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Rainfall Probability Analysis, Runoff Assessment and Water-Harvesting-Based Cropping Planning in Vihokhu Watershed, Dimapur, Nagaland, North-Eastern India

Kivishe [a], R. C. Nayak [b++], Leiyachui Pherim [c#], Sewak Ram [b†] and Samar Thakuria [d#*]

[a] Department of Soil and Water Conservation, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus, Nagaland, India.
[b] Department of Soil and Water Conservation, School of Agricultural Sciences, Nagaland University, Medziphema, Nagaland, India.
[c] Department of Plant Pathology, School of Agricultural Sciences, Nagaland University, Medziphema, Nagaland, India.
[d] Department of Agricultural Extension Education, School of Agricultural Sciences, Nagaland University, Medziphema, Nagaland, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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Abstract

Aims: The study was undertaken to assess dependable rainfall availability, estimate runoff and crop-water surplus or deficit, and develop a water-harvesting-based cropping plan for Vihokhu watershed of Nagaland, India.
Study Design: Hydrological data for a 15-year period (2007–2021) were analysed for annual, monthly and weekly rainfall, dependable rainfall probability, runoff generation, crop-water requirement and water-storage potential.

[++] Professor; [#] Ph.D. Research Scholar; [†] Associate Professor;
**Corresponding author: E-mail: samarthakuria1234@gmail.com;*

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Place and Duration of Study: Vihokhu watershed, Kuhuboto Block, Dimapur district, Nagaland, India; rainfall data covering 2007–2021 were analysed.
Methodology: The watershed covers approximately 807 ha. Rainfall data obtained from the Dimapur Soil and Water Conservation Office were analysed at annual, monthly and weekly intervals. Weekly rainfall was estimated at 60, 70, 75 and 80% probability levels using probability analysis, with the 75% probability level selected for agricultural planning. Runoff was estimated using Binnie's runoff coefficient method. Crop-water requirements were assessed weekly for crops grown or proposed for Kharif, Rabi and Zaid seasons. Surplus runoff was evaluated for storage and subsequent irrigation use.
Results: The watershed received an average annual rainfall of 1564.11 mm during 2007–2021. Annual rainfall ranged from 1047.8 mm in 2017 to 1876.7 mm in 2012. July was the wettest month, receiving an average of 312.34 mm, while January and December received only 17.26 and 16.98 mm, respectively. At 75% probability, rainfall was absent during Weeks 1–14 and 41–52, indicating a prolonged dry period. Estimated runoff was concentrated mainly during Weeks 15–40. The accumulated runoff available for storage was estimated at 233.54 ha-m, of which approximately 151.80 ha-m was considered effective after accounting for 35% losses. The proposed cropping plan covered 175 ha and included rice and soybean in Kharif, mustard, beans, pea and onion in Rabi, and maize and potato in Zaid. Three water-harvesting ponds were proposed for storing runoff for non-monsoon irrigation.
Conclusion: Vihokhu watershed has considerable potential for integrated rainfall-runoff management. Harvesting monsoon runoff and storing it for dry-season irrigation can support multi-season cropping and improve utilisation of available water resources.

Keywords: Watershed; rainfall probability; runoff; crop-water requirement; water harvesting; irrigation; Nagaland.

1. Introduction

Water is one of the most important natural resources for agricultural production and rural livelihoods. The availability of water, however, depends not only on the total quantity of rainfall received but also on its temporal and spatial distribution. In rainfed and hilly agricultural regions, rainfall received during a short monsoon period may generate substantial surface runoff, while the same area may experience water scarcity during the remaining part of the year. Therefore, effective water-resource management requires assessment of rainfall availability, runoff generation, crop-water demand and storage potential as an integrated system (Molden, 2007; Rockström *et al.*, 2010; Food and Agriculture Organization of the United Nations [FAO], 2017).

Watershed management provides an appropriate framework for integrating land, water and agricultural resources. The major objectives of watershed management include controlling harmful runoff, utilising runoff for beneficial purposes, reducing soil erosion and sediment generation, improving groundwater recharge and making efficient use of land and water resources (Wani *et al.*, 2003; Joshi *et al.*, 2005; Kerr, 2002). Integrated watershed interventions can improve water availability, reduce land degradation and support agricultural productivity, particularly in rainfed and resource-constrained regions (Rockström *et al.*, 2010).

Nagaland receives substantial rainfall, particularly during the southwest monsoon. However, agricultural production in many parts of the state remains highly dependent on seasonal rainfall. In Dimapur district, irrigation has traditionally involved diversion of small hill streams to agricultural fields. Such systems may provide localised irrigation but do not necessarily ensure sufficient water availability throughout the agricultural year. The strong seasonality of rainfall in the northeastern hill region makes water conservation and efficient utilisation particularly important for sustaining agricultural production during relatively dry periods (ICAR Research Complex for NEH Region, 2017).

Vihokhu watershed, situated in Kuhuboto Block of Dimapur district, covers approximately 807 ha. The watershed was selected for water-resource assessment because substantial rainfall is received during the monsoon, while considerable quantities of water are lost as runoff. The original study aimed to promote agricultural production, utilise cultivable and degraded land and develop suitable soil and water conservation technologies for the watershed. Watershed-based planning is particularly relevant in such areas because land use, slope, rainfall, runoff and agricultural water requirements are closely interconnected (Singh *et al.*, 2014).

Rainfall analysis is an essential component of agricultural water planning. Average rainfall values may overestimate dependable water availability because rainfall varies substantially between years and weeks. Consequently, probability-based rainfall analysis is commonly used for agricultural planning, irrigation scheduling and estimation of dependable rainfall. In the present study, rainfall was analysed at different probability levels and the 75% probability level was selected for planning. The study specifically considered 60, 70, 75 and 80% probability levels. Probability analysis provides a more conservative estimate of rainfall availability and can reduce the risk associated with agricultural planning based solely on long-term mean rainfall (Subramanya, 2008). Recent probability-based analyses likewise show that dependable weekly rainfall estimates can provide a practical basis for crop planning under rainfed monsoon conditions (Singh *et al.*, 2025; Menon & Bhattacharyya, 2025).

Weekly analysis is particularly useful for agricultural water planning because crop-water requirements and irrigation scheduling vary with crop growth stage. Short-term rainfall variability can create periods of water surplus and deficit even within the same cropping season. Therefore, weekly rainfall analysis can provide a more practical basis for matching rainfall availability with crop-water requirements and determining supplementary irrigation requirements (Doorenbos & Pruitt, 1977; Allen *et al.*, 1998; FAO, 2017). The present study used weekly rainfall totals and compared crop-water requirements with rainfall available at the 75% probability level.

Runoff is another important component of the watershed water balance. When rainfall exceeds infiltration, interception and other losses, a portion of rainfall becomes surface runoff. In sloping watersheds, uncontrolled runoff can contribute to soil erosion and transport of valuable topsoil. Conversely, appropriately harvested runoff can become a valuable source of irrigation water during dry periods. Runoff estimation is therefore an important component of watershed planning, particularly where rainfall is concentrated during the monsoon season (Subramanya, 2008; U.S. Department of Agriculture, Natural Resources Conservation Service [USDA-NRCS], 2004; Wani *et al.*, 2003). The present study estimated weekly runoff using Binnie's runoff-coefficient approach. Recent watershed-scale modelling further demonstrates the value of evaluating streamflow and sediment response together when characterising hydrological behaviour for watershed management (Fermansyah *et al.*, 2026).

The use of water-harvesting structures can potentially reduce the seasonal mismatch between water availability and agricultural demand. Water stored during the monsoon can be released during Rabi and Zaid periods when rainfall is inadequate. Farm ponds, small reservoirs, check dams and related water-harvesting structures can increase the availability of water for supplementary irrigation and may also contribute to groundwater recharge under suitable site conditions (Kerr, 2002; Rockström *et al.*, 2010). The present study therefore proposed water-harvesting ponds and other conservation measures to capture a portion of monsoon runoff and improve water availability during the non-monsoon season. Recent field- and watershed-scale studies further indicate that rainwater-management interventions can improve the capture and productive use of rainfall under water-limited agricultural conditions (Feng *et al.*, 2024; Liansangpuii *et al.*, 2024).

Recent studies reinforce the importance of integrating rainfall variability with water-harvesting and agricultural planning. Garg *et al.* (2021) demonstrated that agricultural water-management interventions can alter runoff, groundwater recharge and cropping opportunities, while also creating downstream trade-offs. Garg *et al.* (2022) showed that rainfall-runoff relationships and runoff probabilities can help identify areas suitable for decentralised rainwater harvesting. Dharani *et al.* (2023) reported that rainfall variability and probability analysis provide a useful basis for crop planning in rainfed environments. Hangshing *et al.* (2022) specifically highlighted rainwater harvesting as an important component of sustainable water-resource management in Nagaland. These findings support the integrated rainfall, runoff, crop-water and storage framework adopted in the present study.

Against this background, the present study integrates rainfall probability analysis, runoff estimation, crop-water requirement, water-storage assessment and cropping planning to develop an integrated water-resource management strategy for Vihokhu watershed. The approach is intended to identify periods of dependable rainfall, quantify potential runoff, assess water surplus and deficit and determine the potential for storing excess monsoon runoff for subsequent agricultural use. Such an integrated assessment can provide a scientific basis for improving water-use efficiency and promoting multi-season agricultural production in hilly watersheds of Nagaland.

The central research gap addressed in this study is the absence of a unified, site-specific assessment linking dependable weekly rainfall, runoff generation, crop-water requirements, seasonal water surplus or deficit, storage potential and a corresponding multi-season cropping plan for Vihokhu watershed. Consequently, the extent to which monsoon runoff can be stored and subsequently used to address non-monsoon crop-water deficits has not been quantified within a single watershed-scale framework. The present study addresses this gap by evaluating these hydrological and agricultural components together.

2. Objectives

The study was conducted with the following objectives:

1. To assess dependable weekly rainfall and available water resources at the 75% probability level.
2. To estimate weekly runoff and quantify water surplus or deficit in relation to crop-water requirements.
3. To develop a water-harvesting-based cropping plan using the estimated runoff-storage potential of the watershed.

3. Methodology

3.1 Description of the Study Area

The study was conducted in Vihokhu watershed of Kuhuboto Block, Dimapur district, Nagaland, India. The watershed covers approximately 807 ha.

Dimapur district has a humid subtropical climate. The study area receives rainfall primarily from the southwest monsoon, while rainfall during the winter period is comparatively low. The soils of the district are predominantly loamy to sandy loam, and soil acidity is an important characteristic of the area.

The agricultural system is strongly influenced by monsoon rainfall. Irrigation in the district is commonly supported by diversion of small hill streams.

