HNUE JOURNAL OF SCIENCE
Natural Sciences 2025, Volume 70, Issue 3, pp. 171-182
This paper is available online at http://hnuejs.edu.vn/ns
DOI: 10.18173/2354-1059.2025-0047

ASSESSMENT OF METEOROLOGICAL DROUGHT SEVERITY IN THE FORMER HA GIANG PROVINCE, NORTHERN VIETNAM

Vuong Van Vu[1], Hoang Luu Thu Thuy[1,*], Vo Trong Hoang[1], Tran Thi Mui[1], Pham Thi Cuc[1], Tong Phuc Tuan[1], Le Thi Thu Hien[1], Nguyen Thanh Binh[1], Ahmad M. Manschadi[2], Tran Xuan Hoang[3]

[1]*Institute of Earth Sciences, Vietnam Academy of Science and Technology, Hanoi city, Vietnam*

[2]*Department of Agriculture Sciences, BOKU University, Vienna city, Austria*

[3]*Northern Mountainous Agriculture and Forestry Science Institute, Phu Tho province*

*Corresponding author: Hoang Luu Thu Thuy, e-mail: thuy_hoangluu@yahoo.com

Received August 7, 2025. Revised September 11, 2025. Accepted September 30, 2025.

Abstract: The former Ha Giang Province in Northeastern Vietnam, characterized by complex mountainous terrain and climatic variability, is prone to drought. This study assesses meteorological drought severity using the aridity index (K) and monthly drought frequency (P), derived from meteorological data (1960–2024) collected at 18 meteorological, hydrological, and rainfall stations across the study area. Results show that monthly K values ranged from 0.1 to 3.1, peaking in February, while annual averages ranged from 0.1 to 0.5. Based on P, drought severity was classified into three levels: mild, moderate, and severe, with the highest frequencies in December and April. These findings provide a scientific basis to support disaster prevention and drought mitigation efforts in the region.

Keywords: meteorological drought, Ha Giang, aridity index (K), monthly drought frequency (P).

1. Introduction

Drought is a natural disaster that severely affects large populations and has contributed to some of the most devastating famines in human history [[1]], [[2]. It can cause a wide range of impacts on socio-economic systems and ecosystems, including agricultural losses, public water shortages, reduced hydropower supply, and decreased labor productivity. Although drought affects various sectors of the economy, agriculture remains one of the most severely impacted, making it particularly vulnerable to drought-related hazards [3]]-[6].

Drought indices are effective tools for quantifying and assessing drought conditions at various spatial scales. They have been applied at the local level in studies such as those by Peng Wang et al. (2020) and Sébastien Desbureaux & Aude-Sophie Rodella (2019) [[7]], [[8]]; at the regional level in works by Jiang, J. & Zhou, T. (2023), Odongo, R. A. et al. (2025), Benjamin Lloyd-Hughes & Mark A. Saunders (2002), Aktürk, G. et al. (2024) [9]-[12]; and at the global level in studies by Gebrechorkos, S. H. et al. (2023, 2025) [13], [14]. Currently, a wide variety of drought indices are employed worldwide. Among them, some indices rely solely on precipitation data, such as the Standardized Precipitation Index (SPI), Deciles, the Effective Drought Index (EDI), the China Z Index (CZI), the NOAA Drought Index (NDI), and the Rainfall Anomaly Index (RAI). Other indices combine precipitation and temperature variables, including the Sahel Drought Index (Sa.I), the Weighted Anomaly Standardized Precipitation Index (WASP), the Aridity Index (AI), the Crop Moisture Index (CMI), the Drought Reconnaissance Index (DRI), and the Standardized Precipitation Evapotranspiration Index (SPEI), which incorporates evapotranspiration estimates. A further group of indices integrates evaporation data, such as the Water Balance Index (K), the Aridity Anomaly Index (AAI), and the Penman Drought Index. In addition, depending on the assessment objectives, many indices incorporate additional variables such as crop coefficients, vegetation cover, groundwater levels, soil water availability, reservoir storage, streamflow, solar radiation, modeling outputs, or satellite-derived information. Examples include the Surface Water Supply Index (SWSI), the Reclamation Drought Index (RDI), the Crop-Specific Drought Index (CSDI), the Agricultural Reference Drought Index (ARDI), and the Aggregate Dryness Index (ADI). However, the choice of drought index is often dependent on the specific natural characteristics of a region as well as the availability and quality of observational data in that area.

