

Predicting drought stress under climate change in the Southern Central Highlands of Vietnam

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Abstract

In the Southern Central Highlands of Vietnam, droughts occur more frequently, causing significant damage and impacting the socio-economic development of the region, especially affecting various industries and agriculture. During the dry season, rivers, streams, and reservoirs often face limited water availability, exacerbated by increasing drought severity in recent years. Recognizing the escalating severity of droughts, the study offers novel contributions by conducting a comprehensive analysis of surface water resource distribution in Lam Dong province, with a focus on assessing water demand for agricultural production, a crucial factor in ensuring sustainable crop growth. To achieve this, the study utilizes a combination of the MIKE-NAM and MIKE-HYDRO basin models, allowing for a comprehensive assessment of the water balance. Two scenarios are considered for simulation in the current-2020 (SC1) and climate change-2025 (SC2), with SC2 being based on climate change and sea level rise scenarios provided by the Ministry of Natural Resources and Environment (MONRE). Furthermore, the study utilizes the Keetch–Byram Drought Index (KBDI) to measure drought severity, revealing prevalent dry and moderately droughty conditions in highland districts with precipitation ranging from 50% to 85%. Severe drought conditions emerge at 95% precipitation levels, indicating an increased frequency and geographic scope of severe droughts. Additionally, the study highlights that under abnormally dry conditions, water demand for the winter-spring crop is consistently met at 100%, decreasing to 85%, 80%, and less than 75% for moderate, severe, and extreme droughts, respectively. These findings offer insights into future drought conditions in the Lam Dong province and their potential impact on irrigation capacity, crucial for adaptation strategies.

Keywords: Water balance, droughts, KBDI, MIKE models, climate change

1. Introduction

While constituting a relatively small percentage of the Earth's total water supply, rivers and lakes are important water resources given their accessibility (Beck & Bernauer, 2011). However, population growth, increased economic activity, and unsustainable water management practices have resulted in the over-exploitation of those limited freshwater resources (Beck & Bernauer, 2011; Vörösmarty et al., 2010), with climate change and water contamination further straining them (Milano et al., 2013). An increase in the severity of hydrological extremes, i.e., floods and droughts, has also been observed in recent years (Mishra & Singh, 2010). Droughts affect water supplies, reducing water availability and declining water quality, and can cause crop losses and disruptions to riparian ecosystems (Mishra & Singh, 2011; Riebsame, 2019), amongst other impacts.

In the Southern Central Highlands of Vietnam, Lam Dong province's predominantly hilly terrain features high plateaus interspersed with small valleys, which contribute to its distinct natural characteristics, notably climatic conditions and good soil quality, providing the province with excellent potential for agriculture and forestry, mainly to cultivate crops such as tea, coffee, vegetables, flowers, and medicinal plants (Giang, 2015; Hoang & Tuan, 2015; Jähne et al., 2023; Tum et al., 2016). The seasons and the regional topography greatly influence the uneven distribution of surface water resources across space and time within the province. Even though water resources are abundant during the rainy season, most rivers, streams, and reservoirs become depleted during the dry season, causing water shortages, with the severity of the latter increasing annually. Although available, groundwater is situated at depths 70-100 m below ground level, making it challenging to abstract. In addition, due to climate change, weather patterns in recent years have been abnormal, and more extreme, such as increasing temperatures, decreasing humidity, and longer dry seasons in Lam Dong. The trend towards prolonged dry periods and increasing frequency of droughts has been observed, with decreasing

rainfall during the dry season. While rainfall intensity during the rainy season tends to increase, most rivers and streams in Lam Dong have relatively small catchment areas due to steep terrain and strong division, resulting in limited water retention. Consequently, this has greatly affected agricultural production, livelihoods, and the province's socio-economic development. According to a report by The Southern Institute of Water Resources Research (SIWRR) of Vietnam, the water resources (surface and groundwater) of Lam Dong, while not yet at an alarming level, are at risk of depletion without effective management and utilization solutions. Various irrigation planning projects and resource surveys for surface water and groundwater in the Central Highlands region have been implemented, along with scientific research projects within the framework of the Science and Technology Program for the Central Highlands 3 (TN3/11-15) Vietnam, which have somewhat explored water resources related issues for the entire Central Highlands region, including Lam Dong province. However, these calculations have been done at a macro level and lack specific balance considerations for Lam Dong province. Therefore, whenever Lam Dong faces drought, the province's agricultural production guidance remains somewhat passive. To contribute to a strategic enhancement of water usage efficiency and proactively respond to droughts' growing severity, assessing the shifts in drought patterns and their impacts under climate change is crucial for water surface planning and management in Lam Dong province.

