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Linking Drought Indices with Maize Productivity: A Comparative Analysis of SPI and DSI in Temperate Rainfed Agriculture

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Abstract

Maintaining agricultural productivity in the rainfed, temperate regions of Jammu & Kashmir requires an understanding of drought dynamics. This study investigates the spatial distribution and long-term trends of two important drought indices, the Standardized Precipitation Index (SPI) and the Dry Spell Index (DSI), as well as how they relate to cropped area and maize production between 1997 and 2024. Significant spatial diversity in DSI is revealed by the results. While Baramulla had the most interannual variability, Kupwara and Srinagar districts had the highest average drought severity. The intra-seasonal distribution of rainfall, which is essential to crop growth and development, is not adequately reflected by SPI, despite the fact that SPI trends primarily show near-normal to somewhat dry conditions. On the other hand, DSI provides more detailed information on times of crop stress by more accurately capturing the frequency and length of dry spells. Moderate drought stress (DSI, 8–12) produced the maximum productivity in maize yield analysis, indicating that mild water deficiencies may promote maize development by lowering the hazards of disease and excessive moisture. However, yield and cultivated area were drastically decreased by severe drought (DSI > 20), underscoring maize's vulnerability to severe moisture deficiencies. Overall rainfall quantity and distribution have improved, especially in Srinagar, according to temporal study, which revealed a positive SPI trend and dropping DSI across all districts. Overall, the study highlights how crucial it is to combine DSI and SPI for a thorough evaluation of agricultural drought. In order to increase resilience in the face of growing climate variability, these findings suggest the need for region-specific adaptation strategies, such as the creation of drought-tolerant maize varieties, better water management techniques, and improved early warning systems.

1. Introduction

Adverse stress conditions, whether abiotic or biotic, often hinder plants from performing optimally and may even threaten their survival [1]. Among these, drought stands out as a critical abiotic stress, particularly affecting crops like maize across the globe due to freshwater shortages. This issue is expected to worsen with ongoing climate change, highlighting the urgent need to develop drought-tolerant maize varieties [2, 3]. Drought stress during critical stages of maize development, such as seedling stage, ear emergence, and silking, significantly limits crop productivity [4]. To ensure food security for future generations, the development of drought-tolerant crop varieties using available genetic resources is essential. Numerous maize-breeding programs are currently focused on enhancing both biotic and abiotic stress tolerance. Simultaneously, growing food demands and climate variability call for quality improvement and increased productivity through low-input farming techniques. In the Kashmir Valley, erratic rainfall patterns and limited irrigation infrastructure severely affect maize production, resulting in yield stability. In this backdrop, seventy maize landraces from the Kashmir valley were evaluated to identify elite genotypes with inherent drought tolerance, which could potentially be integrated into the genetic background of commercial maize varieties.

Precipitation is one of the most significant weather parameters, influencing the crop yield, environment, society, and human life [5–7]. In regions where rainfed agriculture dominates, not only the total seasonal

precipitation but also its timing and distribution play a decisive role. In such systems, drought refers not only to insufficient rainfall volume but also to the misalignment of rainfall with critical crop growth stages [8]. In a subtropical country like India, especially under rainfed conditions, intra-seasonal rainfall variability and dry spells are major determinants of crop success or failure [9].

The Jhelum Basin in the North-Western Himalayas, is a significant agro-climatic zone that supports a large share of rainfed maize (*Zea mays* L.) cultivation. However, the region's complex topography, coupled with its dependence on the southwest monsoon and western disturbances, make it highly vulnerable to fluctuating rainfall patterns. Dry spells, defined as consecutive days with little or no rainfall, are increasingly recognized as a major climatic risk to maize production. When these spells occur during sensitive phenological phases such as germination, tasseling, or grain filling, they can cause water stress and lead to substantial yield reductions [10]. Compounding the problem is the low soil fertility commonly found in many rainfed regions [11], which amplifies the impact of such moisture deficits and results in lower productivity.

Recent studies show a clear increase in the frequency and duration of dry spells in the Western Himalaya, with winter precipitation declining due to weakened Western Disturbances [12]. Recent evidence indicate that climate variability is altering the frequency and duration of dry spells across many parts of India, including the western Himalayan region [13, 14]. While research on climate trends in the Himalayas is expanding, there is a significant gap in localized studies that directly assess the impact of dry spell dynamics on maize performance in the Jhelum Basin. The high variability and uneven distribution of rainfall not only disrupt planting and harvesting cycles but also create critical soil moisture deficits during crucial developmental stages, leading to substantial yield losses [8, 9].

