VIETNAM ACADEMY OF SCIENCE AND TECHNOLOGY
INSTITUTE OF PHYSICS

The 8th Academic Conference on Natural Science for Young Scientists Master & PhD. Students from ASEAN Countries

Vinh City, Vietnam. August 27-30, 2023

PROCEEDINGS

Publishing House for Science and Technology

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THE 8th ACADEMIC CONFERENCE ON NATURAL SCIENCE FOR YOUNG SCIENTISTS, MASTER AND PhD STUDENTS FROM ASEAN COUNTRIES

(CASEAN - 8)

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PREFACE

The 8th Academic Conference on Natural Sciences for Young Scientists, Masters and PhD. Students from ASEAN countries (CASEAN-8) has been successfully held both online and offline on 28-30 August 2023 in Vinh City, Nghe An Province, Vietnam.

The main purpose of the Conference is to provide a good opportunity for young scientists, Master and PhD. students, coming from universities and institutes in ASEAN countries to develop regional exchange activities, mutual understanding and cooperation as well as stimulate scientific training and education.

There were about 300 participants in different fields of natural sciences and from Cambodia, Laos, Malaysia, Myanmar, Philippines, Thailand, and Vietnam. More than 200 scientific reports were presented at the conference. Furthermore, some senior scientists and professors (from China, Japan, South Korea, Russia, Czech Republic,...) were invited to give their talks. The Conference created favorable conditions for all participants to establish new cooperative linkages and also strengthen our friendship.

The CASEAN-8 Proceedings book has published the papers which were presented in the conference and selected by the editorial committee with a standard referee procedure.

We have to say that the success of the CASEAN-8 Conference was resulted from active contributions of all the conference committees, the session chairmen and the participants.

On this occasion, we express our deep thanks to the ASEAN Co-Organizers and Co-Sponsors. Specially, we sincerely thanks to International Centre of Physics (ICP), Institute of Physics (IOP), Vietnam Academy of Science and Technology (VAST) and Vinh University for all its wonderful cooperation and great contribution to CASEAN-8.

We would like to thank the conference secretariat and technicians for their dedication and hard works./.

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CLIMATE CHANGE IMPACT ON DROUGHTS IN VIETNAM: A PERSPECTIVE FROM THE CMIP6-VN DATASET

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Abstract. This study assesses climate change's impact on droughts in Vietnam using the updated high-resolution CMIP6-VN dataset, covering historical and future climate projections from various CMIP6 GCMs across seven sub-climatic regions in Vietnam throughout the 21st century. Drought is investigated using the Standardized Precipitation-Evapotranspiration Index (SPEI) and the Mann-Kendall trend test, with a primary focus on the mid-future (2040–2069) and far-future (2070–2099) periods. The findings indicate that during the first half of the 21st century, Vietnam can expect alternating periods of dry and wet conditions across all scenarios. Water scarcity is projected to be less of a concern in the far future, particularly under the SSP1-2.6 scenario. However, even though drought may not be a significant issue in the far future, regions like the Central Highlands and the Southern areas could still be susceptible to its effects under the highest emission scenario. These research findings shed light on Vietnam's vulnerability to drought disasters and the potential consequences of ongoing climate change. The outcomes of this study are expected to provide crucial insights for policymakers, disaster management agencies, and stakeholders. This information will aid in developing effective strategies for adaptation and mitigation, enhancing the country's resilience against the escalating threat of droughts.

Keywords: *CMIP6-VN, Drought, Vietnam, global warming, disaster.*

I. INTRODUCTION

Drought, a natural weather event marked by long periods of little to no rain, presents a significant challenge to places that rely on farming and water resources. Vietnam, located in Southeast Asia, is a prime example of how climate, farming, and drought are closely connected, making it a noteworthy area for thorough investigation and study. Vietnam is often known as the "Rice Bowl of Southeast Asia" and heavily depends on farming as a vital part of its economy. However, the vulnerability of this sector to unpredictable weather becomes apparent due to the frequent occurrence of drought. Over the last fifty years, drought has affected Vietnam in over 40 of those years, causing disruptions in farming and having a significant impact on people's lives. As global warming continues, Vietnam faces an increasing risk of droughts. According to experts, global temperatures are likely to rise by 1.5 degrees by the 2030s, with continued warming in the 21st century. This climate change is expected to have a big impact on the frequency and severity of droughts, compounding the challenges Vietnam faces.

