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Research Article

# Assessment of climate change mitigation and changed cropping patterns for extensive periods at various scales

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## ABSTRACT

Climate changes arise due to drastic changes in weather patterns, temperature variations, drawdown water table, wind, and atmospheric pressure. To know farmers' perception about climate change and its impact on agriculture. A study was conducted in District Dir Lower (A hilly and rain-fed area with a subsistence farming system), Khyber Pakhtunkhwa, Pakistan. This study showed that there was a significant change in cropping patterns. The major crops still are wheat (90 % area), maize (*Zea mays*) and rice (*Oryza sativa*) (30 % and 29% area, respectively). At the same time, some of the crops were eliminated due to area limitations and economic benefits i.e. Opium (*Papaver somniferum* L.). The increase in the number of animals or their preferences and improved crop yield were not ascribed to climate change rather were correlated with improved production technologies and adaptation strategies. Study results showed that summer has prolonged (28 weeks) and winter is getting shorter (only 8 weeks) while spring and autumn have shrunk (about 4 and 3.5 weeks respectively) significantly or in some cases disappeared altogether. The monsoon rains are received about 4 to 5 weeks later while winter rains are received about 6 to 7 weeks later as compared to the past. The temperature of the four seasons (Winter, Spring, Summer and Autumn) has increased by 20, 27, 30 and 27% respectively. Water table depth was reported down (by about 30 to 40 feet) in various areas of the district, especially in the areas where eucalyptus trees were grown abundantly.

**Keywords**: Adaptations. Climate Change. Cropping Pattern. Seasonal Variations. Water Table.

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## INTRODUCTION

Climate change refers to variations in atmospheric conditions over longer periods that occur due to human and natural phenomena. These phenomena increase the Earth's temperature by emitting high levels of greenhouse gases (GHG) into the atmosphere (Zein *et al*., 2015). It has emerged as a limiting factor for agricultural productivity worldwide due to water scarcity, inferior quality production, and pest occurrence in agriculture farms (Lipczynska-Kochany, 2018). Similarly, Pakistan's agricultural society has also observed food and water shortages along with variations in weather patterns and tendencies that have badly influenced forest and livestock management (Hussain *et al*. 2020). As the global temperature is expected to rise by 3°C by 2040 and 5°C to 6°C by the end of this century, Pakistan has been the 7th most vulnerable country to the risks of climate change from 1996 to 2015 according to the latest Global Climate Risk Index 2017 report of “GERMANWATCH” (nonprofit organization) (Kreft *et al*., 2017). Pakistan lies in a heat surplus zone, where the temperature increases are expected to be higher than the global average, adversely affecting its agriculture sector, which is the backbone of Pakistan’s economy (Janjua 2010). Over the past few years, since 2003, September has been recorded as the 4th warmest month, while the Earth's and sea surface temperatures were noted to be the 5th warmest in September ($CO_2$ Earth, 2018). The GHG emission was recorded as enormously high (5.8%) in 2010 in Pakistan and globally (Carter *et al*., 2015). Additionally, several other Asian countries like Pakistan are also facing adverse conditions of climate change due to urbanization, industrial growth for the economy, and decline of resources that led to disturbance in sustainability and ecological balance (Shaffril *et al*., 2018). These countries and the majority of the world regions are dependent on non-renewable natural resources and continuously mishandling them which need to be addressed through the implementation of climate change policies. This climate change in Pakistan have been recorded to severely influence seasons, pest outbreaks and human diseases, environmental conditions (uneven rainfalls, water shortage, temperature fluctuations, land sliding, earthquakes), and Himalayan glaciers melting at a very rapid rate (Hussain *et al*., 2018).

Climate change is vigorously decreasing the production of cereals such as wheat and rice. With a 1 °C increase in temperature, there will be approximately 0.02% loss in wheat production by 2030, while a 2 °C increase will lead to 0.75% loss. The agricultural lands are suffering a lot due to intense heat, higher water demands and less available water due to weak monsoon and less rainfall in the northern half (Rasul, 2008). Similarly, the fisheries sector will also be influenced negatively due to high water temperatures with less availability. Thus, climate change seriously affect livelihood in Pakistan by disrupting day-to-day business. Due to these alterations, there are high threats to food supplies, profitability, food security, and sustainable agricultural production. The consequences could be mitigated by analyzing long-term climatic trends and agricultural adaptations at various levels (Perkins *et al*., 2018). Likewise, greenhouse gas emissions could be lowered without compromising agricultural outputs through minor modifications in agricultural practices like nutrient management, tillage methods, and water application as well as proper livestock management in livestock-crop mixed-farming systems and elevating typical agroforestry mechanisms (Aryal *et al*., 2020).

**Background and Rationale of the Study**

The farmers are involved in agricultural activities all over the world. They know that the issue of climate change is very sensitive and is of utmost importance to them. In the present study, only those farmers are successful who can perceive the effects of climate change and can adapt their production activities according to the changing climatic conditions. The present study was conducted to evaluate the farmers' perception of District Dir Lower regarding the changing climate, and its effect on the environment, wildlife, crops, fruit trees, vegetables, farming animals and agricultural activities. This study was also focused on recording the farmers' level of understanding regarding changes in climate, temperature, intensity and pattern of precipitation as well as seasonal variations. The study’s main objective was to track the impact of changing climate on Agronomic and Horticultural crops, cropping patterns, livestock, and wildlife.

## MATERIALS AND METHODS

### Study area and procedure

The data were collected from the District Dir Lower (Fig. 1) in three union councils (UC) during November 2017. The three UCs in Dir Lower included UC Khungi (Tehsil Timergara), UC Ouch (Tehsil Adenzai) and UC Munda Qala (Tehsil Munda) (Table 1).

**Table 1.** Tehsil, UC and Villages comprising respondent for FGD

| Tehsil | Union Council | Villages |
|---|---|---|
| Timergara | Khungi | Khungi bala, Khungi payeen, Shikolye, Saddo, Dabbar, Danwa, Tangy and Syar Dara |
| Adenzai | Ouch | Ouch, Maina Battan and Chakdara |
| Munda | Munda Qala | Mian Kalay, Munda Khas, Shalkandae, Guddar and Takkwaro |

Each Union Council (UC) included respondents who were farmers from various villages within the same UC, aged between 35 and 70 years. On average, they recalled climate-related changes over 20 years. These UCs were selected based on the prominence of agriculture in the area. Farmers were invited to participate and gathered at convenient locations, such as a nearby Hujra, a community center for farmers, or a building of the Agriculture Extension Department. The study team employed both qualitative and quantitative methods to capture the farmers' perceptions.