In Vietnam, numerous studies have applied drought indices to assess drought conditions. These include the use of SPI, CZI, EDI, and PN to evaluate drought across different climatic regions of the country [15]; the Ped and J indices in the Central Region [16]; SPI, A, and TC indices in the South Central Coast [17]; the SPI index in the Mekong Delta [18] and Quang Nam Province [19]; and the K index in Ninh Thuan [20] and Binh Thuan Province [21]. In addition, climate change scenarios have been incorporated into drought assessments. For instance, Vu Thanh Hang et al. (2011) [16] employed the regional climate model RegCM3 to project drought variability in Central Vietnam for the period 2011–2050. The projections under the A1B scenario indicate that droughts are likely to occur more frequently and with greater severity in the future, particularly during 2031–2050 in the Central Region. Dao Ngoc Hung et al. (2022) [22] applied the K index to Hai Duong Province for the period 2021–2050 under different climate change scenarios.

The former Ha Giang Province, located in the Northeastern mountainous region of Vietnam, occupies a strategic border position and plays an important role in trade with the People's Republic of China. The province covers a natural area of approximately 7,884.37 km², bordering China to the north, Yen Bai and Lao Cai to the west, Tuyen Quang to the south, and Cao Bang to the east.

The topography of the former Ha Giang Province is characterized by elevations ranging from 800 to 1,200 m above sea level and is strongly dissected (exemplified by the Nho Que Gorge). It can be divided into three geomorphological zones: (i) the Dong Van karst plateau (including Quan Ba, Yen Minh, Dong Van, and Meo Vac districts), with heavily dissected limestone surfaces; (ii) the high mountainous region in the west (Hoang Su Phi and Xin Man districts), with altitudes of 1,000–2,000 m and dome-shaped uplifted blocks that are deeply incised; and (iii) the lower mountains and intermontane valleys, which make up the remaining area, extending from Bac Me through Ha Giang City and Vi Xuyen to Bac Quang.

Situated in a tropical monsoon zone and characterized by mountainous terrain, Ha Giang's hydrothermal regime is strongly influenced by both monsoonal circulation and regional topography. The climate is divided into two distinct seasons: (i) the dry season (from November-December to March-April), dominated by the Northeast monsoon, characterized by low rainfall and cooler temperatures; and (ii) the rainy season (from May to October), dominated by the Southwest monsoon, with heavy rainfall and higher temperatures.

The mean annual temperature is approximately 23 °C at an elevation of 100 m and about 15 °C at 1,500 m. Annual precipitation varies widely, ranging from 1,500 to 4,500 mm, with Bac Quang being one of the wettest areas, recording more than 4,500 mm annually. The average annual relative humidity ranges between 80% and 86%. In addition, sunshine duration, wind, evaporation, and runoff also exert significant influences on the region's hydrothermal conditions.

The climatic and edaphic conditions of the former Ha Giang Province are favorable for the cultivation of temperate crops, short- and long-term industrial crops, and various forest species, particularly tea plants. Among these, *Shan Tuyet* tea (a specialty snow tea variety) is of notable importance. As of 2023, the province had approximately 21,000 hectares of tea plantations, with nearly 18,700 hectares dedicated to *Shan Tuyet* tea [23]. This variety is typically found in clusters along streams or beneath forest canopies, with some trees reaching up to 400 years of age. It is primarily grown at elevations above 600 meters above sea level in areas such as Lung Phin (Dong Van), Phin Ho, Tung San, and Thong Nguyen (Hoang Su Phi); as well as Tham Ve, Bo Duot, Thuong Son, and Cao Bo (Vi Xuyen). However, *Shan Tuyet* tea is largely cultivated on sloping terrains (8–30°) with soils derived from old-growth forests. These soils are typically shallow, with cultivation layers often only 50–70 cm deep, and depths exceeding 1 meter are rare. Notably, even during the rainy season, tea plants often suffer from drought stress because steep slopes prevent effective water retention. This is a major factor contributing to reduced tea yields, as erosion impairs the soil's nutrient availability and limits root absorption. Therefore, this study aims to assess the level of meteorological drought in the former Ha Giang Province, thereby contributing to more efficient and sustainable water resource management in support of long-term socio-economic development.

2. Content

2.1. Data and methods

2.1.1. Data sources

Meteorological, hydrological, and rainfall data from 19 stations in Ha Giang Province were obtained from the Center for Meteorological and Hydrological Information and Data Archiving. [24]. The dataset includes monthly and annual Piche evaporation, as well as monthly and annual precipitation records for the period 1960–2024. For rain gauges, however, the data are available only until 2017. In this study, we incorporated the rain gauges to increase the density of the observational network, thereby enabling a more detailed analysis of the spatial and seasonal variability of drought frequency and intensity.

