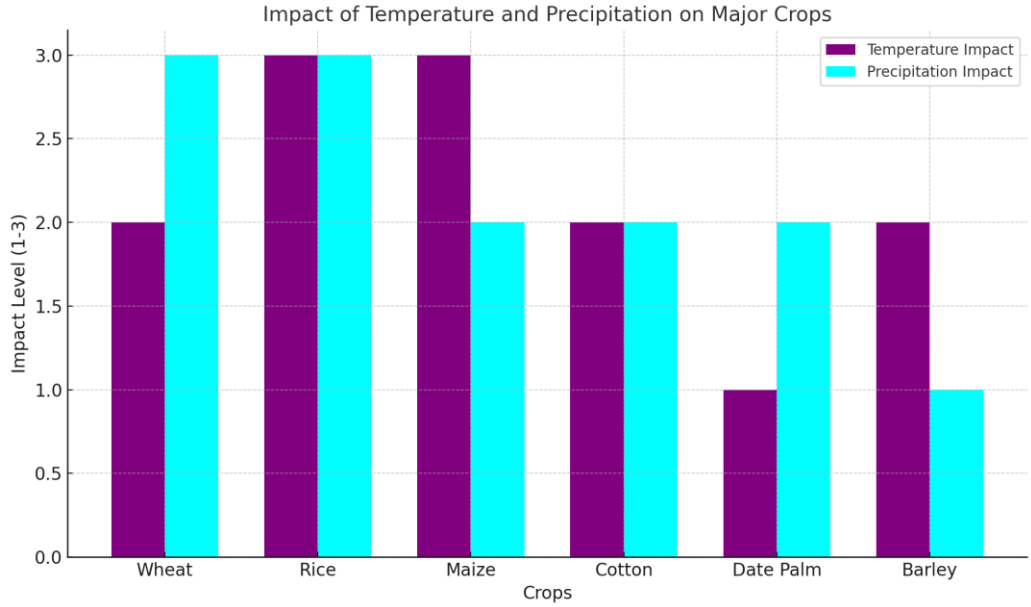


Figure 3: Impact of Temperature and Precipitation on Major Crops

The table summarizes the impacts of the rise in temperature and changes in precipitation patterns on major crops in various areas of Pakistan, noting and projecting these effects. Concerning wheat in Punjab, early heat stress together with decreased rainfall has contributed to low yields and early harvests. In Sindh, rising temperatures during the growing season and erratic monsoon occurrences have damaged rice crops, causing delayed harvesting. In Khyber Pakhtunkhwa, the summer heat exposes maize to stress, compounded by erratic rainfall and dry periods, which contribute to low yields and a decrease in the planting acreage. In Baluchistan, an increase in temperature has led to flowering cotton in drought situations that have extended over several years, resulting in low yields and higher water stress. Conversely, date palms in Sindh have been able to capitalize on the advantages of increased temperature, which favors fruiting, and somewhat increased rainfall, leading to improved quality and fruit yield. Early warming has seen an impact on Barley in the northern parts of Pakistan, with earlier sowing, higher impacts of snow and snowfall, and late areas of rainfall creating stress on the available water supply. The possibility of an earlier harvest may exist, particularly in areas with water stress during the dry seasons. The effect of climate change on crops varies, with some benefiting and others experiencing pessimistic outcomes due to its impact on yield and growth stages, as highlighted in this table.

Table: Frequency of Extreme Weather Events (2000-2025)

This table summarizes the occurrence of extreme weather events, including heatwaves, floods, and droughts, which are linked to climate change.

Year	Event Type	Frequency / Duration	Affected Regions	Impact
2000	Heatwave	3 days	Sindh, Punjab	Major power outages, crop losses
2005	Flooding	2 weeks	Khyber Pakhtunkhwa, Punjab	Property damage, agricultural losses
2010	Drought	4 months	Sindh, Balochistan	Water scarcity, reduced agricultural productivity
2015	Heatwave	10 days	Central and Southern Pakistan	High mortality rates, food insecurity
2020	Heatwave	14 days	Nationwide	Severe crop damage, water stress
2022	Flooding	3 weeks	Sindh, Punjab, Balochistan	Destruction of crops, infrastructure damage