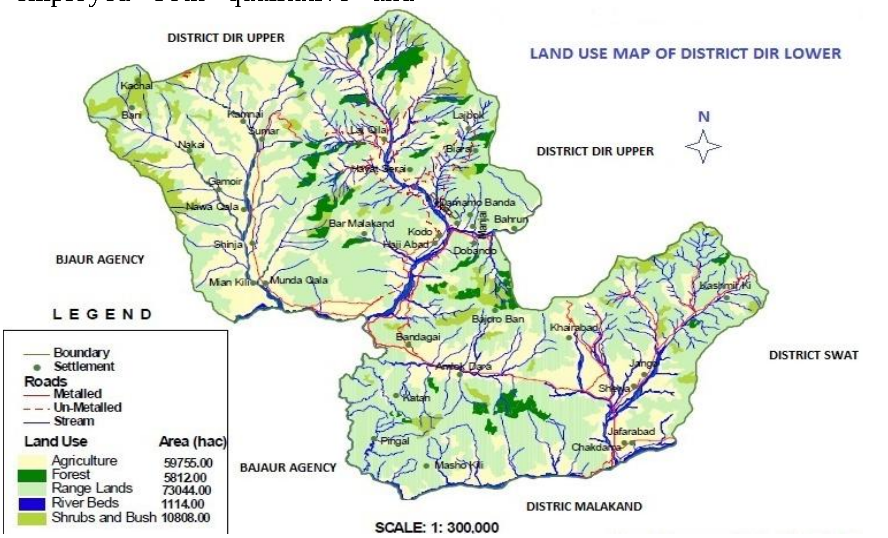


**Fig. 1.** Land Use map of the studied area (Dir Lower), KP, Pakistan.

**Geography, Site Description and Climate**

Dir Lower is one of the 26 districts of the north-western Khyber Pakhtunkhwa province of Pakistan. It lies between 34◦84' North latitude and 71◦90' East longitude with an altitude of 1112 meters above sea level. The topography of Dir Lower is dominated by mountains and hills which are part of the ranges of southern Hindukush, lies in the valley of River Panjkora. It is bounded on the north by Dir Upper district, on the east by Swat district, on the south by Malakand district and Bajaur agency, while on the west it is bordered by Afghanistan. The total geographical area of the district is 1,58,300 hectares. It is a rugged, mountainous zone with peaks rising to 5,000 meters (16,000 ft.) in the north-east. Major valleys of the area include Timergara, Jandool, Maidan, Samarbagh, and Asbanrh. The total reported area of the district is 1,42,638 ha, whereas the total cultivated area including net sown and current fallow is 41,004 ha. The forested area spans 77,515 hectares, but it is rapidly being converted into agricultural land and residential areas, primarily due to rapid population growth. The cultivable waste area is 15,389 ha and the area not available for cultivation is 8730 ha. Out of the total cultivated area, 17,643 ha is irrigated, which is only 43% of the cultivated area. Major sources of irrigation are private canals, tube wells, government canals and left pumps. Of the total cultivated area, 57% depends on monsoon and winter rains only (Nasir *et al*. 2018). The climate of Dir Lower can be described as mild temperate. The summer season is hot and winter is extremely cold, harsh and a bit long (Muhammad *et al*., 2021) in overall upper and lower Dir. A steep temperature rise occurs from May to June, and then very hot from July to the end of August but during September weather turns normal, especially at night. A rapid fall in temperature occurs from October onwards. July is the hottest month while December and January are the coldest month, and the temperature generally falls below freezing point. Annual average rainfall varies from 700 mm to 1200 mm. Most of the rainfall occurs in July, August, December, January and February and relative humidity is higher in these months. According to the Population Census of Pakistan 2017, the population of Dir Lower is 1,435,917 with a 3.7% increase from 1998 to 2017, one of the highest in the country. Total number of households is 155,338 (PBS, 2017).

**Sampling procedure**

This study followed a qualitative approach using focus group discussions (Fig. 2), guided by a well-structured questionnaire that included both open and closed-ended questions. The questionnaire covered topics such as crops cultivated over the past 20 years, shifts in cropping patterns and sequences, changes in crop and livestock productivity, variations in temperature, monsoon and winter rainfall, the frequency of dry spells and droughts, and trends in surface and groundwater availability, including drinking and irrigation water.

**Fig. 2.** Focused Group Discussion with farmers at different locations.

**Statistical analysis**

The responses and interpretations were primarily based on consensus answers, further refined by averaging data across the three Union Councils. Fractions were rounded to whole numbers. Data were organized in Microsoft Excel and analyzed using SPSS (Statistical Package for Social Scientists). Frequencies and percentages for each question were calculated and presented in tables or graphs. For non-parametric variables and to assess associations between attributes, the Chi-square test was applied using cross-tabulations, with results displayed in multi-variable or segmented bar charts (Basit *et al*., 2022).

The equation for the Chi-Square test is;

$$X^2 = \Sigma\,(Oi - Ei)2/Ei$$

Where,

O = observed frequency

E = expected frequency

For each *observed* number in the table subtract the corresponding *expected* number (*O-E*)

Square the difference $(O-E)^2$

Divide the squares obtained for each cell in the table by the *expected* number for that cell $[(O - E)^2 / E]$

Sum all the values for $(O - E)^2 / E$.

Whereas, for the calculation of frequency distribution with different responses from respondents the following formula was used (Basit *et al*., 2022).

$$Percentage = \frac{Absolute\ Frequency\ (Part)}{Total\ number\ of\ Cases\ (Whole)} \times 100$$

**RESULTS**

**Farming and crop production in the study area**

According to the study results, key winter vegetables cultivated for both commercial and household use occupy approximately 1% of the total cultivated area. These include garlic (*Allium sativum* L.), onion (*Allium cepa* L.), pea (*Pisum sativum* L.), turnip (*Brassica rapa* L.), radish (*Raphanus sativus* L.), carrot (*Daucus carota* L.), coriander (*Coriandrum sativum* L.), cauliflower (*Brassica oleracea* var. *botrytis*), spinach (*Spinacia oleracea* L.), and fenugreek (*Trigonella foenum-graecum* L.). The primary winter crop is wheat (*Triticum aestivum* L.), which covers approximately 90% of the cultivated area, followed by barley (*Hordeum vulgare* L.), mainly grown as fodder on about 4% of the land. *Brassica* (*Brassica campestris* L.) is cultivated on marginal lands, along field boundaries, and as a relay crop with wheat, accounting for around 3% of the area. Winter fruits are grown on roughly 2% of the total land.

