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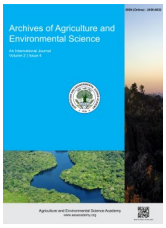

ORIGINAL RESEARCH ARTICLE

Farmers' Perceptions of the impact of climate change on apple production in lower Mustang, Nepal

Shristi Adhikari[1*], Ram Hari Timilsina[2], Anusuya Aaradhana Panthee[1] and Ashmita Sapkota[1]

[1]Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan - 44200, Bagmati Province, NEPAL
[2]Associate Professor, Department of Agricultural Extension and Rural Sociology, Agriculture and Forestry University, Rampur, Chitwan - 44200, Bagmati Province, NEPAL
[*]Corresponding author's E-mail: shristiac531@gmail.com

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ABSTRACT

Undoubtedly, climate change is becoming a worldwide concern due to its great sensitivity and detrimental effects on livelihood. The government, policymakers, and other relevant stakeholders are striving to come up with novel and innovative approaches to combat the effects of climate change. Nevertheless, understanding and perceptions of the issue among local farmers are more crucial before making mitigation or adaptation plans. It's them who are actually more exposed to these environmental works and who are on the frontlines of climate change. So, the study was conducted in 2022 at Lower Mustang to understand how farmers perceive climate change, how it has impacted apple production, and to find discrepancies between their perceptions and the actual change in climatic variability recorded by the Department of Hydrology and Meteorology (DHM). Temperature and precipitation were two climatic variables that were taken into account to investigate the significant effects they have on the rate of apple production. Altogether, 60 households from Lower Mustang were selected randomly for the study. Pre-tested interviews, focus group discussions, key informant interviews, as well as secondary data from DHM, the Ministry of Agriculture and Livestock Development (MoALD), etc. were used to collect the required information. The majority of farmers observed an increase in temperature (83.30%) and an unpredictable increase in rainfall (98%), which are consistent with the actual change in temperature and precipitation recorded between 1991 and 2021. Findings show that the average annual temperature and mean annual precipitation are increasing at a rate of 0.012°C per year and 0.4146 mm per year, respectively. This has resulted in the outbreak of significant amounts of diseases and insect pest infestations that have a direct impact on the quality and quantity of apples. The majority of farmers acknowledged that rainfall was the most significant climatic hazards that negatively impacted apple production, followed with hailstones having an impact on apples during flowering and fruiting. Farmers in the study area are limited to intercropping practices, mostly as an adaptation strategy to combat the impacts of climate change. The study concluded that farmers perceived climate change; they are aware of the term 'Climate Change' but haven't taken any significant adaptation measures towards it. So, there is an immediate need for effective adaptation mechanisms, taking into account farmers' perspectives, to make Lower Mustang self-sufficient in apple production.

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INTRODUCTION

The United Nations Intergovernmental Panel on Climate Change (IPCC) defines climate change as any change in climate over time, whether due to natural variability or as a result of

human activity (IPCC, 2007). According to the IPCC (2014), there has been a clear warming of the climate system since the 1950s, and many of the changes that have been documented are unprecedented over a period of decades to millennia. Additionally, 3.7 to 4.8 degrees Celsius of warming are expected if the warming trend continues, according to the IPCC (2014). Due mostly to population and economic expansion, anthropogenic greenhouse gas (GHG) emissions have risen since the pre-industrial era and are currently at an all-time high. This has led to atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are causing climate change (IPCC, 2007). Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability to many ecosystems, including human systems (IPCC, 2014). Food security and human livelihoods will be increasingly jeopardized beyond 2030 owing to climate change impacts (FAO, 2017).

Nepal is listed as among the ten most vulnerable countries hit by climate change (MoF, 2022). The increase in average temperature in Nepal is higher than the average temperature of the world (MoF, 2022). But it is responsible for only 0.04 percent of total GHG emissions in the world (MoF, 2022). The Himalayas are assumed to be undergoing serious climate change impacts affecting the socio-economic status of the local people living there (Chaudhary & Bawa, 2011). According to the Hindu-Kush Himalayan (HKH) Assessment Report, even 1.5 degrees Celsius is too hot for our mountains (ICIMOD, 2019). Increased temperatures, depletion of water supplies, increased northern winds, strong winds, decreased snowfall, and extended droughts were found to be the major climatic hazards in Mustang district (Khanal, 2014). Due to changes in climatic conditions, Lower Mustang, which was formerly known for producing Apple products, has experienced a fall in Apple productivity to the point where some lower belt sections no longer produce apples at all.

