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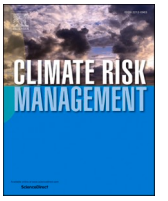

Perceptions of and adaptation to climate change in mountainous agro-pastoral communities: The case of the Afghan central highlands

Qurban Aliyar [a,b], Marzieh Keshavarz [c,*], Mohammad Wali Salari [d], David Haro-Monteagudo [e], Morteza Esmaelnejad [f], Neil Collins [g]

[a] Department of Forestry and Natural Resources, Faculty of Agriculture, Bamyan University, Bamyan, 1601, Afghanistan
[b] School of BEES & Environmental Research Institute, University College of Cork, Cork, Ireland
[c] Department of Agricultural Extension and Education, College of Agricultural Economics and Development, University of Tehran, Karaj, Iran
[d] Department of Biotechnology and Seed Production, Faculty of Agriculture, Kabul University
[e] Department of Geography and Environment, School of Geosciences, University of Aberdeen, Aberdeen AB243UF, UK
[f] Department of Geography, University of Birjand, Birjand, Iran
[g] Nazarbayev University, 53, Kabanbay batyr Ave., Nur-Sultan City 010000, Republic of Kazakhstan

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ABSTRACT

Agriculture is the primary source of livelihood for agro-pastoral families in the central highlands of Afghanistan. However, their livelihoods have been significantly affected by climate change. This study examines climate change perceptions, consequences, and adaptive capacity from agro-pastoral communities' experiences and behaviours in the five central provinces of Afghanistan. A survey was conducted in 521 agro-pastoral households to collect data on socioeconomic factors, perceptions, and adaptation indicators. The results show how agro-pastoral communities are affected by climate change, how they adapt, and which factors influence their decision-making and challenges when using traditional knowledge in adaptation. The analysed data revealed perceptions of both the positive and negative consequences of climate change. Positive consequences include shorter cold seasons, fewer avalanches, improved accessibility, reduced fuel requirements for heating, and extended grazing seasons. However, the perceived negative consequences of climate change include recurrence of severe and sustained droughts, decreased snowfall, and reduced crop yields. Additionally, K-means cluster analysis revealed low, medium, and high levels of adaptation to climate change. Agro-pastoral families have adopted various strategies to improve their adaptation to climate change, including crop, soil, water, livestock, expenditure, and livelihood management. Furthermore, socio-demographic factors, drought severity, perceived climate change, and perceived climate change impacts were the main determinants of adaptation to climate change. This study outlines the main gaps and drivers to help future researchers, managers, and decision-makers prioritize their actions based on farmers' concerns and their adaptive capacity to abate climate change impacts.

* Corresponding author at: Department of Agricultural Extension and Education, College of Agricultural Economics and Development, University of Tehran, Karaj, Iran.

E-mail addresses: keshavarzmarzieh@gmail.com (M. Keshavarz), mwalisalari@gmail.com (M.W. Salari), david.haromonteagudo@abdn.ac.uk (D. Haro-Monteagudo), esmailnejad.m@birjand.ac.ir (M. Esmaelnejad), neil.collins@nu.edu.kz (N. Collins).

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1. Introduction

Natural disasters and environmental risks pose a significant threat to agro-pastoral societies, leading to increased displacement and vulnerability (Guye et al., 2023; Schilling and Werland, 2023). This vulnerability is often exacerbated by prolonged warfare and political unrest, which reduce the resilience of these communities to climate-induced risks (Destrijcker et al., 2023; Schilling and Werland, 2023). Afghanistan is highly susceptible to climate change impacts, including variations in temperature, precipitation, snowmelt patterns, recurring droughts, and flash floods (Esmailnejad and Aliyar, 2023). With a climate change risk index of 8.2, Afghanistan is ranked as the third highest at-risk country among 190 nations (Afghanistan, 2022). In addition, this country ranks as the eleventh least prepared country for climate shocks and tenth most vulnerable to climate change worldwide (ND-GAIN, 2021). Afghanistan faces substantial climate-induced risks that amplify humanitarian needs (OCHA, 2022). Like many other developing countries, the vulnerability of Afghan agro-pastoral regions has worsened because of low agricultural productivity, rapid natural resource degradation, poor governance, and insufficient development due to economic marginalization (Chaudhary et al., 2021; Nagano and Sekiyama, 2023; Sharma et al., 2023). Therefore, a better understanding of the resilience and vulnerability of agro-pastoralists to climate variability and change is crucial for scaling up adaptation strategies (Gebeyehu et al., 2021; Tamene et al., 2023).

To assess the resilience and vulnerability of agro-pastoralists to climate change, it is imperative to identify their perceptions of climatic events. Their perception of environmental threats plays a vital role in tailoring initiatives aimed at improving environmental and agricultural activities (Mekonnen et al., 2021; Singh and Kerven, 2023). However, their perceptions of climate change are influenced by existing knowledge, local practices, and access to information, all of which can affect effective adaptation (Ali et al., 2023; Azeem and Alhafi Alotaibi, 2023; Karimi et al., 2023; Latif et al., 2023; Manh et al., 2023; Mu et al., 2023; Sujakhu et al., 2023). Previous studies highlighted a gap between perception and environmental actions, indicating that the complexity of the global problem contributes to this disparity (Empig et al., 2023; Hurlimann et al., 2023; Ojala, 2023; Wamsler et al., 2023). Nevertheless, environmental perception is likely to protect and sustain families in response to climate crises (Dhar et al., 2023; He et al., 2023; Nesbitt-Ahmed, 2023; Nosheen et al., 2023). In the local context, farmers who are aware of the effects of climate change on their enterprises are more likely to support and participate in initiatives aimed at addressing this issue (Chisale et al., 2023; Sargani et al., 2023; Sarker et al., 2023). For instance, a previous study by Aliyar et al. (2022b) revealed that perceptions of climate change influence support for adaptive actions among central highland farmers.