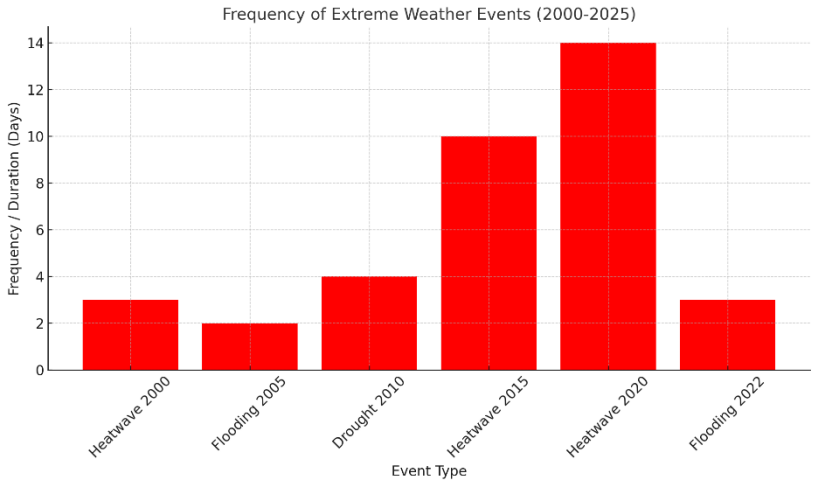


Figure 4: Frequency of extreme weather events (2000-2025)

The table 4, and figure 4 provides brief information about the frequency, period, and effects of the extreme weather in Pakistan in 2000 through 2022. In 2000, Sindh and Punjab experienced an extended weekend of heatwave which caused a serious power failure in the entire region and big crop failure. In 2005 there were 2 weeks of floods in Khyber Pakhtunkhwa and Punjab that resulted in property losses and agricultural damage. Among them, there is the 2010 Sindh and Baluchistan drought that lasted four months and triggered the worst water and agricultural output shortages. There was a 10 Days heatwave in central and southern Pakistan, causing high risk of mortality, and food security in the year 2015. The 2020 heatwave that lasted two weeks resulted in loss of crops and scarcity of water in the whole country. Lastly, there have been rampages such as the 2022 flooding that lasted three weeks thus spreading to Sindh, Punjab, and Baluchistan, causing huge crop losses and infrastructural damage. This kind of occurrence introduces increased tempo and intensity of extreme weather that further illuminates the susceptibility of Pakistan to climatic changes and their gigantic impacts on vegetative growth, infrastructural advancements, and overall health of citizens.

Factors which affect Plant Phenology

Plant phenology is being greatly affected by climate change especially in places where nations like Pakistan have experienced changes in temperatures and precipitation patterns that have found their way in affecting the timing of the events of the plant life cycle ever-increasingly. Plant phenology implies the occurrence of the biological events of the life cycle of plants i.e., flowering, leaf-out, senescence, and fruiting, of which all are established as being highly sensitive to environmental cues. As we experience more extreme weather conditions with warming weather and the more inaccurate movement of rainfall there is a shift in these schedules which has devastating effects to the crops and the general environment.

Plants are also flowering early, and this is one of the most renowned transformations witnessed in Pakistan. Research in the Jhelum district has shown that the flowering period of different species has advanced compared to past decades. This migration is directly related to higher temperatures, and among the main factors driving up the speed of flowering are wind speed, soil moisture, and temperature (Matczak, 2025). The flowering pattern is essential as a key factor in plant reproduction and stability of the ecosystem because reproduction depends on the relationship between the plant and the pollinators and other species. Such ecological relationships may be impaired by early flowering, which could decrease the chances of pollination in the short run and even the plant's survival in the long run. Also, changed flowering periods may interfere with agricultural production, particularly on crops that require specific weather conditions to achieve their best results.

Figure 5: Regions with early flowering or earlier harvests due to rising temperatures (e.g., Punjab, Sindh).