In 2022, the Intergovernmental Panel on Climate Change (IPCC) released its latest comprehensive report on global climate change, known as AR6, along with new climate scenarios [1]. These scenarios are based on the latest data from the CMIP6 project, which incorporates the most recent global developments in climate science. Within the view of the

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AR6 report, Vietnam is once again highlighted as one of the countries most vulnerable to the effects of climate change. Given that drought stands as a significant concern in Vietnam, numerous research efforts have been launched to investigate this issue. These studies not only aim to uncover the root causes of drought [2, 3, 4] and its potential socioeconomic impacts [5, 6] but also seek to predict future trends in drought occurrences [7]. However, it is essential to note that a substantial portion of this research relies on data from the previous CMIP5 scenario, which was released by the IPCC back in 2013 [8]. Furthermore, the most recent national climate change scenario provided by the Ministry of Natural Resources and Environment (MONRE) in 2021 is also based on the CMIP5 dataset [9]. This reliance on older data potentially overlooks the crucial insights stemming from global developments over the past decade, which could result in reduced accuracy and confidence in the findings.

In response to the pressing need to address the changing drought landscape in Vietnam, this study stands out by focusing on the exploration of future drought scenarios. Our primary goal is to comprehensively examine and present drought projections in Vietnam, utilizing the latest data from the IPCC's CMIP6 dataset. Notably, this study represents one of the pioneering endeavors to tackle the issue of drought by harnessing the most up-to-date climate projection methodologies available today, emphasizing its novelty in the field. The outcomes of this research endeavor will serve as a critical compass, not only shedding light on the anticipated trends and intensities of drought in Vietnam but also probing the disparities between these fresh findings, informed by the latest information, and the existing body of research within the scientific literature. This exploration into the divergence between past assessments and our present understanding will contribute to a more robust comprehension of Vietnam's vulnerability to drought in the context of a dynamically changing climate.

II. DATA AND METHODS

2.1. Study area

This research centers on Vietnam, situated in Southeast Asia between approximately 8.2°N to 23.4°N latitude and 102.1°E to 109.5°E longitude. Vietnam's varied landscape encompasses mountains, highlands, and coastal plains, experiencing a pronounced tropical monsoon climate characterized by distinct wet (June to August) and dry (December to April) seasons, with droughts often occurring during the dry season.

The study investigates drought impacts and future projections within Vietnam's seven sub-climatic regions, distinguished by their distinct climate patterns and topographical features [10]. These sub-regions are listed as follows: (1) Northwest (NW), (2) Northeast (NE), (3) Red River Delta (RRD), (4) North Central (NC), (5) South Central (SC), (6) Central Highland (CH), and (7) South (S) (Fig.1).

2.2. Meteorological data and scenario

In this study, we investigate historical and projected drought in Vietnam, utilizing near surface temperature (*T2m*), maximum/minimum daily temperature (*Tmax*/*Tmin*), and precipitation data (*Pr*) from the CMIP6-VN dataset, which comprises information from 22 downscaled models [11]. The CMIP6-VN dataset, derived from downscaling the CMIP6 dataset by the IPCC, offers a finely tuned climate representation that specifically caters to Vietnam's mainland territory.

