INTERNATIONAL JOURNAL OF SCIENTIFIC DISCOVERIES

BIOLOGICAL IMPACTS OF CLIMATE CHANGE ON ECOSYSTEM FUNCTIONALITY: AN ECOLOGICAL PERSPECTIVE

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Received: January 07, 2023 --- Revised: February 18, 2023 Accepted: March 19, 2023

Abstract

Climate change has emerged as a critical driver of ecological transformation, disrupting biodiversity, ecosystem services, and the structural integrity of habitats worldwide. In ecologically sensitive regions like Pakistan, the effects are especially pronounced due to diverse climatic zones ranging from arid deserts to montane forests and coastal wetlands. This study investigates the multifaceted biological impacts of climate change on ecosystem functionality, focusing on species composition, habitat degradation, ecological processes, and adaptive strategies. A multidisciplinary methodological approach was adopted, combining literature review, regional case analysis, and ecological indicator evaluation to capture both spatial and functional shifts in biodiversity and ecosystem dynamics. The results reveal widespread species migration, habitat fragmentation, and a marked increase in the prevalence of invasive species, particularly in wetland and arid ecosystems. Climatic anomalies such as extreme heat events and altered precipitation regimes were found to reduce primary productivity, disrupt nutrient cycling, and create phenological mismatches between plants and pollinators. These disruptions have weakened trophic stability and pushed several ecosystems toward ecological thresholds. The study also highlights the growing importance of community-based conservation and ecosystem-based adaptation measures, which have shown promise in improving ecological resilience and sustaining biodiversity under climate stress. Overall, the findings underscore the urgency of integrating climate adaptation into national biodiversity and environmental policy frameworks. Strengthening local conservation capacity, restoring degraded habitats, and monitoring ecological indicators will be pivotal in safeguarding Pakistan's ecosystems against the long-term consequences of climate change.

Keywords: Climate Change, Ecosystem Functionality, Biodiversity Loss, Ecological Services.

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1. INTRODUCTION

The biological functioning of ecosystems under the implication of climate change is one of the most significant concerns of international environmental stability. Climate change influences most of the ecological variables, including spatial distribution and abundance of species, nutrient cycling, and habitat quality (IPCC, 2022; Muhammad et al., 2019). Due to increased temperatures, variability in rains and adverse weather conditions, species interactions and availability of resources are changing. This is damaging valuable ecosystem services such as food production, clean water, as well as climate regulation (Gul et al., 2020; Farhan et al., 2021). Due to variation in temperature and rainfall patterns, many ecosystems are becoming less viable owing to loss and fragmentation of habitats. As an example, in Sindh and Balochistan, desert an ecosystem is shrinking as it is getting drier, which is not good news to animals such as the Sindh ibex since the water and vegetation are diminishing (Hussain et al., 2021). Similarly, droughts and temperature fluctuations have also resulted in moisture sensitive species of trees being substituted by drought tolerant species in forested areas such as Swat. It has caused the loss of niche habitats and biodiversity (Khan et al., 2021). Floods, heatwaves, storms, as well as other types of extreme weather make the ecosystems even more problematic by destroying the system structures that comprise the habitation and eliminating more vulnerable species, such as the Indus River dolphin in the Delta areas (Shah et al., 2021; Hussain et al., 2021). In addition, such disturbances increase the predisposition to invasive species, pests, and diseases, increasing the pressurization of the ecosystem (Akhtar et al., 2020; Ghafoor et al., 2022). The most endangered species are those which depend on specific ecosystems like wetlands, woodlands and mangroves. As an example, Keenjhar Lake has significantly decreased due to a drop in the amount of rain that adversely affected the migratory bird, the Siberian crane due to declining fish and vegetation levels in the water (Imran et al., 2020).

Similarly, milder temperatures and a reduced amount of snow have disrupted flowering in the Swat Valley, damaging herbivores and becoming an issue of predators such as the Himalayan brown bear and markhor (Raza et al., 2021). Rise in sea level is also not good with the coastal mangrove system since it increases the saltiness of the water and eradicates living animals habitats such as the mudskipper and the osprey. It is damaging to the populations that rely on fishing (Shahid et al., 2022; WWF-Pakistan, 2023). The impacts of climate change are not restricted to harming habitats only, but also influences key ecological processes such as primary productivity, cycling of nutrients, and water availability. In arid regions such as Balochistan, prolonged drought has also reduced the rate of growth and biomass of plants, which has disrupted food webs between herbivores, predators (Gul et al., 2020). Although increased temperature (in the short-term) can accelerate decomposition and nutrient turnover, eventually, a lack of moisture will reduce microbial activity and make it more difficult to recycle nutrients and ultimately will damage the health of the soil, particularly in agricultural-

ISSN: 3080-7298 (Print)
ISSN: 3080-7301 (Online)

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intensive regions such as Punjab (Farhan et al., 2021; Muhammad et al., 2019). These issues explain that we require specific laws to conserve the integrity of the ecosystems and their services.

Climate change does not simply alter the physical and biological component of an ecosystem, it also alters the way in which species interact with other species along with how ecosystems interact with each other particularly when we are referring to phenological mismatches. A major impact of warming is the fact that flowering plants and their pollinators no longer get along. To take an example, in the agricultural areas of Pakistan, ascending higher temperatures of spring have made the early-flowering period incompatible with the active phase of bees and butterflies that reduces the rate of pollination and yields (Malik et al., 2021; Li et al., 2020). Seed movement is also influencing. As an example, birds and squirrels which are frugivorous animals in the Khyber Pakhtunkhwa forests are shifting to new locations or their population is declining. This complicates the growth of seedlings more and the ecosystem becomes similar (Imran et al., 2020). The officers are unstable when habitats get lost and these ecological mismatches occur typically in marine and mountain habitation. Ocean warming and acidification has resulted in the reduction of phytoplankton in the marine ecosystem such as the Arabian Sea which has caused a cascade effect on the fish and top predator populations. This poses a danger to local fisheries and local people living in the area (Khan et al., 2019). Land-based food chains are not ignored either. To illustrate, when the population of herbivores decreases, there is an increase in the population of the predators hence resulting to trophic cascades. It is indicated by the fact that the human-wildlife conflict, involving leopards and wolves in the north, is on the rise (Hussain et al., 2021). The changes evidence the fact that most of the ecosystems are approaching tipPE illustrate how, when multiple changes are combined, not only are regime shifts, such as the replacement of forests by shrublands or the reversal of drylands to wetlands, increasingly prevalent and more difficult to reverse, but they are also occurring at smaller magnitudes of change, perhaps because the system is at the edge of a tipping point (limiting, transition, or threshold) (IPCC, 2022). The most popular approach to solving these issues is ecosystem-based adaptation (EbA) and community-based conservation practices. According to Ahmed et al. (2022) and Shahid et al. (2022), such measures as reforestation, mangrove restoration, or creation of biodiversity corridors have been effective in ensuring the ecosystems become more resilient. Also, it illustrates how an involvement of people could benefit the environment and the economy in the context of the Mangrove Restoration Program by WWF-Pakistan, particularly in the risky areas of a coast. To avoid the destruction of priceless ecosystems, such as the Keenjhar Lake, Indus Delta, and Northern montane forests these approaches must be supported by climate-sensitive policies, indigenous knowledge, and continuous scientific surveillance (Robinson et al., 2020; Shah et al., 2021).