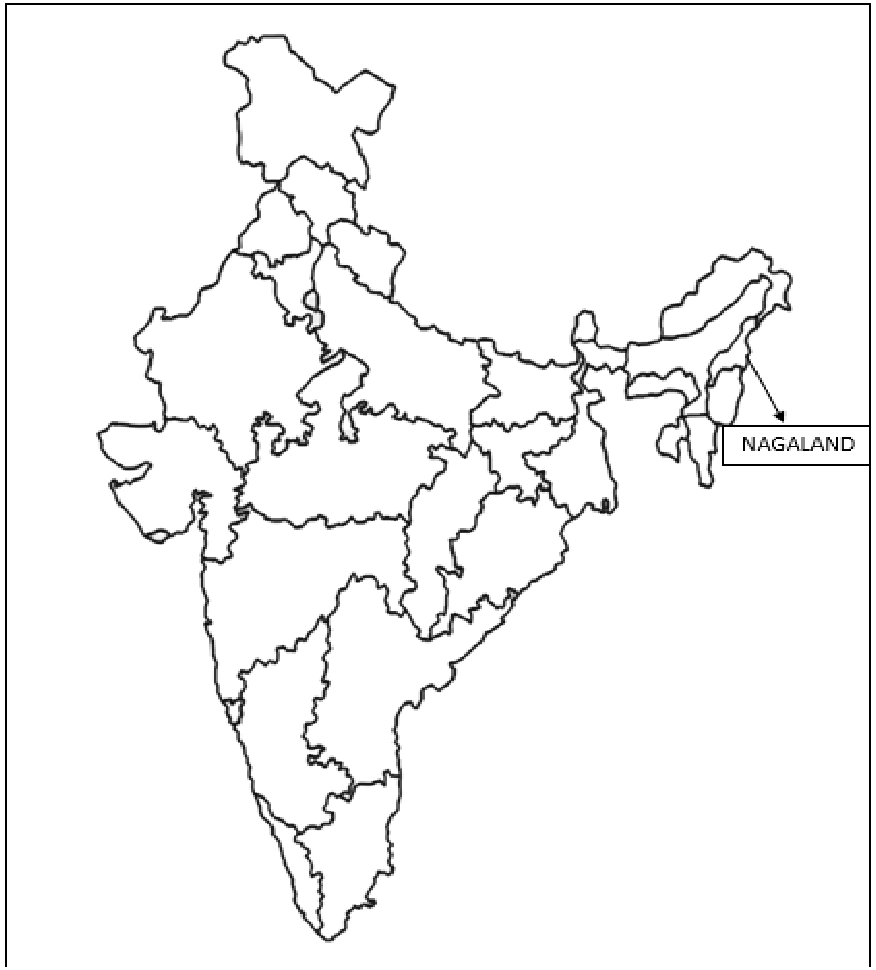

Fig. 1. Location Map of Nagaland in India

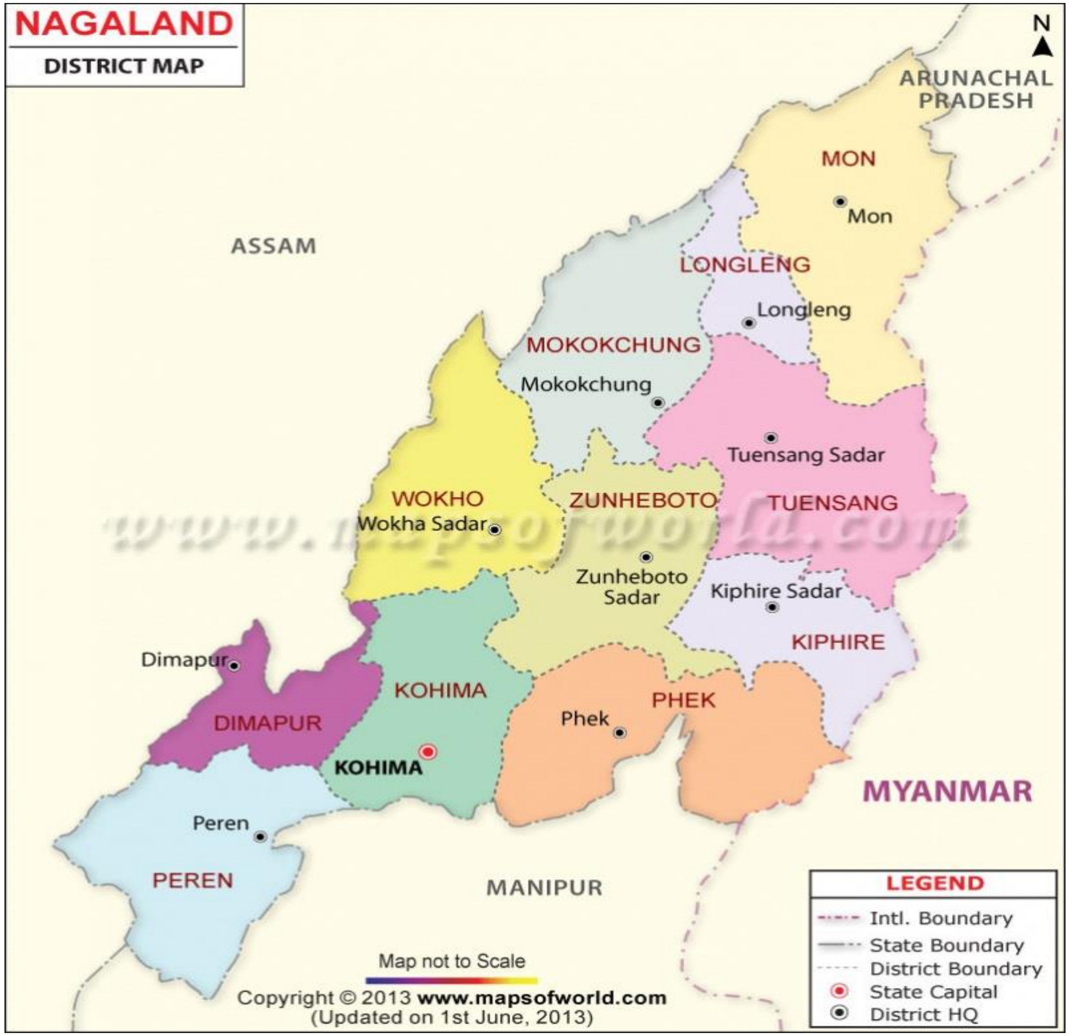

Fig 2. Location Map of Dimapur in Nagaland

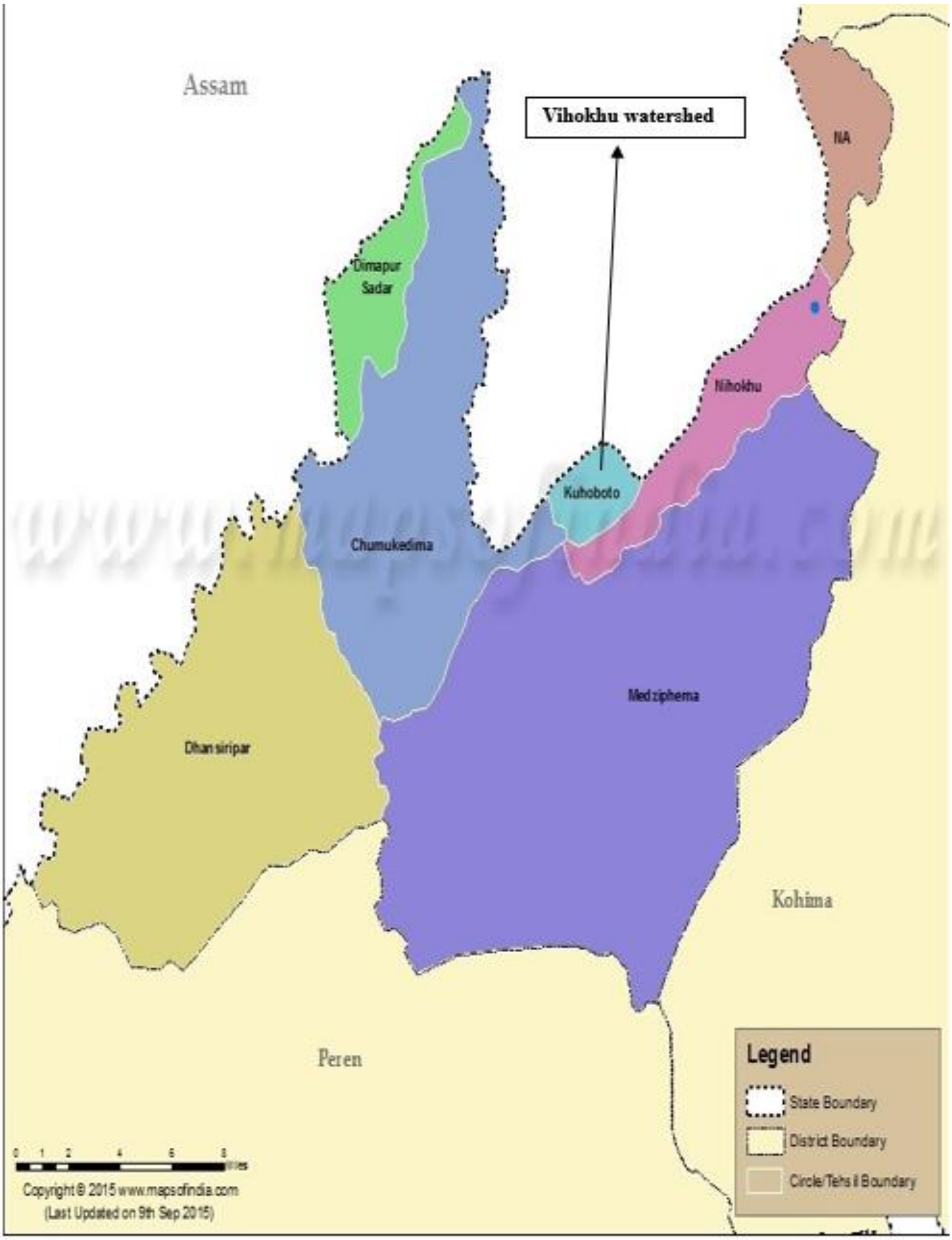

Fig 3. Vihokhu watershed in Dimapur district

3.2 Data Source and Period

Rainfall data for 15 years (2007–2021) were used. Because no meteorological station was available in the immediate vicinity of the watershed, data from the Dimapur Soil and Water Conservation Office, located approximately 24 km from the Vihokhu watershed, were used for hydrological analysis.

Rainfall data were analysed at:

- annual scale;
- monthly scale;
- weekly scale;
- seasonal scale; and
- different probability levels.

The original methodology specifically considered average, maximum and seasonal rainfall and rainfall at the 75% probability level for individual weeks.

3.3 Probability Analysis of Rainfall

Because rainfall is uncertain and variable, probability analysis was undertaken to estimate dependable weekly rainfall.
The study analysed rainfall at 60, 70, 75 and 80% probability levels. The 75% probability level was selected as the basis for agricultural water planning.

The Weibull plotting-position method was used to estimate rainfall probability. Rainfall observations were arranged according to magnitude and assigned ranks.