The central highlands of Afghanistan, housing five major river basins, are significant hotspots for both agriculture and animal husbandry (Ali and Shaoliang, 2013; Jawid, 2020). The vulnerability of the agricultural sector to climate change is particularly high in this region, impacting land coverage, water resources, mean annual precipitation, and river discharge. Over the last three decades, unexpected changes in temperature have been observed in the central areas of Afghanistan (Aliyar et al., 2022b). The rate of change surpasses global scales, with mean annual maximum temperatures rising by 0.71 °C, and significant reductions in mean annual precipitation (6.9 mm annually) between 1986 and 2016. These changes can lead to environmental degradation and profoundly affect the subsistence and well-being of rural people in terms of agriculture, water availability, and livestock grazing (Aliyar et al., 2022b; Habib et al., 2021). For instance, recurrent droughts have detrimental effects on farming systems, animal rearing, and water resources,

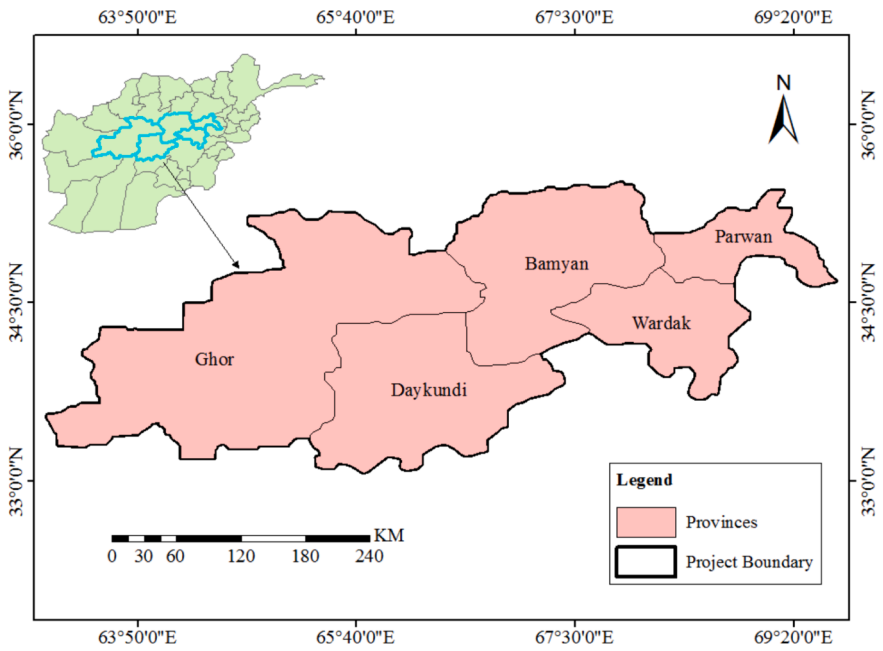

Fig. 1. Geographical location of the study area.

resulting in increased poverty rates. Droughts have affected women, children, landless individuals, and nomadic communities, who experienced livestock losses due to migration, hunger, poor rangeland conditions, and reduced water availability (Ali and Shaoling, 2013; Aliyar and Collins, 2022). Insufficient rainfall led to an approximately 50–57 % reduction in orchard production, affecting crops such as grapes, pomegranates, apples, apricots, and almonds (Qureshi and Akhtar, 2004). In addition, both irrigated and rain-fed farming systems have experienced drought impacts, resulting in a 22 % decline in planted areas and a 56 % decrease in wheat harvest (Assil and Dash, 2011). Moreover, nomadic pastoralists suffered losses of over 90 % of their sheep and 40 % of their camel population (Degen and Weisbrod, 2004), while in Samangan province alone, 1,400,000 animals were sold at low prices, with 30 % dying as a result of drought (OCHA, 2023).

There is inadequate information regarding the impacts of climate change in central areas, particularly regarding the perceptions and adaptation strategies of agro-pastoralists. Therefore, our main objectives are to: 1) determine agro-pastoralists' perceptions of climate change, 2) investigate climate change-perceived impacts and consequences, 3) identify currently applied adaptation strategies to climate change, and 4) evaluate the driving factors behind adaptation.

Gaining an in-depth understanding of farmers' perceptions of climate change in Afghanistan will be helpful in developing improved adaptation strategies to mitigate the impacts of climate change, thereby enhancing farm and pasture management, and other economic sectors.

2. Materials and methods

2.1. Study area

This study was conducted in the central highland provinces of Afghanistan, specifically in Parwan, Wardak, Bamyan, Ghor, and Daykundi (Fig. 1). These areas were selected for several reasons: (1) they are highly vulnerable to climate change impacts; (2) the livelihoods of the local population depend on agro-pastoral production; and (3) there is a dearth of information regarding climate change vulnerability in these areas. The central highland is one of the five agro-climate zones in Afghanistan, characterised by deep valleys and mountain ranges that reach up to 6,400 m above sea level (Aich et al., 2017). The population of the five provinces is 3,183,973, and the population density is 36.07 per km^2. Only 3 % of the population lives in urban areas; the rural majority is reliant on the agriculture sector for their livelihood (NSIA, 2021). The region is predominantly composed of rangelands (75 %), with 8 % classified as barren areas (Fig. 2). Agriculture occupies 8 % of the territory, and most of it is primarily irrigated (6 %), whereas a smaller portion is rain-fed (2 %). Due to the mountainous environment, agriculture in the central highlands is mainly small-scale (FAO, 2016).

The Baba Mountains range from northeast to southwest and serve as the origin of major rivers in Afghanistan, including the