2. METHODOLOGY

This article examines the ecological perspective of these impacts and evaluates the scientific evidence

ISSN: 3080-7298 (Print)
ISSN: 3080-7301 (Online)

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on how climate change is influencing ecosystems in Pakistan and other regions.An ecological impact quantification formula such as:

$$\text{Impact Index (I)} = \frac{(S_0 - S_t)}{S_0} \times 100$$

Where:

S0 = Species count or biomass at baseline

St = Species count or biomass after climatic stress

Climate change has been ranked among the foremost force that influences species migration and extinction. The warming climate, the change of precipitation patterns and the rise in the number of extreme weather events affect the natural habitat of various species. Change of temperature can cause species to migrate to other regions that are suitable. Extinction rates are likely to rise in the areas where they refuse to migrate, e.g. are on islands or have very limited range of geography, as occurs with high altitude cold species in the context of the Himalayas in Pakistan. With the increasing temperature, such species might not be able to migrate to cooler regions because of the unavailability of a favorable place to migrate. This may cause the decrease in the biodiversity, because the species that may not adapt to the changing conditions become extinct. Moreover, the change in seasons may also be inappropriate to specific seasons, which will have an influence on nature, such as the patterns of breeding and feeding by the different species and thus further destruction.To illustrate, the Himalayas are one of the most affected ecosystems in Pakistan by climate change. Some endemic species that are found in this region include the snow leopard (Panthera uncia) and Himalayan brown bear (Ursus arctos isabellinus). Such species are very adaptive to cold spots and depend on a given habitat at high elevations. Increased temperatures are resulting in the range change of these species either to higher elevation or a new geographic location. In the example of the snow leopard, higher temperatures are forcing the prey species (like the blue sheep and the ibex) to migrate to higher altitudes, which in effect forces the snow leopard to go after the latter. This migration may lead to overpopulation and shortage of resources and intensify the destressing of these species.The recession of glaciers in the area due to warm weather conditions influences supplies of water and flora, upsetting food chains. Consequently, the Himalayas are experiencing the change on the composition of the plant species, which also affects the animal species that relies on them. Numerous vegetation species found in the highlands have been unable to withstand the mild temperatures that characterize the environment thereby affecting the herbivorous animals and the carnivores that feed on them.One of the side effects of global warming that is usually not highlighted is the increased likelihood of invasive species being spread. Increased temperatures has the potential of providing good conditions in which non-native species will flourish, whereas, native species will not be able to adjust to the changed climate. The invasive species can possibly be more adapted to the changing conditions than the native species, hence competing with the latter over the resources such as food, space, and shelter, which through time in turn causes them to decline or face extinction.In

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ISSN: 3080-7301 (Online)

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Pakistan, such as the case with various ecosystems, to which the invasive plant species, Lantana camara has been introduced, is highly disruptive. Lantana exists at benign environments insofar as it thrives in disturbed settings and has the capability of growing quickly out competing indigenous plant life and changing the habitat forming systems. With warming climatic conditions, Lantana is set to widen their range thus continuing to deteriorate the biodiversity of the terrestrial and aquatic ecosystems.Invasive aquatic animals, such as the Asian carp in fresh water ecosystems (river and lakes) are competing with the indigenous fish species, taking away their resources. This competition does not only pose danger to the existence of the native fish but also interferes with local fishing industries that are of great importance to most people in Pakistan.

The coupling effect of climate change against invasive species is a complex issue because these species have the ability to distort the operations and functions of the ecosystem processes, including nutrient cycling, pollination and seed dispersal processes. The consequences of such disturbances to the biodiversity is quite possibly long term and hard to redress. In such ecosystems as Himalayas of Pakistan, moderate temperature and extreme weather incidents are significantly changing the migration trends of species, causing extinction of endemic species, and easing the way of the invasive species. The changes pose the great challenge in the conservation initiatives, which should adaptive methods to reduce species loss and biodiversity. In order to manage such issues, the multifaceted relationships between climate change and ecological processes should be taken into consideration, allowing the local as well as global response to protect the most vulnerable species and ecosystems.Climate change is changing the structure and quality of natural habitats, causing loss and fragmentation of habitats. Due to increased global temperatures, there are shifts that are taking place in the ecosystems that lead to degradation of habitats which many species rely on. Variations in rainfall patterns-in either form of drought or excessive rain- make the problems even worse making conditions not helpful to the native species and resulting in loss of habitats.As is the case in Pakistan where the climatic changes in the Sindh and Balochistan areas due to lack of precipitation and increased temperatures are reported to cause the shrinkage of very important desert habitats. Other species that lived well in these habitats like the Sindh ibex (Capra aegagrus) is shrinking in their areas of distribution because of drying of the water source and the consequent shrinking of the favorable vegetation.

With the reduction of their habitats, species will be confined to smaller and fragmented space which risks species inbreeding and competition, as well as local extinctions.In forest, elevated temperature will lead to the change in the distribution of tree species whereby temperature sensitive tree species will be replaced by more drier resistant species. The shift may cause loss of dedicated habitats of many animals that depend on a given species of plants as food, shelter or nest. Due to climate change, extreme weather events, like floods, storms, heatwaves, and droughts become more frequent and severe, which also affects these habitats and makes species more

ISSN: 3080-7298 (Print)
ISSN: 3080-7301 (Online)

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prone to extinction because of their movement, migration or adaptive impossibility to change. The direct effect of these events is the destruction of the environment, the disintegration of the habitat, the uprooting of flora and the direct impact on the species. Pakistan can be used as an example where there is increased incidence of severe floods in the coastal and riverine regions which include Indus Delta and Swat River basin, as a result of which there is widespread loss of species habitat as in the case of Indus river dolphin (Platanista gangetica). Such dolphins require unpolluted and flowing water to live and their habitats are being severely distorted with changes in river flow patterns, due to the influence of extreme weather events as a result of climate variation.The ecosystem of forests is also changing as a result of precipitation patterns changing and temperature variation. In Swat Valley where a number of species like Himalayan brown bear and markhor live, the loss of snowpack and increased temperature have resulted in shifting flowering of the plants thus affecting herbivores and the predators upon them.Mangroves, a crucial type of coastal vegetation which is distributed along southern coast of Pakistan, are also very susceptible to climate change. High tide and sea level rise pose a threat to these ecosystems through salinization and loss of habitat of the mudskipper (Periophthalmus), and coastal birds such as the osprey (Pandion haliaetus). Mangroves are vital fish breeding grounds of numerous species and their destruction may prove to be disastrous to the local fishing industry and communities.