Water balance models are designed to simulate the movement and distribution of water over a given catchment. They are widely used in hydrological studies because they are computationally efficient and reliable and can be run with limited data through calibration and validation (Mao et al., 2018). Moreover, they can be run using outputs from models used to project future climates to assess the potential impacts of climate change and other factors, such as land cover/ land use change on water availability, thereby helping with planning and managing water resources. A variety of water balance

models exist, for instance, the Water Evaluation And Planning System (WEAP) (Lévite et al., 2003), SWAT (Abeysingha et al., 2015; Arnold et al., 2012; Himanshu et al., 2017), LISFLOOD (Van Der Knijff et al., 2010), HEC-HMS (Halwatura & Najim, 2013), and the Modeling Integrated for Knowledge and Engineering (MIKE) software suite, i.e., MIKE-HYDRO basin (Kumar et al., 2021; Santos et al., 2015; SANTOS et al., 2018), MIKE-NAM (Makungo et al., 2010; Shrestha et al., 2020), and MIKE SHE (Paparrizos & Maris, 2017; Zhang et al., 2021).

Furthermore, it is worth noting that drought significantly impacts the susceptibility of plants to wildfires, leading to heightened water stress in vegetation during dry periods. The water potential of plants becomes a crucial indicator for assessing the degree of water stress they experience (Xanthopoulos et al., 2006). The KBDI employs data on rainfall and maximum temperature to estimate the cumulative influence of daily precipitation and evapotranspiration on the soil's water balance (Dennison et al., 2003; Keetch & Byram, 1968). The successful demonstration of the potential applications of KBDI in monitoring drought and predicting crop yields has been evident in the Lower Mekong River Basin, the central highland regions of Vietnam, and Indonesia (Hosoya & Takeuchi, 2012; Quyen et al., 2017; Shofiyati et al., 2014; Thang et al., 2014; Thanh et al., 2023; Thuc et al., 2013).

The MIKE HYDRO basin software, developed by the Danish Hydraulic Institute, serves as a decision support tool for integrated water resources planning and management. It offers comprehensive hydrological models tailored for watershed-scale solutions, facilitating the management of water distribution within basins, including reservoir and hydropower operations (SANTOS et al., 2018). Due to its robust features aligning with the research focus, this paper employs a combination of MIKE-NAM and MIKE-HYDRO basin models to evaluate the water balance of Lam Dong province, alongside the Keetch–Byram Drought Index (KBDI) for analyzing drought conditions under present and future climate change scenarios. These tools play a pivotal role in

simulating basin flow dynamics, thus contributing significantly to effective water resource management. They are particularly instrumental in drought monitoring, proposing sustainable water utilization strategies, and ensuring efficient allocation of water resources for agricultural purpose in Lam Dong.

2. Materials and methods

2.1. Case study

Lam Dong is one of Vietnam's five provinces in the Central Highlands region. It is located in the South-Central Highlands ([Figure 1](#)), it maintains an average elevation ranging from 800 to 1500 meters above sea level, covering a land area of, covering an area for 9774 km² ([Hang et al., 2020](#); [Ta Huu et al., 2023](#)). Lam Dong covers 3.1% of the country's total area and 17.9% of the Central Highlands area. The province's topography mainly comprises plateaus, with most of the area forested ([Jolk et al., 2010](#)). In addition, Lam Dong has a unique topography with mountain ranges running from north to south. The northern part is mainly the Yang Bong Mountain range, reaching 1749 m above sea level. The southern mountain ranges include 1950 m high Dan Sena Peak, 2163 m high Lang Biang Peak, and 1948 m high Hon Giao Peak ([Huu et al., 2022](#)). Lam Dong province experiences a tropical climate characterized by distinct dry and rainy seasons, influenced by the South Asian monsoon. From 2002 to 2018, the province received monthly rainfall varying from 130 mm to 180 mm, amounting to a yearly total of 1750 mm to 3150 mm. During this period, the temperature slightly increased from 18 °C in 2002 to 18.4 °C in 2018 ([Tran et al., 2021](#)).