During the summer season, the major crops are maize (*Zea mays* L.) and rice (*Oryza sativa* L.), covering approximately 30% and 29% of the cultivated area, respectively. The predominant rice varieties include Fakhre Malakand (also known as China) and JP-5 (locally referred to as Begamay). Due to limited irrigation water and low rainfall, around 30% of the land remains fallow in summer. Summer vegetables, occupying about 7% of the cultivated area, include tomato (*Lycopersicon esculentum* L.), cucumber (*Cucumis sativus* L.), various squashes (*Cucurbita* spp.; locally known as tienda, maroo, tori, and kadoo), okra (*Abelmoschus esculentus* L.), brinjal (*Solanum melongena* L.), and chillies (*Capsicum* spp.). Summer fruits, primarily stone fruits and citrus, are cultivated on about 4% of the land. Additionally, crops such as sugarcane (*Saccharum officinarum* L.), lentils (*Lens culinaris* L.), and beans (*Phaseolus vulgaris* L.) are grown on a smaller scale during their respective seasons (Fig. 3).

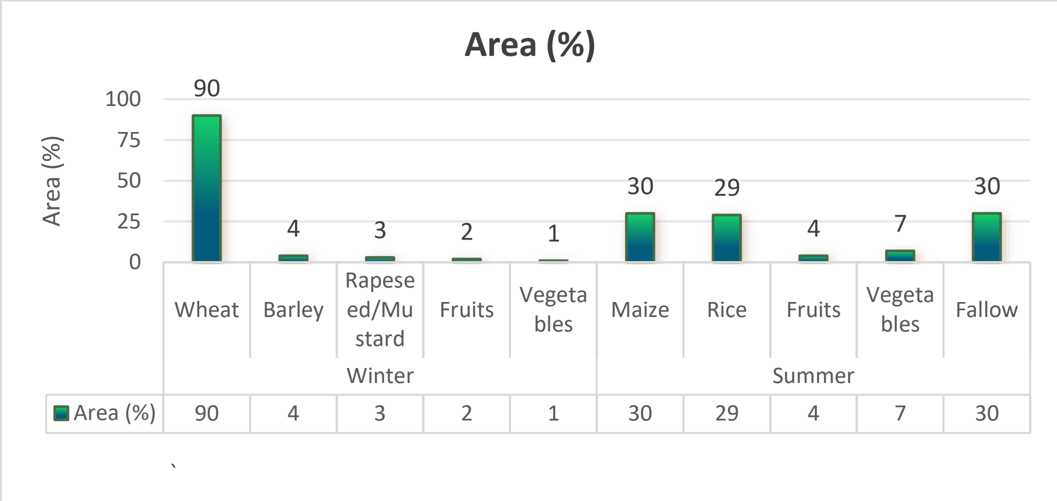


**Fig. 3.** Major crops grown at Dir Lower

### Temperature and Precipitation

Respondents unanimously reported noticeable changes in seasonal temperatures over the past 20 years (Fig. 4). Temperature increases were observed across all seasons, with a key indicator being the disappearance of winter frost. Additionally, people no longer feel the need to gather around fires for warmth during winter, as they did in the past. Winter temperatures have risen by approximately 20%, while spring temperatures have increased by about 27%. The most significant rise was observed in summer, with June–July temperatures increasing by nearly 30% compared to previous decades. Respondents attributed these seasonal temperature increases to a decline in rainfall. Similarly, autumn temperatures have increased by 27%, primarily due to the prolonged duration of summer. Rising temperatures lead to reduced rainfall, which contributes to drought conditions associated with climate change, significantly impacting crop yields.

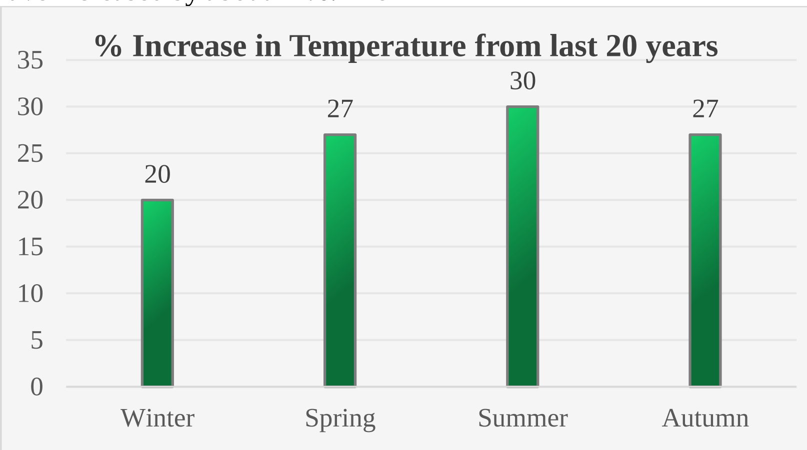


**Fig. 4.** Percent (%) increase in ambient temperature during different seasons for the last 20 years

### Change in annual precipitation

The respondents were unanimously of the opinion about larger changes in the starting time, duration and intensity of both summer monsoon and winter rainfall as compared with the last 20 years. According to the respondents, monsoon rains, locally known as *Pashakal* which typically begin about 4.5 weeks later than they did in the past, shifting from the traditional July–August period to August–September (Fig. 5).