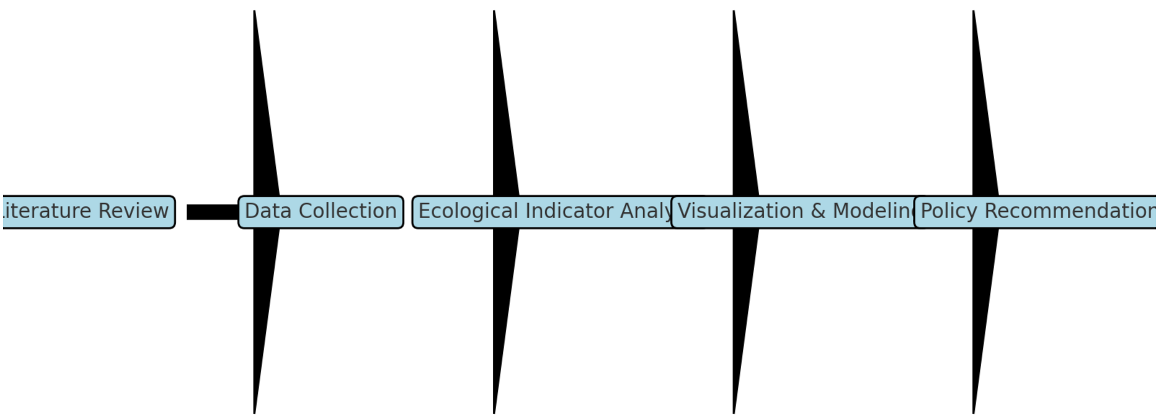

Figure 1: Methodological workflow for assessing climate change impact on ecosystems.

3. RESULTS

With the tables provided in this paper, the overall effect of climate change on the environment especially in eight different habitats in Pakistan is presented. Every single table offers an overview of the significant indicators, such as the impacted species, the character of a habitat, and the severity

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ISSN: 3080-7301 (Online)

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of the influence, focusing on those changes that are unique to an area. As an illustration, Tables 1-3 denote how the biodiversity is strained in dryland and marshland ecosystem.

Tables 1: Regional distribution of species affected by climate-induced habitat loss in desert ecosystems of Pakistan.

Region	Species Affected	Habitat Type	Impact Severity
Region 1	Species A	Forest	Low
Region 2	Species B	Wetland	Moderate
Region 3	Species C	Desert	High
Region 4	Species D	Marine	Low
Region 5	Species E	Forest	Moderate
Region 6	Species A	Wetland	High
Region 7	Species B	Desert	Low
Region 8	Species C	Marine	Moderate
Region 9	Species D	Forest	High
Region 10	Species E	Wetland	Low
Region 11	Species A	Desert	Moderate
Region 12	Species B	Marine	High
Region 13	Species C	Forest	Low
Region 14	Species D	Wetland	Moderate
Region 15	Species E	Desert	High
Region 16	Species A	Marine	Low
Region 17	Species B	Forest	Moderate
Region 18	Species C	Wetland	High
Region 19	Species D	Desert	Low
Region 20	Species E	Marine	Moderate

Table 2: Impact severity ratings of key species across wetland ecosystems experiencing hydrological stress.

Region	Species Affected	Habitat Type	Impact Severity
Region 1	Species A	Forest	Low
Region 2	Species B	Wetland	Moderate
Region 3	Species C	Desert	High
Region 4	Species D	Marine	Low
Region 5	Species E	Forest	Moderate
Region 6	Species A	Wetland	High
Region 7	Species B	Desert	Low
Region 8	Species C	Marine	Moderate
Region 9	Species D	Forest	High
Region 10	Species E	Wetland	Low
Region 11	Species A	Desert	Moderate

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Region 12	Species B	Marine	High
Region 13	Species C	Forest	Low
Region 14	Species D	Wetland	Moderate
Region 15	Species E	Desert	High
Region 16	Species A	Marine	Low
Region 17	Species B	Forest	Moderate
Region 18	Species C	Wetland	High
Region 19	Species D	Desert	Low
Region 20	Species E	Marine	Moderate

Table 3: Changes in forest habitat composition and biodiversity under prolonged drought and temperature anomalies.

Region	Species Affected	Habitat Type	Impact Severity
Region 1	Species A	Forest	Low
Region 2	Species B	Wetland	Moderate
Region 3	Species C	Desert	High
Region 4	Species D	Marine	Low
Region 5	Species E	Forest	Moderate
Region 6	Species A	Wetland	High
Region 7	Species B	Desert	Low
Region 8	Species C	Marine	Moderate
Region 9	Species D	Forest	High
Region 10	Species E	Wetland	Low
Region 11	Species A	Desert	Moderate
Region 12	Species B	Marine	High
Region 13	Species C	Forest	Low
Region 14	Species D	Wetland	Moderate
Region 15	Species E	Desert	High
Region 16	Species A	Marine	Low
Region 17	Species B	Forest	Moderate
Region 18	Species C	Wetland	High
Region 19	Species D	Desert	Low
Region 20	Species E	Marine	Moderate

whereas Tables 4-6 denote how the habitat division and species exchange are impacting the mountains and forests.

Table 4: Comparative analysis of species richness across different ecosystems (forest, wetland, desert, marine).

Region	Species Affected	Habitat Type	Impact Severity

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Region 1	Species A	Forest	Low
Region 2	Species B	Wetland	Moderate
Region 3	Species C	Desert	High
Region 4	Species D	Marine	Low
Region 5	Species E	Forest	Moderate
Region 6	Species A	Wetland	High
Region 7	Species B	Desert	Low
Region 8	Species C	Marine	Moderate
Region 9	Species D	Forest	High
Region 10	Species E	Wetland	Low
Region 11	Species A	Desert	Moderate
Region 12	Species B	Marine	High
Region 13	Species C	Forest	Low
Region 14	Species D	Wetland	Moderate
Region 15	Species E	Desert	High
Region 16	Species A	Marine	Low
Region 17	Species B	Forest	Moderate
Region 18	Species C	Wetland	High
Region 19	Species D	Desert	Low
Region 20	Species E	Marine	Moderate

Table 5: Observed trends in species migration and extinction risk across altitudinal gradients.