The plotting-position relationship was represented as:

$$P = \frac{m}{N+1} \times 100$$

where:
P= probability of occurrence (%),
m= rank of the rainfall observation, and
N= number of observations.
The resulting dependable weekly rainfall values were used for subsequent water-balance analysis.

3.4 Runoff Estimation

Runoff was estimated using Binnie's runoff coefficient method.
The relationship was:

$$R = KP \tag{1}$$

where:
R= runoff depth,
P= precipitation, and
K= runoff coefficient.
The study describes Binnie's method as a simple linear relationship between runoff yield and total rainfall.

The runoff depth was converted into volume according to watershed area:

$$V = R \times A \tag{2}$$

where:
V= runoff volume,
R= runoff depth, and
A= watershed area.
Runoff was assessed on a weekly basis to match the weekly crop-water requirements.

3.5 Assessment of Crop-water Requirement

The crop-water requirement was assessed for crops cultivated or proposed for different agricultural seasons.

The analysis considered:

- crop;
- season;
- sowing period;
- growth period;
- crop-water requirement;
- cultivated area; and
- weekly rainfall availability.

The methodology specified that crops grown during Kharif, Rabi and Zaid seasons were to be evaluated according to weekly crop-water requirements.

The weekly rainfall at 75% probability was compared with crop-water demand.

When rainfall exceeded the crop-water requirement, the excess was considered potentially available for drainage, runoff or storage.

When rainfall was below crop-water requirement, the difference represented the irrigation requirement.

3.6 Water-Storage Requirement

The cumulative runoff generated during the rainy season was assessed for storage.

The basic water balance was represented as:

$$S_t = S_{t-1} + I_t - O_t - L_t \tag{3}$$

where:
S_t= storage at time t,
S_{t-1}= previous storage,
I_t= inflow/runoff,
O_t= irrigation release, and
L_t= losses.

Storage planning considered evaporation, deep percolation and continuous stream-flow losses.

3.7 Cropping Model

A cropping model was developed based on available water resources and crop-water requirements.
The proposed cropping model covered approximately 175 ha and included:

- rice and soybean during Kharif;
- mustard, beans, pea and onion during Rabi; and
- maize and potato during Zaid.

The model was intended to utilise stored monsoon runoff for irrigation during periods of inadequate rainfall.

3.8 Water-harvesting Structure

The proposed water-harvesting structures were designed conceptually according to runoff availability, storage requirements and the topography of the watershed.

The original study proposed three water-harvesting ponds for the watershed.
The study also emphasised the role of ponds, check dams, boulder dams, chutes and spillways in reducing peak runoff and storing water for non-monsoon agricultural use.

4. Results and Discussion

Watershed management involves the planned use and conservation of land and water resources to control runoff, reduce soil erosion, conserve water and improve agricultural productivity. Conservation measures such as mechanical and vegetative barriers are adopted to reduce runoff velocity and protect soil and water resources, particularly on moderate to steep slopes.

Watersheds may deteriorate due to unplanned land use, deforestation, mining, construction, industrialisation, shifting cultivation, fires, overgrazing and soil erosion. Therefore, effective watershed management aims to control harmful runoff, reduce erosion and sedimentation, minimise downstream flooding, improve groundwater storage and promote sustainable use of land, forest and fodder resources.

Major components of watershed management include conservation farming, controlled grazing, irrigation and drainage management and erosion-control measures. The effectiveness of watershed management depends on factors such as watershed size and shape, topography, soil characteristics, rainfall, land use and vegetation cover.

Planning watershed development requires hydrological, soil, land-use and socio-economic data. Hydrological information includes rainfall, temperature, humidity, evaporation, sunshine, streamflow and sediment flow, while soil, topographic, geological, vegetation and socio-economic information support appropriate planning and implementation.

This paper focuses on estimating rainfall and runoff and their effective utilisation for improved agricultural production.

4.1 Hydrological Data Analysis (Precipitation)

The following section provides a detailed examination of precipitation and streamflow in the watershed.

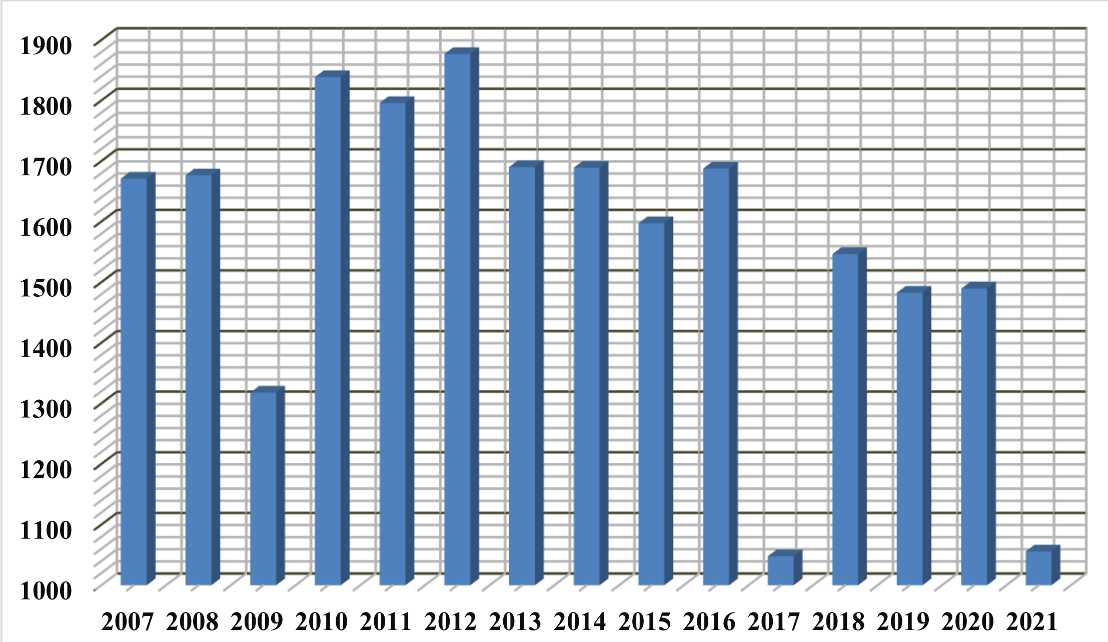

Fig. 4. Annual rainfall at Vihokhu watershed (2007-2021), mm

4.1.1 Analysis of Annual Rainfall Data

Hydrological data for the Vihokhu watershed were obtained from the Dimapur Soil and Water Conservation Office, located approximately 24 km from the watershed. The station was selected as the reference weather station because no meteorological station was available within or near the study area. Annual rainfall data for the 15-year period from 2007 to 2021 were analysed to assess the rainfall pattern and water availability in the watershed. The annual rainfall recorded during the study period varied considerably, ranging from 1,047.8 mm in 2017 to 1,876.7 mm in 2012, with a mean annual rainfall of 1,564.11 mm. The rainfall recorded during the individual years was 1,671.0 mm (2007), 1,676.3 mm (2008), 1,317.7 mm (2009), 1,838.6 mm (2010), 1,795.8 mm (2011), 1,876.7 mm (2012), 1,690.0 mm (2013), 1,688.9 mm (2014), 1,597.3 mm (2015), 1,687.7 mm (2016), 1,047.8 mm (2017), 1,546.2 mm (2018), 1,482.5 mm (2019), 1,489.4 mm (2020) and 1,055.8 mm (2021).

Table 1. Annual Rainfall (mm) 2007-2021 received at Vihokhu watershed (Kivishe *et al.*, 2025)

Year	Rainfall, mm
2007	1671
2008	1676.3
2009	1317.7
2010	1838.6
2011	1795.8
2012	1876.7
2013	1690
2014	1688.9
2015	1597.3
2016	1687.7
2017	1047.8
2018	1546.2
2019	1482.5
2020	1489.4
2021	1055.8

The results indicate substantial inter-annual variation in rainfall, with relatively high rainfall during 2010–2016 and comparatively lower rainfall in 2017 and 2021. Of the 15 years analysed, 10 years received more than 1,500 mm of annual rainfall, indicating considerable rainfall availability in the watershed. Such variability is important for watershed planning because rainfall directly influences runoff generation, water availability, soil erosion, and the performance of water-harvesting and conservation measures. Therefore, the analysis of long-term rainfall data provides an important basis for assessing runoff potential and developing suitable water-management and agricultural planning strategies for the Vihokhu watershed (Kivishe *et al.*, 2025).

4.1.2 Analysis of Monthly Rainfall Data

The monthly rainfall data for the 15-year period from 2007 to 2021 are presented in Table 2. The analysis revealed a distinct seasonal pattern in rainfall distribution across the Vihokhu watershed. Monthly rainfall varied considerably during the study period, with the highest monthly rainfall of 432.4 mm recorded in July 2010, while zero rainfall was recorded in December 2009 and December 2014. The mean monthly rainfall was lowest during December (16.99 mm), January (17.27 mm), February (21.72 mm), March (38.45 mm) and November (36.50 mm), indicating relatively dry conditions during the winter and early spring months. In contrast, rainfall increased substantially from April onwards, with mean monthly rainfall of 101.99 mm in April, 192.75 mm in May, 270.40 mm in June, 312.35 mm in July and 272.75 mm in August.

The rainfall pattern indicates that the watershed receives the majority of its annual precipitation during the June–August period, with July being the wettest month. The mean rainfall during September and October was 166.19 and 116.76 mm, respectively, showing a gradual decline after the monsoon period. Overall, the monthly rainfall distribution demonstrates a pronounced seasonal concentration of precipitation, which has important implications for runoff generation, soil erosion, water harvesting and agricultural water management in the watershed. The high rainfall received during the monsoon months provides considerable potential for rainwater harvesting and runoff management, while the low rainfall during the dry months highlights the need for appropriate water-conservation measures to support agricultural activities.