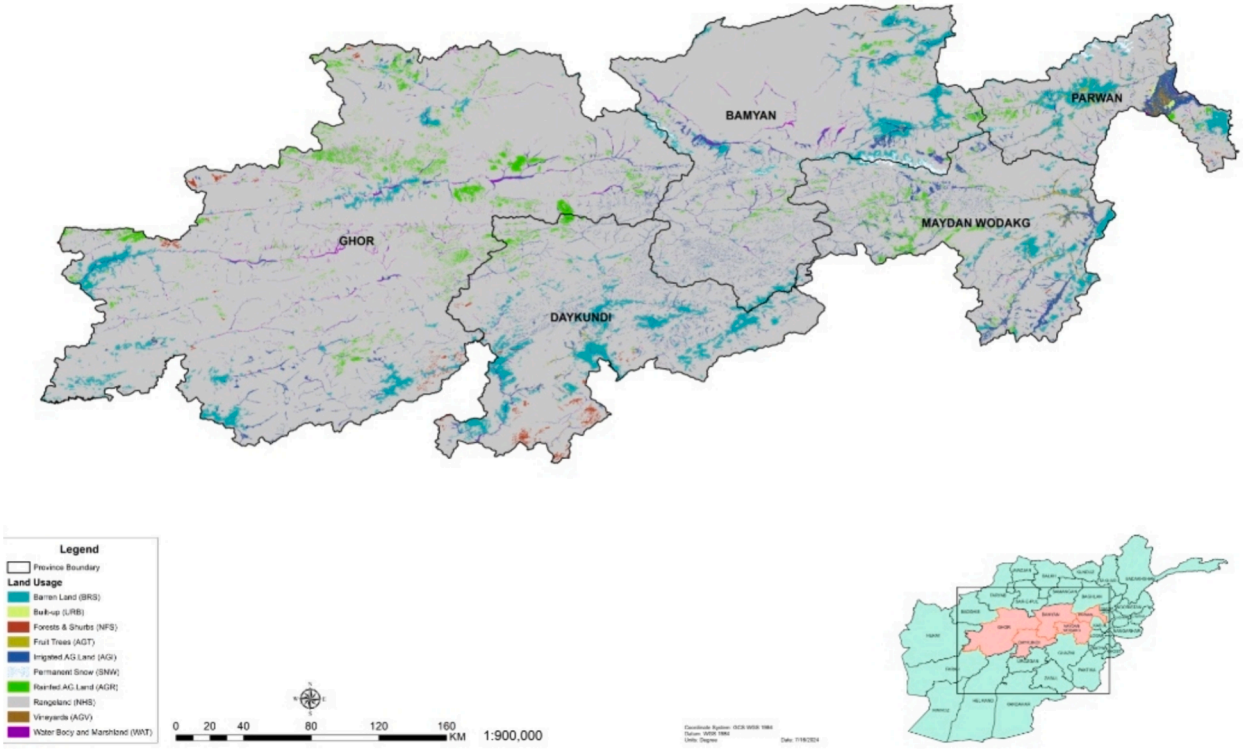

Fig. 2. Land use map of the study area.

Helmand, Kabul, Harirood, and Baghlan rivers. The climate in the central highlands is heterogeneous, with a general pattern of dry summers and cold snowy winters. Precipitation levels vary significantly both geographically, topographically, and temporally, with recorded maxima and minima ranging from 559 mm in 1991 to 90 mm in 2011 (Aliyar and Esmailnejad, 2021). The mean annual precipitation in the center of Daykundi Province was reported to be 214 mm during the period 1986–2019 (Aliyar and Eltfs, 2021). The melting of snow that accumulates during winter contributes to river discharge, and snowfall is common in the highlands during winter and early spring, leading to increased water flow in the main streams (Lashkaripour and Hussaini, 2008).

Approximately 21 % of the region's territory is situated at an altitude of 3,200 m above sea level, encompassing the summits and foothills of mountains that serve as grazing areas during the late spring and summer. The population in these areas is relatively sparse owing to harsh climatic conditions, land unsuitable for cultivation, and the difficulty of traversing steep slopes during snowfall seasons, particularly in winter. Small valleys in high mountains are home to agro-pastoral communities and small farms. In addition to farming, animal husbandry plays a significant role in the livelihoods of the local inhabitants. Nomads and shepherds graze their livestock on pastures during spring and summer, while labourers collect fodder from farms and rangelands to store for animals during snowfall seasons.

The mountains and hillsides at 3,200 m above sea level are surrounded by a series of valleys at lower latitudes, accounting for 79 % of the region's area. These valleys are typically steep and consist of scree or earth covered by thistles, coarse grass, hogweed, rhubarbs, and cushion plants. The range of species in these areas is used for grazing by animals. Potatoes and wheat are the main crops in the upper lands, whereas horticultural crops are grown in the lower areas. Local inhabitants keep livestock including sheep, goats, chickens, and cows. Communal agro-pastoralists in these areas are often characterised by low incomes, limited access to healthcare, and unreliable access to water and they live in areas where infrastructure is underdeveloped. They experience the highest levels of poverty and unemployment in all of Afghanistan.

2.2. Sampling and data collection

A semi-structured questionnaire was developed based on existing literature (Kamrimi et al., 2018; Ng'ang'a et al., 2020). A total of 25 agro-pastoral household heads were selected for pre-testing the questionnaire in the Bamyan, Parwan, Wardak, Ghor, and Daykundi provinces. Adjustments were made to improve the flow of questions based on the feedback received during the pre-testing phase, leading to the final questionnaire available in the supplementary material. The questionnaire considered socioeconomic, demographic, and agro-pastoral information. The questions covered climate change variability and consequences, perceptions, and coping techniques used by agro-pastoral families. When developing the study's goals and acquiring data from agro-pastorals, basic research ethics were considered. Agro-pastorals were also given a thorough description of the study's purpose as suggested by Karimi et al. (2018).

The final comprehensive questionnaire was used to collect data from a sample of 521 agro-pastoralist households in the study area, based on the random sample size formula of McClave et al. (2008). The household sampling frame was developed by the main researcher and facilitated by a local field assistant, respective village chief, and village elders. This sampling frame was used to proportionally calculate the sample size and randomly select households based on village population statistics (Table 1). The sample of the population was obtained from the National Statistics and Information Authority (NSIA, 2020).

A structured questionnaire was administered using open-ended questions face-to-face by a team of 15 well-trained students, and the principal investigator (PI) supervised data collection, which was conducted between May and June 2021. Information on household socioeconomic data, perceived climate change variables, including temperature rise, precipitation reduction, drought and flood incidence, pest outbreaks, wind violence, frostbite during the growing season, increased cold and heat waves, and changes in precipitation patterns. The impacts of these changes on agro-pastoralists' lifestyles were also reviewed, which included aspects such as shorter cold seasons, lower avalanche occurrence, opening of impassable paths during the winter, reduced use of fuel for heating, prolonged grazing seasons, increased opportunities for expanding horticulture areas, lower snowfall, degradation of water resources, reduction of crop yields, and adaptation to agronomic, water and soil, livestock, expenditures, and livelihood diversification, as well as the driver of adaptation.

2.3. Data analysis

The collected data were processed using IBM's Statistical Package for the Social Sciences (SPSS) version 24. Descriptive analysis percentage and quantity was performed to first provide an overall picture of climate change's perceptions and consequences for agro-

Table 1
Geographical location, population and number of survey respondents.