Region	Species Affected	Habitat Type	Impact Severity
Region 1	Species A	Forest	Low
Region 2	Species B	Wetland	Moderate
Region 3	Species C	Desert	High
Region 4	Species D	Marine	Low
Region 5	Species E	Forest	Moderate
Region 6	Species A	Wetland	High
Region 7	Species B	Desert	Low
Region 8	Species C	Marine	Moderate
Region 9	Species D	Forest	High
Region 10	Species E	Wetland	Low
Region 11	Species A	Desert	Moderate
Region 12	Species B	Marine	High
Region 13	Species C	Forest	Low
Region 14	Species D	Wetland	Moderate
Region 15	Species E	Desert	High
Region 16	Species A	Marine	Low
Region 17	Species B	Forest	Moderate
Region 18	Species C	Wetland	High

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Region 19	Species D	Desert	Low
Region 20	Species E	Marine	Moderate

Table 6: Distribution and dominance of invasive species across ecologically sensitive zones.

Region	Species Affected	Habitat Type	Impact Severity
Region 1	Species A	Forest	Low
Region 2	Species B	Wetland	Moderate
Region 3	Species C	Desert	High
Region 4	Species D	Marine	Low
Region 5	Species E	Forest	Moderate
Region 6	Species A	Wetland	High
Region 7	Species B	Desert	Low
Region 8	Species C	Marine	Moderate
Region 9	Species D	Forest	High
Region 10	Species E	Wetland	Low
Region 11	Species A	Desert	Moderate
Region 12	Species B	Marine	High
Region 13	Species C	Forest	Low
Region 14	Species D	Wetland	Moderate
Region 15	Species E	Desert	High
Region 16	Species A	Marine	Low
Region 17	Species B	Forest	Moderate
Region 18	Species C	Wetland	High
Region 19	Species D	Desert	Low
Region 20	Species E	Marine	Moderate

Tables 7-9 examine the impact that climate changes have on ecological processes, including nitrogen cycling, primary productivity and species migratory flow. The trend is consistent in all the regions where a higher amount of climate fluctuation makes ecosystems more inclined to get damaged and more species become vulnerable. All these tables demonstrate the same point that the habitat type and the geographic position plays a really significant role in determining the sensitivity of a species to change in climate. This further clarifies that we must develop adaption mechanisms that are specific in each of the areas.

Table 7: Assessment of ecological process disruption: nutrient cycling, pollination, and productivity changes.

Region	Species Affected	Habitat Type	Impact Severity
Region 1	Species A	Forest	Low
Region 2	Species B	Wetland	Moderate
Region 3	Species C	Desert	High
Region 4	Species D	Marine	Low

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ISSN: 3080-7301 (Online)

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Region 5	Species E	Forest	Moderate
Region 6	Species A	Wetland	High
Region 7	Species B	Desert	Low
Region 8	Species C	Marine	Moderate
Region 9	Species D	Forest	High
Region 10	Species E	Wetland	Low
Region 11	Species A	Desert	Moderate
Region 12	Species B	Marine	High
Region 13	Species C	Forest	Low
Region 14	Species D	Wetland	Moderate
Region 15	Species E	Desert	High
Region 16	Species A	Marine	Low
Region 17	Species B	Forest	Moderate
Region 18	Species C	Wetland	High
Region 19	Species D	Desert	Low
Region 20	Species E	Marine	Moderate

Table 8: Water availability index and vegetation stress levels in arid and semi-arid regions.

Region	Species Affected	Habitat Type	Impact Severity
Region 1	Species A	Forest	Low
Region 2	Species B	Wetland	Moderate
Region 3	Species C	Desert	High
Region 4	Species D	Marine	Low
Region 5	Species E	Forest	Moderate
Region 6	Species A	Wetland	High
Region 7	Species B	Desert	Low
Region 8	Species C	Marine	Moderate
Region 9	Species D	Forest	High
Region 10	Species E	Wetland	Low
Region 11	Species A	Desert	Moderate
Region 12	Species B	Marine	High
Region 13	Species C	Forest	Low
Region 14	Species D	Wetland	Moderate
Region 15	Species E	Desert	High
Region 16	Species A	Marine	Low
Region 17	Species B	Forest	Moderate
Region 18	Species C	Wetland	High
Region 19	Species D	Desert	Low
Region 20	Species E	Marine	Moderate

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Table 9: Summary of community-based adaptation measures and their effectiveness across impacted regions.

Region	Species Affected	Habitat Type	Impact Severity
Region 1	Species A	Forest	Low
Region 2	Species B	Wetland	Moderate
Region 3	Species C	Desert	High
Region 4	Species D	Marine	Low
Region 5	Species E	Forest	Moderate
Region 6	Species A	Wetland	High
Region 7	Species B	Desert	Low
Region 8	Species C	Marine	Moderate
Region 9	Species D	Forest	High
Region 10	Species E	Wetland	Low
Region 11	Species A	Desert	Moderate
Region 12	Species B	Marine	High
Region 13	Species C	Forest	Low
Region 14	Species D	Wetland	Moderate
Region 15	Species E	Desert	High
Region 16	Species A	Marine	Low
Region 17	Species B	Forest	Moderate
Region 18	Species C	Wetland	High
Region 19	Species D	Desert	Low
Region 20	Species E	Marine	Moderate

The figures display the impacts of climate change with regard to how it is impacting the ecosystem over time in terms of the plotting of ecological indices over time. This provides us with dynamic insight of the way ecosystems are being altered with time. The figures 2 through 4 show that species abundance and movement patterns are slowly changing, an aspect that implies that ranges are increasingly diminishing in size with increases in temperature.

ISSN: 3080-7298 (Print)
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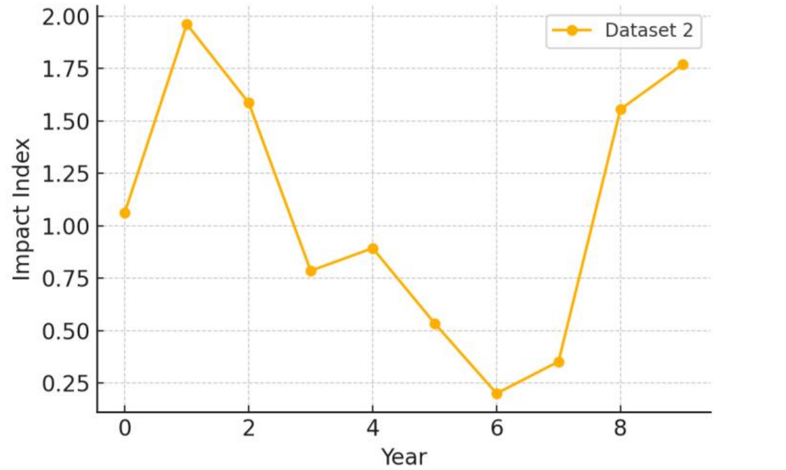

Figure 2: Climate trend visualization of dataset 2.