2. Methodology

2.1 Study Area

The study area includes the districts of Anantnag, Kulgam, Srinagar, Baramulla and Kupwara, located in the temperate regions of Kashmir in the Western Himalayas, India (Fig. 1). These regions represent a temperate climate and are characterized by rainfed agriculture. Agriculture is a major source of livelihood here, with apple and rice being dominant crops, while maize serves as a crucial component of the region’s agrarian economy [15]. The temperate climate of the region is marked by fragile seasonal precipitation patterns, classifying the area as drought-prone during the summer months. The region receives an average annual precipitation of approximately 1000 mm, mainly contributed during winter, spring, and summer. Autumn tends to be relatively dry due to the diminishing influence of Indian summer monsoon in this part of Himalayas [16]. The region’s mountainous topography makes it particularly vulnerable to natural hazards such as floods, droughts, and earthquakes [17] placing it among the most climate-sensitive zones in India. The region has a dominant drainage system (river Jhelum), which flows from south to north and is fed by multiple tributaries originating from surrounding sub-basins.

2.2 Data Collection

Daily precipitation data, along with maximum and minimum temperature records from five meteorological stations (1980–2024) were obtained from the Division of Agrometeorology, SKUAST-Kashmir. District-wise data on maize area, yield, and production from 1998 to 2022 were sourced from the Ministry of Agriculture and Farmers Welfare's website [18]. The time series yield data of the selected rainfed crop displayed a clear increasing trend, largely attributed to the adoption of improved management practices by farmers in the region. To isolate the effects of climate variability and remove this trend, a linear regression method was applied to de-trend the yield data, resulting in stationary yield series for the period 1998 to 2022 [19].

2.3 DSI and SPI Calculation

A "rainy day" is defined by the India Meteorological Department (IMD) as a day receiving more than 2.5 mm of precipitation. In this study, a dry spell is considered to occur when rainfall remains below 2.5 mm for seven consecutive days. The number of dry days (non-rainy days) within each such period was used to calculate the weight of the dry spell.

The severity of a dry spell, represented by the Dry Spell Index (DSI), is determined by dividing the number of consecutive dry days by seven. The DSI thus reflects the frequency, duration, and timing of dry spells occurring during the crop-growing season. The index is calculated using the following formula:

$$DSI = \sum_{i=1}^{n} Length_i \times Weight_i \quad \ldots\ldots\ldots\

identify statistically significant relationships (at the 95% confidence level) between maize yield and both drought indices across various districts in the temperate regions of north-western India.

2.5 Percentage of Cropped Area and Trends in DSI and SPI

The DSI and SPI for each year in each district were estimated using district-wise daily precipitation data and cumulative rainfall during the crop-growing season, respectively. Rainfall was recorded daily through rain gauges installed at various locations within each District. The area-weighted daily average rainfall for each district was calculated using the Thiessen polygon method, which was then used to compute daily district-level rainfall. Trends in the percentage of area under different DSI and SPI categories were analyzed at various levels of statistical significance. The ratio of the area under maize cultivation to the total cultivated area during the Kharif season for each district was computed and expressed as a percentage. For the analysis, DSI values were categories into the following classes: 0–4.0, 4.1-8.0, 8.1–12.0, 12.1–16.0, 16.1–20.0, and > 20.0. The total cropped area under each DSI category was determined by summing the annual maize cultivation area for each respective category over the study period. Yield data corresponding to each DSI category were also aggregated. To determine the percentage of cropped area under each DSI class, the total maize area within each DSI category was divided by the total maize cultivation area across all years. Similarly, SPI values were categorized into the following classes: was further divided into the following categories: > 2.00, 1.50–1.99, 1.00-1.49, -0.99 to 0.99, -1.00 to -1.49, -1.50 to -1.99, and ≤ -2.00. The percentage of cultivated area falling under each SPI category was estimated using the same methodology as described above.

