



Modelling and mapping weekly rainfall for crop planning in north-western Himalayan states

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North-Western (NW) Himalayan states of India represents states of Jammu & Kashmir (J&K), Himachal Pradesh (HP) and Uttarakhand which vary significantly on total rainfall as well as its weekly distribution causing many difficulties in crop planning, water balance and conservation practices (Jana *et al.* 2015, Yadav *et al.* 2015, Ray *et al.* 2015). In these states, *kharif* crops are sown mainly after monsoon arrival, subsequently suffer moisture stress during intermittent dry spell in different growth phases. Similarly, rainfed winter crops are grown on residual soil moisture of the field. Hence, all these cropping systems mostly depend upon weekly rainfall amount and its distribution probability over the time. For crop planning in Shivalik region, Alam *et al.* (2015) reported that 25th June to 1st week of July as an optimum time of sowing of maize crops with assured 25 mm rainfall at 70% probability level. Similar result was reported for Doon valley region of Uttarakhand by Sharda *et al.* (2005). However, in NW Himalayan region, no such systematic studies have been conducted to indicate the spatio-temporal variation of rainfall distribution pattern, which is prerequisite for any regional crop planning, implementation of conservation practices and related problems. To address the issue, a comprehensive study was undertaken to analyse the spatio-temporal probability distribution of rainfall events for *kharif* crops planning in NW Himalayan region of India. The analysis was carried out with high resolution gridded point (0.25°×0.25° resolution) and long term (1901 to 2019) rainfall data.

The daily rainfall (mm) gridded data of 0.25° × 0.25° resolution for 119 years (1901–2019) collected from IMD website (<https://imdpune.gov.in/>) and converted into standard meteorological week (SMW) data employing standard procedure according to which, SM week 1 corresponds to 1–7 January, SM week 2 to January 8–14 and so on. The SM week 9 has 8 days (25 February–3 March) for leap year and 7 days for other years. The SM weeks from 24 (11–17 June) to 32 (6–12 August) have been considered for the analysis, as they cover the rainy season and rainfed maize crop growth period in the region. As weekly rainfall data fits well for log normal distribution (Sharda and Das 2005, Alam *et al.* 2015, 2016), two-parameter log-normal distribution has been fitted to describe the weekly rainfall and rainy-days of NW Himalayan region for each grid. A random variable x is said to have two-parameter log-normal probability distribution if its probability density function (pdf) is given by:

$$f(x) = \begin{cases} \frac{1}{x\sigma\sqrt{2\pi}} \exp\left\{-\frac{1}{2} \frac{[\log(x) - \mu]^2}{\sigma^2}\right\}, & \mu > 0, \sigma > 0 \\ 0 & \text{otherwise} \end{cases}$$

where, μ and σ are known as location and scale parameters, respectively.

Before fitting the distributions to the data sets, log-normal behaviour of data sets and independence of observations were tested by Anderson-Darling test and Wald-Wolfowitz test, respectively. Details of methodology have been reported by Sharda *et al.* (2005) and Alam *et al.* (2015). To check the fitting, we have randomly selected few SMWs of one grid and tested the goodness of fit. Histograms and PP plot of log-normal distribution fitted data sets revealed that data follows log-normal distribution. Moreover, the non-significant ($p=0.37$) AD value (0.39) of Anderson-Darling test accepts the null hypothesis and indicates that the data follow log-normal distribution. Minimum assured amount of rainfall (mm) at 70% probability level was computed using log-normal distribution for each grid and for each of the SMW 24 to 32 weeks and (Fig 1). Similarly, rainy days was also computed using log-normal distribution