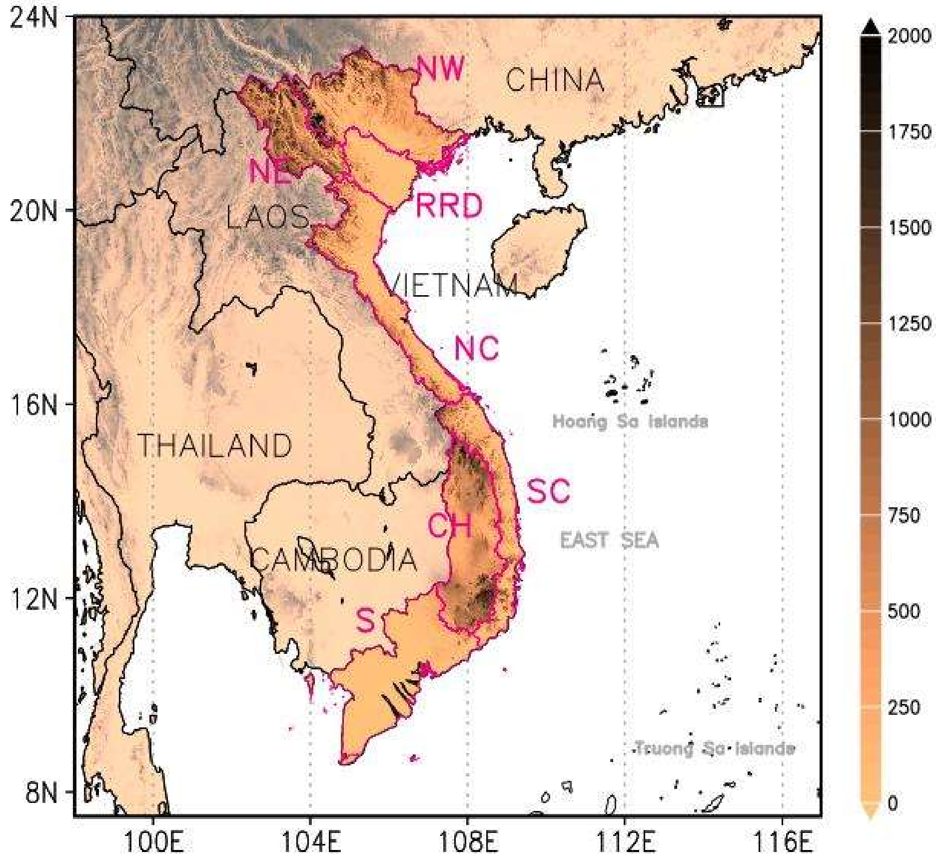

Fig. 1. *Distribution of the seven sub-climatic regions in Vietnam on top of the Hydroshed topographic map.*

We establish a robust framework for assessing future climate change by using historical simulations from 1980 to 2014 as our reference baseline, adhering to the World Meteorological Organization's (WMO) standard definition of climate as a 30-year average of weather conditions. Subsequently, we project climate changes for both mid-term (2040–2069) and long-term (2070–2099) periods. The exploration of these mid-future and far-future timeframes allows us to delve into the broader, long-term challenges posed by climate change. This study considers three distinct Shared Socioeconomic Pathways (SSPs): SSP1-2.6 (Sustainable development), SSP2-4.5 (Middle of the Road) and SSP5-8.5 (Fossil-fuel Development) scenarios [1]. The total of 22 CMIP6-VN models were used in this study, including: ACCESS-CM2, ACCESS-ESM1-5, AWI-CM-1-1-MR, BCC-CSM2-MR, CMCC-ESM2, CNRM-CM6-1-HR, CNRM-ESM2-1, Can-ESM5, EC-Earth3-Veg, EC-Earth3, FGOALS-g3, GFDL-ESM4, GISS-E2-1-G, HadGEM3-GC31-LL, INM-CM5-0, IPSL-CM6A-LR, MIROC-ES2L, MIROC6, MPI-ESM1-2-HR, MRI-ESM2-0, NESM3 and UKESM1-0-LL.

2.3. Drought analysis

Drought analysis method for this study primarily centers on the Standardized Precipitation Evapotranspiration Index (SPEI), a robust meteorological drought indicator that

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considers both precipitation and potential evapotranspiration. SPEI is determined by comparing long-term precipitation and evapotranspiration records. This involves a statistical transformation, converting one type of frequency distribution (e.g., gamma) into another (typically normal or Gaussian). Given the critical role of agriculture in Vietnam's economy, particularly concerning short-term droughts, our study places a special focus on these conditions. To assess their impact, we compute the SPEI at various time scales, employing the one-month SPEI index as a key tool. To calculate evaporation data for SPEI, which is not included in the CMIP6-VN dataset, we employ the Hargreaves method. This method is a well-established approach in drought assessment, as referenced in [12]. The equation used for this purpose is as follows:

$$PET = \alpha.(T + 17.78).\sqrt{(T_{max} - T_{min})}.R_s$$

where ET represents potential daily evapotranspiration (mm/day), and α = 0.0023 is the empirical coefficient initially introduced by Hargreaves and Samani (1985) [12]. The variables *Tmax* and *Tmin* denote the maximum and minimum daily temperatures (C °), respectively, while R_S, a function of latitude, stands for incident solar radiation converted to a depth of water (mm/day).