Central Highland	Area (km^2)	Population (2020)	Sample size (n = 520)	
			Frequency	Percentage
Parwan	5715.1	737,700	121	23
Wardak	10348.3	669,740	109	21
Bamyan	18029.2	495,557	81	16
Ghor	36657.4	764,472	125	24
Daykundi	17501.4	516,504	85	16

Source: (NSIA, 2020).

pastoral households. Second, a K-means cluster analysis was used to identify the adaptation patterns of agro-pastoralist households. The study assumed a positive relationship between each indicator and adaptive strategies, implying that higher levels of knowledge, participation, perception, and skills corresponded to higher adaptive capacities. Third, analysis of variance (ANOVA) was used to determine whether indicator values significantly differed between clusters and to infer the main determinants of adaptation strategies. Finally, hierarchical regression analysis was employed to investigate the drivers of adaptation among agro-pastoral families. Hierarchical regression analysis is a statistical method used to examine the relationship between multiple independent and dependent variables. This technique involves entering variables into the regression equation in a specified order to assess their incremental predictive power. It involves breaking down the analysis into multiple steps or levels, where each level represents a different aspect of the relationship between the variables. This method is particularly useful when there are multiple predictors of the dependent variable and when the relationship between the variables is complex. In addition, hierarchical regression analysis can help to identify which independent variables are most important in predicting the dependent variable, as well as any potential interactions between the variables. Overall, hierarchical regression analysis is a valuable tool to understand complex relationships between variables in data. The variables used for our hierarchical regression analysis were perceived climate change, perceived impacts of climate change, drought severity, and socio-demographic factors, such as age, gender, marital status, education, household size, and farming experience. In addition, the data were investigated for multicollinearity. In this respect, the strength of the correlation between independent variables was assessed by the variance inflation factor (VIF). VIF suggests moderate correlation, implying that multicollinearity was not severe enough to affect the model's variables.

3. Results and discussion

3.1. Factors associated with climate change in mountainous agro-pastoral zones

The surveyed agro-pastoralists identified several aspects associated with climate change perception (Fig. 3), with the primary ones being temperature rise (94 %), reduced precipitation (89 %), and increased frequency of drought events (87 %). This indicates a high level of awareness among the respondents, as more than 80 % acknowledged these climate change factors. Regarding other climate-related variables, respondents reported increased pest outbreaks (66.6 %), frostbite during the growing season (53.9 %), and violent winds (74.5 %). These factors have negative effects on crop productivity and livestock yield, resulting in reduced agricultural income.

The interviewees also noted increased heat waves (80.4 %) and more severe cold periods (82 %) in the study area. More frequent heat waves were observed during late spring and early summer, leading to increased transpiration from the vegetation cover. In contrast, the winter months in recent years were perceived as colder and had more snowfall events than those four decades ago. Moreover, the respondents attributed changes in precipitation patterns to changes in vegetation cover and rising temperatures. The majority of respondents (81.2 %) emphasised that fluctuating precipitation patterns have resulted in low agricultural production and food insecurity. Changing precipitation patterns have also led to floods, recurring droughts, and famine in Afghanistan, including the provinces in the area of study.

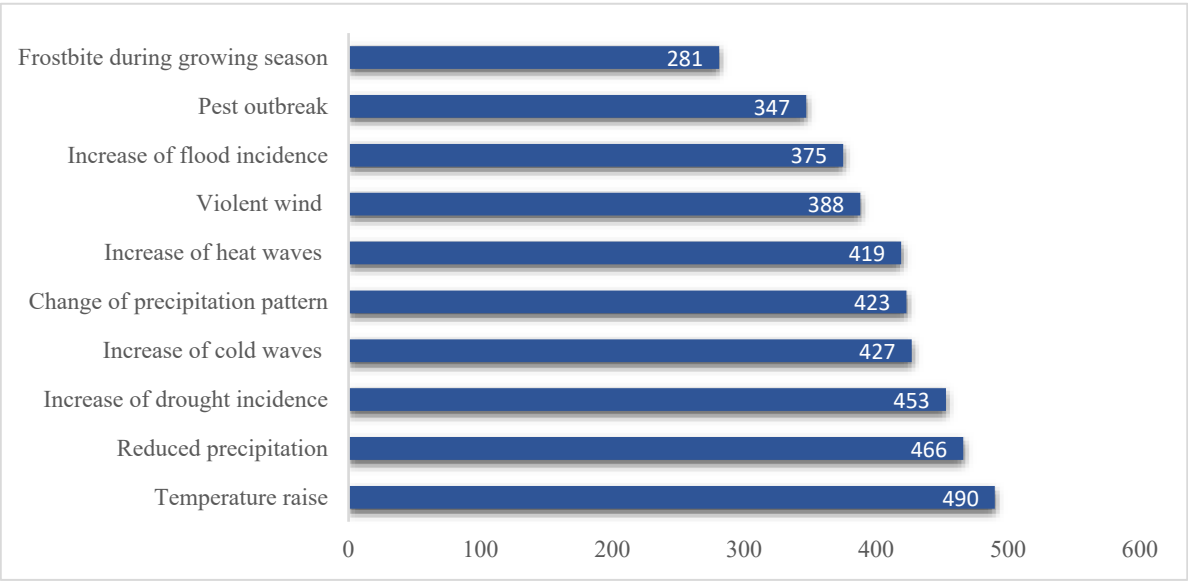

Fig. 3. Evidence of climate change as perceived by agro-pastoral families.

3.2. Climate change impacts in mountainous agro-pastoral zones

Agro-pastoralists believed that climate change would have both positive and negative consequences (Fig. 4). In mountainous areas with harsh climates, farmers have historically experienced long, cold seasons from late fall to early spring. However, they have experienced shorter cold seasons in recent years because of climate change (31.7 %). This change extended the harvest period, as snowfall occurs later in the year. Another major positive effect is the opportunity to expand cultivated areas (73.9 %). In general, farmers in both the low- and high-altitude areas of the central highlands have experienced harsh climates. However, respondents reported a decrease in avalanche occurrence (77.2 %) and the opening of impassable paths (95.4 %) during cold seasons as positive impacts of climate change. Furthermore, 92 % of the respondents stated that they have consumed less fuel for heating during cold seasons in recent years. Additionally, they noted a prolonged grazing season (90.8 %) for animal husbandry owing to rising temperatures. These observations were considered to be positive impacts of climate change in the central highlands.