Table 2. monthly rainfall received (mm) 2007-2021 at Vihokhu watershed (Kivishe *et al.*, 2025)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2007	11.4	33.4	15.6	125.8	343.5	248.5	356.4	311	165.8	55.6	2.2	1.8
2008	18.4	24.5	31.9	72.1	160.2	285.2	292.7	379.4	211.6	142.8	25.1	32.4
2009	17.3	10.6	36.2	73	103.6	203.8	311.6	288.8	188.9	44.2	39.7	0
2010	35.6	0.2	72.6	126.2	144.4	423.5	432.4	277.3	167.8	110	38.6	10
2011	12	31	56.8	163.5	276	419.7	341.4	278	110.3	41.1	38.9	27.1
2012	18	20.3	44	135.4	287.5	365.9	368	309.6	155	108.7	44.8	19.5
2013	23.6	29.2	62.6	90.4	174.5	353.5	332.3	306.3	193.3	67.8	31.2	25.3
2014	10.4	17.3	27.3	167.1	269.7	329.1	306.5	255	142.2	110.9	53.4	0
2015	16.2	28.6	13.3	149.5	230.2	245.4	220.6	305	211.9	131.7	26.5	18.4
2016	15	23	38	109.8	140.5	269.4	391.7	222.5	262.9	84.5	93.6	36.8
2017	24.9	8.4	12.4	46.2	71.8	120.9	211.7	287.8	65.8	156.9	35.6	5.4
2018	5.5	23.9	58.5	57	138.5	162.8	348.2	319.5	248.4	118.4	45.2	20.3
2019	16.4	24.9	45.1	85.5	222	205.2	265.5	173.6	110.2	291.7	18.8	23.6
2020	20.5	10.7	18.4	69.4	176.7	258.4	246.9	242.2	137.4	254.5	41.6	12.7
2021	13.8	39.8	44	59	152.1	164.7	259.3	135.3	121.4	32.6	12.3	21.5

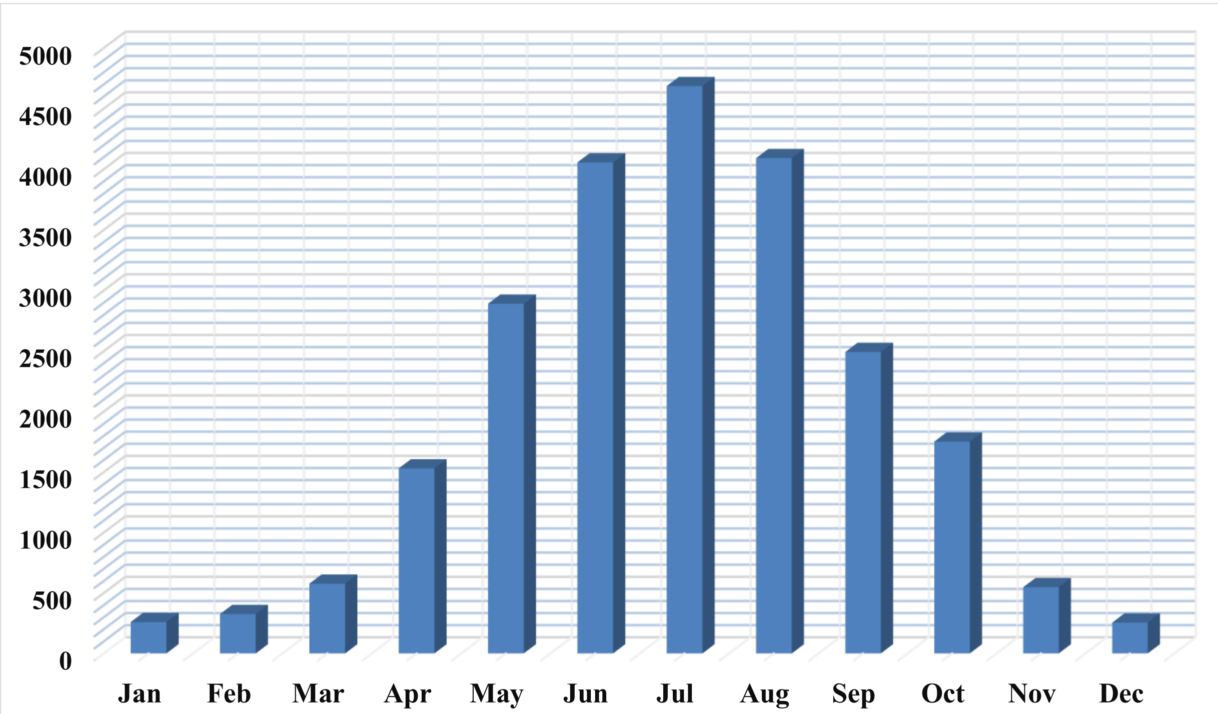

Fig. 5. Monthly rainfall at Vihokhu Watershed (2007-2021), mm

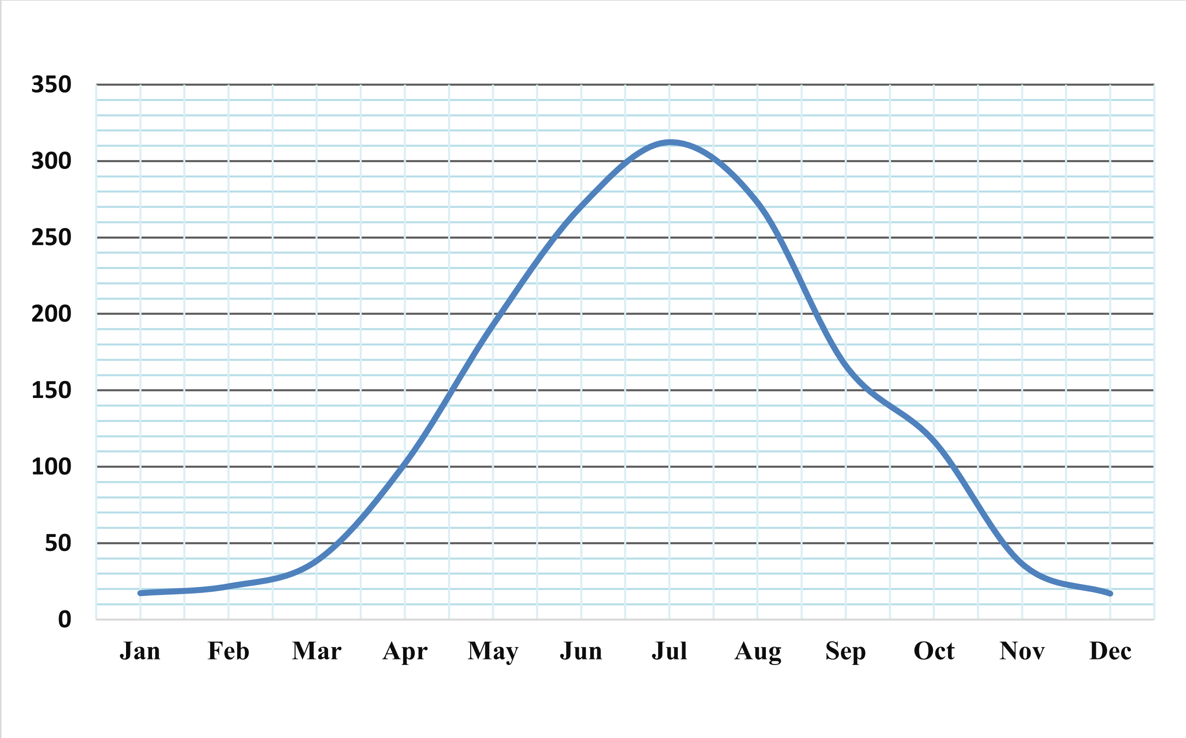

Fig. 6 Average Monthly Rainfall at Vihokhu Watershed (2007-2021), mm

Fig. 6 shows a sudden rise and fall, indicating a high degree of precipitation variability in the watershed. Fig. 6 presents the average monthly rainfall. In addition, Table 3 presents three statistical metrics for these values, including the average ($\bar{X}$), standard deviation (σ), coefficient of variation (C_v), and coefficient of skewness (C_s).

Table. 3 Mean Monthly Rainfall (mm) received at Vihokhu Watershed (2007-2021) (Kivishe *et al.*, 2025)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17.26	21.72	38.44	101.99	192.74	270.4	312.34	272.75	166.19	116.76	36.5	16.98

Mean= 130.34, SD = 110.32, C_v = 0.85, C_s = 0.57

The mean monthly rainfall during 2007–2021 varied considerably across the Vihokhu watershed (Table 3; Figs. 5 and 6). The overall mean monthly rainfall was 130.34 mm, with a standard deviation of 110.32 mm and a coefficient of variation of 0.85 (85%), indicating high rainfall variability. July received the highest mean rainfall (312.34 mm), followed by August (272.75 mm) and June (270.40 mm), whereas December (16.98 mm) recorded the lowest. The coefficient of skewness (0.57) indicated moderate positive skewness, reflecting the concentration of rainfall during the monsoon months. This seasonal variability highlights the importance of rainwater harvesting and runoff-management measures in the watershed.

4.1.3 Analysis of Weekly Rainfall Data

Weekly rainfall analysis was conducted using seven-day rainfall totals for the period 2007–2021 to assess the temporal distribution of rainfall and its implications for agricultural water management in the Vihokhu watershed. The analysis was carried out at 60, 70, 75 and 80% probability levels, and the estimated weekly rainfall values are presented in Table 4. The corresponding rainfall patterns are illustrated in Figs. 7 and 8. The use of weekly rainfall data provides a basis for identifying periods of relatively adequate and inadequate rainfall during the crop-growing season and for supporting irrigation and water-management planning.

The results presented in Table 4 indicate considerable seasonal variation in weekly rainfall. At the 60% probability level, no rainfall was estimated during Weeks 1–10 and 43–52. At the 70, 75 and 80% probability levels, rainfall was absent during Weeks 1–14 and 41–52, indicating that these periods represented the comparatively driest part of the year. Rainfall availability increased substantially during the intervening weeks, particularly during the monsoon period. Fig. 8 clearly illustrates the seasonal rise and decline in weekly rainfall at the different probability levels.

The 75% probability level was considered for dependable rainfall assessment and agricultural planning in the watershed. At this probability level, weekly rainfall during Weeks 20–37 ranged from 20.4 to 74.3 mm, demonstrating considerable variation in rainfall availability during the crop-growing period. The rainfall distribution showed an increasing trend during the onset of the rainy season, followed by relatively higher rainfall during the central period and a subsequent decline towards the end of the season, as shown in Figs. 8 and 9. Such variation is important for determining the availability of rainfall for crop use, runoff generation and water storage.

The weekly rainfall analysis provides useful information for crop planning and water-resource management in the Vihokhu watershed. Although rainfall during the monsoon period provides substantial water availability, its uneven distribution indicates that rainfall alone may not consistently satisfy crop-water requirements throughout the growing season. Therefore, periods of relatively low rainfall should be considered when planning supplemental irrigation and water-harvesting measures. The 75% probability rainfall distribution can consequently serve as a useful basis for planning the utilisation of available water for irrigation, drainage and storage and for developing suitable agricultural water-management strategies in the watershed.