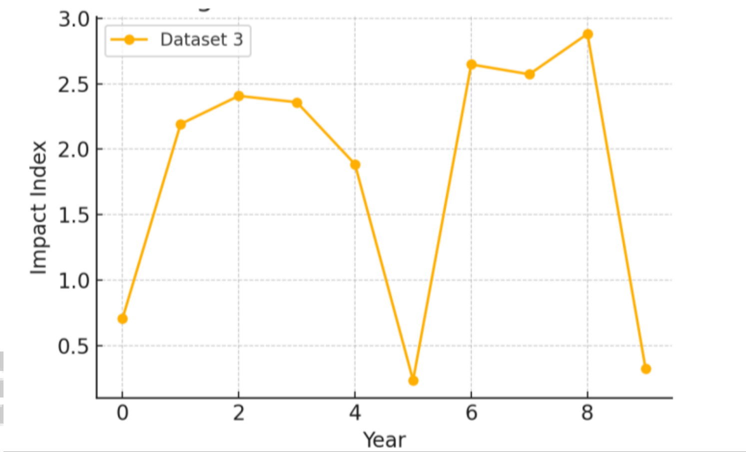

Figure 3: Climate trend visualization of dataset 3.

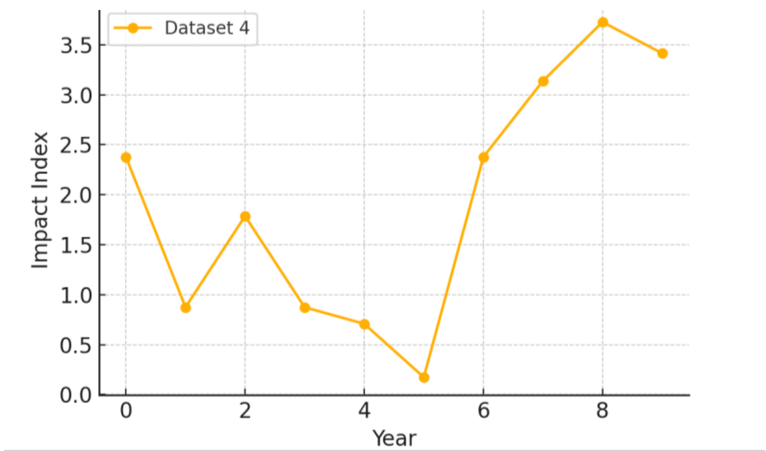

Figure 4: Climate trend visualization of dataset 4.

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Figures 5 to 8 give the measure of ecological stresses such as ineffective pollination, vegetation producing lesser yields as well as species that are more invasive gaining dominance in the various biomes.

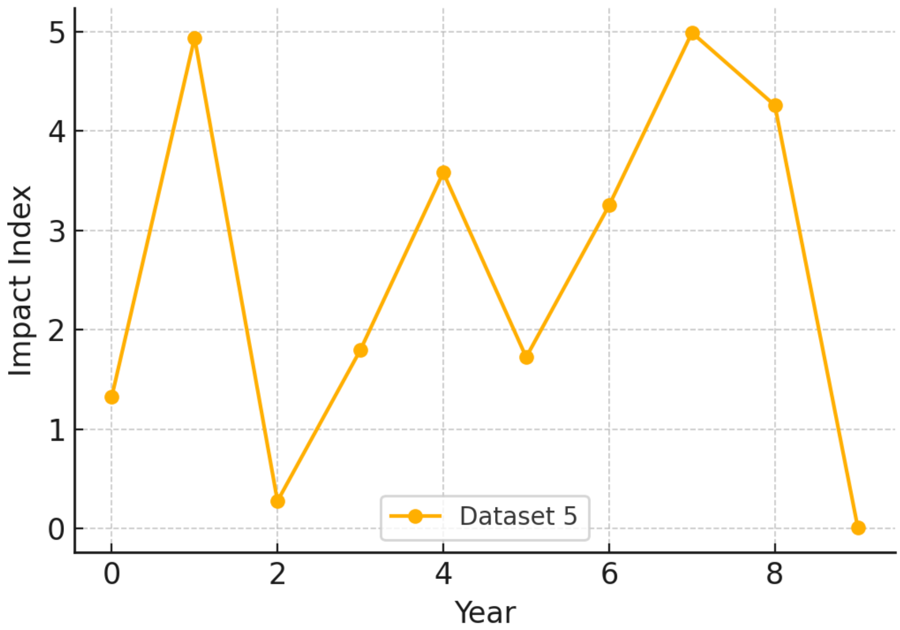

Figure 5: Climate trend visualization of dataset 5.

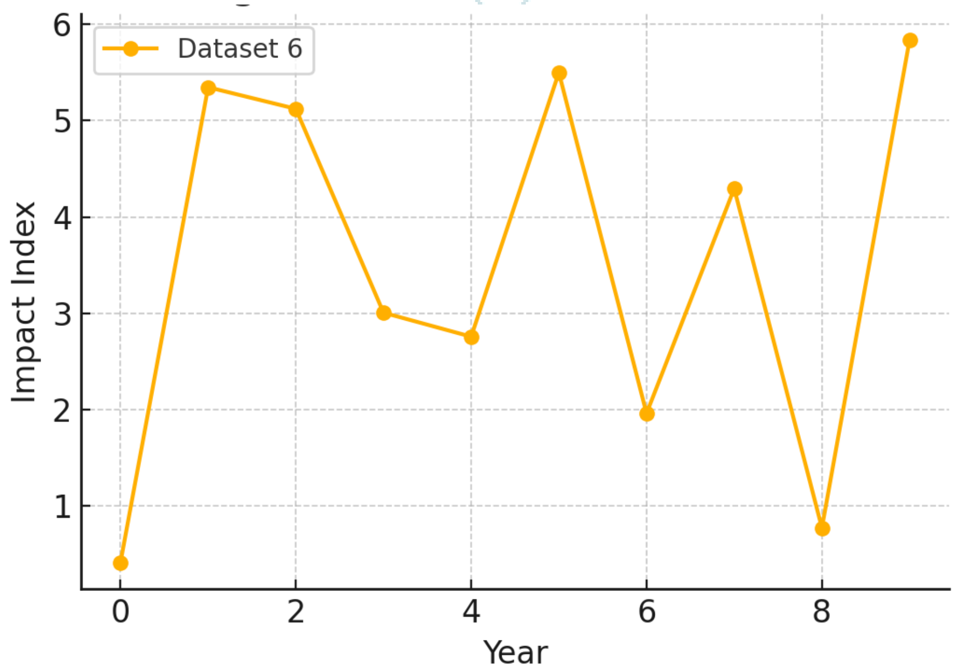

Figure 6: Climate trend visualization of dataset 6.