In contrast, those surveyed highlighted the adverse effects of climate change on decreasing water resources, increasing recurring droughts, and reducing crop yields. All participants mentioned the increased severity and intensity of drought over the last two decades. In addition, 33.8 % of farmers attributed the lower snowfall to climate change, which was supported by historical precipitation trend analysis from 1987 to 2016, showing a notable decrease in precipitation (Aliyar and Esmaeilnejad, 2022). The degradation of water resources (78.7 %) has also been perceived as a negative impact of climate change, with reports of *karezes* (traditional underground water channels) and shallow wells drying up over the last three decades (Habib, 2014). Approximately 74 % of the respondents revealed a reduction in crop yield as a consequence of climate change, which is consistent with the findings of Savage et al. (2009), who identified a relationship between declining wheat productivity and climate change in Afghanistan.

3.3. Adaptation strategies of agro-pastoral households to climate change

The K-means cluster analysis revealed three different groups that describe the extent of adaptation to climate change amongst agro-pastoral households, categorised as follows: 1) low adaptation (31.3 % with a mean adaptation value ($\overline{A}$) of 28.25); 2) medium adaptation (41.8 %, $\overline{A}$= 30.94); and 3) high adaptation (26.9 %, $\overline{A}$= 33.91), consistent with the findings of Karimi et al. (2018), Keshavarz et al. (2014), and Zarafshani et al. (2020).

Agro-pastoralists have employed various adaptation measures to mitigate the impacts of climate change (Table 2). The results in Table 2 reveal that agro-pastoralists frequently and widely utilised agronomic strategies, such as growing early maturing and drought-tolerant crops, crop diversification and rotation, changing crop patterns and planting dates, and cultivating resistant varieties. This may be motivated by the fact that agricultural production plays a crucial role in agro-pastoralists' livelihoods in Afghanistan. Other

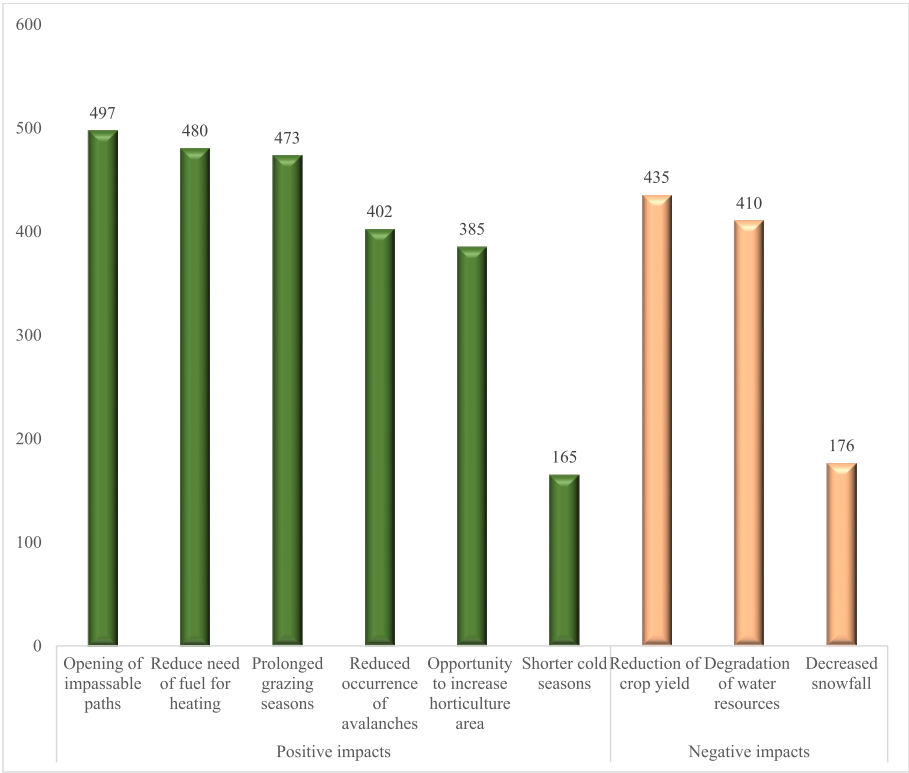

Fig. 4. Perceived impacts and consequences of climate change.

Table 2
Adaptation strategies by adaptation classes.

Adaptation strategies		Frequency of use (%)			Priority of use (rank)		
		LA	MA	HA	LA	MA	HA
Agronomic management	Growing early maturing crops	96.3	97.2	100.0	3	2	1.5
	Growing drought tolerant crops	98.1	92.2	70.0	2	3	5
	Crop diversification	77.9	56.9	20.0	9	9	15
	Changing cropping pattern	64.4	41.7	26.4	12	12	10
	Cultivating resistant varieties	33.7	50.5	67.1	17	11	6
	Changing planting date	100.0	100.0	100.0	1	1	1.5
	Crop rotation	93.3	85.8	79.3	5	5	4
Soil and water management	Construction of small check dam/pond	25.8	34.4	25.7	19	15	11
	Reduction of cultivation area	95.7	76.6	37.1	4	6	7
	Changing irrigation time	89.0	59.6	19.3	7	8	16
	Improving irrigation canals	11.0	15.1	7.9	21	20	18
	Watershed management	59.5	31.2	20.7	14	16	14
Livestock management	Raising small livestock	66.9	67.0	35.0	11	7	8
	Cultivating forage crops	31.9	12.4	1.4	18	21	21
	Forage storage	90.2	86.7	87.9	6	4	3
Expenditure management	Loan	78.5	52.3	22.1	8	10	13
	Reducing food expense	24.5	19.3	17.1	20	19	17
	Selling assets	58.3	22.0	6.4	15	18	20
Livelihood diversification	Seasonal migration	69.3	39.9	22.9	10	13.5	12
	Off-farm job	61.3	39.9	35.0	13	13.5	9
	Handicraft	48.5	25.7	7.1	16	17	19

studies have identified the widespread adoption of agronomic strategies in Afghanistan (Aliyar, 2018; Aliyar and Collins, 2022; Aliyar et al., 2022b).

These findings also highlight the interrelationship between soil and water management and agricultural adaptation practices. Approximately 30 % of the respondents in each adaptation group constructed small check dams or ponds to conserve rainwater, recharge groundwater, and prevent soil erosion. In addition, the low- and medium-adaptation groups extensively adopted reducing cultivation areas and adjusting irrigation timings. Iqbal et al. (2016) noted water management strategies against drought, including a reduction in water harvesting and minimising water wastage during irrigation. Aliyar et al., (2022b) emphasised that farmers applied irrigation methods based on affordability. These options primarily focus on risk reduction rather than maximising benefits.