Apple is one of the most sustainable commodities for mountainous people living in Mustang. The total apple farming area in Mustang is 1440 ha, and production is 6,848 MT with a productivity of 12.45 MT/ha (MoALD, 2022). So, apple has contributed significantly to sustain and enhance the livelihood of apple farmers in Mustang. Commercial apple tree cultivars do best in cold, humid areas with chilly winters and cool springs and summers. However, snowfall and rain patterns have shifted as global warming increases (Bhadra *et al.*, 2021). Findings show that the average annual temperature of Lower Mustang has risen by 0.021 degree Celsius/year and annual precipitation has increased by 1.83mm/year over the last 45 years (Hamal *et al.*, 2022). Consequently, this increase in temperature and erratic rainfall have caused an outbreak of weeds, diseases, and pests that have adversely affected the quality and quantity of apples (Adhikari *et al.*, 2021).

According to the Mustang Agricultural Development Office, the district's apple production is 30% less than it was a year ago. The market demand for apples is growing annually. However, the amount and quality of apples produced in the apple garden are not satisfactory because of various diseases and insects. In particular, there has been a significant decline in apple production in the villages of Lower Mustang, such as Lete, Kobang, Khanti, Tukuche, and Marpha (Khanal, 2014). High Altitude Crops like apples have also been observed for showing offseason flowerings (Malla, 2008).

Thus, it is crucial for developing a clearer understanding of the relationship between changes in climatic variables and the rate of apple production. Temperature and precipitation were two climatic variables that were taken into account for analyzing their significant effects on apple production rates. The specific goal was to determine the difference between farmers' perceptions of and actual changes to climatic variability, as recorded by the Department of Hydrology and Meteorology (DHM). It is anticipated that the research findings will assist policymakers in making plans and strategies considering farmers' perspectives, which will lessen farmers' vulnerability to these unfavorable effects.

MATERIALS AND METHODS

Description of the study areas

Gharapjhong and Thasang Rural Municipalities of Lower Mustang were selected for the study. It is because this area suffers a huge loss in apple production at the current phase due to climatic change. To achieve the set objectives, a preliminary field visit was conducted, gathering information regarding the geographical, institutional, and socio-economic characteristics of the study area through direct field observation and informal conversation with the farmers. The pre-testing of the interview schedule for the household survey was done with 10 respondents from a nearby location, which gave us an idea of how to build a questionnaire for the research. It is very important to determine the sample size to get accurate research findings. Estimates of the registered apple farmers' data were obtained from the PMAMP PIU Mustang Apple Super Zone and Agriculture Knowledge Center (AKC) Mustang, and a sampling frame of 178 farmers was made. From these areas, 60 households were selected on a simple random basis to explore perceptions of climate change issues and identify adaptation strategies among apple-growing farmers. Simple random sampling was done to avoid any kind of bias and have an equal chance of being selected. The questionnaire was prepared in English but was asked in Nepali so that farmers could understand, get connected, and express their opinions in a more convenient manner in their mother tongue. Information on the level of understanding of farmers on climate change, ranking of climatic hazards perceived by farmers, change in climatic variables (temperature and precipitation), and its impact on flowering, fruiting, and harvesting time of apples based on farmers' perceptions was collected.

A total of three Focus Group Discussions (FGD) were conducted to generate additional information about the situation of apple production and to cross-check the information obtained from household surveys. Key informant interviews were conducted with leaders of farmers' groups, progressive farmers, and subject matter specialists of the AKC office who provided the required primary information. Climatic data for Mustang was

taken from Jomsom Meteorological Station, recorded by the Department of Hydrology and Meteorology. Furthermore, secondary data were obtained from the Ministry of Livestock and Agricultural Development (MoALD), different published and unpublished literature, annual reports, newsletters, brochures, etc.