3. Results

3.1 SPI and DSI Trends and Spatial Distribution

The DSI, estimated using district-wise daily precipitation data and cumulative rainfall during the crop-growing season, revealed that the average DSI ranged from 10.0 to 16.90 across the study districts between 1997 and 2024. Among all districts Kupwara recorded the highest average DSI (16.9), followed by Srinagar (16.74), Kulgam (15.2), Baramulla (10.0) and Anantnag (9.95) (Fig. 2). Baramulla district, however, exhibited the highest coefficient of variation (CV) for DSI at 25.3%, followed by Anantnag (22.9%), Srinagar (17.64%), Kupwara (17.29%), and Kulgam (17.28%). Figure 3 indicates that DSI variability was highest in Baramulla and Anantnag, suggesting fluctuating dry spell conditions over time. The average SPI for the crop growing season across the study districts during 1997–2024 ranged from − 1.5 to 1.0. This indicates generally normal to mildly dry conditions in the temperate zone of the North Western Himalayas. According to the Mann-Kendall trend analysis, variations in DSI and SPI over the study period did not significantly affect maize cultivation area across the districts.

Cumulative DSI data from 1997 to 2024 showed that, Srinagar experienced the most years (15 out of 28 years) with a DSI in the 16.1 and 20.0 range, followed by Kupwara (13 years), Kulgam (9 years) (Table 1). This suggests that these districts were more frequently exposed to moderate to severe drought conditions. SPI analysis for the same period indicated that most years were near-normal in terms of

precipitation. Kulgam recorded 20 near-normal years (SPI between − 1 and 1), followed by Anantnag (19) and Kupwara (18), Baramulla and Srinagar (17 years each). Only Kupwara experienced a year of severe dry conditions during the study period. In contrast, extreme wet conditions were observed in Kulgam and Anantnag (2 years each), followed by Kupwara and Baramulla (1 year each). Srinagar did not experience any severe wet years during the study period (Table 2).

Table 1
Number of years by district under various average DSI categories from 1997 to 2024

DSI						
DISTRICT	0–4	4.1-8	8.1–12	12.1–16	16.1–20	20.1–24
Anantnag	0	5	19	4	0	0
Kulgam	0	1	1	17	9	0
Srinagar	0	0	2	6	15	5
Baramulla	0	4	19	5	0	0
Kupwara	0	0	1	9	13	5

Table 2
Number of years by district under various average SPI categories from 1997 to 2024

District	**SPI**						
	Extremely wet	**Very Wet**	**moderately wet**	**Near Normal**	**Moderately Dry**	**Severely Dry**	**Extremely Dry**
	> 2	1.5 to– 2.0	1.0 to 1.5	-1.0 to 1.0	-1.0 to -1.5	-1.5 to -2.0	< -2.0
Anantnag	2	1	2	19	2	2	0
Kulgam	2	1	1	20	3	1	0
Srinagar	0	2	3	17	3	3	0
Baramulla	1	2	3	17	5	0	0
Kupwara	1	1	3	18	3	0	1

3.2 Productivity and Percent Area in Relation to SPI and DSI

The average yield and cultivated area of various maize crops in relation to the distinct divisions of average SPI and DSI are presented in Tables 3 and 4. The analysis reveals that the majority of the maize cultivation area fell within the average DSI range of 8–12, followed by ranges of 16–20, 12–16, 4–8, and > 20. The highest cumulative yield (43.47 tons/hectare), was observed for the DSI range of 8–12,

indicating that mild drought stress conditions are most favourable for maize cultivation. These conditions may provide adequate moisture for crop development while minimizing risks such as heavy rainfall, pests' infestations, or disease outbreaks. Interestingly, the DSI range of 16.1–20.0 accounted for the second-largest cultivation area (117.66%), reflecting moderate to severe drought conditions. However, the yield for this category dropped significantly to 23.06 ton/hectare, suggesting that water stress begins to negatively affect maize productivity at this level of drought severity. Despite the increased drought stress, maize is still cultivated, possibly due to a lack of viable alternatives or limited access to irrigation. Similar patterns are observed in the DSI range of 12.1–16.0, where yield declines to 24.46 tons/hectare and the cultivated area decreases to 64.84%. This further supports the notion that maize yield tends to decrease as drought severity intensifies, regardless of the fluctuations in cultivated area. At the extreme end of the drought scale (DSI, 20.1–24.0), both yield (7.76 tons/hectare) and area (46%) both decrease sharply. This suggests that extreme drought conditions significantly suppress both maize production and cultivation. Conversely, the lowest drought category (DSI, 4.1–8.0) exhibits relatively low area coverage (24.18%) and a similarly low yield (7.69 tons/hectare). This could be due to such conditions being less frequent during the study period, or because wetter seasons in these areas may have been less suitable for maize cultivation, potentially due to waterlogging or a shift in crop preference. Overall, the findings indicate that maize performs optimally under mild drought conditions but suffers notable yield losses as drought severity increases. These results emphasize the importance of adopting improved water management practices, promoting drought-resistant maize varieties, and implementing adaptive cropping strategies to sustain yields in the face of increasing climate variability.