However, understanding the sustainability of management strategies is crucial, particularly in supporting adaptation options. Table 2 reveals that most respondents tended to adapt reactively and on an ad hoc basis, rather than proactively. For instance, raising small animals was prominent in the low- and medium-adaptation groups (66.9 % and 47 %, respectively). Shahbaz and Boz (2020) indicated that large ruminants are more affected by climate change impacts and mixed farming, reducing the number of animals, providing more drinking water, utilising tree shade, and diversifying animal species are adaptation strategies considered by herder families. Furthermore, herders utilise their own farmland and rangeland areas for grazing and harvesting fodder during the growth season, storing it for consumption during the harsh and cold seasons. This practice was significantly applied by the majority of the adaptation groups (low, 92.2 %; medium, 86.7 %; and high, 87.9 %, respectively).

Among the traditional strategies employed by agro-pastoralists, expenditure management is a coping strategy during disasters. These results indicate that rural families rely primarily on agriculture and livestock for subsistence on a large scale. However, during climate crises, farmers have resorted to off-farm strategies. Loans emerged as an important coping strategy in the low (78.5 %) and medium adaptation (52.3 %) categories, being less prevalent in the high adaptation (22.1 %) category. Natural disasters and political instability significantly affect farmers' income from agriculture and livestock production, leaving them with limited options for revenue generation, often resulting in the sale of assets, such as tools, land portions, and animals. Approximately 58.3 % of the low-adaptation group used this strategy, while the other two groups implemented it to a lesser extent. A few households across all three adaptation categories practice reducing food expenses. These responses align with studies by Hasan and Nursey-Bray (2018), Hossain et al. (2018), and Shaffril et al. (2019), who also highlighted that taking loans, selling property, and borrowing money are adaptive strategies to overcome difficulties.

To mitigate the food shortage gap, households employ coping strategies such as seasonal migration and pluri-activity, including taking off farm jobs and making and selling handicraft products. Seasonal migration was mostly practiced by households in the low adaptation group (69.3 %), being less prevalent in the medium and high adaptation groups (39.9 % and 22.9 %, respectively). Migrants often come from larger households, and the combination of food insecurity and an induced labour shortage drives them to diversify economic risks through migration. This finding aligns with studies by Aliyar and Collins (2022) and Aliyar et al. (2022b), which highlight farmers' migration to neighbouring countries during critical conditions, with remittances potentially helping to address the impacts of disasters.

Working off farms is widely applied as a coping mechanism (see Table 2) and serves as an alternative to mitigate the effects of climatic disasters on agro-pastoralist livelihoods. However, the political situation has led to an increased unemployment rate and exacerbating poverty. Additionally, women face restrictions, including being unable to attend higher-grade school or university, resulting in decreased educational attainment and associated earning potential. In response, handicraft activities have gained

importance in women's communities. The low adaptation group engaged in handicrafts (48.5 %), such as carpet weaving, embroidery, or hand weaving of cloth and making items of clothing as a means to diversify their income streams. This finding aligns with Tabbo et al. (2016), who reported handicrafts and rural migration as the preferred strategies among farmers facing critical climate conditions.

One-way ANOVA was employed to analyse the differences in adoption rates among the adaptation groups. The results in Table 3 indicate significant differences in the adaptive strategies employed by different adaptation groups. Compared to the low- and medium-adaptation groups, households in the high-adaptation group make more use of agronomic and soil and water management strategies such as cultivating resistant varieties and adjusting cultivation area to water access. In addition, these households lost no opportunity to increase their income without relying on high interest loans or selling their assets at the lowest prices. Furthermore, most high-adaptation households make their livelihoods diversify without adopting seasonal migration (Tables 2 and 3). On the other hand, significant opportunities are provided for improving agronomic, soil, and water management strategies under climate change. However, most low-adaptation households apply low-cost strategies and make less contribution to increased soil and water sustainability (Tables 2 and 3). Even after applying various agronomic and livestock management strategies, the low-adaptation group is not economically viable and significantly relies on high-interest loan facilities and family assets. In addition, several low-adaptation families diversify their livelihoods through seasonal migration, producing handicrafts, and engaging in off-farm activities, while these income generating activities are seasonal (Tables 2 and 3). These adaptation strategies align with studies by Reddy et al. (2021) and Stringer et al. (2020).

3.4. Drivers of adaptation to climate change

Hierarchical regression analysis was conducted to identify the drivers of climate change adaptation using five models. Table 4 shows the stepwise entry of the variables into each of the models considered. Model 1 included demographic variables, such as gender, age, education, and household size. Model 2 incorporated the income variable (total annual income). Model 3 adds land size and farming experience variables. Model 4 introduced the drought severity variable. Finally, Model 5 included the variables of perceived climate change and perceived climate change impact.

The results show that the specified variables account for 45.5 % of the total variance in the adaptation of agro-pastoral households to climate change (Table 4). These calculations indicate the affirmed variables in the model and explain a notable portion of the variation in adaptation measures. Model 3, which included land size and farming experience along with the variables in Models 1 and 2, exhibited a positive and significant relationship with households' adaptation measures. It seems that the wealth of experience and indigenous knowledge possessed by farmers greatly influences their adoption of strategies, which aligns with the findings of Deressa et al. (2009) and Mogomotsi et al. (2020).

Model 4 incorporated the predictor variable of drought severity, which further increased the variation explained by 12.9 % in the sequential procedure. Model 5, which included perceived climate change and its perceived impacts, resulted in a R^2 value of 45.5 %. These findings support those of previous studies on climate change adaptation. For instance, Esham and Garforth (2013) and Khan et al. (2021) found a positive relationship between climate change perception, risk perception, and the adoption of adaptive measures. Similarly, Al-Amin et al. (2019) identified the influence of intrahousehold perception and drought severity on decision-making regarding the choice of strategies. Kuruppu and Liverman (2011) emphasised the significance of perception-based variables and human cognition as important determinants of climate change adaptation.

The standardised regression coefficients reveal that perceived climate change impacts are the main predictor of agro-pastoralism's adaptation to climate change ($\beta = 0.362$, $p \leq 0.001$), as shown in Table 5. By adding this variable to Model 5, the final model's predictive power for agro-pastoral households' adaptation to climate change increased ($\Delta R^2 = 0.149$). These results are consistent with previous studies (e.g., Biglari et al., 2019; Khanal et al., 2018) that highlighted the significant role of climate change perception in determining household adaptation.