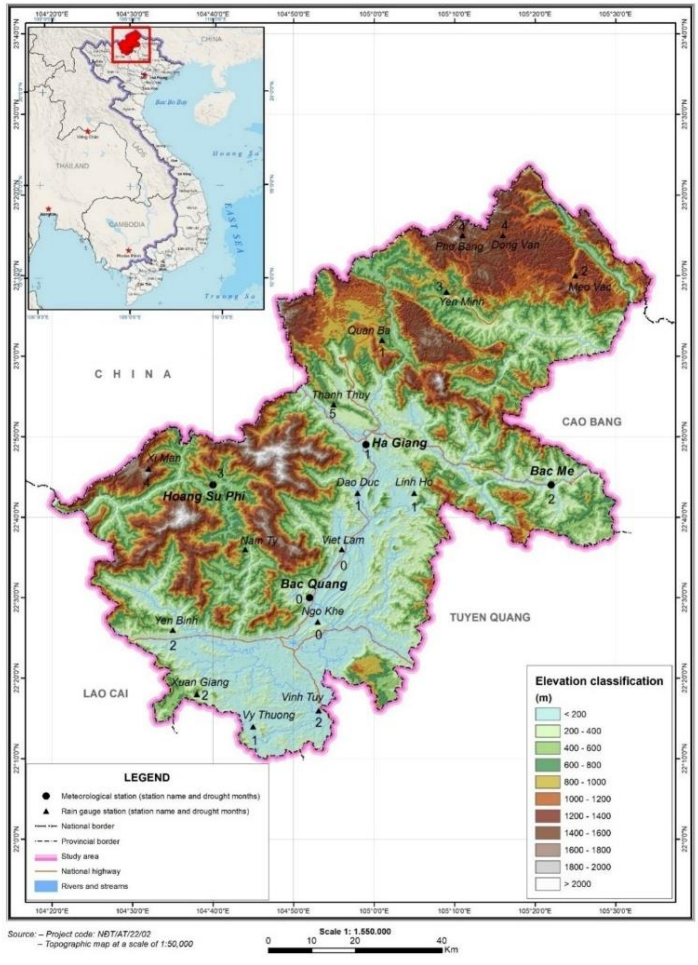

Figure 1. Topographic map and locations of 19 stations of the study area

2.1.2. Calculation methods

The severity of meteorological drought in Ha Giang was assessed using two indicators: the aridity index (K) and the monthly drought frequency (P), based on meteorological data from 1960 to 2024.

**** The aridity index (K)***

Meteorological drought severity was evaluated using the aridity index (K), defined as the ratio between the dominant loss and gain components of the regional water balance. Specifically, this index compares Piche evaporation with precipitation to reflect atmospheric dryness. The aridity index was calculated on both monthly and annual scales using the following formulas:

- Monthly aridity index:

$$K_m = \frac{E_m}{P_m} \quad (1)$$

E_m: the monthly average Piche evaporation (mm);

P_m : the monthly average precipitation (mm).

- Annual aridity index:

$$K_y = \frac{E_y}{P_y} \quad (2)$$

E_y: the annual average Piche evaporation (mm);

P_y: the annual average precipitation (mm).

Based on empirical thresholds tailored to local climatic conditions, drought severity was categorized into five levels, as presented in Table 2.

Table 1. Monthly drought classification based on the Aridity Index K [25]

Severity Level	Upper Limit of Monthly Aridity Index *K*
Very humid	< 0.5
Humid	0.5 ÷ 1
Slightly dry	1 ÷ 2
Dry	2 ÷ 4
Very dry	> 4

**** Monthly drought frequency*** **(** P_{md} **)**

Drought severity at each location was evaluated using the monthly drought frequency (P_{md}), calculated as follows:

$$P_{md} = \frac{m(H_m)}{n(H_m)} \quad (3)$$

P_{md}: monthly drought frequency (%);

H_m: monthly drought event;

$m(H_m)$: number of years in which a monthly drought event occurred;

$n(H_m)$: total number of years with available observations.

Monthly drought events were determined based on long-term precipitation data.

The drought threshold varied depending on the climatic season, following the criteria proposed by Nguyen Duc Ngu [25]. A month was classified as a drought month if its precipitation did not exceed the following thresholds:

- Winter (November, December, January, February): P_m ≤10mm;
- Spring (March, April) and Autumn (September, October): P_m≤30mm;
- Summer (May, June, July, August): P_m ≤80mm.