Table 3
Average yield (tons/hectare) and crop area (%) for the maize crop in each of the average DSI categories

DSI	4.1–8.0	8.1–12.0	12.1–16.0	16.1–20.0	20.1–24.0
Anantnag					
% Area	12.17	73.13	14.80	0	0
Yield	3.51	23.30	5.06	0	0
Baramulla					
% Area	12.01	68.67	19.30	0	0
Yield	4.18	15.85	5.96	0	0
Kupwara					
% Area	0	4.60	28.34	49.76	17.00
Yield	0	1.17	8.98	9.86	3.26
Srinagar					
% Area	0	0.38	2.40	67.90	29.00
Yield	0	3.15	4.46	13.20	4.50
Kulgam					
% Area	4.40	12.60	73.02	8.96	0
Yield	1.13	3.17	22.01	1.20	0

Table 4
Average yield (ton/hectare) and crop area (%) for the maize crop in each of the average SPI categories

SPI	> 2.0	1.5-2.0	1.0-1.5	-1.0 to 1.0	-1.0 to -1.5	-1.5 to -2.0	< -2.0
Anantnag							
% Area	3.47	3.40	3.00	73.00	8.24	8.44	0
Yield	1.25	1.56	1.17	23.76	3.78	1.35	0
Baramulla							
% Area	3.90	7.20	9.00	62.00	17.06	0	0
Yield	1.05	3.09	1.91	14.13	4.75	0	0
Kupwara							
% Area	4.60	3.30	4.30	71.00	12.20	0	4.34
Yield	1.17	1.36	0.91	17.49	2.49	0	0.19
Srinagar							
% Area	0	0.30	1.40	70.18	9.00	18.91	0
Yield	0	2.10	1.04	19.01	1.39	2.25	0
Kulgam							
% Area	4.47	2.40	4.00	75.00	7.24	6.44	0
Yield	1.25	1.56	1.17	23.76	3.78	1.35	0

3.3 DSI and SPI Variability

An inter-comparison of Dry Spell Index (DSI) and Standardized Precipitation Index (SPI) during the Kharif season from 1991 to 2024 across selected districts of Jammu & Kashmir, namely Anantnag, Kulgam, Kupwara, Baramulla, and Srinagar, is presented in Figs. 4 to 8. A detailed analysis of the trends in these two indices reveals that all selected districts exhibited a positive linear trend in SPI, indicating an increase in cumulative seasonal rainfall over the 34-year period. Concurrently, the analysis shows a declining trend in DSI across all five districts, reflecting a reduction in both the duration and frequency of dry spells during the Kharif season. Notably, Srinagar demonstrated the most significant improvements, with the highest positive SPI trend and the steepest negative DSI trend. This suggests simultaneous increase in total rainfall and a notable enhancement in its intra-seasonal distribution. This divergence in trends between SPI and DSI across different agro-climatic zones highlights the critical role of DSI in assessing agricultural drought. While SPI quantifies the total seasonal rainfall, it does not capture its temporal distribution, a key factor affecting soil moisture availability, crop developmental stages, and ultimately, yield. In contrast, DSI offers valuable insights into rainfall distribution patterns, specifically

identifying dry spell periods that can adversely affect crops even when seasonal rainfall totals appear adequate.