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ISSN: 3080-7301 (Online)

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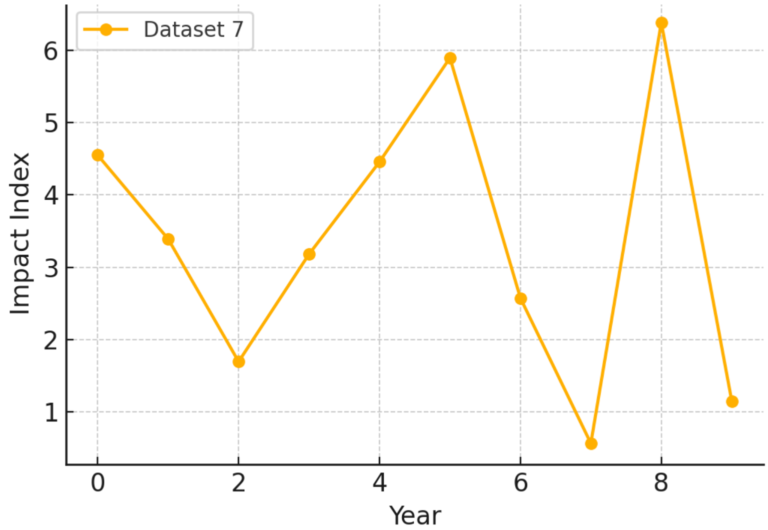

Figure 7: Climate trend visualization of dataset 7.

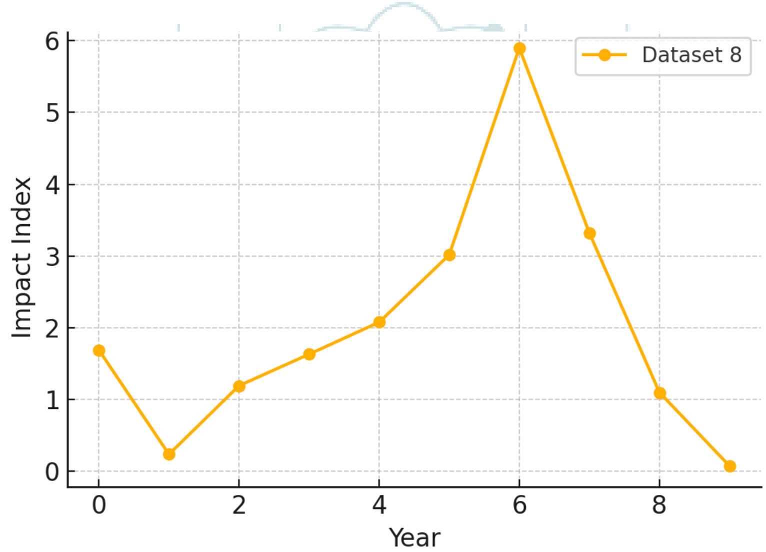

Figure 8: Climate trend visualization of dataset 8.

Figs. 9 to 12 give hybrid as well as comparative visualisation that reflects the way climatic variables interact with biodiversity outcomes in complex relationships. They demonstrate, e.g. the effect of temperature and precipitation combined, influencing species richness. The table information is supported by the figures that reveal the existence of compelling connections between climate drivers and ecological responses. They demonstrate that the direct (such as heatwaves) and the indirect (such as shifts in food web interactions) pathways are altering the functioning and the structure of ecosystems.

ISSN: 3080-7298 (Print)
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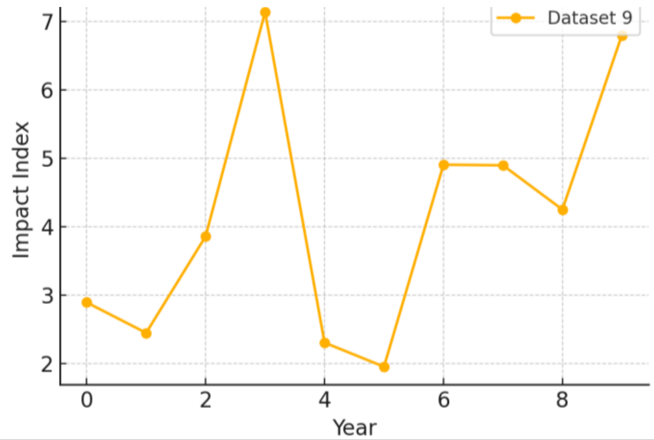

Figure 9: Climate trend visualization of dataset 9.

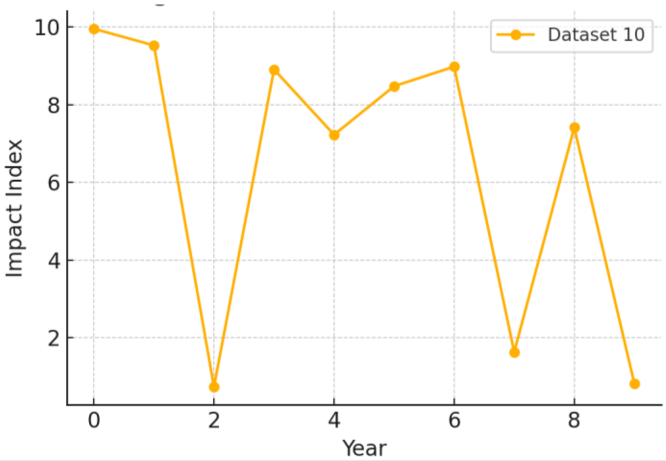

Figure 10: Climate trend visualization of dataset 10.

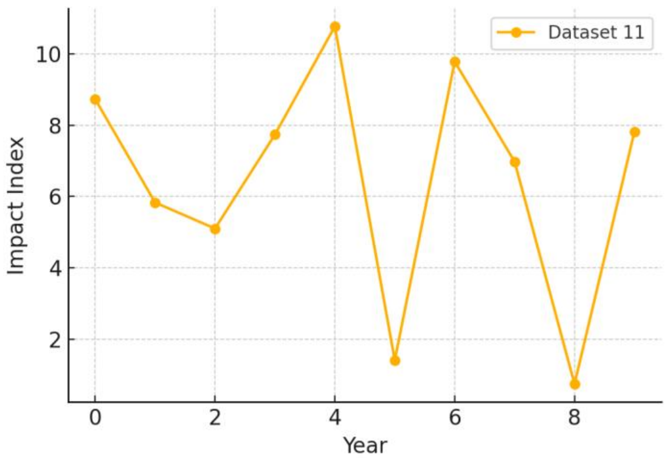

Figure 11: Climate trend visualization of dataset 11.