Data analysis methods

Data analysis was done through various assistive media used for the qualitative and quantitative analysis of data, like Statistical Package for Social Science (SPSS 16 version) and Microsoft Excel. Major information obtained in the form of yes or no, increase, decrease, or not felt was changed to a dummy for further analysis. The data on area, production, and productivity were obtained from the Ministry of Agriculture and Livestock Development (MoALD) and the Agriculture Knowledge Center, Mustang. Similarly, the climatic data on rainfall and temperature was obtained from the Department of Hydrology and Meteorology (DHM), Jomsom Meteorological Station. The processing of monthly temperature data was done in the required form. If T_{max} and T_{min} represent the maximum and minimum temperature for a specific month, respectively, the monthly average temperature for each month was calculated as (T) = (Tmax+Tmin)/2. The same method was employed to calculate the annual average temperature, taking data from January to December. The processing of rainfall data was done in the required form. Collected daily and monthly rainfall data was processed to find annual rainfall (R).

$R = R_1 + R_2 + R_3 + R_4 + \ldots\ldots + R_{12}$, where, R_1, R_2, R_3, R_4, ……., R_{12} refers to the rainfall from January to December.

Likert- type scale was used for the ranking of climatic hazards. Indexing was computed by using the following formula:

$Iimp = \sum(Si^* fi / N)$

where,

Iimp = Index of importance

$\sum$ = Summation

N = No. of respondent

Si = Scale value

fi = Frequency of importance given by respondents

Qualitative information obtained during field surveys, like major climatic hazards, changes in flowering, fruiting, and harvesting times, new diseases, pests, and suggestions, was analyzed and expressed qualitatively.

RESULTS AND DISCUSSION

Farmers' perceptions about climate change

Based on the study, 55% of all respondents are aware of the term "climate change," but they are unaware of its adaptation strategies. On the other hand, 37% of respondents have quite an understanding of climate change, 1% have a better grasp of it, and 7% have no clue at all. Despite the fact that only 55% of farmers are familiar with the word, they can feel the impacts of climate change through their experiences, which was revealed during the interview schedule and Focus Group Discussion (FGD). For the highest proportion of farmers (57%), their own experiences are the source of knowledge about climate change and its impact on apple production. Besides self-experiences, 23% have learned things through the media, which is followed by organizations (19%) and neighbors and colleagues (1%).

Ranking of climatic hazards perceived by farmers

As illustrated in Table 1, the study indicated that the main climate hazards in the Lower Mustang include rainfall, hailstones, drought, floods, and landslides. Among them, the most common that has ruined apple production is rainfall, which is followed by hailstones that degrade apple quality during flowering and fruiting seasons. Drought was placed third as well, although irrigation systems have been developed in quite a few places. Similarly, floods and landslides rank in the fourth and fifth positions, respectively, which do have negative impacts on the amount and quality of apples. When asked about the impact of climate change on apple production, most of the apple farmers responded that production is reduced. According to them, the untimely, erratic rainfall has attributed the most to this reduced production.

Table 1. Ranking of Natural Hazards Based on Farmers' Perceptions, Field Survey (2022).

Natural hazards	Strongly affected	Affected	Neutral	Unaffected	Strongly unaffected	Total	Overall rank
Rainfall	57	2	1	0	0	296	I
Hailstones	2	43	9	2	4	217	II
Drought	1	6	30	12	11	154	III
Floods	0	9	18	30	3	153	IV
Landslides	0	0	2	16	42	80	V

Table 2. Shift in Flowering, Fruiting, and Harvesting Times of Apples Based on Farmers' Perceptions, Field Survey (2022).

Shift in flowering, fruiting, and harvesting times of apples	Percent
Agree	59%
Disagree	28%
Unsure	13%
Total	100%

Table 3. Change in Flowering and Fruiting Times of Apples Based on Farmers' Perceptions, Field Survey (2022).

Change in flowering and fruiting times of apples	Percent
Early	46%
Late	21%
Same	32%
No Idea	1%
Total	100%

Table 4. Change in Harvesting Times of Apples Based on Farmers' Perception, Field Survey (2022).

Change in harvesting times of apples	Percent
Same	49%
Depends on Nepalese festive seasons	32%
No idea	13%
Early	3%
Late	3%
Total	100%

Table 5. Trend of Productivity of Apples Based on Farmers' Perceptions, Field Survey (2022).