2.2. Results and discussion

2.2.1. Aridity index (K)

The annual aridity index (K_y) range from 0.1 to 0.5, corresponding to humid to very humid conditions, indicates that the study area generally remains moist throughout the year. However, based on the monthly aridity index (K_m), Ha Giang experiences one distinct dry period (K_m > 1), extending from November–December to March-April of the following year, with a duration of approximately 4–6 months (Table 2).

Table 2. Monthly and annual average Aridity Index (K)

No.	Stations	1	2	3	4	5	6	7	8	9	10	11	12	Year	Dry period
1	Hoang Su Phi	2.7	3.1	1.7	1.1	0.5	0.3	0.2	0.2	0.4	0.7	1.3	2.8	0.5	***11-4***
2	Ha Giang	1.1	1.3	1.0	0.8	0.3	0.2	0.1	0.2	0.3	0.5	0.8	1.3	0.3	***12-3***
3	Bac Me	1.4	1.9	1.3	0.9	0.4	0.2	0.2	0.2	0.4	0.6	0.9	1.8	0.4	***12-3***
4	Bac Quang	0.5	0.6	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.6	0.1	-

As illustrated in Figure 2, the annual aridity index (K_y) exhibits interannual fluctuations, typically ranging from –0.2 to 0.2, with considerable variability in amplitude across years. Positive deviations are particularly evident during El Niño events, notably in 1977–1978, 1979–1980, 1987–1988, and 1991–1992 [26].

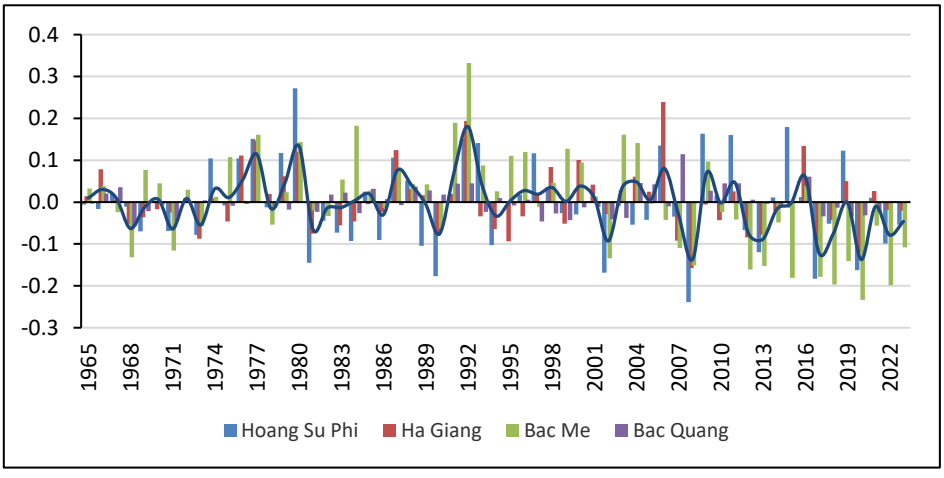

Figure 2. Annual deviation of the Aridity Index (K_y)

The monthly aridity index (K_y) in the former Ha Giang Province exhibits significant intra-annual variation, ranging from 0.1 to 3.1. These values reflect a wide spectrum of moisture conditions, from very humid to dry, depending on the season (Figure 3).