Lam Dong province is the watershed for two major river systems. The first system includes the Krong No River - Srepok - MeKong River, covering a basin area of 1248 km². The second system, with a basin area of 8524 km², consists of the Dong Nai - La Nga River, along with the Da Dang, Da Nhim, Dai Nga, and Da Huoai rivers, and several tributaries on the left bank of the upstream Dong Nai Thuong River. These rivers flow towards the

Southeast region and supply water to downstream areas of the Dong Nai River and Binh Thuan Province (Hang & Phung, 2019). This region is important for cultivating long-lasting industrial crops, forestry, mineral extraction, livestock farming, and tourism and service industries (Figure A1). It has attracted substantial foreign investment, contributing significant economic value to the province. This development has played a crucial role in population stabilization and poverty reduction. However, the current situation highlights a concerning trend of decreasing water resources in Lam Dong province, leading to water scarcity issues in various areas of the province (Hang et al., 2020).

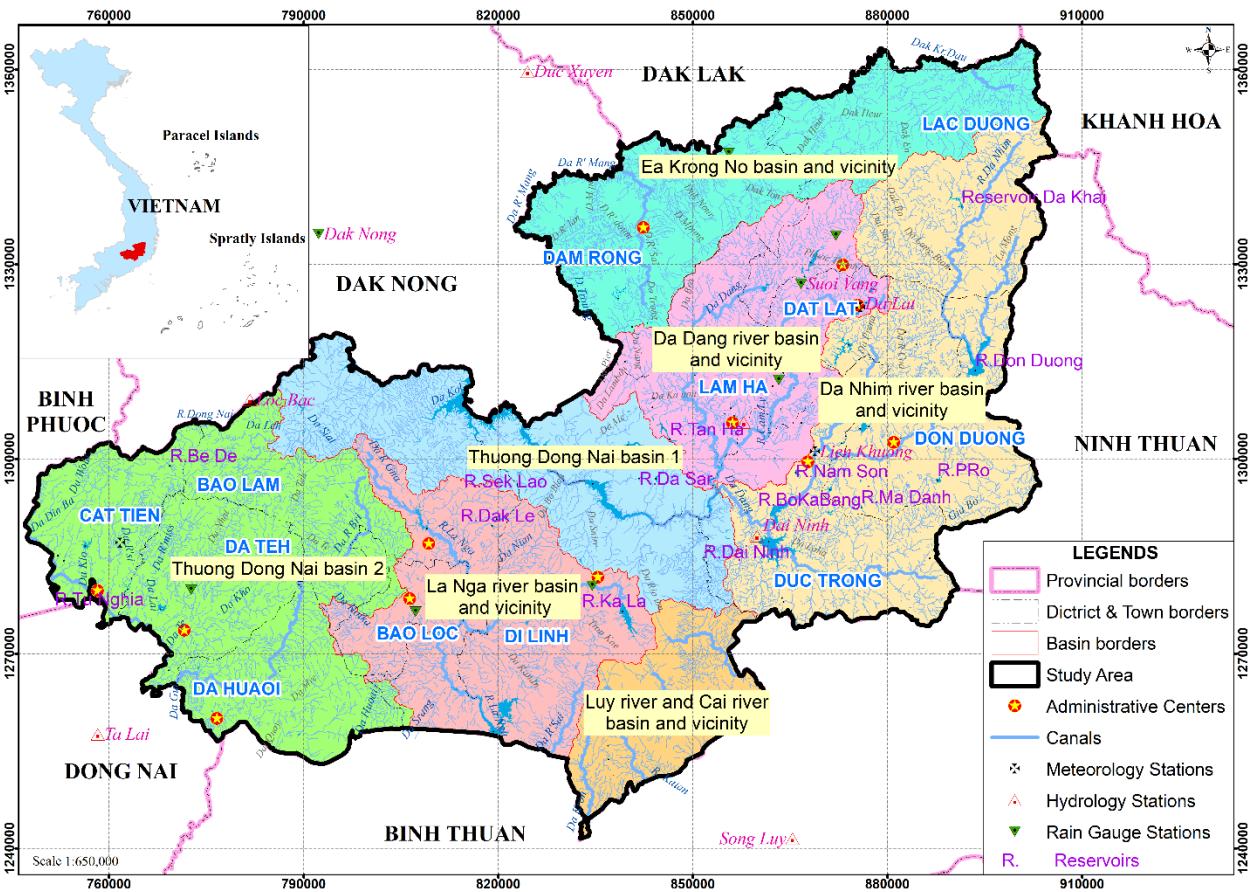


Figure 1. Location of the study area.