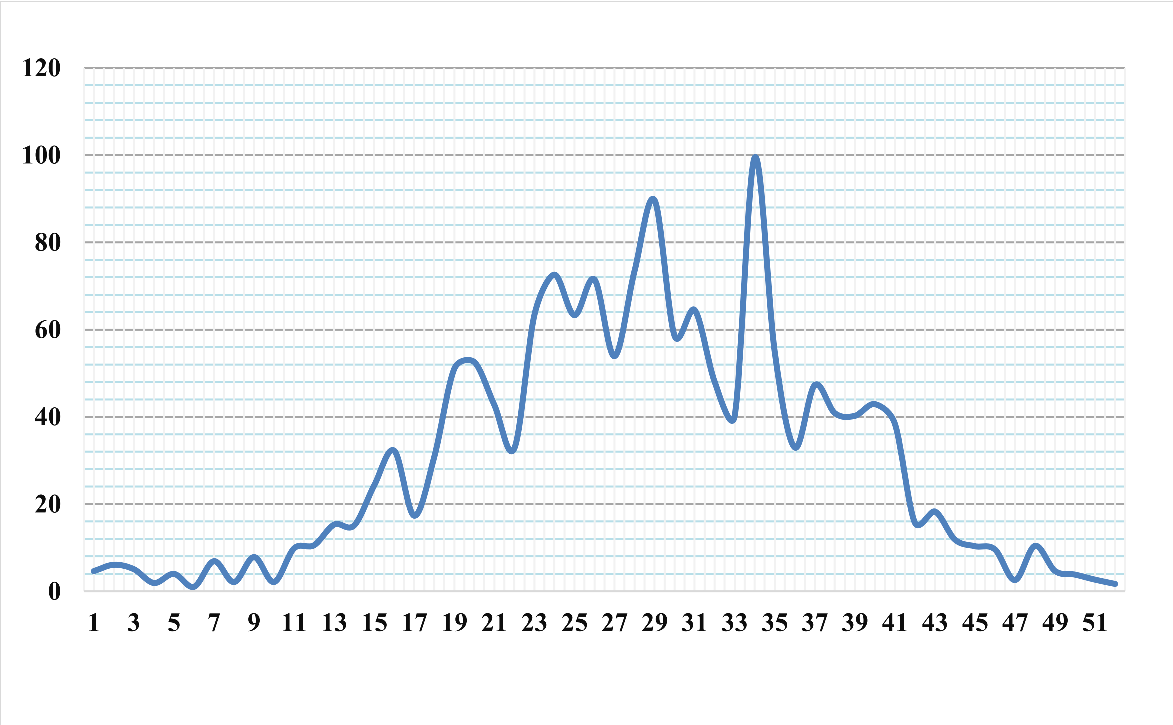

Fig. 7. Weekly Rainfall pattern at Vihokhu Watershed (2007-2021), mm

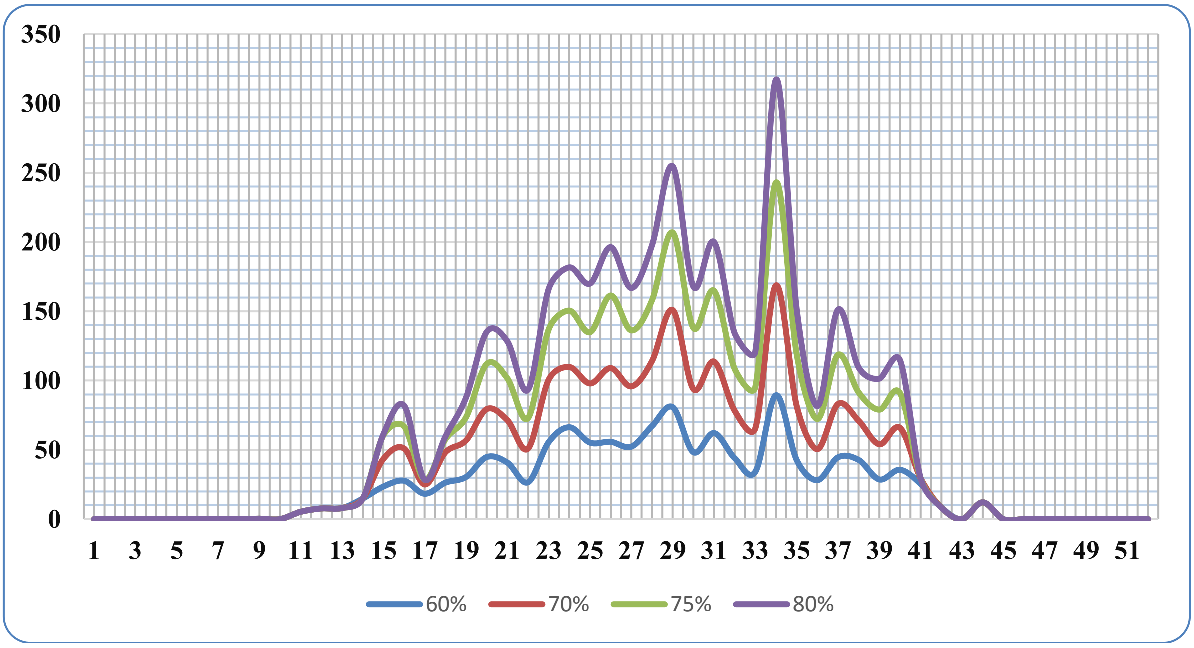

Fig. 8 Weekly Rainfall pattern, mm at different level of probability at Vihokhu watershed (2007-2021), mm

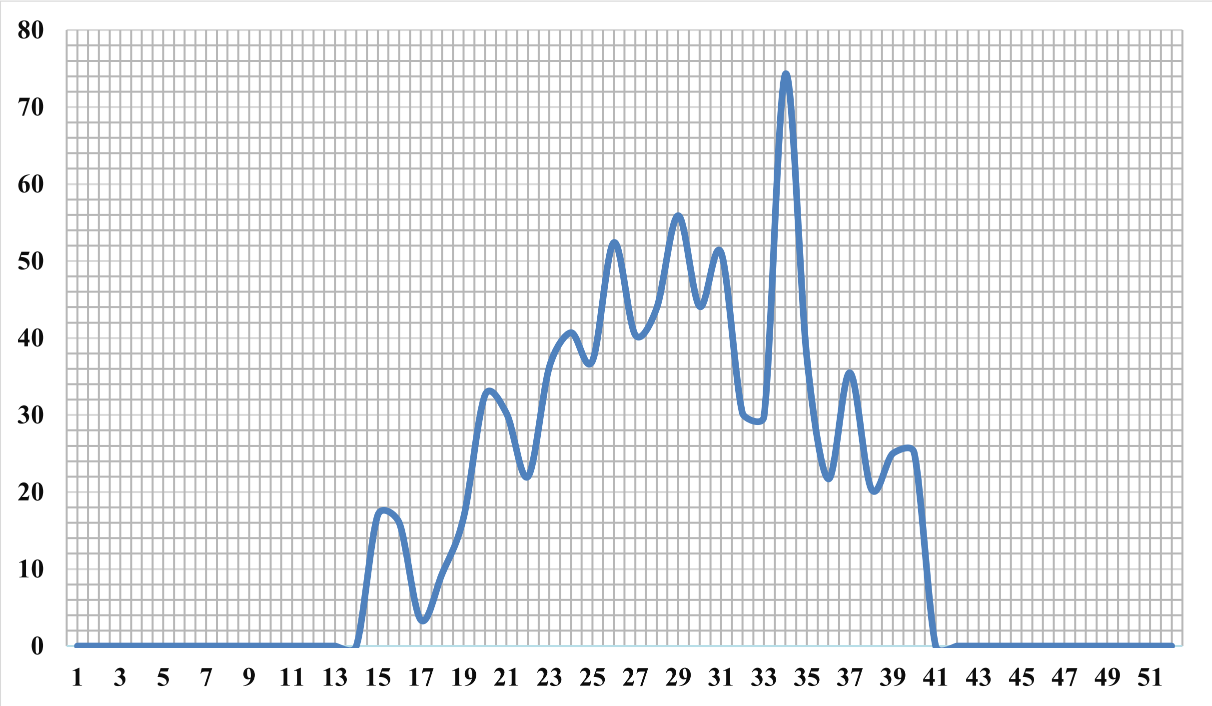

Fig. 9. Rainfall distribution at 75% level of probability (2007-2021), mm

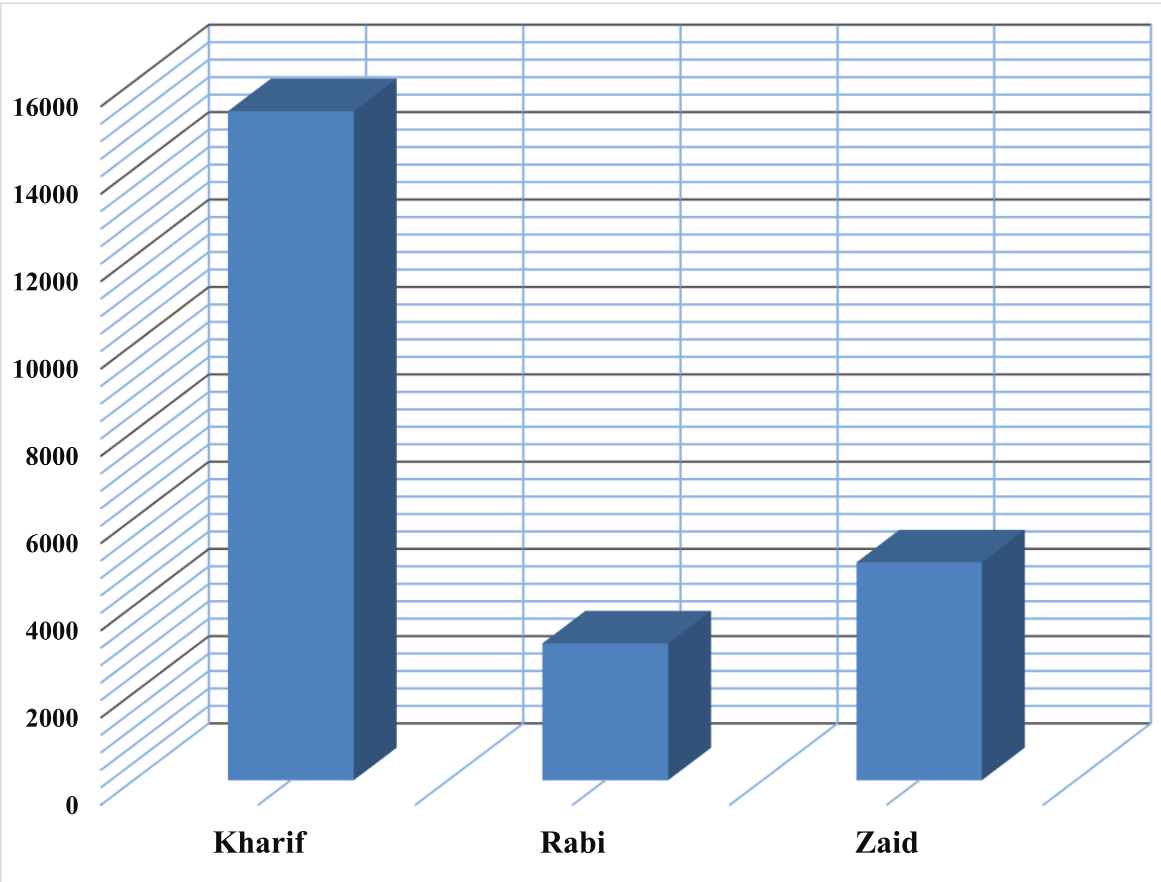

Fig. 10. Seasonal Rainfall Pattern at Vihokhu Watershed (2007-2021), mm

Table 4. weekly rainfall pattern at different level of probability, mm (2007-2021) (Kivishe *et al.*, 2025)