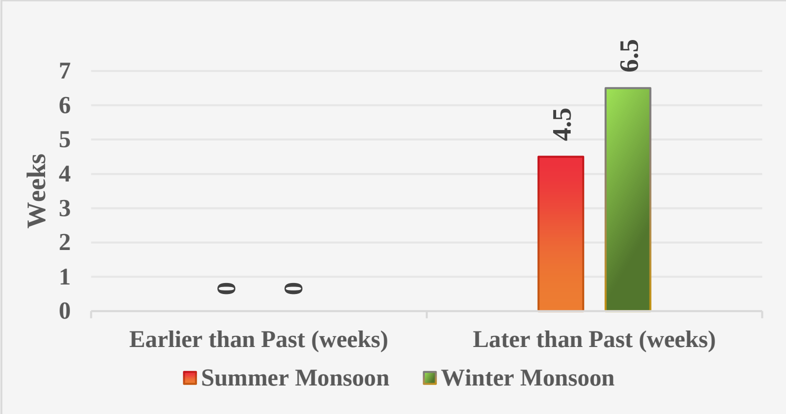


**Fig. 5.** Perception of community about earliness or lateness in summer and winter monsoon

It was also reported that winter rainfall normally starts 6.5 weeks later than usual used to occur about 20 years before. In support, they gave an argument by saying that in the past winter rains used to start before the wheat cultivation but now it is delayed and the winter rainfall starts after wheat cultivation. Some of the respondents thought that winter rainfall had almost shifted to the spring or late spring season. People also observed changes in the intensity and quantity of both the summer monsoon and winter rainfall (Fig. 6). They mentioned that summer monsoon rains have decreased by about 45%. The respondents also noticed variations in the intensity of winter rainfall over the last 20 years, and less rainfall is observed now, which is decreased by about 50% in the winter season.

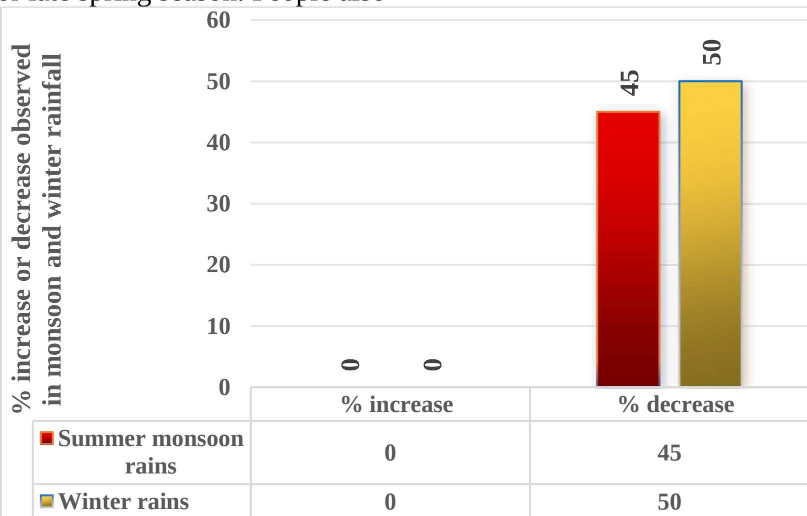


**Fig. 6.** Percent (%) increase or decrease observed in monsoon and winter rainfall amount as compared with the past 20 years

**Change in Drought condition**

Drought refers to an extended period of little or no rainfall, leading to physiological stress in key winter and summer crops. Respondents thought that the duration of the drought period has increased in various seasons as compared with the past 20 years back (Fig. 7). In the past, a dry spell in winter used to be about 3.5 weeks while nowadays, the dry period has highly increased to about 11 weeks. People argued that now most of the winter period is dry and there is no rainfall, especially in the early months. Respondents noted that winter rain used to be low in intensity and lasted for about 6 to 7 days, but now they resemble monsoon rains, characterized by short, intense downpours.

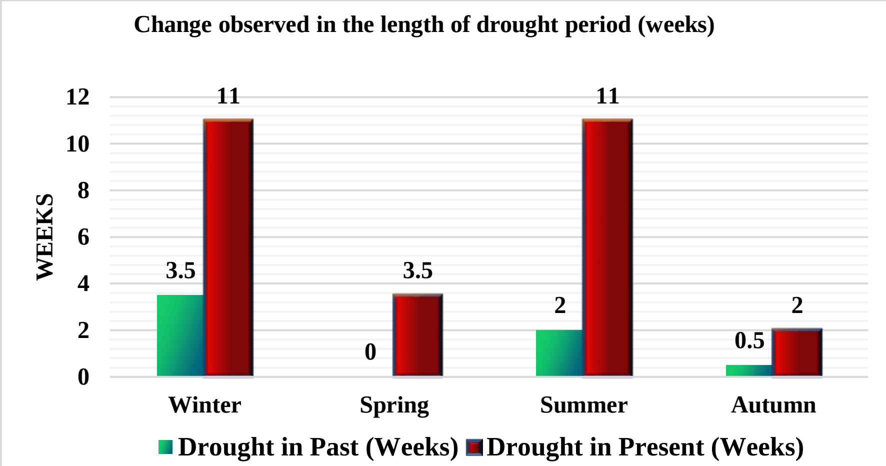


**Fig. 7.** Community's perception about change in the length of drought period (weeks) from 20 years before

According to the respondents, in the past there used to be no dry spell even for a single week in spring. Now the dry spell has increased to 3-4 weeks in spring. The summer dry spell period used to be two weeks in the past but now the drought period has increased to an average of 11 weeks. The reason why most of the farmers left their land after the wheat harvest (Fig. 8). The respondents stated that in autumn the dry period used to be less than one week but now the autumn season has become shortened and there is a dry spell for about two weeks. To support their observations of increasingly dry autumns and winters, respondents linked the rise in throat infections and cold/flu cases to prolonged, dusty conditions in the absence of rain. In recent years, winters have been nearly rainless, amounting to complete drought while winter rains appear to have shifted toward the spring season.

**Fig. 8.** Fields remained fallow in summer due to unavailability of irrigation water and no rainfall are now prepared for sowing wheat

**Change in duration of the season**

The respondents of the Lower Dir noticed variation in the length of the four seasons of the year. According to their observation, in the past length of the winter season used to be about twenty weeks (Fig. 9). Winter used to start in November and continue till March. Nowadays, the length of winter has shortened to eight weeks only. It starts in December and ends at the end of January. Spring used to be at least 8 weeks long. It used to start on 15 February and end on 15 April. Now spring is only 4 weeks and lasts in the month of March. Summer used to be about 12 weeks long starting on 15 May and ending on 15 August. Nowadays significant increase has taken place in the length of summer. It is about 28 weeks long now. It starts at the beginning of April and ends at the end of October. Autumn used to exist, having a length of approximately 6 to 7 weeks. According to the respondents, autumn has almost disappeared now, and its length is only 3 to 4 weeks. Participants reported that the autumn season has merged with winter.