Trend of productivity of apples	Percent
Increase	31.70%
Decrease	68.30%
Total	100%

Difference between farmers perceived and actual changes in climatic variables as recorded by the department of hydrology and meteorology

Based on a ranking of natural hazards perceived by farmers, temperature and precipitation were determined to be the key climatic variables that have significantly impacted the quality and quantity of apples. According to surveyed households from Lower Mustang, there has been more temperature variance recently than there has been in previous decades. It was reported that farmers felt that summers were getting much hotter and winters were getting less chilly. Snowfall, hailstorms, and frost patterns have changed from the past. Last year, there was no snowfall. People were therefore concerned that there would be no apples in the near future if there was no snowfall.

According to farmer perception, 83.30% of farmers considered that the temperature had increased over the last ten years compared to before. 10.10% had no idea, 3.30% responded that the temperature trend had decreased, and 3% responded that it had remained the same as shown in Figure 1. This is consistent with the climate data displayed in Figure 2, which were obtained from the Department of Hydrology and Meteorology (DHM). The trend analysis of the annual average temperature of Mustang shows that it is increasing at a rate of 0.012°C per year in the last 30 years (1991-2021). This directly validates the farmers' perception of increasing temperatures. Variations in precipitation have also been widely noticed in comparison to the past based on the surveyed households. There have been changes in the amount and intensity of rainfall. During the apple's maturation phase, there was erratic and typically high rainfall, which brought with it a huge number of insects, diseases, and pest infestations that impacted the apples' flavor and quality. The majority of respondents (98%) said that rainfall has increased dramatically during the past 10 years, while 2% said that it might remain the same. This is consistent with the trend analysis of annual mean precipitation over the last 30 years (1991-2021) as recorded by the Department of Hydrology and Meteorology (DHM). The trend analysis with the equation y=0.4146x+18.228 clearly indicates the annual mean precipitation has been increasing by 0.4146mm per year, which validates the farmer's perception of having erratic rainfall patterns as shown in Figures 3 and 4. Sharing the History of Apple Farming in Mustang, one of our progressive farmers, Mr. Nirijhar Man Sherchan, shared that ''Temperature is the most important climatic factor for apple cultivation. As apples are a temperate crop, they need colder weather for a long flowering period in the winter and subsequent budding. If the normal temperature of a day is more than 25°C, flowering is not possible. For better growth and maximum production of apples, annual rainfall in the range of 1000-1200 mm is required. So, an increase in temperature and uneven rainfall is responsible for the decrease in quality and quantity of apples.

Farmers' perceptions on the effects of climate change on apple flowering, fruiting, and harvesting times

The following weather parameters are considered necessary for apple growing by the apple growers in Lower Mustang:

- Flowering season: during this season, it was good if there was no rainfall, frost, hailstorm, or windstorm.
- Fruiting season: during this season, which is the longest stage of the apple cycle, it was good if there were no hailstorms and fog, less rainfall, and enough sunshine hours and temperature.
- Enough sunshine hours were required for apple color, or nice color in apples, depending on the variety of apple. Winter season: there should be snowfall.

However, the study revealed that a majority of respondents (59%) agree that there has been a shift in the timing of apple flowering, fruiting, and harvesting due to rising temperatures and heavy rainfall. Conversely, 28% of respondents disagree, and 13% are unsure of the change, as indicated in Table 2. In terms of flowering and fruiting time, 46% of respondents said that there has been early flowering and fruiting that has rendered apples flavorless, followed by 32% who said the timing is roughly the same, 21% who said late flowering and fruiting have been observed, and 1% who said they had no idea as shown in Table 3. In terms of harvesting time, as indicated in Table 4, 49% of respondents said that the harvesting time is roughly the same, 32% said that it depends on the occasion (such as Nepalese festive seasons, which take place between August and October), 13% said they had no idea, 3% said it might be early harvesting, and 3% said it might be late harvesting compared to earlier. When asked about the impacts of such alternations in the fruiting and flowering times, apple growers in Lower Mustang said, "It rains too much, and there is almost no snow in the winter. So, we are afraid to have no apple cultivation in the near future.