Farming experience emerged as the second major predictor of adaptation to climate change ($\beta = 0.344$, $p \leq 0.001$), as shown in Table 5. When farming experience was added to Model 3 along with land size ($\beta = 0.161$, $p \leq 0.001$), it contributed to an 11.6 % change in R^2, indicating that the variable explained a significant portion of the variation in respondents' adaptation. This finding aligns with the results of Asfaw et al., (2019), Esham and Garforth (2013), Gebrehiwot and Van Der Veen (2013), and Pinthukas (2015). Table 5 also shows that drought severity ($\beta = 0.196$, $p \leq 0.001$) and perceived climate change ($\beta = 0.119$, $p \leq 0.005$) are significant predictors of households' adaptation to climate change. These findings suggest that farmers who have experienced severe droughts and

Table 3
Adaptation strategies followed by adaptation classes.

Management strategies	Adaptation			F	Sig.
	Low (n = 163)	Medium (n = 218)	High (n = 140)		
Agronomic management	8.36[a]	8.76[b]	9.37[c]	54.18	0.000
Soil and water management	7.19[a]	7.83[b]	8.90[c]	176.05	0.000
Livestock management	4.11[a]	4.34[b]	4.76[c]	37.36	0.000
Expenditure management	4.39[a]	5.06[b]	5.54[c]	104.32	0.000
Livelihood diversification	4.21[a]	4.94[b]	5.35[c]	88.87	0.000

In each row, means followed by the dissimilar letters differ significantly ($P<0.05$ for the least significant difference test).

Table 4
Summary results of agro-pastorals' adaptation to climate change.

Model	R	R^2	Adjusted R^2	R^2 change	*F* change	Sig. of *F* change
1[a]	0.245	0.060	0.052	0.060	7.378	0.000
2[b]	0.246	0.060	0.050	0.000	0.159	0.690
3[c]	0.420	0.176	0.164	0.116	32.267	0.000
4[d]	0.553	0.305	0.293	0.129	85.159	0.000
5[e]	0.674	0.455	0.443	0.149	62.490	0.000

[a] predictor: (constant), household size, education, gender, age.
[b] predictor: see Model 1, income.
[c] predictor: see Model 2, land size, farming experience.
[d] predictor: see Model 3, drought severity.
[e] predictor: see Model 4, perceived climate change, perceived impacts of climate change.

Table 5
Regression coefficients for final model of drivers of agro-pastoral adaptation to climate change.

Variable	Unstandardized coefficients	Standardized coefficients	*P* value
Constant	26.265	–	–
Gender	1.394	0.114	0.001
Age	−0.019	−0.101	0.091
Education	0.229	0.108	0.022
Household size	0.065	0.052	0.157
Income	−3.212E-006	−0.050	0.172
Land size	0.253	0.161	0.000
Farming experience	0.064	0.344	0.000
Drought severity	−0.439	−0.196	0.000
Perceived climate change	−0.161	−0.119	0.003
Perceived impacts of climate change	0.586	0.362	0.000

perceived more climate change have implemented more adaptive mechanisms in response to the impacts of climate change.

Furthermore, the socio-demographic attributes of agro-pastoralists, particularly gender ($\beta = 0.114$, $p \leq 0.001$) and education ($\beta = 0.108$, $p \leq 0.05$), were found to be influential in determining better adaptation measures. These findings are in line with other research that highlights the complex relationship between socio-demographic factors and adaptation, especially in predicting specified adaptation measures (e.g., Hisali et al., 2011; Reddy et al., 2021). However, Di Falco et al. (2011) found no significant influence of socio-demographic factors, such as gender, on certain adaptation attitudes like crop management and water management practices, as discussed by Esham and Garforth (2013).

4. Awareness and perceived impacts of climate change among agro-pastoralists

This study investigates the awareness of agro-pastoralists regarding climate change and its impact on the central highlands of Afghanistan, as well as how climatic stressors influence their choice of adaptation strategies. The findings revealed that most respondents demonstrated a clear awareness of climate change both in the past and future. The farmers' observations aligned well with meteorological data from the central highlands, which indicated increased temperatures and decreased precipitation (Aliyar et al., 2022b). These findings are consistent with those of other studies conducted in the central highlands of Afghanistan (Aliyar, 2018; Aliyar and Collins, 2022; Aliyar et al., 2022b; Jawid, 2020). In addition, the study highlighted the significant perception of increased frequency and severity of drought among the respondents, which is supported by research conducted in the Hindu Kush Mountains (Qutbudin et al., 2019), west Afghanistan (Bhattacharya et al., 2004; Iqbal et al., 2018), south Afghanistan (Alami et al., 2018), north Afghanistan (Omerkhil et al., 2020), Iran (Keshavarz et al., 2014), and Pakistan (Ashraf and Routray, 2013; Durrani et al., 2021). The respondents also reported an increased incidence of floods, pest outbreaks, frostbite during the growing season, violent winds, heat waves, cold waves, and changes in precipitation patterns. These assertions were supported by the occurrence of frequent and destructive floods in Afghanistan in 2002–2004, 2009, 2012 and 2019 (Beekma and Fiddes, 2014; Hagen and Teufert, 2009; Manawi et al., 2020). Similar findings have been observed in studies focusing on disease outbreaks in northwestern Afghanistan and changes in precipitation patterns in Afghanistan (Aliyar et al., 2022a; Mohabbat et al., 1976; Suryavanshi et al., 2022). These results indicate that farmers have an accurate understanding of climate change, as has been highlighted by Nunfam et al. (2019). This could be attributed to several factors. First, the socio-demographic characteristics of farmers can influence their understanding and perception of climate change. Literate farmers may have better access to information, education, and resources, which could contribute to a deeper understanding of climate change. Second, the findings suggest that awareness-raising programs implemented by NGOs or governments can play a crucial role in disseminating information about climate change and its impacts, contributing to an increase in the widespread adoption of mitigation and coping strategies. These programs aim to increase public awareness and understanding of climate-related issues including their causes, consequences, and possible adaptation strategies. Such initiatives can contribute to the knowledge and awareness of farmers, enabling them to effectively recognize and respond to climate change. Lastly, repeated exposure to

climate change impacts can enhance farmers' understanding of and concern for climate change. Farmers who have experienced the adverse effects of climate variability and change firsthand are more likely to recognise and acknowledge their existence and take the necessary measures to adapt. This experiential learning can lead to a deeper and more accurate perception of climate change. It is important to note that while these hypotheses provide possible explanations for the similarities in the findings, further qualitative research would be beneficial providing an opportunity to explore other potential factors influencing farmers' perceptions of climate change. Factors such as cultural beliefs, local knowledge systems, and communication networks within farming communities can also contribute to farmers' understanding and perception of climate change.