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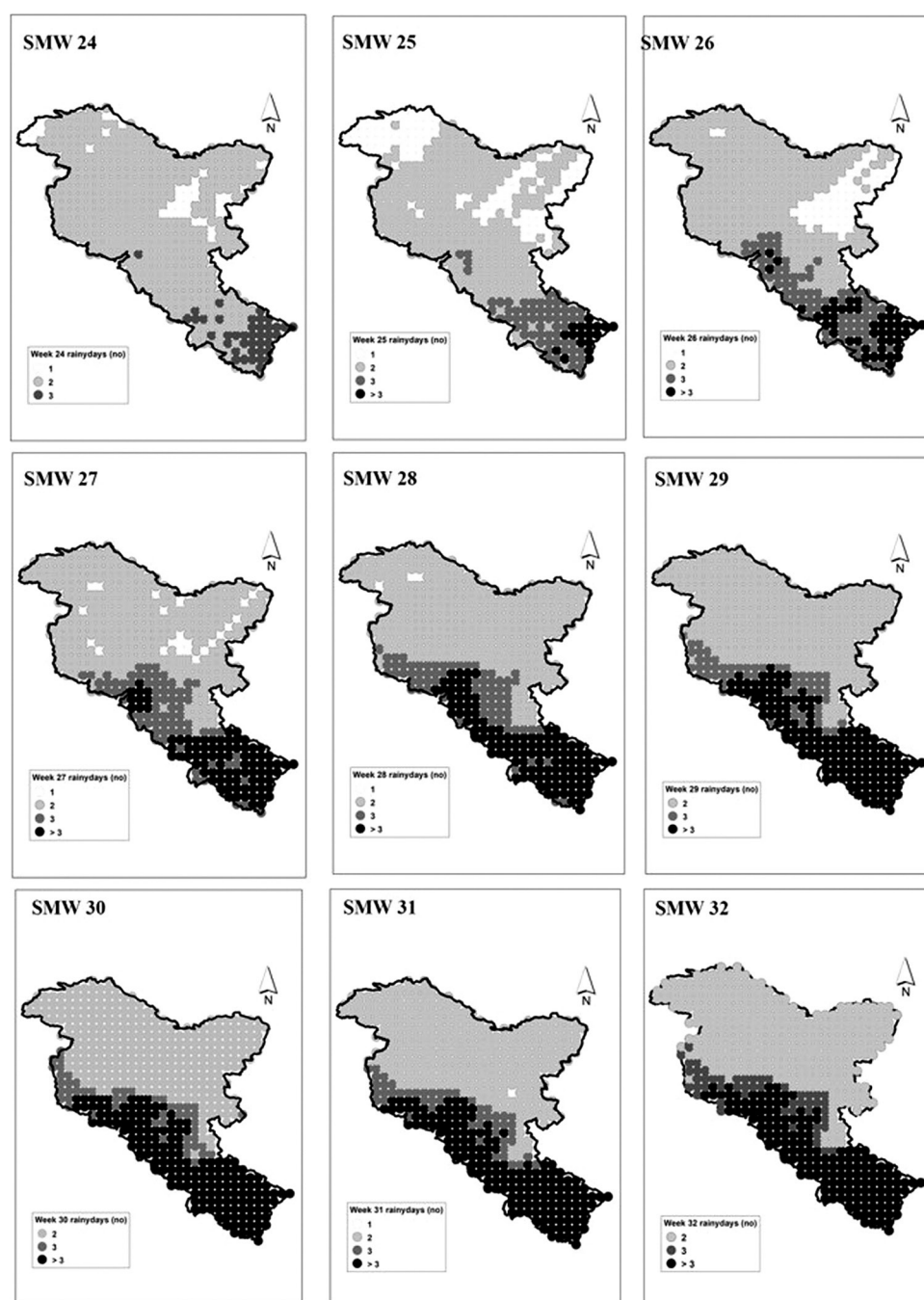


Fig 1 Spatio-temporal distribution of rainfall (mm) at 70% probability in the NW Himalayan region states.

and mapped for NW Himalayan region at 70% probability level and presented in Fig 2. For mapping of gridded rainfall data, open-source QGIS software was used.

Probability analysis of rainfall distribution (Fig 1 and 2) shows that at 70% probability level, in maximum area, J&K experienced less rainfall (<10 mm) events, HP experienced medium rainfall (10-20 mm) and Uttarakhand with high (>20mm) rainfall indicating a wide range of sowing time of *kharif* crops for different states. Similar trend was also observed in number of rainy days at 70% probability level across the states (Fig 1 and 2). It is interesting to note that

from spatial mapping of the SMW, rainfall as well as rainy days varied widely in these three states. Further detailed observation shows that in J&K states, maximum rainy days were found at 25 SMW covering maximum area (2.7 m ha) suggesting 1st week of July as optimum time of sowing, whereas in HP, it was 26th SMW, i.e. 2nd week of July was the maximum with both rainfall amount and rainy days covering 0.54 m ha area. But, in case of Uttarakhand state, in maximum area (0.68 m ha), rainfall distribution was found widely scattered over SMWs which ranges from 26-28 SMW for rainfall and 30-31 SMW for rainy days, thereby needs appropriate decision for choosing suitable crops for the time duration. This signifies that no specific variety is sufficient, only timely specific, i.e. early and late sown varieties were a wise decision for crop planning. Our results though corroborate with the results of Sharada *et al.* (2005) for Doon valley conditions in SMW but this study further added more knowledge on rainy days probability in different landform situations for entire *kharif* crop planning/sowing in Uttarakhand. Experiences and various studies reported that rainfall amount, as well as distribution and rainy days during different crop growth stages were crucial

for sustenance of crops in these Himalayan states (Yadav *et al.* 2020). However, from this study it was revealed that no single or uniform SMW is applicable for crop planning for all the states. All states experienced maximum rainfall pattern and rainy days in different SMWs. Therefore, judicious crop planning with contingency management needs to be devised based on the SMWs rainfall and rainy days probability pattern. Moreover, the spatio-temporal maps will help in site-specific decision making for entire *kharif* crop planning adjusted to different landforms in NW Himalayan region.