Week No	60%	70%	75%	80%
1	0	0	**0**	0
2	0	0	**0**	0
3	0	0	**0**	0
4	0	0	**0**	0
5	0	0	**0**	0
6	0	0	**0**	0
7	0	0	**0**	0
8	0	0	**0**	0
9	0.3	0	**0**	0
10	0	0	**0**	0
11	5.3	0	**0**	0
12	7.7	0	**0**	0
13	8	0	**0**	0
14	14.8	0	**0**	0
15	23.5	20	**17**	0.8
16	27.7	23.3	**16**	15
17	18.3	6.7	**3.4**	0
18	26.3	21.9	**9.4**	2
19	30.4	26.4	**16.7**	14.2
20	44.8	34.6	**32.6**	23.1
21	40.8	30.6	**30.2**	26.7
22	26.6	24.3	**22**	20.5
23	55.6	45.1	**36.3**	29.2
24	66.3	43.5	**40.7**	31.2
25	55.2	42.7	**37**	35.1
26	55.8	53.2	**52.4**	34.9
27	52.3	43.5	**40.4**	30.6
28	67.2	46.9	**43.9**	39.7
29	80.8	70.1	**55.9**	47.8
30	48.3	45.6	**44.1**	29.8
31	62.1	51.6	**51.1**	35.2
32	44	34.2	**30.2**	25.7
33	34.2	31.4	**29.8**	25.6
34	89.4	79.3	**74.3**	74.2
35	42.6	39	**37.4**	32.4
36	28.1	22.4	**21.7**	9.4
37	44.6	38.5	**35.5**	32.6
38	42.7	28.3	**20.4**	18
39	28.6	25.4	**25**	22.4
40	35.6	30.3	**25.1**	23.7
41	25.4	4	**0**	0
42	8.4	0	**0**	0
43	0	0	**0**	0
44	12.1	0	**0**	0
45	0	0	**0**	0
46	0	0	**0**	0
47	0	0	**0**	0
48	0	0	**0**	0
49	0	0	**0**	0
50	0	0	**0**	0
51	0	0	**0**	0
52	0	0	**0**	0

4.1.4 Analysis of Seasonal Rainfall Data

The annual rainfall was divided into three agricultural seasons, namely kharif, Zaid and rabi, to assess its seasonal distribution in the Vihokhu watershed. Based on the 75% probability level, the kharif season (Weeks 24–42) received the highest cumulative rainfall of 701.2 mm, followed by the Zaid season (Weeks 10–23) with 147.3 mm, while the rabi season (Weeks 43–9) received negligible rainfall. The seasonal rainfall distribution is presented in Fig. 10.

The results indicate that dependable rainfall in the watershed is concentrated mainly during the kharif season, whereas rainfall availability is considerably lower during the Zaid and rabi seasons. This seasonal pattern has important implications for agricultural planning and water-resource management. The higher rainfall during the kharif season provides opportunities for runoff collection and water harvesting, while stored water can potentially be utilised during periods of lower rainfall to support crop production and supplemental irrigation.

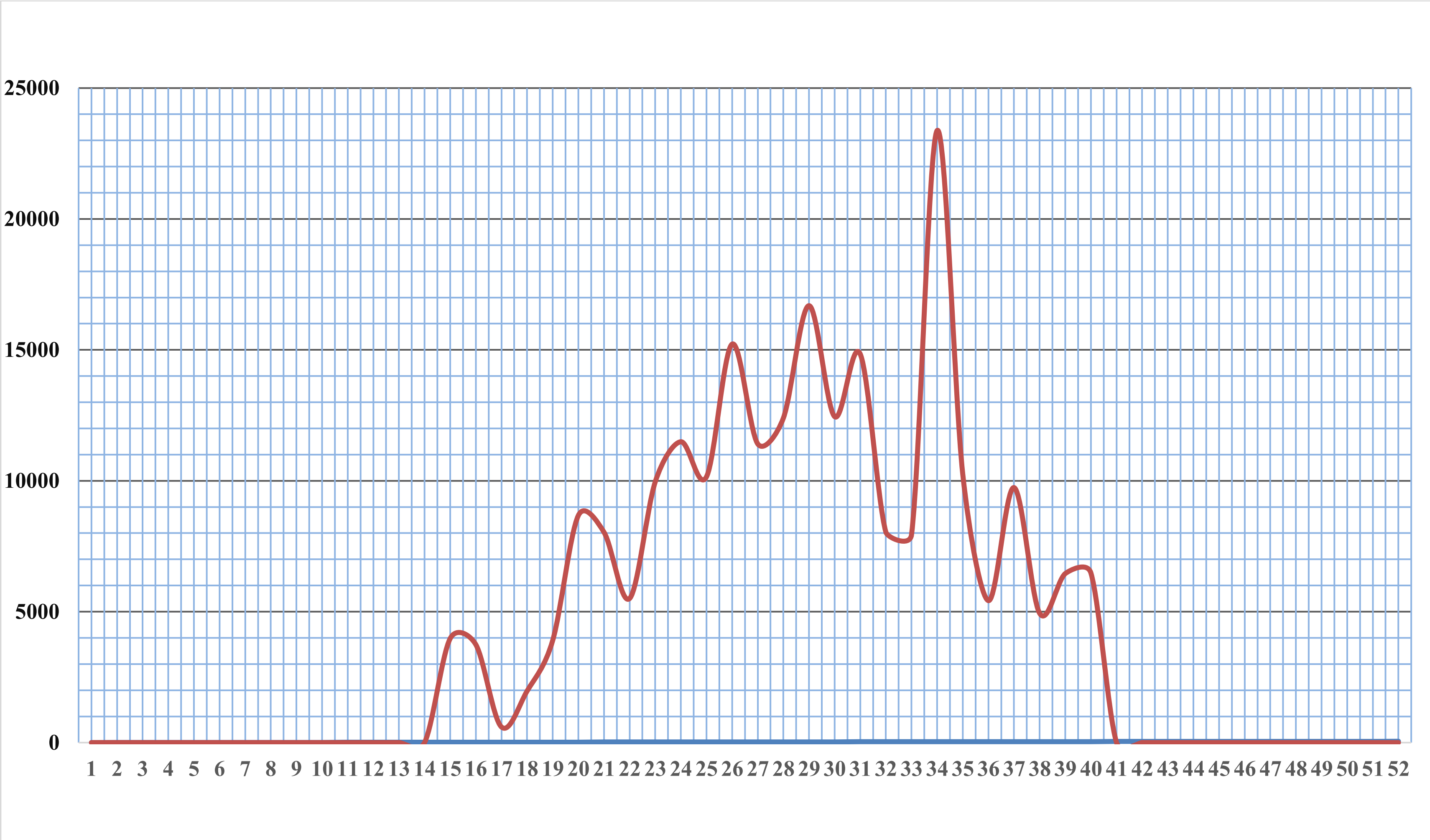

Fig. 11. Weekly Estimated Runoff Pattern at Vihokhu Watershed (2007-2021), ha- mm

4.2 Hydrological Data Analysis (Stream Flow)

For the development of water resources in a watershed, streamflow data obtained from the watershed are crucial.

These data enable estimation of the amount of water that could be safely stored in a water-harvesting facility or pond in the watershed. During non-monsoon periods, crops may be irrigated with this stored water. Streamflow data are analysed on a weekly water-availability basis, and the available runoff/storage may also be used to estimate the effective crop area that could be brought under cultivation in a given season under a specified cropping pattern.

4.2.1 Runoff Depth

The runoff value (equivalent depth) was estimated using the relationship between rainfall and runoff. Table 5 presents this information.

4.2.2 Runoff Volume

Similar calculations were made to determine the equivalent runoff volume for each week by multiplying the watershed area, ha, by the runoff depth, mm; the results are shown in Table 5.

4.2.3 Weekly Stream Flow Data Analysis

The amount of water to be redirected from the storage reservoir to the crops is determined through weekly analysis of streamflow data because watershed planning involves agricultural activities, particularly supplying water to crops at weekly irrigation intervals. A graph of the stream's weekly input is shown in Fig. 11. According to Fig. 11, the runoff curve varies from Week No. 15 to Week No. 40, with zero runoff recorded in certain weeks (1-14 and 41-52) and Week 34 recording the highest runoff at 23378.79 ha-mm. The abrupt rise and fall of the runoff curve suggest that there is greater scope to moderate this substantial runoff by storing it in a water-harvesting pond. Due to baseflow restrictions in the downstream watershed, these water resources cannot be fully utilised for irrigation, and they also cannot all be stored in reservoirs or water-harvesting ponds because of other losses, including evaporation and deep percolation from the reservoir. Construction of a water-harvesting structure is recommended.

4.3 Crops Grown in the Watershed and Their Water-Requirement Analysis

A watershed's cropping strategy is essential both for maintaining good soil health and for maximising regional agricultural output and productivity.

4.3.1 Recommended Crops and Their Growing Periods

The recommendations of the state agricultural department and the cropping pattern followed by rural farmers both show that the land is suitable for growing crops throughout the year. In addition, kharif crops such as rice and soybean can be grown successfully, while winter crops such as peas, beans, mustard and onions can also be grown. Potato and corn can be grown as Zaid crops. The different crops and growing seasons are presented in Appendix C, as recommended by the state department of agriculture.

4.3.2 Proposed Area Under Different Crops

Of the estimated 175 ha of cultivated land in the Vihokhu watershed, it was advised that rice and soybean be cultivated on 46% of the total cultivable land during the kharif season; peas, beans, mustard and onions on 26% of the total cultivable area during the rabi season; and maize on 28% of the total cultivable area during the Zaid season.

4.3.3 Crop Water Requirement (equivalent depth)

Appendix D provides information on the crops' weekly water needs and requirements.

4.3.4 Storage Pond and Groundwater Release (Equivalent Depth)

Irrigation needs and agricultural water demands were calculated on a weekly basis. Since maximum rainfall is received during the monsoon season and exceeds crop-water needs, whereas the remaining seasons receive very little or no rainfall, it is evident that irrigation from storage reservoirs or groundwater will be required during some weeks. Therefore, irrigation plans were devised according to the cropping pattern.