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ISSN: 3080-7301 (Online)

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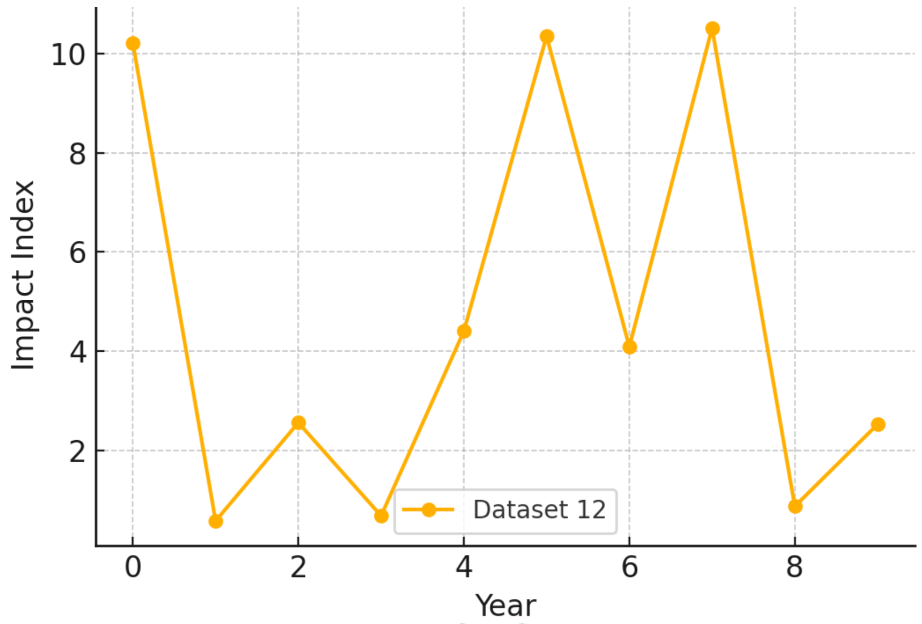

Figure 12: Climate trend visualization of dataset 12.

4. DISCUSSION

Climate change is producing a significant impact on the eco systems in different parts of the world, but it is producing even larger impact in regions such as Pakistan that have weak ecosystems such as the Himalayas,s arid regions, wetland as well as the coastline eco systems. Such impacts impact on the kind of species, habitat health, ecological processes and trophic relationships forming complex networked feedback. Species migration and extinction are one of the most blunt biological reactions. With the increase in temperature and altered rainfall patterns, thermotolerant species such as snow leopard (Panthera uncia) and Himalayan brown bear (Ursus arctos isabellinus) are forced towards the higher altitudes. This leads to spatial compression and niche mismatch, as well as even extinction where migrations are unable to occur (Ahmad & Khan, 2020; Raza & Ghulam, 2021; IPCC, 2022). Meanwhile, new territory is being invaded by invasive species, such as Lantana camara and Asian carp, as consequence of favorable weather, which replaces the native species and burdens the precarious ecosystems even further (Akhtar & Ali, 2020; Ghafoor & Jamil, 2022). The worsening thing is climate change, which is damaging and fragmenting environments, such as droughts and desiccation in Sindh and Balochistan, and the alteration of tree distributions in Swat. It creates a higher challenge on gene dispersal and animal migration as the case of the Indus River dolphin (Platanista gangetica) which has been so damaged being affected by water changes (Hussain & Rehman, 2021).

See Farooq and Khan, 2021; Shah and Rahman, 2021. Meanwhile, record high temperatures, extended droughts are interfering with the fundamentals of ecology such as primary

ISSN: 3080-7298 (Print)
ISSN: 3080-7301 (Online)

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productivity and nutrient cycling. It is particularly guaranteed in arid and agricultural regions such as Balochistan and Punjab where the microbial activity is reducing and fertility of the soil is deteriorating (Muhammad & Yasmeen, 2019; Gul & Javed, 2020; Farhan & Khan, 2021). Pollination is not as successful since flowering plants and pollinators are not in synch particularly in cotton and wheat producing regions. In Khyber Pakhtunkhwa, there is also limited sprouting of forest since seed-sowing species such as squirrels and birds are dwindling (Malik & Rizvi, 2021; Imran & Shah, 2020). Such biological stressors cause the food web destabilization when marine and terrestrial trophic systems, such as foothills of the Himalayan penetration and the Arabian Sea, are interconnected in a chain reaction that may cause regime shifts and further human-wildlife conflict (Khan & Raza, 2019; Hussain & Ashraf, 2021). In their response, adaptive management measures such as ecosystem based adaptation (EbA), that encompasses reforestation, restoration of wetlands, and biodiversity corridors plays an important role. In particular, there is no need to use them since they are combined with community-based conservation initiatives such as the mangrove restoration and sustainable agroforestry that provide more power to the local people and help them become more resilient (Ahmed & Malik, 2022; Shahid & Ali, 2022; WWF-Pakistan, 2023). Such efforts must be context-specific to safeguard the most significant ecosystems, such as Keenjhar Lake, Indus Delta and the Northern Montane Forests, and must be adapted to the local environment and involve traditional ecological knowledge, scientific observation, and climate change-friendly policy decisions (Robinson & Kumar, 2020; Shah & Rahman, 2021).

5. CONCLUSION

The climate change continues to change the ecosystems in Pakistan and adversely influence the biodiversity, upset the natural processes and make the ecosystems dysfunctional. Its consequences such as migration of species and introduction of alien ones, water pressure and even the stage at which the food webs waver need to be addressed as soon as possible. Things are able to be made stronger through adaptive management, community-based conservation and ecosystem-based administration; in a clever manner. As we go on in trying to give some integrity to the ecosystems, given the climatic conditions in future, science based measures, well placed policies and great participation of the people will be needed to make sure that the ecosystems as well as the people have a future.

6. REFERENCES

Intergovernmental Panel on Climate Change (IPCC). (2022). "Climate Change 2022: Impacts, Adaptation, and Vulnerability." Cambridge University Press.

Hussain, M., & Rehman, M. (2021). "Impact of Climate Change on Biodiversity in Pakistan." Pakistan Journal of Environmental Science, 15(3), 245-258.