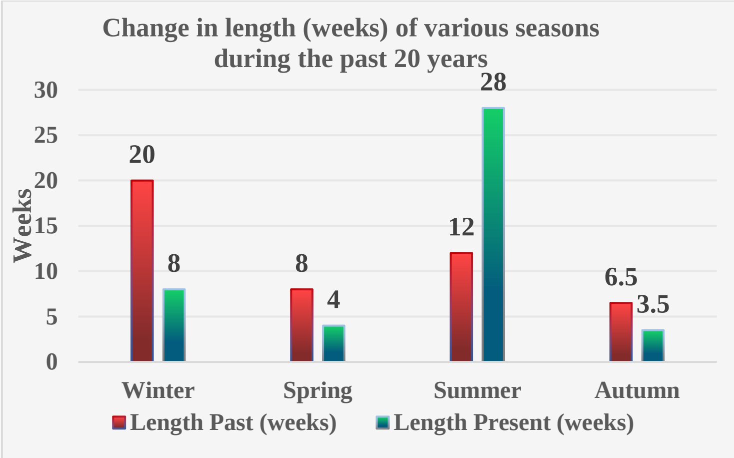


**Fig. 9.** Community's perception about change in length (weeks) of various seasons during the past 20 years

**Influence of climate change on animals' productivity and crop yields**

**Change in animals' number and productivity**

Respondents from various villages observed changes in the number and productivity of livestock, including cows, buffaloes, goats, and sheep. There was a significant increase in animal production, both in terms of numbers and the quantity of meat and milk as compared to the past. However, these increases in productivity are not attributed to climate change. Instead, the new breeds of goats and cows, modern feeding practices and nutritious food like kal (Oil cake), wanda and other fodders has increased the milk production primarily. While buffaloes have higher food demands, they are less productive than cows, which remain the dominant livestock species (Fig. 10).

**Fig. 10.** Dominant livestock species of the area (Dir Lower) is cow

Sheep, on the other hand, show reduced productivity in both milk and wool, with lower reproductive rates (typically producing only one lamb per year). As a result, the number of buffaloes and sheep has declined. In the past, livestock mainly survived on open grazing, and farmers kept male sheep primarily for fattening and slaughtering during Eid festivals. Some respondents also noted that the diminishing number of water streams has contributed to the decline in buffalo populations. However, villagers near the Panjkora River reported that the number of buffaloes has remained steady, or possibly even increased, due to the consumption of its milk as its richer in fat (Kuch) and has higher market demand.

**Change in crops' area and productivity per unit area**

Respondents from various villages observed significant increases in crop productivity, reporting much higher yields compared to the past (Fig. 11). However, these changes in crop productivity are not attributed to climate change. Instead, the improvements are credited to advances in agricultural technology, including the use of better seeds, fertilizers, pesticides, and mechanized farming methods. High yielding varieties, Quality seeds, affective pesticides and fertilizers has nearly doubled the production of wheat and maize. Rice, which was once grown throughout Dir Lower, is now only cultivated in paddy fields near the Panjkora River. The decline in rice cultivation across the rest of Dir Lower is due to a shortage of surface water, primarily from natural springs that once fed the fields. These springs, which were historically replenished by rainfall, have either dried up or significantly diminished. While tube wells have the capacity to pump water, they are not economically viable for rice irrigation. Regarding barley, respondents reported a decrease in its cultivation due to low yields and fewer livestock. Additionally, barley is considered less economical compared to wheat and maize.

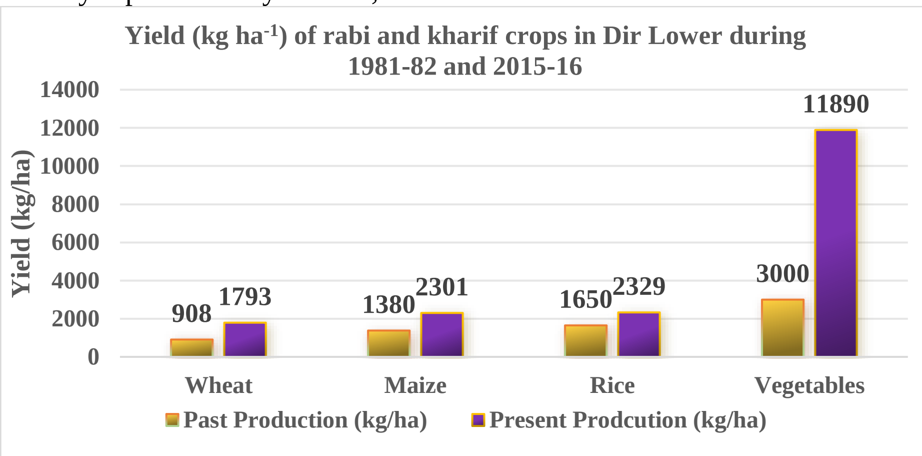


**Fig. 11.** Yield (kg ha$^{-1}$) of wheat, maize, rice and vegetables (rabi and kharif combined) in Dir Lower during 1981-82 and 2015-16

**Change in vegetables' area and productivity per unit area**

Most respondents reported an increase in vegetable cultivation and production compared to the past (Fig. 11). This trend is driven by the growing market, higher profits, and hybrid varieties. The adoption of new methods like tunnel farming, aquaculture and off-season vegetable production is expected to expand the total cultivation area for vegetables in future. One notable change is in tomato production. Farmers are now able to grow tomatoes twice a year due to the extended summer season. According to farmers, the longer summer allows for two harvests in one year.

After harvesting wheat the first crop of tomato is planted followed by the second crop in September. The higher temperatures in the October or early November are warm enough to ensure the proper harvesting of the second crop of tomato. This was not possible in the past, and it stands out as the only opportunity observed that climate change has provided for farmers.

**Current and past seasonal crops**

The respondents reported great changes in the crop area during the last 20 years. Fig. 12 shows variation in area under different crops in the past and present. According to the farmers, among the cereals, wheat area has increased. In the past, it used to grow in about 60% of the area but now it is grown in 90% of the area in winter. The reason for the increase in area is the increased demand because it is a staple food and has now become a cash crop. Both maize and rice both has decreased. In the past, these both used to grow on about 66% of the area in Kharif but now their area has decreased to 59%. In the case of maize, the decrease is due to low demand, water scarcity and shortage of rainfall but in the case of rice, it is solely due to water scarcity. Rice is now grown only on the paddy fields along the bank of the Panjkora River. In the past, during rabi about 15% of the area people used to grow barley and about 10% rapeseed/mustard. But these crops have been reduced to 4 and 3% respectively because these crops have little commercial value and the demand for wheat has increased therefore few farmers are interested in cultivating barley and mustard. The respondents stated that the cultivation of vegetables and fruits has tremendously increased. Among all vegetables, tomatoes have emerged as the most economical crop. People get two crops of tomato per year. Similarly, onion, chillies, cucumber, squashes, cauliflower turnip etc. have shown a large increase in area. Growers are showing interest in these vegetables because they are comparatively easy to grow. These are short-term crops, and their good quality seed is easily available and cash crops having higher net return. Opium used to grow in about 13% of the area but now it is not cultivated due to government restrictions.