Table 5. Weekly runoff depth and runoff volume storage at different weeks available at Vihokhu watershed (2007-2021)

Week No	Binnie's runoff coefficient, K	Rainfall, P at 75% level of probability, mm	Runoff (R), mm	Runoff (R), ha-mm
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0.29	17	4.93	3978.51
16	0.29	16	4.16	3744.48
17	0.22	3.4	0.74	597.18
18	0.26	9.4	2.44	1969.08
19	0.29	16.7	4.84	3905.88
20	0.33	32.6	10.75	8675.25
21	0.33	30.2	9.96	8037.72
22	0.31	22	6.82	5503.74
23	0.34	36.3	12.34	9958.38
24	0.35	40.7	14.24	11491.68
25	0.34	37	12.58	10152.06
26	0.36	52.4	18.86	15220.02
27	0.35	40.4	14.14	11410.98
28	0.35	43.9	15.36	12395.52
29	0.37	55.9	20.68	16688.76
30	0.35	44.1	15.43	12452.01
31	0.36	51.1	18.39	14840.73
32	0.33	30.2	9.96	8037.72
33	0.33	29.8	9.83	7932.81
34	0.39	74.3	28.97	23378.79
35	0.34	37.4	12.71	10256.97
36	0.31	21.7	6.72	5423.04
37	0.34	35.5	12.07	9740.49
38	0.3	20.4	6.12	4938.84
39	0.32	25	8	6456
40	0.32	25.1	8.03	6480.21
41	0	0	0	0
42	0	0	0	0
43	0	0	0	0
44	0	0	0	0
45	0	0	0	0
46	0	0	0	0
47	0	0	0	0
48	0	0	0	0
49	0	0	0	0
50	0	0	0	0
51	0	0	0	0
52	0	0	0	0

Table 6. Proposed area of crop grown in the Vihokhu watershed

	Proposed crop to be grown	Area (ha)
Kharif season (46%) cropping intensity	Rice	60
	Soybean	20
Rabi season (26%) cropping intensity	Mustard	20
	Beans	15
	Pea	10
	Onion	10
Zaid season (28%) cropping intensity	Maize	20
	Potato	20

Table 7. Weekly storage water release for irrigation at Vihokhu Watershed

Week No	Water need, mm	Water need, ha-mm	Rainfall ha-mm	Irrigation req, ha-mm	Runoff, ha-mm	Storage ha-mm	groundwater need, ha-mm	Surplus storage, ha-mm
1	70	3850	0	3850	0	0	3850	156073
2	75	4125	0	4125	0	0	4125	151948
3	30	900	0	900	0	0	900	151048
4	25	750	0	750	0	0	750	150298
5	20	600	0	600	0	0	600	149698
6	20	200	0	200	0	0	200	149498
7	20	200	0	200	0	0	200	149298
8	20	200	0	200	0	0	200	149098
9	10	100	0	100	0	0	100	148998
10	10	100	0	100	0	0	100	148898
11	10	100	0	100	0	0	100	148798
12	70	1400	0	1400	0	0	1400	147398
13	120	4800	0	4800	0	0	4800	142598
14	70	2800	0	2800	0	0	2800	139798
15	70	2800	680	2120	13719	6859.5	-4739.5	4739.5
16	70	2800	640	2160	12912	6456	-4296	4296
17	70	2800	136	2664	2743.8	1371.9	1292.1	1292.1
18	70	2800	376	2424	7585.8	3792.9	-1368.9	1368.9
19	70	2800	668	2132	13476.9	6738.45	-4606.45	4606.45
20	70	2800	1304	1496	26308.2	13154.1	-11658.1	11658.1
21	70	2800	1208	1592	24371.4	12185.7	-10593.7	10593.7
22	70	2800	1980	820	17754	8877	-8057	8057
23	180	14400	2904	11496	29294.1	14647.05	-3151.05	3151.05
24	200	18000	3663	14337	32844.9	16422.45	-2085.45	2085.45
25	150	13500	3330	10170	29859	14929	-4759.5	4759.5
26	140	9800	3668	6132	42286.8	21143.4	-15011.4	15011.4
27	190	13300	2828	10472	32602.8	16301.4	-5829.4	5829.4
28	140	9800	3073	6727	35427.3	17713.65	-10986.65	10986.65
29	120	6000	2775	3225	45111.3	22555.65	-19330.6 5	19330.65
30	130	6500	2205	4295	35588.7	17794.35	-13499.35	13499.35
31	130	6500	2755	3745	41237.7	20618.85	-16873.85	16873.85
32	120	6000	1510	4490	24371.4	12185.7	-7695.7	7695.7
33	130	6500	1490	5010	24048.6	12024.3	-7014.3	7014.3
34	120	6000	3715	2285	59960.1	29980.05	-27695.05	27695.05
35	120	6000	1870	4130	30181.8	15090.9	-10960.9	10960.9
36	90	4500	1085	3415	17511.9	8755.95	-5340.95	5340.95
37	70	3500	1775	1725	28648.5	14324.25	-12599.25	12599.25
38	60	3000	1020	1980	16462.8	8231.4	-6251.4	6251.4
39	30	300	250	50	20175	10087.5	-10037.5	10037.5
40	80	2400	753	1647	20255.7	10127.85	-8480.85	8480.85
41	110	3850	0	3850	0	0	3850	230364.95
42	150	6750	0	6750	0	0	6750	223614.95
43	115	5175	0	5175	0	0	5175	218439.95
44	80	3600	0	3600	0	0	3600	214839.95
45	205	11275	0	11275	0	0	11275	203564.95
46	150	8250	0	8250	0	0	8250	195314.95
47	130	7150	0	7150	0	0	7150	188164.95
48	100	5500	0	5500	0	0	5500	182664.95
49	120	6600	0	6600	0	0	6600	176064.95
50	105	5775	0	5775	0	0	5775	170289.95
51	85	4675	0	4675	0	0	4675	165614.95
52	80	4400	0	4400	0	0	4400	161214.95

4.4 Water Harvesting/Storage Requirement

Since most rainfall occurs during the monsoon season, which lasts from Week No. 26 to Week No. 40, Fig. 10 indicates that irrigation throughout the 52 weeks of the year may be supported by harvested rainfall if water-harvesting structures or reservoirs are available in the watershed. Therefore, construction of water-harvesting structures or reservoirs is advised.

4.4.1 Cumulative Runoff Volume for Storage Requirement, ha-mm

The amount of water to be redirected from the storage reservoir to the crop is determined by weekly examination of streamflow data. The amount, intensity and duration of rainfall are crucial factors in runoff formation and were therefore taken into consideration. The watershed area and runoff depth were multiplied to estimate the streamflow volume for each week. The runoff volume in ha-mm is shown in Table 5, and the cumulative runoff is represented graphically in Fig. 11. Cumulative runoff stored and made available in the watershed from Weeks 42 to 13 is presented in Table 7 after accounting for additional related losses, such as evaporation and deep percolation from the water reservoirs.

4.4.2 Available Cumulative Runoff at the Reservoir

The total amount of water available was 233.54 ha-m according to Appendix B. After accounting for 35 percent losses due to evaporation, deep percolation and continuous streamflow, the actual amount of water available was estimated as (233.54 × 65) 151.80 ha-m, leaving 151.80 ha-m as surplus available for storage.

4.5 Hydrological Data Analysis (Groundwater)

Table 7 indicates that monsoon rainfall, if stored or harvested in storage/ponds, is sufficient to irrigate crops throughout the year. Hence, groundwater use is not required.

4.6 Design and Management of Water-Harvesting Structures

It is advisable to store a portion of runoff received from the watershed during monsoon periods in reservoirs or ponds, wherever possible, so that the stored water can supplement crop-water needs during weeks of low rainfall or during non-monsoon seasons. In addition, this stored water can meet part of the domestic water needs of inhabitants living near the reservoirs. State and Central Government agencies have been supporting the construction of water-harvesting ponds on a large scale in rainfed districts of the country through financial assistance to farmers. It is observed in many states that centrally sponsored schemes currently extend Rs 75,000/- (partially funded) for construction of one water-harvesting pond for 0.25 acres of land.

The size of the ponds depends on the area available at the site and the storage depth required on the basis of crop irrigation-water needs, domestic water needs and the animal population, etc. The type of pond also affects resource requirements (money/funding), with options such as (i) excavation type or (ii) embankment type. As the watershed is located in a hillside area, embankment-type construction will require relatively less funding.

It is proposed that two or three water-harvesting ponds be constructed in the watershed to store water to a depth of not more than 3 m each (greater storage depth may create stability problems in the embankment). The length of the embankment should not exceed 300 m (greater length would require more funds for annual maintenance, which farmers may find difficult to provide). For an ordinary agricultural water-harvesting pond, the capacity recommended for the project under consideration would be around 0.5 x 10 x 3 m x 200 m i.e., 3000 ha-m (embankment type). A cross-section of such a structure is presented below. A curvilinear dyke, if found suitable during survey and site inspection, will provide a better design in terms of structural stability when the highest storage event is considered.

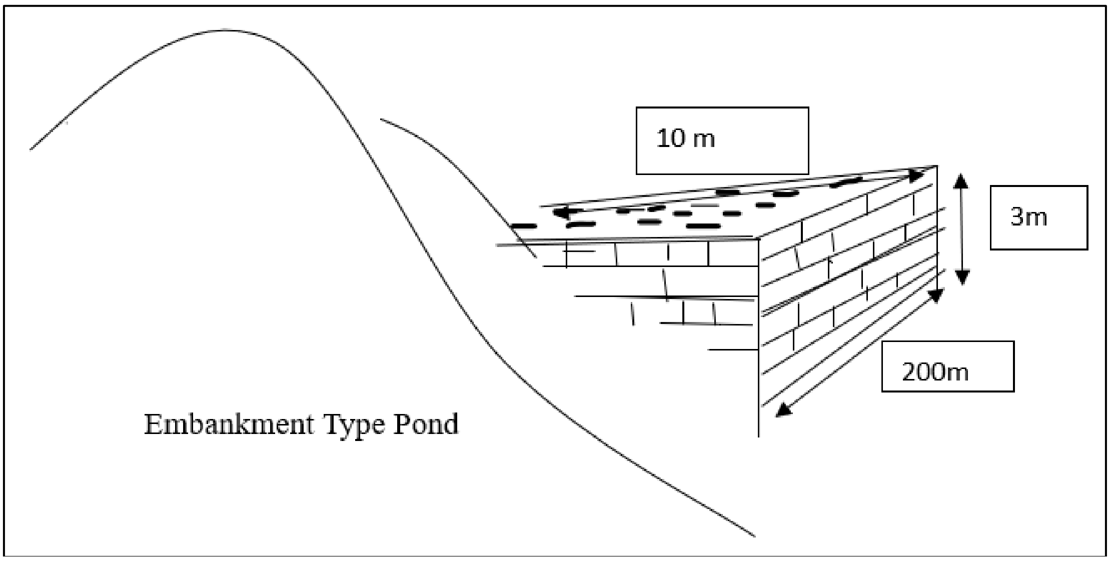

Fig. 12. Recommended Water harvesting structure to be built in watershed

5. Conclusion

The present study assessed rainfall availability, runoff generation, crop-water requirement and water-harvesting potential in Vihokhu watershed of Dimapur district, Nagaland. The watershed received an average annual rainfall of 1564.11 mm during 2007–

2021, but rainfall distribution was highly seasonal. July received the highest average monthly rainfall of 312.34 mm, whereas January and December received only 17.26 and 16.98 mm, respectively. The substantial seasonal variation demonstrates that annual rainfall alone is insufficient for reliable agricultural water planning. Weekly rainfall analysis at the 75% probability level showed that dependable rainfall was absent during Weeks 1–14 and 41–52. Thus, a substantial portion of the year requires irrigation support if crops are to be cultivated continuously. Runoff estimation demonstrated that the monsoon period generates substantial surface-water resources. The cumulative runoff available for storage was estimated at approximately 233.54 ha-m. This water can potentially be harvested and utilised during periods of rainfall deficit. The proposed 175-ha cropping model consisting of rice and soybean in Kharif, mustard, beans, pea and onion in Rabi, and maize and potato in Zaid provides an integrated framework for increasing agricultural water utilisation. The study proposes three water-harvesting ponds to conserve monsoon runoff for non-monsoon irrigation. The overall findings demonstrate that an integrated approach combining dependable rainfall analysis, runoff estimation, crop-water budgeting and water storage can improve agricultural water security in Vihokhu watershed. For practical implementation, detailed engineering surveys, site-specific storage calculations, hydrological monitoring and economic feasibility assessment should be conducted before construction of the proposed structures.