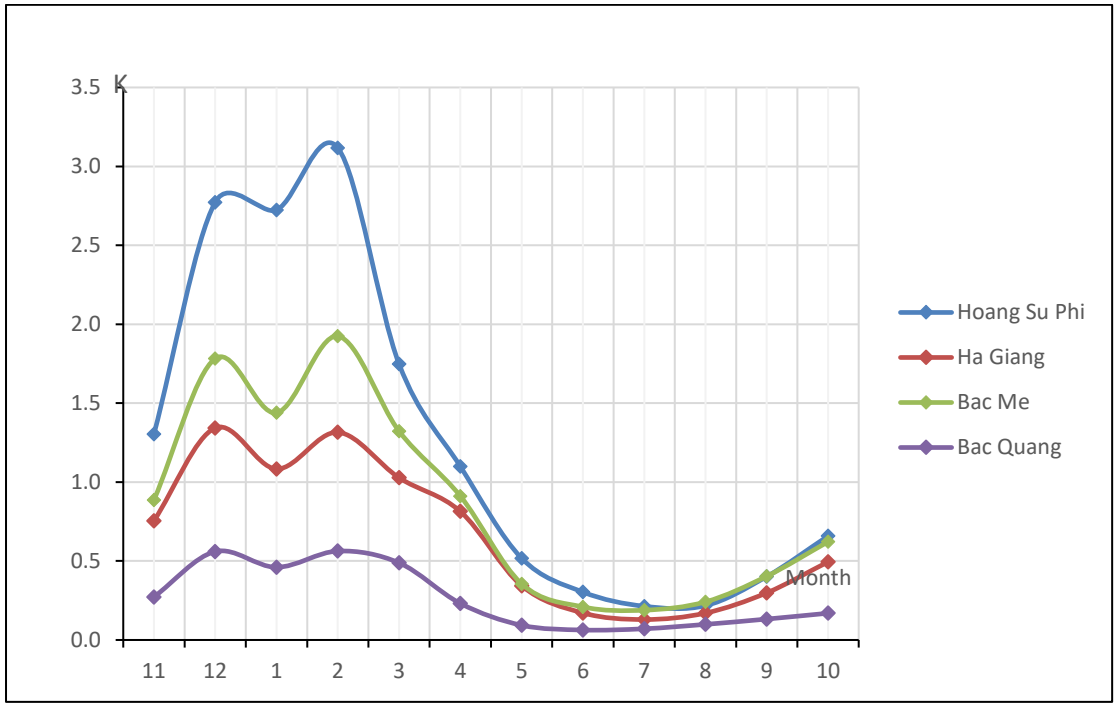

Figure 3. Annual deviation of the Monthly Aridity Index (K)

The annual drought regime in the study area exhibits one primary peak in February and a secondary peak in December, with K_m values generally ranging from 2 to 3, corresponding to dry conditions; a distinct minimum is also observed (Figure 3). The Bac Quang region, which receives over 4,000 mm of annual precipitation and represents one of the heaviest rainfall centers in Vietnam, does not experience any dry months. In this area, the annual aridity index (K_y) indicates very humid conditions, while the monthly aridity index (K_m) ranges from humid to very humid. Across Ha Giang Province, from May to September, aridity indices reach their lowest levels of the year, commonly ranging between 0.1 and 0.4. July and August represent the wettest period, with K_m values of 0.1–0.2 (Figure 3).

2.2.2. Monthly drought frequency

To better understand the spatial and seasonal distribution of drought intensity across the study area, we utilized the monthly drought frequency values (P_{md}). The drought severity at each location was determined based on the number of months (n) exhibiting a significant drought frequency, defined as greater than 30%.

Table 3. Monthly drought frequency (%) across different locations

No.	Station	1	2	3	4	5	6	7	8	9	10	11	12	Months with $P_{md} \geq$ 30%
1	Hoang Su Phi	28	37	43	11	5	0	0	0	0	6	20	42	***3***
2	Ha Giang	7	10	33	6	1	0	0	0	0	6	10	11	***1***
3	Bac Me	23	25	44	8	2	0	0	3	0	15	18	44	***2***
4	Bac Quang	3	2	12	2	0	0	0	0	0	4	6	4	***0***
5	Dong Van	37	37	49	19	7	2	0	5	5	26	26	53	***4***
6	Meo Vac	26	39	51	14	5	8	3	0	3	14	8	27	***2***
7	Yen Minh	30	37	43	12	9	2	0	2	4	22	12	41	***3***
8	Quan Ba	15	25	33	8	10	0	0	7	7	15	21	28	***1***
9	Thanh Thuy	41	40	51	22	22	11	0	4	4	19	33	50	***5***
10	Xin Man	46	51	58	26	23	5	7	5	15	27	15	46	***4***
11	Nam Ty	5	5	14	5	0	0	2	0	2	7	9	19	***0***
12	Dao Duc	6	16	24	6	3	0	0	0	0	12	9	21	***0***
13	Linh Ho	8	13	33	10	5	0	0	3	0	13	18	18	***1***
14	Viet Lam	2	17	25	4	2	0	0	0	0	5	8	14	***0***
15	Ngo Khe	5	3	10	5	2	0	4	3	3	14	17	12	***0***
16	Vinh Tuy	17	17	36	8	8	2	0	0	0	10	27	38	***2***
17	Yen Binh	30	18	23	7	10	2	2	3	0	13	30	40	***2***
18	Xuan Giang	23	21	36	5	10	5	3	15	5	16	24	41	***2***
19	Vy Thuong	24	22	22	5	15	5	0	0	0	15	18	35	***1***

The dry season in the former Ha Giang Province coincides with the northeast monsoon period, during which the territory experiences high drought frequency, particularly from December to March. Drought conditions are not only prevalent during the core winter months but also extend into the late winter and early spring, whereas drought is minimal or nearly absent during the summer and autumn months, which correspond to the region's rainy season (Table 3).

During the winter months, drought frequency typically ranges from 15% to 40%, with December recording the highest values, reaching up to 53% at Dong Van station. These months correspond to the dry season in the region.