To investigate the trend of SPEI values over time, we apply the Mann-Kendall trend test, a non-parametric statistical test widely used for detecting monotonic trends in hydrological and climatic time series data [13].

III. RESULTS AND DISCUSSION

3.1. Mid-term and long-term projection of temperature and precipitation

Fig. 2 provides an overview of the annual temperature and precipitation distribution during the reference period (1985 – 2014), alongside projections for different scenarios and future timeframes. It is projected that average temperatures across all regions of Vietnam are poised to rise in all scenarios, with the most substantial warming expected in the highest emission scenarios compared to sustainable ones. In the SSP2-4.5 scenario, which closely aligns with the current global development trajectory, we observe mid-future temperature projections showing an increase of 1.37 C°. This temperature rise becomes more pronounced in the far-future, reaching 2.18 C°. Notably, far-future temperatures exhibit a more significant increase compared to their mid-future counterparts. Mid-future projections range from a 1.28 C° increase (SSP1-2.6) to 1.98 C° (SSP5-8.5). In the far-future, these figures surge to 1.57 C° and 3.77 C°. Elevated future temperatures indicate a significant influence on the rising trend of water loss, primarily driven by an increase in the evaporation rate, which is closely linked to temperature. Fig. 2 also illustrate temperature distribution variations among Vietnam's seven sub-climatic regions, closely correlated with latitude. Regions situated further south generally experience higher average temperatures. However, the North is expected to witness more pronounced temperature increases compared to the South. The Northwest and Northeast regions are projected to experience the highest temperature increases, which gradually taper toward lower latitudes, reaching their lowest points in the Southern region.

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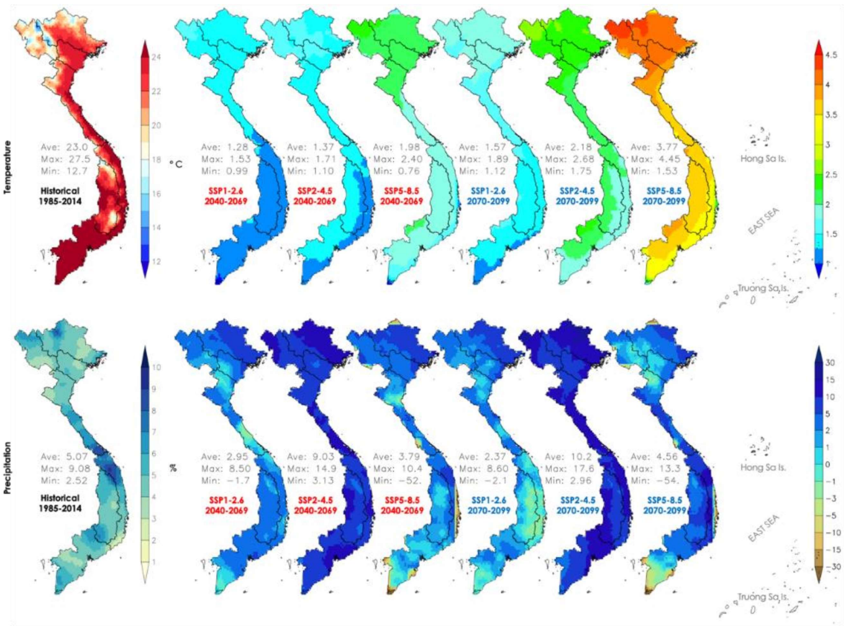

Fig. 2. *Distribution of temperature (top) and precipitation (bottom) in Vietnam for the reference period 1985-2014 and projected variations for the mid-term (2040-2069) and long-term (2070-2099) periods by the CMIP6-VN model ensemble.*