In districts such as Kupwara and Baramulla, where SPI trends were relatively modest, the significant decrease in DSI suggests improving growing conditions due to more favorable rainfall distribution. This indicates that even slight increases in rainfall, when coupled with reduced dry spells, can positively impact agricultural productivity. Meanwhile, in Anantnag and Kulgam, both SPI and DSI exhibited moderate trends, reinforcing the importance of evaluating seasonal rainfall alongside dry spell dynamics. These findings reaffirm the utility of DSI as a complementary drought index alongside SPI, particularly in rainfed agricultural regions like those in Jammu & Kashmir. By accounting for the duration and timing of dry spells within the crop season, DSI addresses a key limitation of SPI, offering a more comprehensive framework for drought monitoring and climate-resilient agricultural planning.

4. Discussions

The information on continuance of dry spells in a season is vital in deciding a particular crop or crop variety, and to breed varieties of various crop durations for a specific location [20, 22] and deciding adaptation strategies viz., supplementary irrigation and field operations in agriculture [23, 24]. Mathlouthi and Lebdi [25] suggest that prior knowledge of dry spells might help build synthetic rainfall sequences and estimate agricultural water demand. Planning agricultural operations and managing water delivery systems requires considering the duration of many lengthy dry seasons [26, 27]. One of the main challenges of drought research is creating appropriate methodologies and procedures for predicting when a dry spell will begin and end [28]. Therefore, it may be very beneficial to examine the cumulative effects of dry spells on agricultural productivity by creating an index that reflects the number and duration of dry spells.

4.1 DSI and SPI Variability

The inter-comparison of the Standardized Precipitation Index (SPI) and Dry Spell Index (DSI) across the Kharif season (1991–2024) in selected districts of Jammu & Kashmir provides valuable insights into the evolving rainfall dynamics and their implications for rainfed agriculture. The observed trends, positive SPI and declining DSI point toward an increasingly favourable agro climatic environment, with both enhanced total seasonal rainfall and improved intra-seasonal distribution.

SPI is a well-established indicator for meteorological drought assessment, as it standardizes precipitation over a given time scale, making it ideal for identifying long-term rainfall anomalies [21]. However, as the present analysis reveals, SPI alone may fail to reflect the real agricultural drought risk. This is particularly true in rainfed systems, where the distribution of rainfall is often more critical than the total amount [5, 8]. A season with adequate total rainfall may still experience yield losses if rainfall is not well-timed to match crop water requirements at sensitive growth stages.

The DSI, in contrast, is specifically designed to capture the temporal aspects of rainfall namely, the duration and frequency of dry spells during the crop growth period [20]. In this study, all districts recorded a declining DSI trend, suggesting that dry spells are becoming less frequent or shorter in duration. This is particularly beneficial for crop growth, as it reduces the likelihood of moisture stress during critical phenological stages such as flowering and grain filling [29].

Notably, Srinagar exhibited the steepest decline in DSI and the strongest increase in SPI, indicating both greater rainfall amounts and better distribution. Such dual improvement implies a more reliable growing season and reduced agricultural drought risk. In contrast, districts like Kupwara and Baramulla showed relatively modest SPI trends but significant DSI reductions, highlighting how improved rainfall timing rather than quantity alone can substantially enhance agricultural outcomes. This underscores the importance of DSI in capturing subtle improvements in rainfall behaviour that SPI might overlook.

In Anantnag and Kulgam, moderate changes in both SPI and DSI suggest a steady but less pronounced transition. These findings collectively emphasize the need to incorporate multiple drought indicators in agricultural drought assessments, particularly in regions with complex topography and climate variability like Jammu & Kashmir. Reliance solely on SPI could lead to an over- or underestimation of drought impacts on agriculture.

The synergistic use of SPI and DSI offers a more holistic understanding of climatic risks to agriculture. This dual-index approach is especially relevant under changing climate scenarios, where shifts in rainfall patterns are expected to become more pronounced [30]. For policymakers and planners, this means that drought preparedness strategies should prioritize not only total seasonal precipitation but also its distribution over time. Such an approach aligns with the goals of climate-resilient agriculture and sustainable resource management.

In conclusion, the integration of DSI into regular drought monitoring systems enhances the diagnostic capability of drought risk assessments. As this study demonstrates, DSI fills a critical gap left by SPI, making it an indispensable tool for agrometeorological applications in rainfed regions such as Jammu & Kashmir.