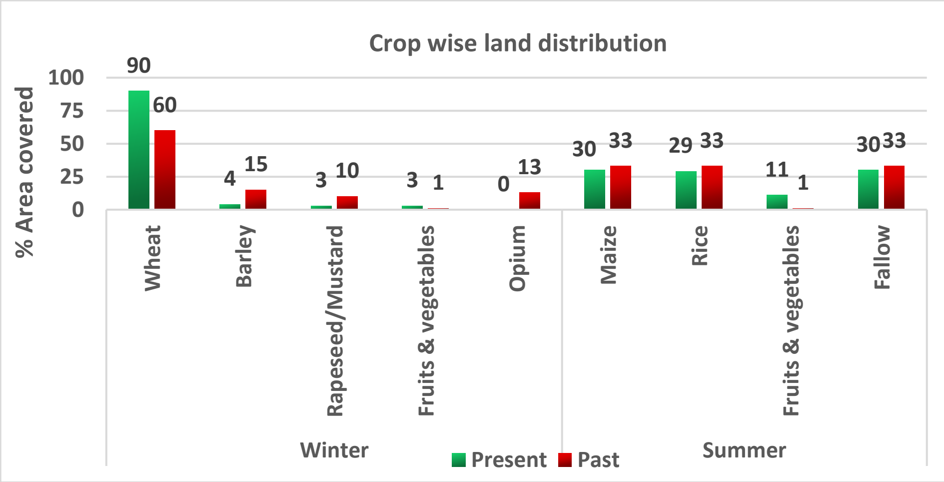


**Fig. 12.** Crop wise land distribution in present and past

**Studied reasons for the change in Cropping Pattern**

These include: 1) Water availability, 2) Demand of the crop, 3) Net return of the crop, 4) Market availability for the output, 5) Availability of technology and inputs, and 6) Change in land holdings.

**Farmer's Adaptation to Climate Change**

**Introduction of new varieties**

All respondents indicated that they now use new varieties and hybrid seeds for various crops, which are high-yielding, drought-resistant, require less water, and mature in a shorter period, resulting in higher productivity. They use new varieties of wheat for sowing under rain-fed conditions, new varieties of rice, and new hybrid seeds for vegetables and maize. The new varieties have increased their production tremendously even under unfavorable conditions.

**Change in sowing time**

Respondents noted that, due to shifting winter rainfall patterns over the years, they have adjusted their crop sowing times. They have introduced late-sowing crop and vegetable varieties that were not practiced 20 years ago. Additionally, some farmers have begun practicing tunnel farming, a method that may expand in the future depending on factors such as farmer expertise, availability of hybrid varieties, fertilizers, and market demand. A few progressive farmers are already using tunnel farming for off-season vegetable production, including tomatoes, cucumbers, squash, and chillies. This technology has gained traction in Dir, following its widespread adoption in Swat and nearby areas, where the former Swiss horticulture project, operated by Interco-operation from 1987 to 2004, played a significant role in its introduction.

**Change in weeding practices**

Respondents thought that they are nowadays mostly using weedicides instead of cultural practices for weed control. They are satisfied with the results of weedicides as compared to the past practices. Change in production due to weedicide application is prominent. They said that some of the weed species are about to be finished with the help of these weedicides and chemical sprays, however, new weeds like parthenium (*Parthenium hysterophorus* L.) are emerging which are difficult to control even with weedicides.

**Changes in irrigation practices**

The irrigation infrastructure in the Lower Dir has now changed as compared to twenty years ago. Now the respondents have their tube wells and lined watercourses in the field. The respondents stated that twenty years ago they used to depend on rainfall, water from river Panjkora and other streams. They also used to depend on natural springs for crop cultivation. The availability of irrigation water through tube wells has also played a role in changing the cropping pattern. The change in cropping pattern and productivity was made possible by the provision of electricity, diesel generators, solar systems and tube wells installation in the area.

**Change in fertilizer application**

Regarding the application of fertilizers, the respondents shared their view that they in the past used farmyard manure (FYM) for crop production but now they are well familiar with the importance and use of chemical fertilizers. Now they use fertilizers like Urea, DAP and Nitrophos etc. optimally with proper split dosage and recommended rate for crop production.

**Any other change**

The respondents stated that they have more facilities available now and their social life has upgraded as compared to the past. They said that now they can grow many crops, fruits, and vegetables in their fields. Awareness of the farmers regarding new varieties of seeds, new techniques of sowing crops, new fertilizers and the use of weedicides has increased. In the past, they had no communication facility with the relevant specialists but now with the technology improvement the communication gap has been bridged and they can get updated information easily regarding crop production.

**Changes in Land Holdings**

The respondents stated that land holdings of the people have decreased due to population increase, fragmentation and division of land. They said that construction of new houses, housing schemes, markets etc., construction of infrastructure and erosion of agricultural land due to water and wind are also some of the reasons for decreased land holdings.

**Water Availability**

The respondents stated that water for irrigation in the summer season has decreased as compared to the past 20 years, however, in late winter to early summer, there is no big issue of water availability. The main sources of irrigation water were streams, springs and rainfall which have now decreased. To overcome water deficiency, the farmers have installed tube wells, which provide water however, the water table is going down, especially in summer. As a result of tube wells installation and making new water channels, the irrigated area has increased to about 43% (Fig. 13). Drinking water was not easily available to every household but now it is available to about 90% of households. It became possible due to tube wells and wells installed on individual and community levels.