2.2. Methodological approach

The MIKE-NAM model is applied to simulate water flow, with the drainage area of the model subdivided into seven distinct sub-basins. These sub-basins, namely the Da Dang River Basin and its vicinity, Da Nhim River Basin and its vicinity, Krong No River Basin and its vicinity, Thuong Dong Nai 1 River Basin, Thuong Dong Nai 2 River Basin, Luy – Cai River Basin and its vicinity and La Nga River Basin and its vicinity, are delineated based on their unique climate characteristics, irrigation systems, water supply systems, small river basins, reservoirs, and measurement stations (Figure 1). The MIKE-HYDRO basin model calculates hydrological parameters, hydraulic characteristics, water balance, and water demand in these sub-basins. The MIKE-NAM model is calibrated and validated using a dataset of flow measurements from two hydrological monitoring stations: Thanh Binh (2001-2017) and Dai Nga (1990-2013).

Furthermore, the research determines the water supply-demand relationships in the agricultural areas of Lam Dong province. For this purpose, two computational scenarios have been developed: one based on existing conditions and trends (SC1) and the other considering the impact of climate change (SC2) according to the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway (RCP) 4.5 and 8.5. Which, SC2 was developed based on the climate change and sea level rise scenarios for Vietnam in 2016 by the Ministry of Natural Resources and Environment (MONRE) of Vietnam. It reflects a trajectory in which greenhouse gas (GHG) emissions persistently increase throughout the 21st century, resulting in high radiation forcing. This scenario represents the highest among the four GHG concentration pathways in the Coupled Model Intercomparison Project Phase 5 (CMIP5) (MONRE, 2016).

2.3. Model Setup

2.3.1. MIKE NAM models

The MIKE-NAM model was initially proposed by Nielsen & Hansen (1973) and later incorporated into MIKE11, developed by the Danish Hydraulic Institute DHI (2017a). It

is a numerical hydrological model that relies on physical structures and experimental equations (Madsen, 2000). This model provides a simplified quantitative representation of the terrestrial phase of the hydrological cycle (DHI, 2017a), with its suitability extensively evaluated in the literature (e.g., Doulgeris et al. (2011); Ghosh et al. (2022); Skoulikaris & Piliouras (2023)).

The MIKE NAM model comprises four interconnected storage elements: (i) surface storage, (ii) lower or root zone storage, (iii) groundwater storage, and (iv) snow storage (Agrawal et al., 2024; Skoulikaris & Piliouras, 2023). However, snow storage is not considered in the current study due to the warm tropical climate of the research area. For the MIKE-NAM model, initial conditions of model parameters, meteorological input data (where rainfall amounts are computed using the Thiessen polygon method to improve capture and evaporation), and streamflow data are necessary for model calibration and validation. The calibration process will determine the nine most crucial parameters of the MIKE-NAM model, as outlined in [Table 4](#) and [Table 5](#).

2.3.2. MIKE-HYDRO Basin models

Developed by the Danish Hydraulic Institute (DHI) (DHI, 2017b), the MIKE-HYDRO basin stands out as a decision support tool meticulously crafted for the purpose of mapping, integrating water resources management, and planning within river basins ([Bessa Santos et al., 2019](#); [Gabor et al., 2019](#)). This software provides comprehensive hydrological modeling solutions on a basin scale, presenting an all-encompassing depiction of water availability and demand ([Doulgeris et al., 2015](#)). The MIKE-HYDRO basin model combines data, including basin characteristics, river networks, water usage, reservoir operations, and hydroelectric factors ([Thanh et al., 2023](#)). The MIKE-HYDRO basin calculation scheme was established for the whole study area. Irrigation works (current), water demand, and water supply for economic sectors at present (2020) and

planning to 2025. All 25 nodes are digitized at water intake works and reservoir locations (Figure 2).