Impact of climate change on apple productivity: a comparison of farmers' perceptions with trend analysis

With the change in flowering, fruiting, and harvesting times of apples, there has also been a change in apple yield in the last 5 years. The majority of farmers reported that, in comparison to the previous five years, apple productivity has gradually declined by 68.30%, as indicated in Table 5, which is consistent with data obtained from the Ministry of Agriculture and Livestock Development (MoALD) source. A normal trend line with a slope of y = -0.4732x+15.214 clearly indicates that trend analysis of apples' productivity has been decreasing in the last 5-7 years, which matches with what farmers have been reporting and is depicted in Figure 5. On the basis of three focus group discussions, what our farmers had to say about the impact of climate change on apple production is: "Apple is an easy cash crop that gives a high yield for a longer period of time and doesn't need much labor or care. However, in the last few years, various issues related to diseases and pests have emerged in apple cultivation. Every year, the amount of rain and temperature rise, giving us the impression that Lower Mustang may soon run out of apples.

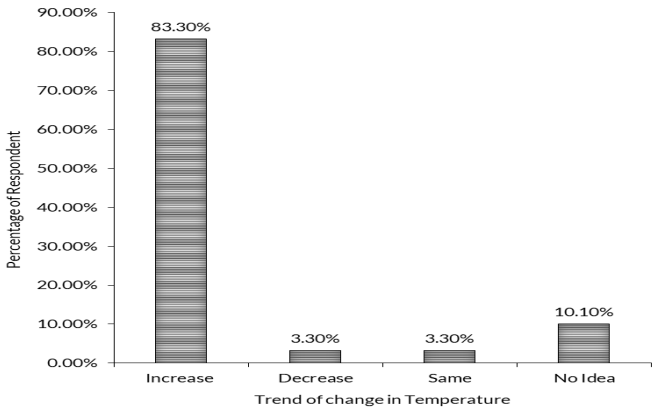

Figure 1. *Change in temperature based on farmers' perception (Field Survey, 2022).*

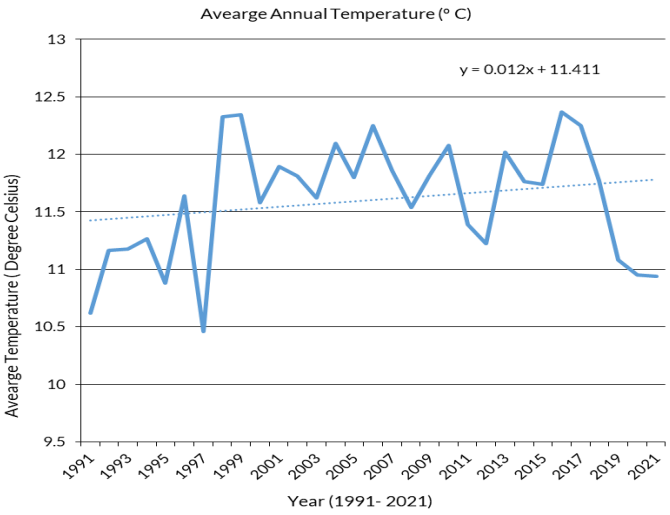

Figure 2. *Trend analysis of average annual temperature (1991-2021) of Mustang (Source: DHM, Jomsom Meteorological Station).*

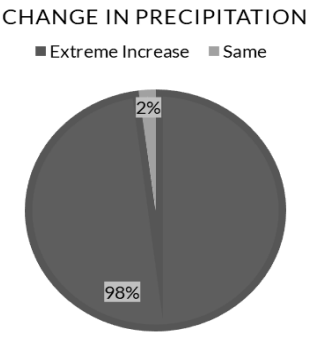

Figure 3. *Change in precipitation based on farmers' perception (Field Survey, 2022).*