6. Limitation

The analysis is based on a 15-year rainfall record from a station located approximately 24 km from the watershed because no meteorological station was available within or near the study area. Consequently, the assessment may not fully represent small-scale spatial variability in rainfall across the watershed. In addition, the proposed water-harvesting structures are conceptual and require detailed site surveys, storage calculations, hydrological monitoring and economic feasibility assessment before implementation. These limitations should be considered when applying the proposed cropping and water-storage plan at field scale.

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Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices

Weekly rainfall in mm (2007-2014) received in Vihokhu watershed. Appendix A

Week No	2007	2008	2009	2010	2011	2012	2013	2014
1	11.4	0	0	20.3	0	0	0	0
2	0	18.4	0	0	0	18	23.6	0
3	0	0	17.3	0	12	0	0	10.4
4	0	0	0	15.3	0	0	0	0
5	12	0	0	0	0	20.3	17.2	0
6	0	2.3	0	0	0	0	0	0
7	18.4	0	6.4	0	20	0	12	17.3
8	0	0	0	0.2	0	0	0	0
9	5.6	22.2	4.2	0	11	0	0	0
10	0	0	0	0	20.3	0	0	0
11	5.3	8.2	0	18.4	12.3	31.6	12.4	0
12	7.7	16.7	0	24.5	0	12.4	35.8	27.3
13	0	7	36.2	29.6	23.8	0	14.4	0
14	20.7	19.6	14.8	0	28.6	20.3	12.1	24.2
15	41.5	20.4	20	28.2	36.1	32.8	23.5	41.7
16	41.6	32.1	0	56	44.2	52.1	15	38.1
17	22	0	28.2	21.6	34.2	30.2	13.5	32.6
18	0	33.2	21.9	40.4	69.4	56.4	26.3	53.5
19	136.2	16.7	30.4	26.4	72.4	60.2	110.9	88.6
20	158	66.2	34.6	44.8	73.2	76.3	23.1	63.2
21	49.3	23.6	26.7	42.2	80.8	50.4	30.2	62.1
22	0	20.5	0	22	37.6	44.2	24.3	32.8
23	48	72.3	60.6	58.5	123.4	117.2	59	20.6
24	73.7	45.2	5.6	164.3	106.6	66.3	89.4	165.3
25	73.6	35.1	83.8	99.2	62.7	82.2	112.7	75.8
26	53.2	132.6	53.8	89.5	116	142.2	78.4	67.4
27	62	43.5	70	64.6	66.8	56.4	40.4	46.9
28	95.5	46.9	103	80.2	62.4	144.7	87.6	111.2
29	74.2	114	21.2	159.4	100.3	80.8	134.4	34.4
30	73.6	48.3	50.6	88.2	20.6	44.1	29.8	93.4
31	51.1	97.4	66.7	71.5	75.6	70.2	62.1	51.6
32	35.6	67.6	83.2	60.1	70.3	66.8	57.3	57.5
33	115	42.8	37.1	50.4	23.1	34.2	32.9	43.6
34	80.8	174.2	125.9	100.3	114.2	99.4	145.9	79.3
35	79.6	37.4	42.6	32.4	40.4	39	48.2	43.6
36	63.2	40.7	22.4	33.4	28.1	38.5	43	27.4
37	40.2	60.4	79.3	62	50.6	59.6	66.8	50.2
38	12.6	53.6	42.8	20.4	18	28.3	53.2	39.6
39	14.2	56.9	44.4	52	33.7	28.6	30.3	25
40	35.6	44.5	44.2	61	25.1	84	31.4	36.7
41	0	74.9	0	52.6	0	24.7	0	36.2
42	0	23.4	0	0	0	0	36.4	25
43	32.5	0	0	0	16	0	0	0
44	23.1	0	13.4	21.7	0	30.2	0	12.1
45	0	0	0	0	13.5	0	0	0
46	0	25.1	0	17	20	0	20.1	0
47	0	0	0	0	5.4	14.6	0	0
48	2.2	0	26.3	10	0	0	0	54.3
49	1.8	0	0	0	0	0	11.1	0
50	0	32.4	0	0	0	19.5	0	0
51	0	0	0	0	27.1	0	0	0
52	0	0	0	0	0	0	25.3	0

Weekly rainfall in mm (20015-2021) received in Vihokhu watershed. Appendix B

Week No	2015	2016	2017	2018	2019	2020	2021
1	0	0	11.7	5.5	0	20.5	0
2	16.2	15	0	0	0	0	0
3	0	6	0	0	16.4	0	13.8
4	0	0	13.2	0	0	0	0
5	0	0	0	0	0	10.3	0
6	0	5.6	0	0	0.2	0	7.4
7	5.8	0	0	23.6	0	0	0
8	22.6	0	8.4	0	0.5	0	0
9	0	17.4	0	0.3	24.2	0.4	32.4
10	0	0	3.2	0	4.2	4.2	0
11	0	0	8.2	15.3	0	0	36
12	0	11	1	0	8	14.2	0
13	13.3	21	0	43.2	32.9	0	8
14	32.6	0	36.2	0	0	17.4	0
15	40.4	31	0.8	0	30.9	0	17
16	54	50.8	5.4	27.3	27.7	23.3	16
17	22.5	18.3	3.4	0	6.7	26.7	0
18	38.6	9.4	0.4	29.7	55.2	2	26
19	58.3	30.2	3	43.6	0	14.2	74.3
20	62.3	45	4.6	32.6	43.3	61.2	0
21	44.4	40.8	30.6	0	58.5	66.6	34.6
22	26.6	24.8	33.6	62.3	85.2	34.7	43.2
23	45.1	55.6	12	29.2	123.4	89	36.3
24	76.4	74.5	23.1	43.5	31.2	83.2	40.7
25	42.7	54.3	30	55.2	37	33.8	71.4
26	81.2	85	55.8	34.9	13.6	52.4	16.3
27	73.2	83.6	26.6	52.3	64.2	30.6	27.4
28	43.9	82.1	67.2	88.6	39.7	20.5	27.8
29	55.9	123.5	70.1	120.3	87.5	47.8	121.3
30	45.6	67.3	47.8	56.4	19.8	131.2	62
31	86.4	35.2	124.3	60.6	77.3	16.8	20.8
32	22	25.7	13	44	34.2	30.2	53.4
33	39.4	34.2	31.4	45.2	25.6	29.8	18.4
34	123	89.4	74.3	74.2	65.6	113.4	31.8
35	95.6	73.2	44.8	126.1	21.2	68.8	31.7
36	36.3	91.6	0	9.4	21.7	38.6	0.4
37	44.6	48.5	32.6	38.5	35.5	30.2	10.2
38	44.1	100.4	0.4	42.7	43.1	43.2	70.5
39	25.7	22.4	32.8	157.8	13.9	25.4	40.3
40	43.1	30.3	23.5	44.6	95.8	23.7	20.2
41	57.4	30.2	49.6	25.4	74.7	146.8	4
42	31.2	0	17.4	32.5	22.4	39.4	8.4
43	0	24	48	10.7	98.8	44.6	0
44	26.5	0	18.4	12.2	0	20.2	0
45	2	93.6	0	15.1	18.6	0	12.3
46	0	0	17	23.1	0.2	21.4	0
47	0	0	18.6	0	0	0	0
48	18.4	0	0	0	23.6	0	21.5
49	0	36.8	0	20.1	0	0	0
50	0	0	5.4	0	0	0	0
51	0	0	0	0.2	0	12.7	0
52	0	0	0	0	0	0	0

Weekly estimated cumulated runoff for storage need (2007-2021) Appendix C

Week No	Runoff, ha-mm	Runoff, ha-m	Cumulated runoff, ha-mm
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0
14	0	0	0
15	3978.51	3.97	3.97
16	3744.48	3.74	7.71
17	597.18	0.59	8.3
18	1969.08	1.96	10.26
19	3905.88	3.9	14.16
20	8675.25	8.65	22.81
21	8037.72	8.03	30.84
22	5503.74	5.5	36.34
23	9958.38	9.95	46.29
24	11491.68	11.49	57.78
25	10152.06	10.15	67.93
26	15220.02	15.22	83.15
27	11410.98	11.41	94.56
28	12395.52	12.39	106.95
29	16688.76	16.68	123.63
30	12452.01	12.45	136.08
31	14840.73	14.84	150.92
32	8037.72	8.03	158.95
33	7932.81	7.93	166.88
34	23378.79	23.37	190.25
35	10256.97	10.25	200.5
36	5423.04	5.42	205.92
37	9740.49	9.74	215.66
38	4938.84	4.93	220.59
39	6456	6.45	227.04
40	6480.21	6.48	233.52
41	0	0	0
42	0	0	0
43	0	0	0
44	0	0	0
45	0	0	0
46	0	0	0
47	0	0	0
48	0	0	0
49	0	0	0
50	0	0	0
51	0	0	0
52	0	0	0

Recommended crop and their growing period in Vihokhu Watershed Appendix D

Week No	Rice	Maize	Pea	Beans	Onion	Soyabean	Mustard	Potato	Water need, mm
1			20	10	20		20		70
2			10	10	25		30		75
3					20		10		30
4					15		10		25
5					10		10		20
6					20				20
7					20				20
8					20				20
9					10				10
10					10				10
11					10				10
12								70	70
13		90						30	120
14		50						20	70
15		50						20	70
16		50						20	70
17		50						20	70
18		50						20	70
19		50						20	70
20		50						20	70
21		50						20	70
22		50						20	70
23	120	50						10	180
24	60	40				90		10	200
25	60	30				50		10	150
26	80					40		20	140
27	140					40		10	190
28	90					40		10	140
29	80					40			120
30	80					50			130
31	80					50			130
32	80					40			120
33	90					40			130
34	80					40			120
35	80					40			120
36	60					30			90
37	40					30			70
38	30					30			60
39						30			30
40						20	60		80
41				70			40		110
42			70	50			30		150
43			50	35			30		115
44			40	20			20		80
45			50	30	80		45		205
46			40	50	40		20		150
47			30	40	30		30		130
48			10	45	20		25		100
49			30	20	50		20		120
50			15	20	40		30		105
51			25	10	25		25		85
52			10	20	20		30		80

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