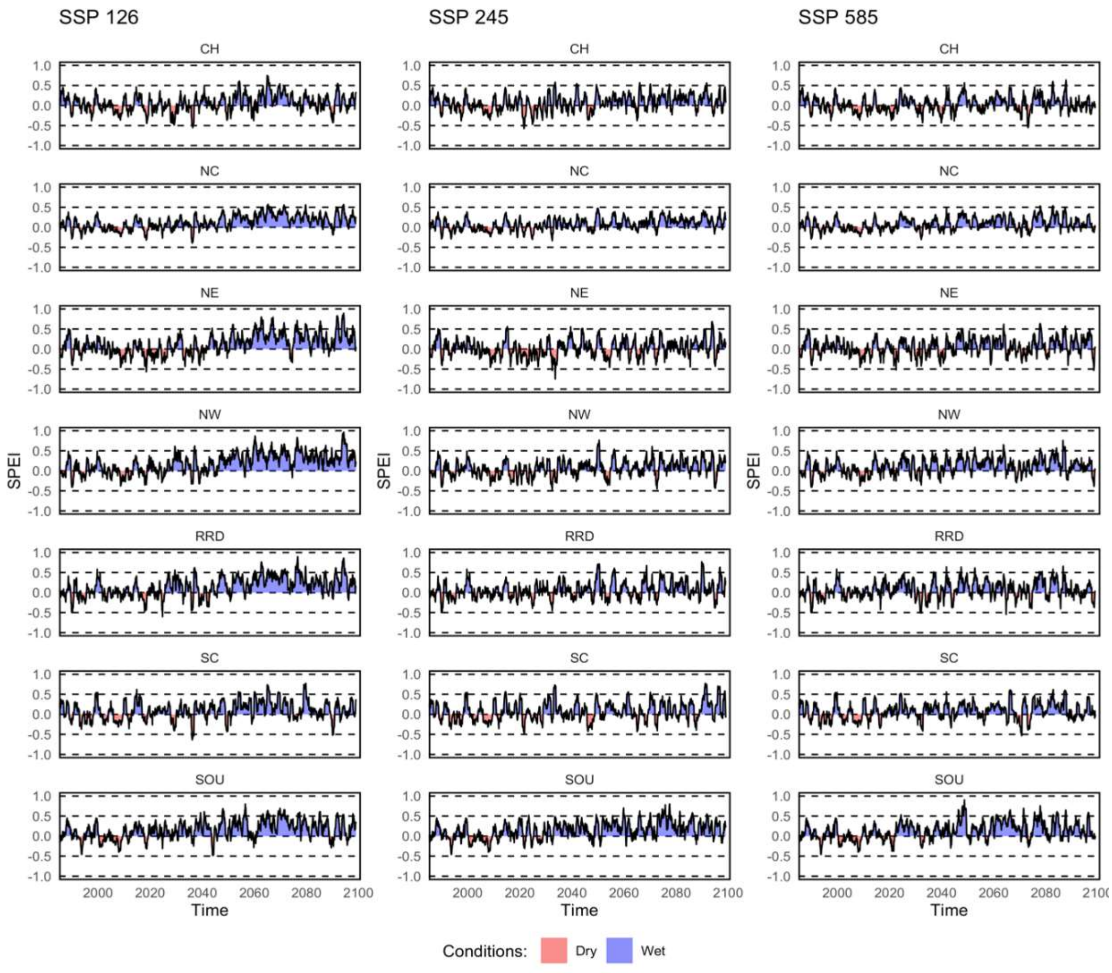

Fig. 3. *SPI index for Vietnam's seven sub-climatic regions from 1980 to 2099 under three scenarios: SSP1-2.6 (left), SSP2-4.5 (middle), and SSP5-8.5 (right).*

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Concerning precipitation, most provinces are expected to witness increased rainfall as global temperatures rise. Projections indicate an increase ranging from 2.95% to 2.37% (SSP1-2.6) to 9.03% to 10.2% (SSP2-4.5) in the mid and far-future, respectively. However, the distribution of rainfall trends does not exhibit a straightforward link to global warming. Notably, SSP2-4.5 envisions wetter future conditions compared to SSP5-8.5. Generally, Northern areas are anticipated to receive more evenly distributed rainfall compared to the South. Among the regions, the Southern area is expected to receive the least rainfall in both mid and far-future scenarios. Conversely, increased precipitation can mitigate the severity of drought, countering the impact of rising temperatures that tend to intensify drought tendencies.