In the spring months, drought frequency remains high in March, ranging from 25% to 50%, making it one of the two driest months of the year. In some high-altitude northwestern areas, such as Xin Man and Thanh Thuy, drought frequency even exceeds 50%. In contrast, April shows a marked decline in drought occurrence, with values dropping to 5–15%.

The summer months are characterized by very low drought frequency. Apart from May, where some locations report values exceeding 10–20%, the remaining months generally show drought frequencies below 10%, with the lowest values occurring in July and August, commonly 0–5%. This period aligns with the most humid phase of the

year, as also reflected in the low aridity index (K). Several stations report 0% drought frequency during these months.

In the autumn months, drought frequency remains below 5% in September, but increases in October, where values commonly range from 10% to 20%, reflecting the transition out of the rainy season.

Based on the monthly drought frequency analysis for Ha Giang province (Table 4), drought severity was classified into three levels:

- Mild drought (Level A): n ≤ 1 month with frequency > 30%
- Moderate drought (Level B): n = 2–3 months with frequency > 30%
- Severe drought (Level C): n ≥ 4 months with frequency > 30%

The spatial patterns of drought severity levels are illustrated in Figure 3.

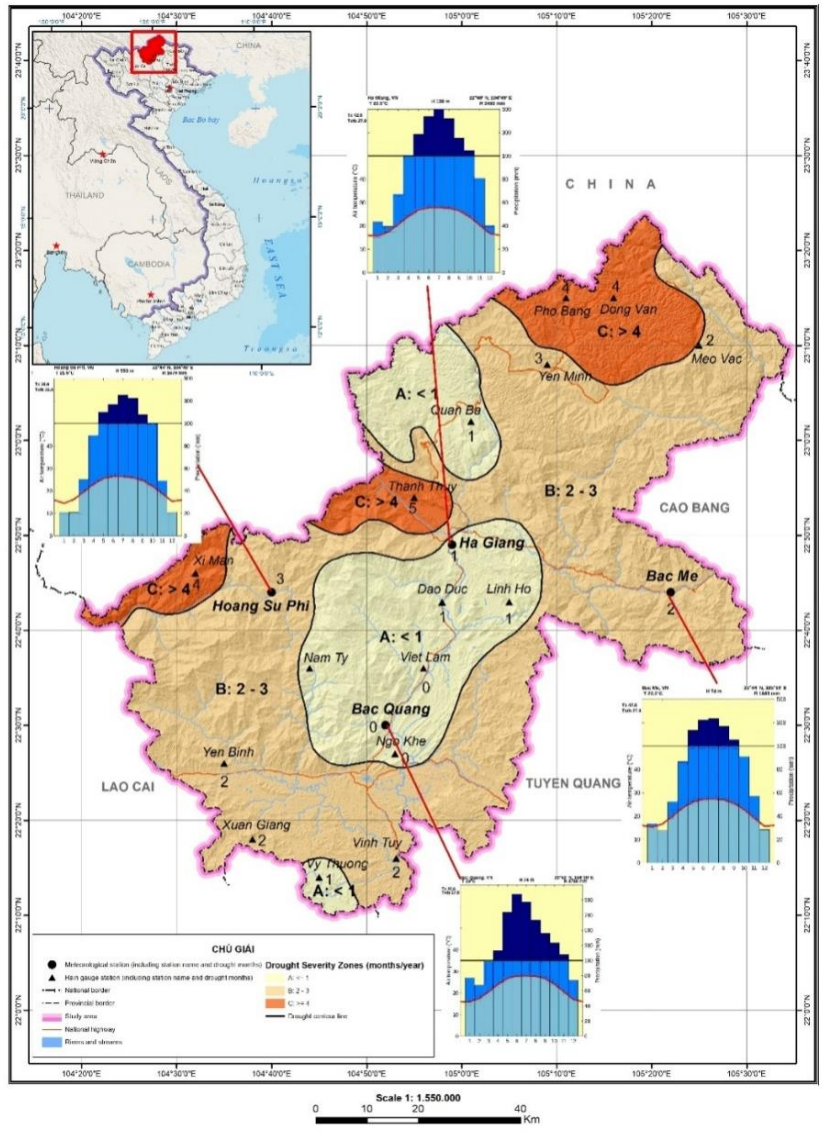

Figure 3. Drought severity map (scale 1:100,000).