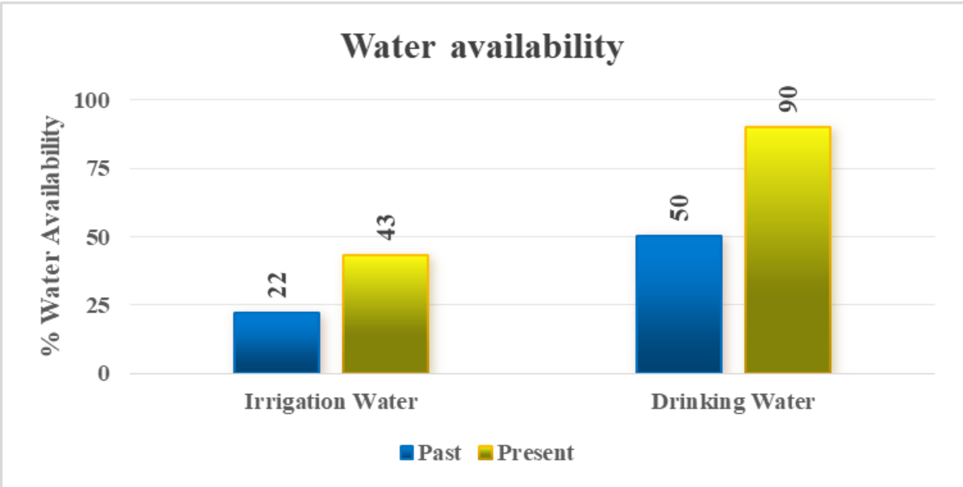


**Fig. 13** Perception of the community about water availability

**DISCUSSION**

Climate change significantly impacts on agricultural regions by reducing crop yields due to rising temperatures and erratic precipitation. Crop productivity, including cash and staple crops, has declined by 5–10% due to lower energy availability during the growing season (Hatfield *et al*., 2009). In Pakistan, per capita water availability and yields of key staples like rice and wheat continue to decline affecting food security and living standards globally (Müller *et al*., 2011). Wheat, Pakistan's primary staple, contributes over 55% of total caloric intake, particularly among poorer households (Jansen and Malik, 2010). Without adaptive policies, cereal output in South Asia may drop by 4–10% by century's end (Lal, 2011), with Pakistan's rice and wheat yields potentially declining 16–19% and 6–8%, respectively (IPCC, 2014). Strategies such as crop rotation, monoculture, and mixed cropping have shown resilience against climate impacts (Diarra *et al*., 2021). Environmental and human factors and use change, greenhouse gas emissions, and deforestation contribute to rising winter and summer temperatures. Disappearing frost and reduced fire dependence have altered seasonal cycles (Hansen *et al*., 2012). Higher temperatures shorten crop durations, reducing yields (Gregory *et al*., 2005). In 2003, a 6°C heatwave cut maize yields by 36% in Italy and fruit and forage by 25–30% in France (IPCC, 2007). Spring warming disrupts water availability and phenology (Piao *et al*., 2019). Increased heatwaves, altered rainfall, and atmospheric changes worsen droughts, reduce soil moisture, and limit crop growth (Trenberth *et al*., 2014).

Rising temperatures (0.4 °C from 1895–1995) have caused hotter days and nights, disrupting cropping patterns, increasing fallow land, land leasing, and driving farmers toward non-agricultural jobs, requiring government support (Amir *et al*., 2020). Extended summers due to autumn warming have caused irregular growing seasons, pest outbreaks, and water management issues. Prolonged heat exposure disrupts crop physiology, making them vulnerable to heat stress and reducing productivity (Hatfield and Prueger, 2015). Rising temperatures and reduced rainfall are interlinked, posing challenges unless irrigation systems improve and drought-resistant varieties are adopted (IPCC, 2021). Disturbed atmospheric patterns have led to erratic rainfall. In Pakistan, the average temperature rose by 0.57 °C and irregular rainfall increased by 25% over the past century (Chaudhry, 2017), causing floods, dry spells, glacier melt, and economic losses. Southern Pakistan suffers from severe water scarcity, with only 10 mm of annual rainfall since 2011 (Hussain *et al*. 2020), affecting 40% of the population over the last 20 years. Global agriculture faces risks from shifting water availability; enhancing water storage is crucial for sustaining food supply. Climate variability has damaged ecosystems and rural economies (Espeland and Kettenring, 2018). Advanced irrigation is needed to counter irregular precipitation. Recurrent droughts threaten rainfed agriculture (Chaudhry *et al*., 2009). Short, intense rainfalls in northern Pakistan, especially Gilgit-Baltistan, have led to droughts. Extended dry spells harm summer crops, reducing yields during critical growth stages due to water shortages (Batool *et al*., 2024). Irregular rain leads to poor soil moisture, runoff, erosion, and agricultural failure, with impacts documented in the Upper Indus Basin from 2001–2011 (Hussain *et al*., 2016).

The observed seasonal shifts in Lower Dir align with global trends, where a temperature rise of 0.6 ± 0.2 °C since 1990 has caused glacier melt, sea level rise (10–20 cm), uneven rainfall, and water shortages. These climate shifts have increased global temperatures by up to 4 °C by 2010 and led to species disappearance; a 1 °C rise affects ecological zones by up to 160 km in latitude (Qureshi and Ali, 2011). Warmer days and nights now dominate, reducing spring and autumn seasons and lengthening summer (Abbas *et al*., 2018). Pakistan, the world's fourth-largest milk producer (4.57 billion litres/year), has over 30 million people employed in livestock (Rehman *et al*., 2017). A temperature rise of 0.9 to 1.5 °C has caused severe droughts, projected to worsen by 2050. The 1998–2004 drought devastated livestock, killing 76% of animals and 84% of directly affected people due to floods (Ullah *et al*., 2018). Long-term climate impacts like water scarcity, disease, and heat stress continue to affect human health and livelihoods (Hussain *et al*., 2018). Livestock diseases have risen, reducing milk and meat production due to water shortage, poor grazing, and feed quality. Livestock contributes 60.54% of Pakistan's agricultural output and 11.22% to GDP (Government of Pakistan, 2019). Climate change is damaging feed sources like fodder and grasses. Most livestock farmers lack financial access; under 7% receive bank support, and 89% are landless (State Bank of Pakistan, 2010). With 80% of its economy dependent on agriculture and glacier-fed irrigation, Pakistan lacks adequate policies to combat the climate crisis, posing major threats to food and economic security (Balkhair *et al*., 2018).