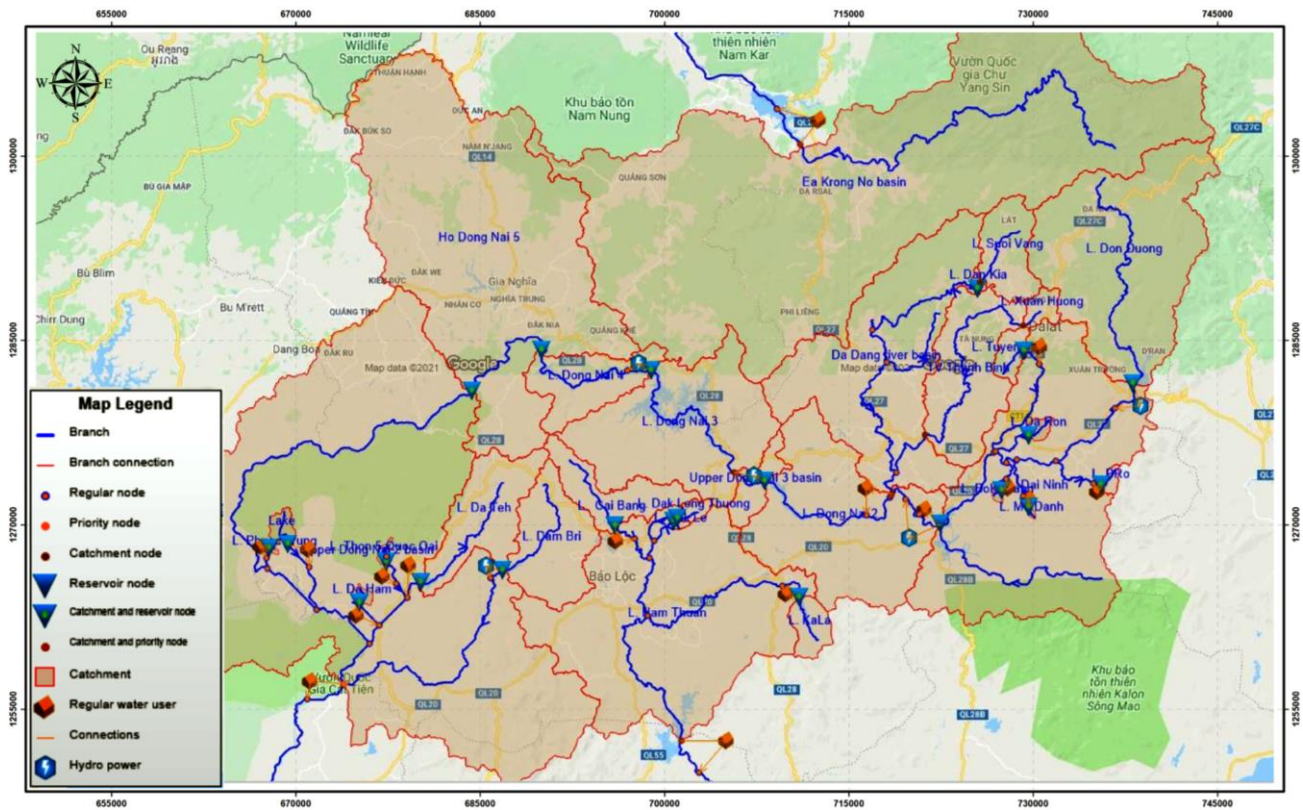


Figure 2. Catchment in the MIKE-HYDRO basin model.