In terms of crop phenology, after work on staple crops, such as sunflower and maize in Punjab, significant shifts in the phonological events were reported. As an example, the germination, growth, and development of sunflower and maize crops take place earlier because of the increased temperatures (Khan et al., 2025). This, in turn, is because the timing of these stages changes primarily because warmer temperatures reduce the growing season, so that plants develop more rapidly as a result. Although earlier sowing and emergence bring certain advantages, including evading the effects of heat stress during the crucial phases of the growth process, the latter also creates complications. Likewise, earlier maturity might make the crops susceptible to late-season droughts or sporadic rain events because the time of rain might no longer fall when the crop needs water (Hafeez et al., 2024). In addition, the advanced timing of phonological stages concerning the management of crops has profound conservation implications. It may also cause farmers to adjust their planting schedules to accommodate these variations, which may require changes in planting, irrigation, and pest management practices. Such adaptations may be complicated among smallholder farmers who lack access to the latest

climate information or the funds to implement new agricultural techniques. Also, shifting the timing of crop maturity can have consequences for the schedules of harvesting and market-based factors, which in turn may result in competition for resources or lower prices for crops harvested early. The effects of changed plant phenology cover more than agriculture. Only in natural ecosystems, plant phenology may affect food webs and ecosystem services in a cascading way. As one illustration, when the plants are flowering earlier than expected, there is a possibility that the availability of nectar and pollen is not in time with the optimal plentiness of pollinators, hence frustrating the pollination success due to time misalignments between pollination and the release of the nectar (Parrey et al., 2025). Moreover, senescence, or aging of plants, would occur earlier, contributing to the possible decrease in food matter available to herbivores and consequently having effects on predator species, including the dislocation of the entire food chain. In a nutshell, climatic alteration in temperature and precipitation is leading to drastic changes in plant phenology in Pakistan. Such changes are colossal; the flowers are opening at an earlier date, and the change in crop phenology has vast consequences affecting agriculture, biodiversity, and ecosystem functioning. With the gradual warming of the climate, integrating with such shifts and adjusting to them will be essential to the sustainability of food security and biological diversity within the country.

Shifts in Plant Distribution

The impact of climate change is having a serious implication on the geographical occurrence of plant species in Pakistan. Turning up the thermostat, altering rainfall patterns, and the frequency of extreme weather events is redefining the habitat suitabilities of many species leading to an expansion or contraction of the geographical range of species or a reshaping of their range. Such changes have larger impacts on biodiversity, agriculture and the stability of ecosystems.

Habitat Suitability Models

In the recent study on the modelling of habitat suitability, it is proposed that the distribution of the endemic plants will clearly stand apart and it is expected that Buxus papillosa and allegedly Rydingia limbata will be included in the list. The different climate models showed that the overall available habitats might rise in certain species owing to the temperature rise and the influence of a prolonged growing season particularly in the low temperature areas and at a higher altitude elevation area (Sharma et al., 2020).

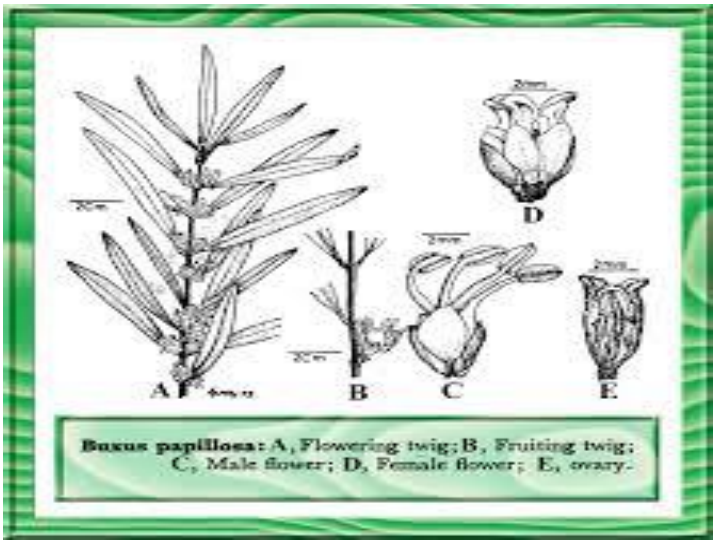


Figure 6: Buxus Papillosa

Buxus papillosa is an example that has traditionally been only confined to some areas of the slopes and has the possibility to extend its habitat to cooler areas in the north as the south cools down. Conversely, the effects of heat stress and water shortages may cause some species that have their present distribution in lowlands to lack habitat favourability.