3.2. Future trends of drought

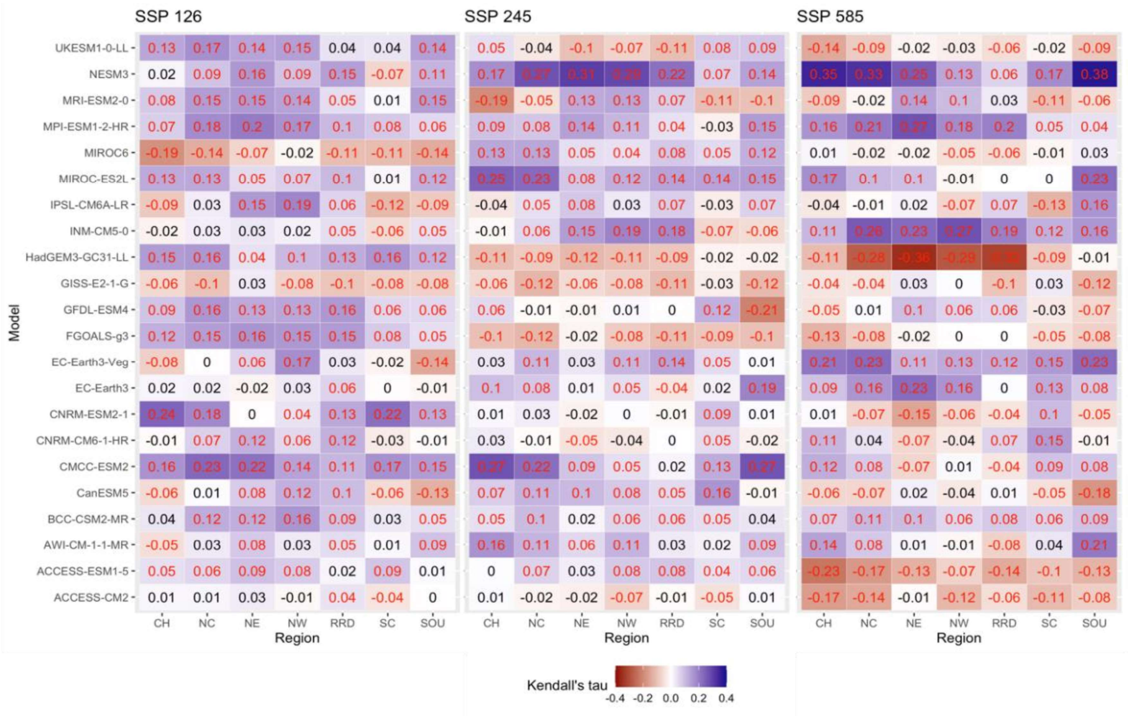

Fig. 4. *Heatmap of Kendall's tau index for CMIP6-VN models across Vietnam's seven sub-climatic regions under three scenarios: SSP1-2.6 (left), SSP2-4.5 (middle), and SSP5-8.5 (right), spanning from 2015 to 2099. In the heatmap, grid cells highlighted in blue denote positive Kendall's tau values, while red cells represent negative Kendall's tau values. The significance of the trend is indicated by values in red text, signifying that they are statistically significant with a p-value less than 0.05.*

Fig. 4 presents an analysis of the trends in the SPEI index from 2015 to 2099 across individual models within the CMIP6-VN dataset using the Mann-Kendall trend test. This investigation focuses on Vietnam's seven sub-climatic regions under three distinct scenarios: SSP1-2.6, SSP2-4.5, and SSP5-8.5. A notable result is that the majority of models reveal statistically significant trends, indicated by p-values below 0.05. Under SSP1-2.6, positive Kendall's tau values predominate, suggesting an overall trend toward wetter conditions by the end of the 21st century. Model consensus on the increasing SPEI trend is strongest in the Northwest (16/22), Northeast (16/22), and the Red River Delta (19/22) regions, while it is comparatively lower in the Central Highlands (14/22) and the Southern (16/22) regions. Conversely, under the higher emission scenarios, SSP2-4.5 and SSP5-8.5, models display a shift away from increasing SPEI trends, with some exhibiting negative trends. However, it's worth noting that in many regions, the increasing trend still surpasses the decreasing trend. Notably, model agreement regarding SPEI trends is less pronounced in the higher emission scenarios compared to SSP1-2.6. Among the scenarios, SSP5-8.5 presents the most concerning outlook for future drought, with 12 out of 22 models indicating an overall decreasing trend in the SPEI index. Generally, the analysis suggests that drought is expected to become less severe in the far future, although occasional short-term drought events may still occur in specific regions, particularly in the Central Highlands and the Southern areas.