2.3.3. Input data

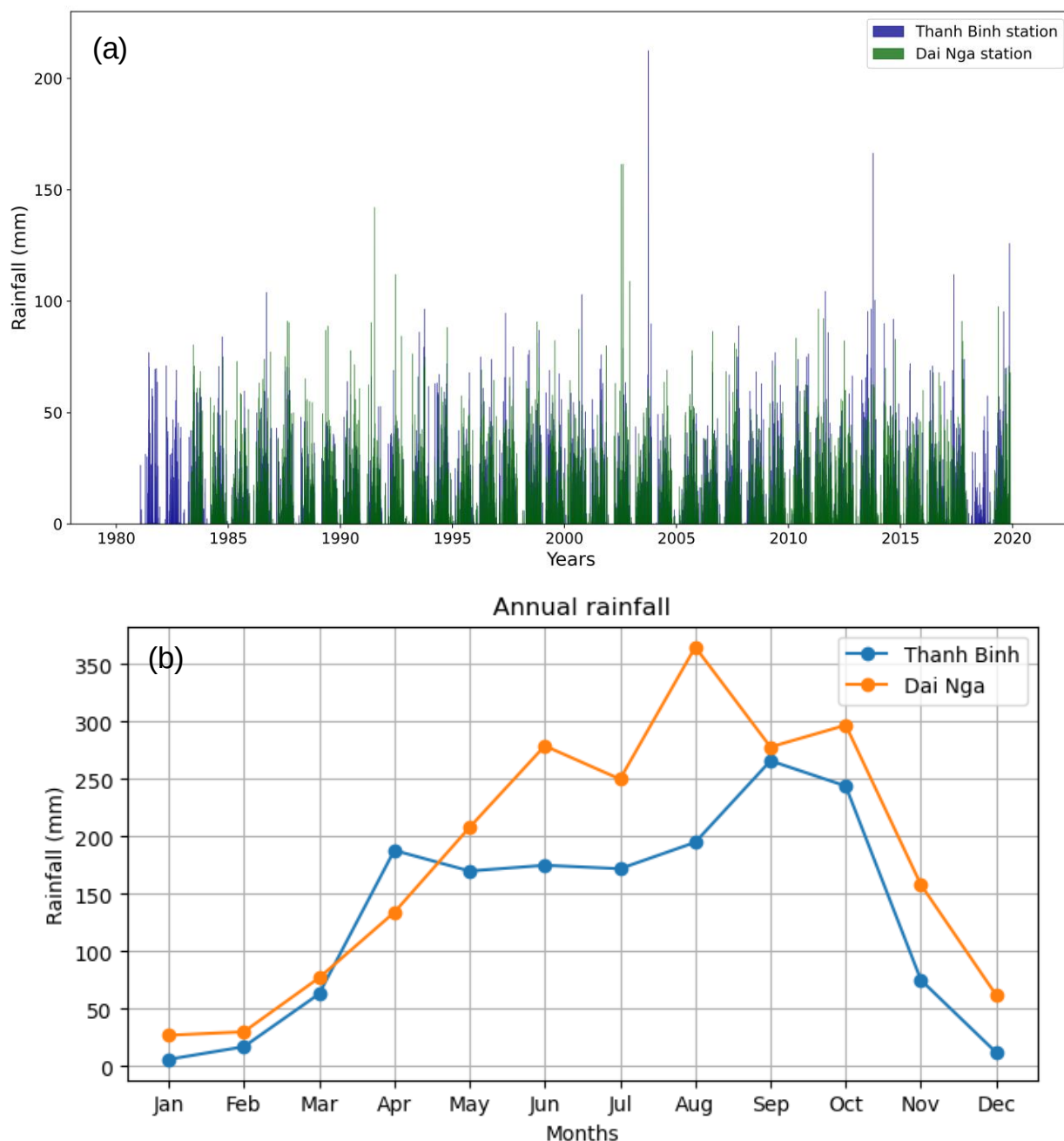
The MIKE NAM and MIKE-HYDRO basin models calculate water balances and allocate water resources. To establish an optimal model, input data such as topographic information, hydrometeorological data, and hydrological infrastructure data within the research area are of utmost importance. In particular, topographic data is derived from a Digital Elevation Model (DEM) with a 30 m x 30 m resolution to delineate watersheds and sub-basins within the study area (Figure 17 - Appendices). Hydrometeorological data were obtained from stations within the study area and its vicinity, encompassing daily rainfall records, evaporation data, and actual flow measurements for model calibration. Based on the available data and station distribution within the study area, suitable

stations are selected for different regions. These include 15 rainfall monitoring stations (Figure 3) within Lam Dong province (Da Lat, Da The, Dam Rong, Di Linh, Lac Duong, Nam Ban, Suoi Vang, Thanh Binh, Lien Khuong, Don Duong, Da Nhim, Dai Ninh, Dai Nga, Bao Loc and Cat Tien), two stations outside the province (Dak Nong and Luy river), three weather monitoring stations (Dat Lat, Bao Loc and Lien Khuong), and two flow measurement stations (Thanh Binh and Dai Nga), with data collected from 1980 to 2019.