The study also examined the perceived effects of climate change, with respondents identifying several positive impacts, such as lower avalanches and obstruction of paths in the winter, reduced fuel requirements for heating, prolonged grazing seasons, and increased horticultural crops. Additionally, a smaller percentage of farmers considered shorter cold seasons to have a positive impact. These responses contrast with the findings of previous studies (Alary et al., 2014; Aliyar et al., 2022a; Escarcha et al., 2018; Habib, 2014; Jawid, 2020; Mandleni and Anim, 2011; Martin and Magne, 2015; Omerkhil et al., 2020; Qutbudin et al., 2019; Shahbaz and Boz, 2020; Suryavanshi et al., 2022), where farmers did not perceive the effects of climate change as opportunities but rather as challenges to their agricultural production, livestock rearing, and water security. These contrasting results seem to be related to the geographical location of Afghanistan's central highlands. In the past, heavy snowfall during cold winters isolated the region's residents, prevented them from accessing social and health services, and limited their economic activities. Increasing temperatures have paved the way for longer crop cultivation and livestock grazing, and less expenditure on fuel for heating. This is consistent with the findings of Jawid (2020), who highlighted that recent warming in the winter and predicted climate change effects are positive due to warming temperatures in the region. However, water resources and crop yield are affected by climate variability and changes in a wide variety of ways. Respondents also expressed concerns about the negative effects of climate change, including lower snowfall, degradation of water resources, and reduced crop yields. These findings are consistent with previous studies that reported declining wheat productivity in Afghanistan and adverse impacts of climate variability on water resources and crop yields (Aliyar and Esmaeilnejad, 2021; Aliyar et al., 2022b; Savage et al., 2009; Sharma et al., 2015).

Regarding adaptation to climate change, the study categorised agro-pastorals into low-, medium-, and high-adaptation groups. This classification aligns with studies that assessed farmers' vulnerability to climate hazards and identified low, medium, and high adaptive capacities (Karimi et al., 2018; Keshavarz et al., 2014; Zarafshani et al., 2020). Farmers in the study area favoured adaptation measures, such as changes in irrigation timing, improved irrigation canals, and watershed management. Shahbaz and Boz (2020) reported similar findings.

The results also identified the factors influencing the choice of specific adaptation strategies. Perceived climate change impacts, farming experience, land size, drought severity, perceived climate change, and sociodemographic factors were found to significantly affect agro-pastoralists' adaptation decisions. These findings are consistent with previous research that has emphasised the positive relationship between climate change perception, risk perception, and the adoption of adaptation measures (Al-Amin et al., 2019; Esham and Garforth, 2013; Khan et al., 2021; Kuruppu and Liverman, 2011).

5. Conclusion

Climate change poses a severe challenge to Afghanistan's central highland region. Climate-related disasters, such as recurring droughts, pose a threat to agro-pastoral livelihoods and sustainability. Therefore, it is crucial to investigate the perceptions of agro-pastoralists regarding climate change and its impacts as well as the factors influencing their adaptation decisions and practices. This study aimed to examine the struggles of the community in the face of climate crises.

The findings indicate that participants perceived climate change through increasing temperatures and decreasing precipitation, aligning with meteorological data from 1987 to 2016. The majority of respondents identified climate change based on indicators such as increased drought and flood occurrences, pest outbreaks, frostbite during growing seasons, violent winds, heat waves, cold waves, and changes in precipitation patterns. Agro-pastoralists believed that climate change would have both positive and negative consequences. Positive impacts included shorter cold seasons, reduced avalanches, improved accessibility, decreased fuel requirements for heating, extended grazing seasons, and increased opportunities for horticulture, whereas negative impacts encompassed reduced snowfall, water resource degradation, and decreased crop yields.

To mitigate the impacts of climate change, the agro-pastoralists in this study area have adopted various adaptation practices, which can be categorized as agronomic, soil and water management, livestock management, expenditure management, and livelihood diversification. It is worth noting that farmers' income in Afghanistan is heavily dependent on agricultural production, highlighting the common use of agricultural adaptation measures (e.g., cultivating early maturing crops, seed treatment, crop rotation, intercultivation systems, and non-traditional crops). Furthermore, household adaptation levels were classified into three clusters: low, medium, and high. It was observed that households with low adaptation utilized adaptive strategies significantly less. Additionally, hierarchical regression analysis revealed that the perceived impacts of climate change, drought severity, farming experience, land size, and sociodemographic factors influenced the adoption decisions of various climate change adaptation measures, emphasizing the importance of achieving sustainable development goals (SDGs) for successful climate change adaptation.

The results of this study could be beneficial for informing adaptation practices in areas affected by climate fluctuations, particularly in the central highland region. In addition, the present study has a number of implications for future research activities. This research was conducted in the Afghan central highlands, and therefore the applicability of its results is limited. Further investigations could be carried out in other mountainous and non-mountainous agro-pastoral regions to make generalizations about the perceptions of agro-pastoral households and their adaptation to climate change. Moreover, this research concentrated on the perceptions of local

households. To investigate if specialists' perceptions are consistent with agro-pastoral households, research can be directed with their collaboration. In ongoing investigations, all the information distilled from the surveys can be used to develop theories of change, or roadmaps, for climate adaptation in Afghanistan or other developing countries. This will help define clear objectives for adaptation as well as the challenges that may be faced along the way.

CRediT authorship contribution statement

Qurban Aliyar: Writing – original draft, Resources, Methodology, Investigation, Data curation, Conceptualization. **Marzieh Keshavarz:** Writing – review & editing, Validation, Formal analysis, Data curation. **Mohammad Wali Salari:** Formal analysis, Data curation. **David Haro-Monteagudo:** Writing – review & editing, Validation, Supervision. **Morteza Esmaelnejad:** Visualization. **Neil Collins:** Validation, Conceptualization.

Declaration of competing interest

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

Data availability

Data will be made available on request.

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