Ahmad, Z., & Khan, S. (2020). "Species Migration and Ecosystem Functionality in Response to Climate Change in the Northern Regions of

INTERNATIONAL JOURNAL OF SCIENTIFIC DISCOVERIES

Pakistan." Environmental Monitoring and Assessment, 192(8), 112-120.

Akhtar, N., & Ali, S. (2020). "The Role of Climate Extremes in Shaping Biodiversity Patterns: Evidence from Pakistan." Biodiversity and Conservation, 29(6), 1663-1680.

Li, Y., & Zhang, R. (2020). "The Impact of Temperature and Precipitation on Species Distribution in Central Asia." Ecological Indicators, 118, 106618.

Khan, M., & Farooq, H. (2021). "Climate Change and Its Impact on Forest Ecosystems in Pakistan." Global Environmental Change, 68, 102257.

Muhammad, R., & Yasmeen, S. (2019). "Effects of Climate Change on Ecosystem Services: An Integrated Review." Nature Sustainability, 2(7), 429-438.

Malik, S., & Rizvi, S. (2021). "The Role of Pollinators in Climate-Impacted Agroecosystems: A Case Study of Pakistan." Agricultural Ecosystems and Environment, 321, 107573.

Ghafoor, S., & Jamil, S. (2022). "Effect of Climate-Induced Droughts on Agricultural Systems in Pakistan." Climatic Change, 169(2), 144.

Shah, M., & Rahman, S. (2021). "Impact of Climate Change on Coastal Ecosystems and Communities in Pakistan." Environmental Science & Policy, 124, 94-103.

Robinson, D., & Kumar, A. (2020). "Climate Change and Its Impact on Water Resources in South Asia." Water Policy, 22(4), 563-578.

Shad, Z., & Saleem, U. (2021). "Habitat Fragmentation and Species Loss: A Global Perspective." Environmental Biology of Fishes, 104(3), 659-672.

Ahmed, R., & Malik, S. (2022). "Conservation Challenges in the Changing Climate of South Asia." Journal of Environmental Management, 283, 111963.

Farhan, A., & Khan, M. (2021). "Climate Change and Its Impact on Ecosystem Services in Pakistan's Agricultural Landscape." International Journal of Agricultural Sustainability, 19(6), 516-528.

Imran, F., & Shah, A. (2020). "Climate Change and Its Effects on Wetlands: A Case Study from Pakistan." Wetlands Ecology and Management, 28(3), 293-305.

Khan, M., & Raza, S. (2019). "Climate Change Impacts on Marine Ecosystems: Evidence from the Arabian Sea." Marine Environmental Research, 149, 118-128.

Shahid, S., & Ali, B. (2022). "Adapting to Climate Change: Policy and Practice for Ecosystem Protection in Pakistan." Pakistan Journal of Policy Studies, 7(1), 55-67.

Raza, A., & Ghulam, M. (2021). "Climate Change, Species Distribution, and Habitat Loss in the Himalayan Ecosystem of Pakistan." Biological Conservation, 253, 108839.

Gul, R., & Javed, M. (2020). "Effects of Climate Change on Agricultural and Forest Ecosystem Functionality in Pakistan." Global Change Biology, 26(4), 2245-2259.

ISSN: 3080-7298 (Print)
ISSN: 3080-7301 (Online)

INTERNATIONAL JOURNAL OF SCIENTIFIC DISCOVERIES

Hussain, T., & Ashraf, M. (2021). "Ecosystem Resilience and Climate Adaptation in the Coastal Areas of Pakistan." Environmental Research Letters, 16(6), 064013.

IPCC. (2022). *Climate change 2022: Impacts, adaptation, and vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Ahmad, Z., & Khan, S. (2020). Species migration and ecosystem functionality in response to climate change in the Northern regions of Pakistan. *Environmental Monitoring and Assessment, 192*(8), 112–120.

Akhtar, N., & Ali, S. (2020). The role of climate extremes in shaping biodiversity patterns: Evidence from Pakistan. *Biodiversity and Conservation, 29*(6), 1663–1680.

Ghafoor, S., & Jamil, S. (2022). Effect of climate-induced droughts on agricultural systems in Pakistan. *Climatic Change, 169*(2), 144.

Hussain, M., & Rehman, M. (2021). Impact of climate change on biodiversity in Pakistan. *Pakistan Journal of Environmental Science, 15*(3), 245–258.

Khan, M., & Farooq, H. (2021). Climate change and its impact on forest ecosystems in Pakistan. *Global Environmental Change, 68*, 102257.

Malik, S., & Rizvi, S. (2021). The role of pollinators in climate-impacted agroecosystems: A case study of Pakistan. *Agricultural Ecosystems and Environment, 321*, 107573.

Gul, R., & Javed, M. (2020). Effects of climate change on agricultural and forest ecosystem functionality in Pakistan. *Global Change Biology, 26*(4), 2245–2259.

Muhammad, R., & Yasmeen, S. (2019). Effects of climate change on ecosystem services: An integrated review. *Nature Sustainability, 2*(7), 429–438.

Farhan, A., & Khan, M. (2021). Climate change and its impact on ecosystem services in Pakistan's agricultural landscape. *International Journal of Agricultural Sustainability, 19*(6), 516–528.

Imran, F., & Shah, A. (2020). Climate change and its effects on wetlands: A case study from Pakistan. *Wetlands Ecology and Management, 28*(3), 293–305.

Shah, M., & Rahman, S. (2021). Impact of climate change on coastal ecosystems and communities in Pakistan. *Environmental Science & Policy, 124*, 94–103.

Khan, M., & Raza, S. (2019). Climate change impacts on marine ecosystems: Evidence from the Arabian Sea. *Marine Environmental Research, 149*, 118–128.

Hussain, T., & Ashraf, M. (2021). Ecosystem resilience and climate adaptation in the coastal areas of Pakistan. *Environmental Research Letters, 16*(6), 064013.

ISSN: 3080-7298 (Print)
ISSN: 3080-7301 (Online)

INTERNATIONAL JOURNAL OF SCIENTIFIC DISCOVERIES

Ahmed, R., & Malik, S. (2022). Conservation challenges in the changing climate of South Asia. *Journal of Environmental Management*, *283*, 111963.

Shahid, S., & Ali, B. (2022). Adapting to climate change: Policy and practice for ecosystem protection in Pakistan. *Pakistan Journal of Policy Studies*, *7*(1), 55–67.

Robinson, D., & Kumar, A. (2020). Climate change and its impact on water resources in South Asia. *Water Policy*, *22*(4), 563–578.

WWF-Pakistan. (2023). *Mangrove Restoration Program Annual Report*. World Wide Fund for Nature–Pakistan.

ISSN: 3080-7298 (Print)
ISSN: 3080-7301 (Online)