By the end of 2019, there were 430 completed and operational water management structures within Lam Dong province. These included 220 reservoirs, 87 dams, and 19 pumping stations. Currently, the province has about 1200 km of canals and channels, of which 885 km have been solidified (accounting for 73.75%); there are also 92 temporary check dams and 12 irrigation canals. Among the 220 reservoirs are 34 large dams, 54 medium-sized dams, and 132 small dams.

In this study, all irrigation reservoirs with complete operational procedures are integrated into computational nodes, totaling 21 irrigation reservoir projects under consideration. The remaining reservoirs and dams are amalgamated into water demand nodes and calculated accordingly. For hydroelectric reservoirs, both seasonal and yearly regulation facilities are accounted for, encompassing a total of 9 reservoirs. The operation of hydroelectric reservoirs follows the inter-reservoir operation procedure within the Dong Nai River Basin System. Additionally, the MIKE-HYDRO basin models setup includes all hydroelectric reservoirs with seasonal and annual regulation processes within Lam Dong province with small reservoirs incorporated into the computational nodes of the model. The model includes five hydroelectric plants directly affecting Lam Dong province's water sources (Da Nhim, Dai Ninh, Dong Nai 3, Dong Nai 2, and Da Mbri). Notable exclusions from the model are AnKroet-Suoi Vang, due to their small size, Dong Nai 4, and Dong Nai 5, which function solely as water reservoirs and do not directly impact Lam Dong province's water sources. Additionally, Ham Thuan Reservoir,

261 **situated outside of Lam Dong province, is not considered in the model.**



262

263 Figure 3. Rainfall at Thanh Binh and Dai Nga for the (a) period 1980 – 2020 and (b)

264 Annual rainfall.

265 The Penman equation is a comprehensive method that combines radiative and

266 radiation-aerodynamic elements to assess evapotranspiration (ET_0). These calculations

are essential for the initial planning of irrigation projects and the ongoing management of water distribution (Droogers & Allen, 2002). Out of the numerous equations available for calculating ETo, the FAO adaptation of the Penman-Monteith equation, introduced by (Allen et al., 1998), is the most widely used. Detailed information about the FAO Penman-Monteith method, along with procedures for determining its various parameters, algorithms, and recommended values, can be found in the following two documents of (Allen, 1994; Allen et al., 1994). The ETo calculation results are described in Table 7 (Appendices).

2.4. Evaluation of model performance

This study employed a range of statistical techniques to evaluate model performance. These include the correlation coefficient (R), the Nash–Sutcliffe efficiency (NSE) coefficient, the Root Mean Square Error (RMSE), the Mean Absolute Error (MAE), and Percent of Bias (PBIAS) (McCuen et al., 2006; Moriasi et al., 2007, 2012, 2015). The detailed calculation equations are provided in Table 1.

Table 1. Model performance evaluation criteria.

Criterion	Symbol	Equation	Range
Correlation coefficient	R	$\frac{\sum_{i=1}^n (O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_{i=1}^n (O_i - \bar{O})^2} \sqrt{\sum_{i=1}^n (P_i - \bar{P})^2}}$	0 to 1
Nash-Sutcliffe efficiency	NSE	$1 - \frac{\sum_{i=1}^n (O_i - P_i)^2}{\sum_{i=1}^n (O_i - \bar{O})^2}$	0 to 1
Root Mean Square Error	RMSE	$\sqrt{\frac{1}{n} \sum_{i=1}^n (O_i - P_i)^2}$	0 to ∞
Mean Absolute Error	MAE	$\frac{1}{n} \sum_{i=1}^n O_i - P_i $	0 to ∞

Percent of Bias

PBIAS

$$\frac{\sum_{i=1}^n (O_i - P_i) * 100}{\sum_{i=1}^n O_i}$$

$-\infty$ to ∞

where: O_i - The observed data at the time i , P_i - The simulated data at the time i , $\bar{O}$ - The mean value of the observed data and $\bar{P}$ - The mean value of the simulated data.