Level A. Mild drought areas are distributed across three distinct zones: (i) the Quaternary limestone plateau of Quan Ba District (average elevation 800–1200 m), (ii) the intermontane valley and depression zone stretching from Ha Giang City to Bac Quang District (average elevation <600 m), and (iii) the southwestern mid- to low-elevation mountainous region of Bac Quang (windward slopes and valley floors, average elevation 400–800 m). These zones possess favorable conditions for the development of temperate crops, short- and long-cycle industrial crops, forestry, large livestock husbandry, and eco-tourism or resort activities. Scattered tea gardens are present in these areas, especially along the valleys extending from Ha Giang City to Bac Quang.

Level B. Moderate drought areas are continuously distributed across a large region of strongly dissected low- to mid-elevation mountains, accounting for the majority of the province's natural land area. Elevation in this zone varies widely, ranging from below 200 m to over 2000 m. The region is well-suited for forestry, agriculture (notably terraced farming), and industrial crop development such as tea, along with eco-tourism potential. Importantly, this area forms the core of Shan Tuyet tea cultivation in Ha Giang, especially along the mountainous slopes of Hoang Su Phi and Xin Man districts.

Level C. Severe drought areas are distributed across three main zones: (i) the Dong Van limestone plateau (average elevation 1200–1400 m), (ii) the intermontane depression of Thanh Thuy (average elevation 200–800 m), and (iii) the northern mid-elevation mountains of Xin Man (average elevation 1000–1800 m). These areas represent the smallest proportion of the province's total land area affected by drought and are generally less topographically fragmented than the mild and moderate drought zones. Land use in these zones primarily includes crops cultivated on sloping fields, forestry, medicinal plants, and tourism development—particularly in the iconic karst landscape of Dong Van Plateau. Tea cultivation in these regions remains relatively sparse and scattered, except for some concentrated tea-growing areas in the western part of Xin Man District.

These characteristics highlight the diverse temporal and spatial manifestations of drought across the province, underscoring the importance of integrating drought information into agricultural planning and crop management.

3. Conclusions

The results indicate that the annual aridity index (K_y) ranges from 0.1 to 0.5, suggesting that Ha Giang Province remains sufficiently humid throughout the year. However, on a monthly scale, most areas experience a distinct dry season, with the monthly aridity index (K_m) exceeding 1.0 from November and December to February or March of the following year, indicating 4 to 6 consecutive dry months. The exception is Bac Quang District, which remains humid year-round with no dry months identified. Notably, the monthly aridity index (K_m) varies significantly across time and space (ranging from 0.1 to 3.1), showing greater variability than the annual index (K_y). Regarding drought frequency, Ha Giang experiences high monthly drought frequencies ($P_{md} \geq 30\%$) predominantly during the winter months from December to March, with

March being the peak drought month. Elevated drought frequencies are also observed in the spring months, whereas summer and early autumn months are generally wet, with drought events being rare or absent across most areas. Moderate drought conditions dominate the majority of the province's area. Severe drought zones are mainly concentrated in the mid-elevation mountains of northern Xinjiang and the Dong Van karst plateau. Mild drought zones are primarily distributed across the karst surface of Quan Ba, the intermountain valleys from Ha Giang City to Bac Quang, and the mid- to low-elevation southwestern mountains of Bac Quang. This study provides a scientific basis for adjusting cropping calendars —especially for tea cultivation— optimizing land use, and implementing adaptive agricultural strategies. It contributes to effective drought risk management, disaster prevention, and mitigation of drought-related damages in the region.

Acknowledgements. This study acknowledges the financial support provided by the project entitled "Scientific and digital Platform for Integrating Remote sensing and agri-climate to support the development of TEa cultivation towards Agriculture 4.0 in the Northeast of Vietnam (SPIRTEA 4.0), project code NĐT/AT/22/02, and project NVCC10.04/25-25.

REFERENCES

[1] FAO, (2018). *The impact of disasters and crises on agriculture and food security*. Retrieved from http://www.fao.org/3/I8656EN/i8656en.pdf.

[2] CRED & UNISDR, (2018). *Economic losses, poverty & disasters: 1998-2017.* Retrieved from https://www.unisdr.org/files/61119_credeconomiclosses.pdf.

[3] Dilley M, Chen RS, Deichmann U, Lerner-Lam AL & Arnold M, (2005). *Natural Disaster Hotspots: A Global Risk Analysis.* World Bank Publications, Washington.

[4] UNDRR, (2019). *Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland.* Retrieved from https://gar.unisdr.org.

[5] World Meteorological Organization, (1975). *Drought and agriculture.* Technical Note 138. WMO, Geneva.

[6] Wilhite DA, (2000). Drought: A Global Assessment. In: *Drought as a natural hazard: Concepts and definitions*. London, Routledge Publishers.