IV. CONCLUSION

This study comprehensively examined drought patterns and trends in Vietnam using the CMIP6-VN dataset. Our investigation extended to the end of the 21st century, considering three distinct climate scenarios: SSP1-2.6, SSP2-4.5, and SSP5-8.5. Drought conditions were assessed using the SPEI index, and we estimated evapotranspiration with the Hargreaves and Samani method. Additionally, the Mann-Kendall trend test was employed to evaluate the significance of drought trends. The study's findings reveal the complex dynamics of drought in Vietnam. In the first half of the 21st century, an alternating pattern of wet and dry conditions is expected, closely resembling the recent historical climate pattern from 1985-2014. Under lower emission scenarios (SSP1-2.6), models generally project increasingly wet conditions in the latter half of the 21st century, offering some relief from short-term water scarcity. However, in the context of higher emission scenarios (SSP2-4.5 and SSP5-8.5), the upward trajectory of water variability appears less pronounced, indicating potential challenges, particularly for the Central Highland and Southern regions. Nevertheless, our research discerns that while short-term water scarcity may not become a severe concern in the future, intermittent periods of drought remain a possibility, especially in regions susceptible to climate fluctuations.

Maintaining awareness and continued research on drought patterns in Vietnam, considering changing climate conditions, is of utmost importance. It is essential to develop strategies that can adapt to local challenges, especially in managing water resources, implementing innovative farming techniques, and strengthening disaster preparedness. Moreover, advocating for sustainable development initiatives and reducing emissions will play a pivotal role in lessening the impact of future droughts, ensuring the resilience of Vietnam's agriculture sector, and safeguarding the welfare of its people.

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REFERENCES

[1] Intergovernmental Panel On Climate Change (IPCC). (2023). Climate change 2022 – impacts, adaptation and vulnerability: Working group II contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (1st ed.). *Cambridge University Press*.

[2] Smakhtin V., & Hughes D., *Environmental Modelling & Software*, **22**(6), 2007, pp. 880-890.

ISBN: 978- 604- 357- 225-4

[3] Le P. V. V., Phan-Van T., Mai K. V., & Tran D. Q., Space-time variability of drought over Vietnam. *International Journal of Climatology*, **39**(14), 2019, 5437-5451.

[4] Stojanovic M., Liberato M. L. R., Sorí R., Vázquez M., Phan-Van T., Duongvan H., Hoang Cong T., Nguyen P. N. B., Nieto R., & Gimeno L., *Water*, **12**(3), 2020, 813.

[5] Van Huynh C., van Scheltinga C. T., Pham T. H., Duong N. Q., Tran P. T., Nguyen L. H. K., Pham T. G., Nguyen N. B., & Timmerman J., *International Soil and Water Conservation Research*, **7**(4), 2019, 362-375.

[6] Tran D. D., Nguyen T. D., Park E., Nguyen T. D., Pham T. A. N., Vo T. T., & Nguyen A. H., *International Journal of Disaster Risk Reduction*, **93**, 2023, pp. 103762.

[7] Nguyen-Ngoc-Bich, P. Phan-Van, T. Ngo-Duc, T. Vu-Minh, T. Trinh-Tuan, L. Tangang, F. T. Juneng L., Cruz F., Santisirisomboon J., Narisma G., & Aldrian E., *International Journal of Climatology*, **41**(12), 2021, pp. 5733-5751.

[8] IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[9] MONRE. Climate change, sea level rise scenarios for Viet Nam. Viet Nam Natural Resources, Environment and Mapping Publishing House. (in Vietnamese), 2020.

[10] Nguyen, D. N. & Nguyen, T. H., Vietnamese climate and climatic resources. *Hanoi Agriculture Press.,* 2004.

[11] Tran-Anh Q., Ngo-Duc T., Espagne E., & Trinh-Tuan L., *Scientific Data*, **10**(1), 2023, pp. 257.

[12] Hargreaves G. H., & Samani Z. A., *Applied Engineering in Agriculture*, **1**(2), 1985, pp. 96-99.

[13] Mann, H. B., *Econometrica*, **13**(3), 1945, pp. 245-259.