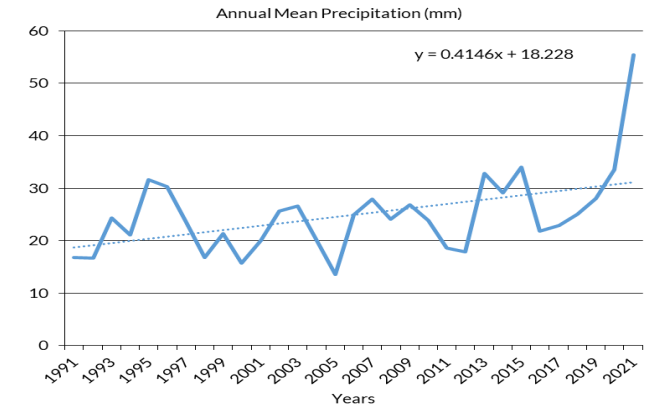

Figure 4. *Trend analysis of annual mean precipitation (1991-2021) of Mustang (Source: DHM, Jomsom Meteorological Station).*

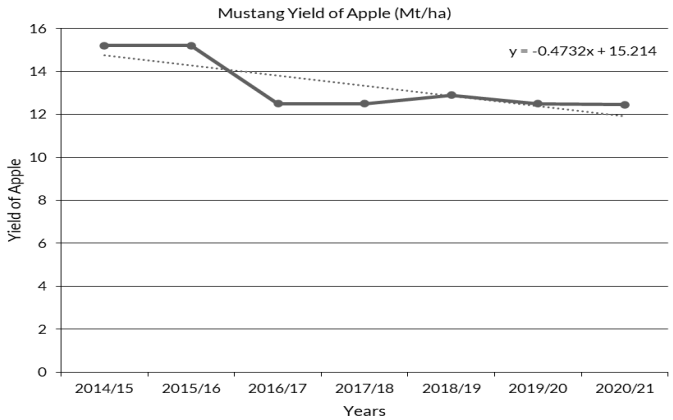

Figure 5. *Trend analysis of apple productivity in Mustang (Source: MoALD, 2022).*

Adaptation measures to combat the impact of climate change

Local knowledge and innovations can offer important insights to solve larger issues, so they should be promoted instead of being ignored or subsided. Farmers in the study area practiced different adaptation strategies to minimize the climate change impacts on their apple farms based on their own experiences and adjusting their farming practices. The majority of farmers (77%) use intercropping as a means of adaptation, with 21% gradually moving their farming to higher altitudes and 2% switching from apple to walnut farming from an economic standpoint. Due to Mustang's difficult geographic location, long-term extension services haven't been able to access the area, which has prevented the local farmers from adopting sufficient adaptation strategies.

Conclusion

This study observed the changing scenarios in the Lower Mustang through a trend analysis of temperature and precipitation. Weather data for the last 30 years (1991-2021) obtained from the DHM indicated that these regions are experiencing various types of weather variability, and the trend is erratic. According to the study, throughout the last 30 years (1991–2021), the average annual temperature and mean annual precipitation have increased at rates of 0.012°C per year and 0.4146 mm per year, respectively. This is consistent with farmers' perceptions of climate change. Hailstones, droughts, floods, and landslides are other climate hazards that are additionally related to this. The increase in negative effects of climate change in Lower Mustang, such as changes in the seasonal calendar and increases in diseases and pests, has resulted in the complete disappearance of apple farming in some areas already. Most people were aware of the term “Climate Change” but they were unaware of the adaptation measures that were required. The government hasn't taken any significant action to address the issue. It came to light that the effects of climate change on apple production had received very little, if any, attention over the course of this study. Thus, there is an immediate need to develop adaptation strategies, but farmers' perceptions and their experiences should be considered while designing plans and policies so that they will help enhance farmers' knowledge about climate change and lessen their vulnerability to the adverse impacts of climate change.

Authors contribution

Conceptualization, S.A. and R.H.T.; Methodology, S.A., R.H.T. and A.A.P.; Software, S.A. and A.S.; Validation, S.A. and A.A.P.; Formal analysis, S.A. and A.S.; Resources, S.A.; Data curation, S.A., Writing—original draft preparation, S.A. and R.H.T.; Writing—review and editing, S.A. and R.H.T.; Visualization, S.A. and A.S.; Supervision, S.A.; Project administration, S.A. and R.H.T.; Funding acquisition, S.A. and R.H.T. All authors have read and agreed to the published version of the manuscript

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Ethical approval: Not applicable.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

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