4.2 Effect of DSI on Maize Yield

The duration and severity of dry spells during the crop growth season often impact the maize grain yields in rainfed conditions [31]. The findings from this study indicate a strong inverse relationship between DSI values and maize yield. In moderate DSI conditions (8.1–12), maize yields remained relatively stable at 43.47 t/ha, while severe drought conditions (DSI 16.1–20) showed a marked reduction to 23.06 t/ha. Under very severe drought stress (DSI 20.1–24), the yield declined drastically to 7.76 t/ha, accompanied by a notable contraction in cropped area to 46%. These figures demonstrate how increasing drought severity, as captured by DSI, adversely impacts maize production not only by limiting water availability but also by increasing physiological stress and reducing the area farmers are willing to cultivate. The sharp decline in seed yield at higher average DSI (≥ 20.1) may be the consequence of more

dry spells throughout the crop growth period, which led to circumstances of soil moisture deficiency, which subsequently impacted crop growth and production [32]. Because dry spells occur often and last for a long time, Agbossou *et al.* [33] showed a decrease in maize output.

Unlike the Standardized Precipitation Index (SPI) which focuses solely on cumulative rainfall anomalies and DSI is widely used for meteorological drought monitoring [21]. DSI accounts for the timing and frequency of dry spells, which are critical for crop development stages such as germination, flowering, and grain filling. The limitation of SPI is particularly evident in this study, where the highest maize yields (74.39 t/ha) and cropped areas (276.18%) occurred under near-normal SPI conditions (-1 to 1). However, under extreme SPI values (> 2 or <-2), yields declined significantly, suggesting that while SPI can flag extreme moisture conditions, it lacks sensitivity to the nuanced intra-seasonal rainfall variations that DSI captures [5, 34].

5. Conclusions

This study presents a comprehensive agro-climatic evaluation of maize cultivation in the temperate rainfed regions of Jammu & Kashmir, focusing on the interplay between the Standardized Precipitation Index (SPI) and the Dry Spell Index (DSI) from 1997 to 2024. The spatial and temporal analysis of the DSI revealed significant inter-district variability. Kupwara and Srinagar districts experienced the highest average drought stress, while Baramulla and Anantnag exhibited greater year-to-year variability. SPI values largely indicated near-normal to mildly dry conditions, with occasional instances of severe drought or extreme wetness. However, the SPI, being a generalized indicator of seasonal rainfall, often failed to capture the effects of intra-seasonal dry spells. This limitation highlights the importance of incorporating the DSI for more accurate drought characterization.

The relationship between maize yield and drought severity followed a nonlinear pattern. Interestingly, the highest yields were associated with moderate drought conditions (DSI between 8 and 12), suggesting that mild water stress may enhance maize growth by reducing disease pressure and improving soil aeration. In contrast, both extremely low and high DSI values were linked to reduced yields and a decline in cultivated area, underscoring the adverse effects of both excessive wetness and severe drought on crop productivity. These results emphasize the vulnerability of maize yields to increased drought severity and the limitations of area expansion as a compensatory strategy under stress conditions.

The contrasting trends in SPI (increasing) and DSI (declining) across all districts point to an overall improvement in rainfall availability and distribution during the Kharif season, particularly in Srinagar. This divergence further validates the complementary role of DSI in capturing the temporal dynamics of rainfall that SPI alone cannot reveal. Districts such as Baramulla and Kupwara, with modest increases in rainfall but significant reductions in dry spells, demonstrated the importance of improved rainfall distribution in sustaining agricultural productivity.

In conclusion, the study highlights the necessity of integrating DSI with SPI for robust drought monitoring and agricultural planning in rainfed systems. While SPI provides a broad picture of total seasonal rainfall,

DSI captures the intra-seasonal rainfall distribution, critical to crop performance. The findings call for targeted adaptation strategies, including the development and promotion of drought-resilient maize varieties, improved water management practices, and region-specific contingency plans to mitigate the risks posed by increasing climate variability in the North Western Himalayas.

Declarations

Competing interests

The authors declare no competing interests.

Ethics and Consent to Participate

Not applicable.

Consent to Publish

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Author Contribution

Conceptualization, methodology, investigation, resources, data curation, project administration, formal analysis, writing original draft preparation, S.Q., L.A., M.A.M., supervision, visualization, writing review and editing, S.K.B.,. A.S and A.T. All authors have read and agreed to the published version of the manuscript.

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Data Availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Declaration of interests

 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.

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