Climate change poses serious threats to agriculture-dependent communities in mountainous regions like Dir, Pakistan, affecting both the economy and livelihoods. Rising temperatures and erratic precipitation patterns have led to reduced crop yields, especially in tropical and arid areas (Abrahão and García-garizábal, 2015). In lowlands, salinization, floods, and sea-level rise add further stress. Agriculture remains the most affected sector globally, and in Pakistan, climate change has significantly reduced productivity of major cash crops such as rice, wheat, sugarcane, and cotton, while also disrupting lifestyles (Abid *et al*., 2015). Despite some short-term gains for example, a 1.55% rise in agricultural output during the 2022 floods due to increased Rabi crop yields overall losses remain substantial. Rice and cotton yields declined by 21.5% and 41%, respectively, while maize, wheat, and sugarcane yield slightly compensated the losses (Government of Pakistan, 2023). Pakistan is projected to face a 30% reduction in cereal crops and 37% in water availability by 2059. Food security is increasingly threatened, and adaptation efforts are limited due to economic and infrastructural barriers (Hussain *et al*., 2020).

To mitigate climate change impacts, farmers in Pakistan have adopted new, improved crop varieties resistant to pests and water shortages (Touré *et al*., 2016). High-yielding seeds and underutilized varieties, known for thriving in poor soils, are being used to boost productivity (Brown, 2009). However, irregular rainfall and temperature increases have severely impacted Pakistan's economy, threatening the native genetic crop varieties (Hussain *et al*., 2016). In areas like Chitral, extreme weather events like glacial lake outburst floods and unpredictable monsoons have devastated crops and livestock. The disappearance of native species due to rising temperatures and $CO_2$ emissions has further stressed the agricultural system (Abas *et al*., 2017). To cope, farmers have adjusted sowing times and cropping patterns, with 76% changing sowing times and 46% altering cropping patterns (Amir *et al*., 2020). Despite these efforts, northern areas face lower productivity due to poor resource management. Farmers increasingly rely on traditional methods like adjusting sowing times and crop varieties, rather than advanced tools such as crop diversification and soil preservation (Abid *et al*., 2019). Governments must invest in soil and water conservation, crop insurance systems, and the development of heat- and drought-resistant varieties to help farmers adapt to climate change.

Climate change has worsen the food security issues, especially in northern regions, making farmers depend on plain areas. To adapt, farmers need advanced recovery tools, but these come at a cost. Adoption of such tools has improved food security by 8-13% and reduced poverty by 3-6% in some areas (Ali and Erenstein, 2017). Educated farmers tend to adopt new tools more quickly, and financially stable farmers are more likely to invest in advanced irrigation methods (Abid *et al*., 2016). Rainwater and terracing techniques are common in Pakistan's mountainous regions, but limited resources and knowledge hinder widespread adoption (Sardar *et al*., 2021). Fertilizers, particularly Urea and Diammonium Phosphate, contribute 30-50% to crop yields in Pakistan, playing a vital role in meeting the growing population's food needs (Yousaf *et al*., 2017). These synthetic fertilizers enhance crop growth by providing essential nutrients like nitrogen, phosphorus, and potassium. In the 20th century, fertilizers increased crop yield by 50%, with significant impacts on crops like rice (19-41%) and rapeseed (61-76%) (Yousaf *et al*., 2017). Without fertilizers, crop yields, particularly in corn and wheat, would decrease by up to 57%. However, overuse of chemical fertilizers can harm soil health, causing issues such as acidity, compactness, and nutrient imbalance. This leads to soil runoff, erosion, and reduced fertility, negatively impacting long-term crop production. Fertilizer production also contributes to greenhouse gas emissions, which affect the environment. To ensure sustainable agriculture, maintaining soil health is crucial, as it supports both ecosystem balance and food security (Phad, 2023). In regions like KPK and Punjab, fertilizers have been used to restore soil fertility lost from floods and heavy rainfall (Khalid *et al*., 2020). Climate change has made agriculture and water resources more vulnerable, necessitating strategies like groundwater restoration, rainwater harvesting, and drought-resistant crops. Adoption of advanced tools like drip irrigation and weather prediction systems is essential, with farmers' education and experience playing key roles in adapting to these changes (Amir *et al*., 2020). However, there is a need for more education to improve awareness and access to these solutions (PBS, 2017).

Urban development is rapidly growing worldwide, with a rising number of urban residents living in poverty. While agricultural land has expanded, driven by the installation of tube wells for irrigation, groundwater depletion may reverse this trend if not addressed in adaptation strategies. Many people in rural areas have shifted away from farming over the past 20 years, preferring government jobs, business, or working abroad (Atif *et al*., 2018). Migration from rural to urban areas is also disrupting ecological and socio-economic systems. Factors like small landholdings, limited access to agricultural resources, and soil erosion hinder effective adaptation to climate change, especially among farmers with fewer resources. Climate change impacts, such as food and water scarcity, heat waves, and social/political tensions, are driving migration (Ellison *et al*., 2017). The growing use of tube wells is due to better technology and economic conditions among larger farmers. However, groundwater depletion is exacerbated by highly permeable underground strata and water use for domestic purposes (Mannig *et al*., 2018). Although the water table recovers in winter, it continues to deplete due to short rainfall durations and increased demand in the warmer months (Shaffril *et al*., 2018).

## CONCLUSION

The farmers are responsible to feed the world. They are well aware that the sensitive issue of climate change is of utmost importance and needs to be addressed on priority basis to ensure food security. The study report showed a clear change in crop cultivation according to the seasons and there was a dramatic fall observed due to the abrupt climate change scenario. Not only the crops, but the temperature rise, humidity fall, and fluctuations in the average rainfall both in summers and winters have been observed by the communities in the studied areas as compared to the past decade. A huge effect on crop production, dairy farming and other cultural practices were also the factors evaluated thoroughly. On the other hand, the farmer communities have introduced new crop varieties and adapted other sources such as irrigation methods, the use of fertilizers and other technologies. Other ways should also be explored to reduce the effects of climate change and ensure food security for the upcoming generations.

### Authors' Contributions

Conceptualization and methodology, A.B; software, A.B. and H.A.; validation, A.B., I.A and A.K; formal analysis, A.B; investigation, A.B; resources and data curation, A.B. and B.R; writing-original draft preparation, A.B and A.K; writing—review and editing, H.A., A.S and S.Z; visualization, M.A., A.B. and A.N; supervision, I.K. And I.A; project administration, I.K. All authors have read and agreed to publish the manuscript."

### Conflict of Interest

The authors declare no conflict of interest

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### Data Availability

Data will be made available on a fair request to the corresponding author.

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