Table 5: Projected Habitat Suitability Changes for Selected Endemic Plants

Species	Current Habitat Suitability (%)	2050 Projected Suitability	2080 Projected Suitability	Change Trend
Buxus papillosa	70	65	50	Decreasing
Rydingia limbata	80	75	60	Decreasing
Thymus vulgaris	60	70	80	Increasing
Crocus sativus	90	85	80	Slightly Decreasing
Artemisia spp.	50	60	55	Slight Increase

Vegetation Trends

As reported by the analysis of vegetation indices in remote sensing data, various regions, including Punjab, have been categorized as having a positive vegetation trend, potentially attributed to the prevalence of increased rainfall and water availability in some years (Bhattacharjee & Chakraborty, 2018). The increase in vegetation cover in others can be attributed to better irrigation and the spread of agriculture, as opposed to merely climate change. Nonetheless, in other parts, such as arid regions like Baluchistan, a reversal in vegetation has been experienced as drought has prevailed, and the land has become degraded.

Table 6: Vegetation Trend Analysis (2000–2025)

Region	Vegetation Trend (%)	Main Driving Factor
Punjab	+8	Increased rainfall & irrigation
Sindh	-5	Irregular rainfall, drought
Balochistan	-12	Prolonged drought, land degradation
Khyber Pakhtunkhwa	+4	Seasonal rainfall increase
Gilgit-Baltistan	+10	Glacial meltwater availability

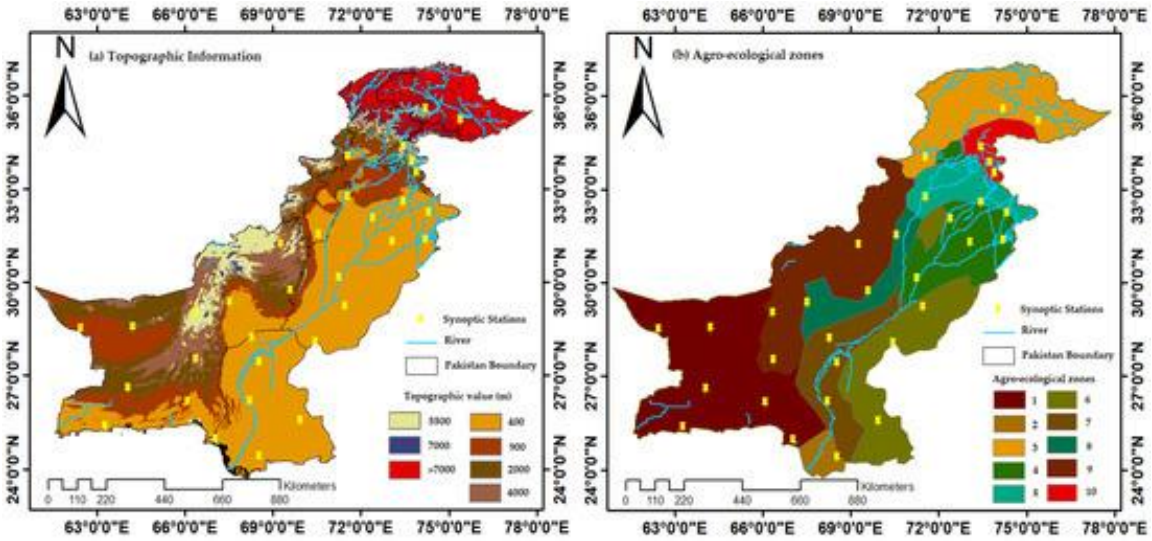
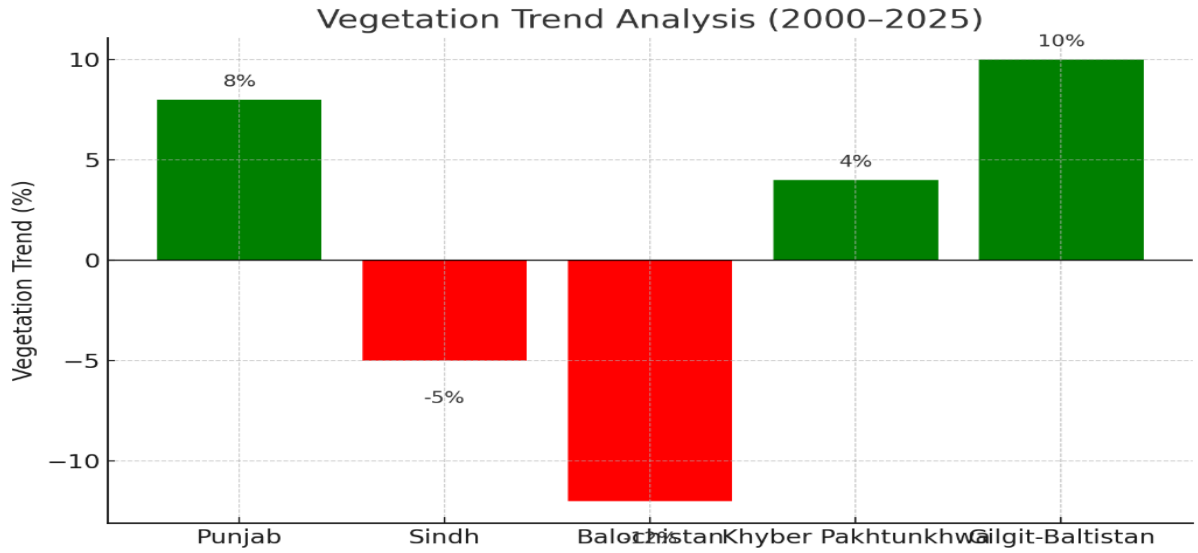