[7] Wang P, Qiao W, Wang Y, Cao S & Zhang Y, (2020). Urban drought vulnerability assessment - A framework to integrate socio-economic, physical, and policy indices in a vulnerability contribution analysis. *Sustainable Cities and Society*, 54, 102004.

[8] Sébastien D & Aude-Sophie R, (2019). Drought in the city: The economic impact of water scarcity in Latin American metropolitan areas. *World Development*, 114, 13-27.

[9] Jiang J & Zhou T, (2023). Agricultural drought over water-scarce Central Asia is aggravated by internal climate variability. *Nature Geoscience,* 16, 154-161.

[10] Odongo RA, Schrieks T, Streefkerk I, Moel HD, Busker T, Haer T, MacLeod D, Michaelides K, Singer M, Assen M, Otieno G& Van LAF, (2025). Drought impacts and community adaptation: perspectives on the 2020–2023 drought in East Africa. *The International Journal of Disaster Risk Reduction,* 119, 105309.

[11] Lloyd-Hughes B& Saunders MA (2002), A Drought Climatology for Europe. *International Journal of Climatology*, 22, 1571-1592.

[12] Aktürk G, Çıtakoğlu H, Demir V & Beden N, (2024). Meteorological Drought Analysis and Regional Frequency Analysis in the Kızılırmak Basin: Creating a Framework for Sustainable Water Resources Management. *Water*, 16(15), 2124.

[13] Gebrechorkos SH, Peng J, Dyer E, Miralles DG, Vicente-Serrano SM, Funk C, Beck HE, Asfaw DT, Singer MB& Dadson SJ, (2023). Global High-Resolution Drought Indices for 1981-2022. *Earth System Science Data*, 15(12), 5449-5466.

[14] Gebrechorkos SH, Sheffield J, Vicente-Serrano SM & Funk C, (2025). Warming accelerates global drought severity. *Nature,* 642, 628–635.

[15] Vu TH & Tran TTH, (2013). Comparison of some drought indices in the climate zones of Vietnam. *Journal of Science of VNU, Natural Sciences and Technology,* 29(2S), 51-57 (in Vietnamese).

[16] Vu TH, Ngo TTH, Nguyen QT & Trinh TL, (2011). Projecting drought changes in the Central region during the period 2011-2050 using the results of the regional climate model RegCM3. *VNU Journal of Science, Natural Sciences and Technology* 27, (3S), 21-31 (in Vietnamese).

[17] Nguyen VT, Mai VK, Nguyen DM & Truong DT, (2014). Research on determining drought indicators for the South Central region. *Journal of Meteorology and Hydrology*, (3) (in Vietnamese).

[18] Tran VT, Huynh VTM & Dang TTH, (2015). Building a drought map of the Mekong Delta in the context of climate change. *Journal of Science of Can Tho University*, (Special Issue-Environment and climate change), 226-233 (in Vietnamese).

[19] Nguyen TNL, Duong QN, Le HNT, Nguyen BN, Tran TP, Nguyen HKL, Tran TT & Nguyen HN, (2019). Drought risk assessment using SPI and TRMM indices in Quang Nam province. *Proceedings of the 2019 National GIS Application Conference* (in Vietnamese).

[20] Le S & Nguyen DV, (2008). Research on selecting the formula for calculating the drought index and applying it to calculate annual drought frequency in Ninh Thuan. *Collection of Science and Technology results*. Southern Institute of Water Resources Research (in Vietnamese).

[21] Ngo TS, Hoang LH, Luyen HC & Nguyen HT, (2018). Assessment of drought situation in Binh Thuan province in the period 1984 - 2016. *Vietnam Agricultural Science Journal*, 16(4), 339-350. (in Vietnamese)

[22] Dao NH, Hoang LTT, Nguyen DT & Doan TT, (2022). Study on drought evolution for Hai Duong province in dry months in the context of climate change. *HNUE Journal of Science: Natural Sciences*, 67(1), 135-145. (in Vietnamese)

[23] VietnamNet, (2022). Ha Giang Shan Tuyet Tea – Native Plant Becomes Valuable Commodity.https://vietnamnet.vn/en/shan-tuyet-tea-valuable-timber-plants-named-vietnam-heritage-trees-2065415.html?utm_source=chatgpt.com (in Vietnamese).

[24] Center for Hydrometeorological Information and Data Storage. Institute of Hydrometeorology and Climate Change (in Vietnamese).

[25] Nguyen DN & Nguyen TH, (2013). *Climate and Climate Resources of Vietnam.* Science and Technology Publishing House, Hanoi (in Vietnamese).

[26] https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.