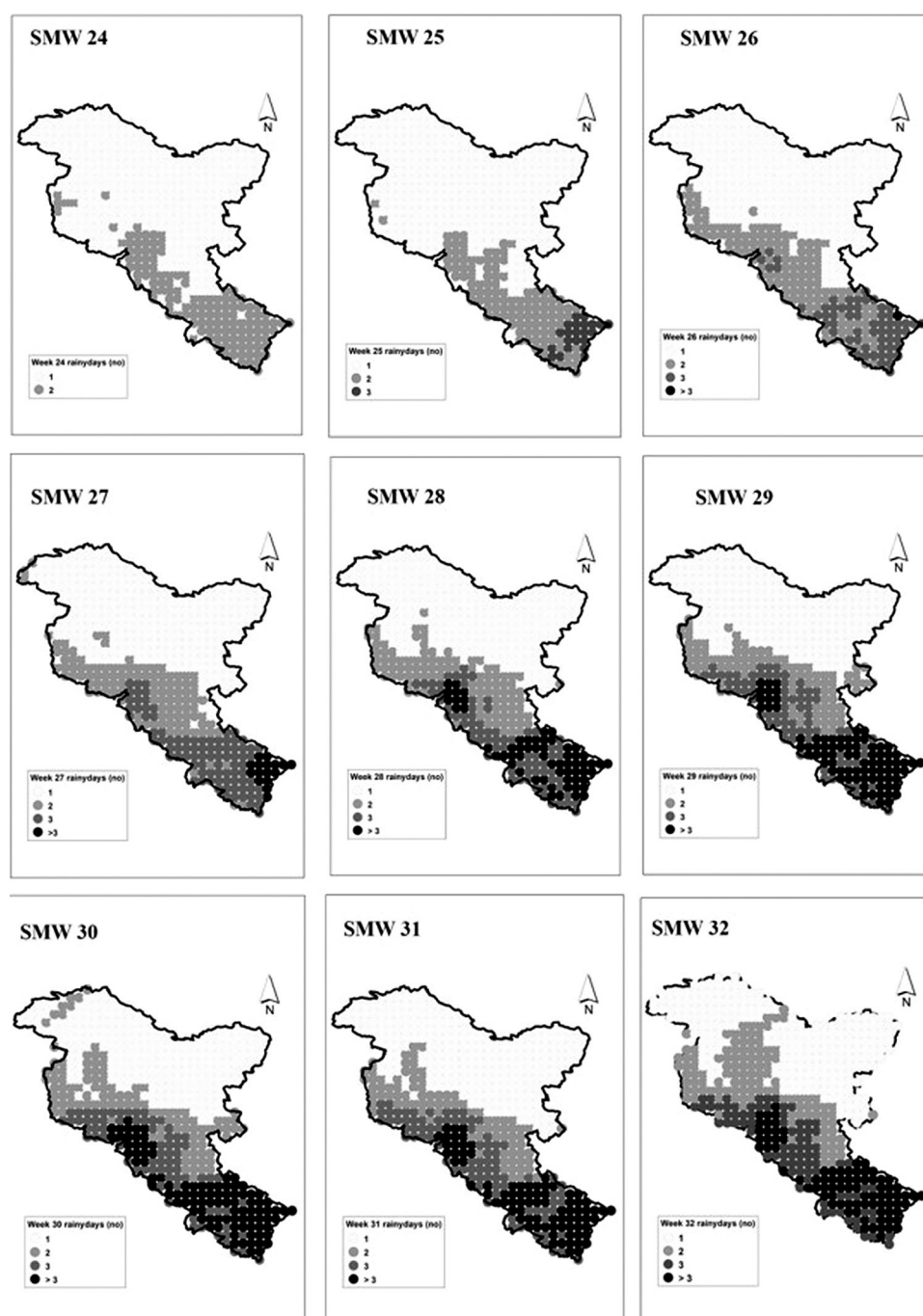


Fig 2 Spatio-temporal distribution of rainy days at 70% probability in the NW Himalayan region states.

SUMMARY

Modelling and mapping of weekly rainfall was carried out for NW Himalayan states of India for *kharif* crop planning. Based on the findings of the study it was observed that, J&K states with area coverage of 2.7 m ha witnessed maximum rainy days at 25 SMW indicating 1st week of July as optimum sowing time for *kharif* crops, whereas in HP, 26th SMW, i.e. 2nd week of July was maximum considering both rainfall amount and rainy days with 0.54 m ha area coverage. But, in case of Uttarakhand, it differs

widely which ranges from 26-28 SMW for rainfall and 30-31 SMW for rainy days category in 0.68 m ha area. The spatial-temporal maps of rainfall distribution will help in site-specific decision making for entire *kharif* crop planning adjusted to different landforms.

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