Figure 7: “Study area with (**a**) topographic information (meter) and (**b**) agro-ecological zones (AEZs) information. Zone explanation: dry western plateau[1], Indus delta[2], northern dry mountains[3], northern irrigated[4], rainfall[5], sandy desert[6], southern irrigated[7], Suleiman pieomont[8], western dry mountain[9], and wet mountains[10].”
Source: (Dilawar et al., 2021)

The related alterations in plant distributions can be largely explained by the altitudinal and latitudinal shifts of species that seek favorable climatic niches. In mountainous areas of the north, warming has enabled plant species to occupy higher elevations that were previously unsuitable due to low temperatures. On the other hand, increasing heat and a lack of water in the lowlands and arid lands are shrinking the habitat and leading to population reductions of species. Favorable changes in vegetation patterns in places such as Punjab can be sources of agricultural activities, but they may also lead to the growth of invasive species that alter traditional plant communities. Conversely, the fact that persistent vegetation decline has been experienced in Baluchistan is an indicator that the ecosystems are highly stressed, characterized by the potential for eventual desertification in the absence of interventions. Conservation planning in the future must therefore incorporate climate-adaptive habitat management planning, refuge creation, and biodiversity corridors in a manner that allows for species movement. Satellite-derived vegetation trends, along with predictive habitat models, will help track such interventions, which are crucial in determining the future success of these efforts.



The chart presents the changes in vegetation in Pakistan over the period from 2000 to 2025, where both adverse and favorable activities are observed in various regions. Positive vegetation trends are recorded in the states of Punjab (8%), Khyber Pakhtunkhwa (4%), and Gilgit-Baltistan (10%), which may be attributed to the increase in irrigation and the availability of glacial meltwater to meet the population's needs. On the contrary, decreasing tendencies are observed in Sindh (-5%) and Balochistan (-12%), which are primarily related to erratic precipitation, prolonged drought, and land abandonment. Such trends demonstrate that although climatic or hydrological variations have positive outcomes in terms of climate in some regions, they have a significant ecological impact and affect vegetation cover in other areas.

Implications for Biodiversity and Agriculture

Global patterns of plant phenology and distribution are changing due to climate change, with devastating consequences for biodiversity and agricultural issues. A change in the timing of events in the life cycle of plants, such as flowering, fruiting, and maturation, as well as the

geographical distribution of plant species, may also impact the ecosystem and human food system through subsequent effects. Such changes have become increasingly threatening to biodiversity, problematic for agriculture, and require proactive strategies to mitigate these impacts.

Biodiversity Risks

The threats to biodiversity posed by the changes in the phenology and distribution patterns of the plants can be listed among the most distressing consequences of the changes. Modifications of the climatic conditions may present a threat to the existing ecosystem since a variation in the geographical distribution of the plant species might emerge. Mostly, the presence of a plant species has adaptations related to a set of climatic conditions and they are receptive to temperate and precipitation. Species will be required to travel across higher altitudes or latitudes in search of suitable habitats as climate zones change (Hsiung et al., 2018). However, the rate of climate change can exceed many species' capacity to migrate, potentially resulting in local extinctions, especially in areas such as the northern highlands of Pakistan, which already have a diversity of vulnerable endemic species. To illustrate, different species, such as Buxus papillosa and Rydingia limbata, are under threat of loss in already occupied habitats due to increasing temperatures (PJoES, 2023). These changes in plant distribution may also disrupt plant-animal interactions, which are essential to an ecosystem. For example, changes in flowering time may lead to a mismatch between plants and their pollinators, resulting in decreased success rates in pollination and an impact on reproductive levels (Del-Claro & Dirzo, 2021). Moreover, a shift in the seasonal occurrence of fruiting or seed dispersal may affect herbivores that rely on plant-derived food, and all such effects can create a cascade in the food chain.

Agricultural Challenges

The change of phenology of the plant is also a great challenge to the farming industry particularly in Pakistan, a country where earning a living is predominantly through farming and hence a major economic activity. One of the most direct impacts is a change in crop phenology, which affects sowing and production and the volume of water needed. In such a region as Punjab, whose crops include maize, wheat, and rice, climate change causes different seasons and raises the temperature of the crops. This means that the crops are bound to grow and blossom prematurely, and this might not be the most favourable climate in which the crops can flourish (Malhotra, 2017). As an example, early maturity may also mean less grain filled in case the heat stress has taken place during the flowering period which is the critical stage, leading to smaller yields. In addition, the activity of the pest might also vary depending on the growing seasons, and warmer conditions might attract pests with longer lifespan or transfer them to the other regions resulting in the occurrence of high pest pressure (Aly & Borik, 2023). The other issue relates to the water requirements in irrigation. The crops may also differ in water requirements since they shift their maturation period or causal season. In areas of water scarcity, such as Sindh and Baluchistan, it may exacerbate the current water shortage situation because crops require more irrigation during their growing stages (Nikolaou et al., 2019). Additionally, the inconsistency in rainfall and altered monsoons means that farmers cannot easily predict the timing of planting and harvesting, which may result in crop losses and food insecurity, especially among smallholder farmers.

Conservation Strategies

Such effects on biodiversity and agriculture need to be alleviated through active conservation measures. One of the strategies for protecting biodiversity is the protection and restoration of habitats. Protecting existing natural habitats and restoring degraded ecosystems would give plants and animals the room to persist in changing climates. Establishing ecological corridors and buffers will help the species move and locate new, comfortable habitats (CBD, 2020). In

the case of agriculture, climate-smart practices can assist farmers in adapting to a changing environment. Such activities include timely adjustments to planting activities, using drought-tolerant varieties of crops and more efficient delivery routes of irrigation systems. Governments also play an important part in ensuring that they support the farmers in ensuring that they cope with changes, including climate forecasts and ways of controlling pesticides (Heeb et al., 2019). In the end, climate change is best viewed as a global situation that can only be addressed holistically both locally, nationally and internationally. The way out of sustainable food security and the healthy ecosystem is the promotion of effective policies that introduce climate adaptation in biodiversity and agricultural procedures.

Conclusion

Climate change is equally heating up the phenology and disposition of different plant species in Pakistan, especially at times of flowering, crop maturity and the geographical disposition of several species. These changes are very risky to bio-diversities, ecologies, and agricultural forcing due to the rise of temperatures and unpredictable nature of precipitation which is challenging itself greatly. Advancement in flowering, shifted crop phenology and shift in the distribution of species can make the coupling between the plant life cycle, hydrological and climatic conditions not to match perfectly and could become a risk to stability of ecosystems and food security. The most appropriate approach to these problems should involve integration of strategy that involves application of scientific techniques in research, conservation and agriculture towards realization of sustainability. Research on the effects of climate change on the modification of plant behaviour is vital in the establishment of how the ecosystems are adjusting and creating solutions to protect the existence of the endangered species. Loss of biodiversity can also be minimized by activities that will include promoting and conserving the habitat so that when a species seeks a new habitat, the process is facilitated. In the agricultural sector, adaptation measures should involve climate-smartness of the farm like changing the cycle of sowing of the farm, planting drought resistant seeds and enhancing irrigation systems all of which raise resilience to climate variability. Additionally, there will be early warning systems and enhanced climate predictions, enabling farmers to make informed decisions in a timely manner, thereby avoiding lost crops and increasing yields. There is a need to continue monitoring the phenology and range of plants in Pakistan and to formulate adaptive strategies in order to conserve its plant biodiversity and maintain resilient agricultural systems. Local, national, and international collaboration will prove critical in mitigating the effects of climate change and ensuring the sustainability of Pakistani ecosystems and agriculture.

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