2.5. Simulated scenarios

In this study, we employed two scenarios to assess drought in Lam Dong, including (1) the Current-2020 scenario (SC1) and (2) the Climate Change-2025 scenario (SC2). Notably, SC2 is based on the 2016 climate change scenario from the MORE, Vietnam, utilizing both RCP 4.5 and RCP 8.5 greenhouse gas emissions. The seasonal rainfall frequency scenario is presented in [Table 8 \(Appendices\)](#), considering two cases: excess water and water scarcity. Rainfall frequency refers to the likelihood of a specific type of rain event. Typically, drought conditions are associated with lower precipitation levels. The categorization is as follows: (1) Excess Water Scenario: High rainfall frequency, often corresponding to a percentage above a certain threshold ($< 50\%$); (2) Abnormally Dry Conditions: Rainfall frequency in the range of 50-75%; (3) Moderate Droughts: Rainfall frequency in the range of 75-85%; (4) Severe Droughts: Rainfall frequency in the range of 85-95%; (5) Extreme Droughts: Rainfall frequency over 95%. This classification aligns with the Technical Regulations on Water Resource Forecasting and Water Use Planning for the Direction and Operation of Agricultural Water Supply in Vietnam (TCKT 01:2019/TCTL), specified by the Ministry of Agriculture and Rural Development ([MARD, 2019](#)).

Anticipated changes in rainfall and water resources in the future are contingent on climate change scenarios, specifically greenhouse gas emission scenarios RCP 4.5 and RCP 8.5, estimated for the years 2025 and 2035 (refer to [Table 9](#) in the [Appendices](#)). Projections indicate a gradual increase in temperatures over the course of the 21st century. At the century's outset, the average annual temperature is expected to rise by 0.7 and

0.9°C compared to the baseline period, corresponding to the RCP 4.5 and RCP 8.5 scenarios, respectively.

In terms of precipitation, the forecast for Lam Dong province entails an overall increase, with the most significant surge expected during winter (December to February) and a more modest rise during spring (March to May). Meanwhile, the increase in summer (July to August) is slightly higher than in spring. For the RCP 8.5 scenario, an expectation is set for a lesser increase during dry months and an augmentation during rainy months. Notably, during the spring months (March to May) in the RCP 8.5 scenario, precipitation is projected to decrease by 8.7% in comparison to the baseline period.

Furthermore, the study incorporates considerations for water infrastructure and hydropower developments aligned with the 2025-2030 plan, encompassing upgrades, repairs, and new constructions (as detailed in [Table 2](#)). These factors are integral components of the scenarios under examination.

Table 2. Description of model scenarios.

No	Factors	Simulation scenarios	
		Current - 2020 (SC1)	Climate change - 2025 (SC2)
1	Water sources	SC1.1: Magnitude 50% SC1.2: Magnitude 85% SC1.3: Magnitude 90%	RCP4.5 and 8.5 GHG emission scenario to 2035
2	Water supply	2019	2025
3	Hydraulic works	Reservoirs, hydropower plants, and dams connected to the network in 2019	Planned hydraulic works, including Reservoirs, hydropower plants, and weirs, in 2025-2030

2.6. Drought indices

The KBDI index, introduced by John Keetch and George Byram in 1965, was originally designed to evaluate the risk of wildfires in the southeastern United States.

KBDI depicts the cumulative moisture deficit in the upper soil layers (Keetch & Byram, 1968; Salehnia et al., 2018). The index rises for each rainless day (the magnitude of increase is influenced by the daily high temperature) and decreases on days with rainfall (Darmawan et al., 2014). Moreover, a noteworthy feature of the KBDI is its indirect consideration of the density of transpiring vegetation, achieved by factoring in the daily moisture deficit using the annual precipitation data for the specific location under investigation (Ruffault et al., 2018). The output values range from 0 to 800 and are classified into four categories (Table 3), where 0 represents saturated soil, and 800 indicates severe drought (Salehnia et al., 2018). The applicability of the KBDI index in drought monitoring and seasonal forecasting has been tested in several studies, for instance (Thanh et al., 2023).

The equation to calculate the KBDI index is as follows:

$$KBDI_t = (KBDI_{t-1} - 100r) + dF \quad (10)$$

$$dF = \frac{[800 - KBDI_{t-1}][0.968^{0.0486T} - 8.30]dt}{1 + 10.88^{(-0.0441R)}} 10^{-3} \quad (11)$$

where dF - Drought factor (0.01 inch); T - Daily maximum air temperature (°F); dt - Time increment (1 day); KBDI_t - current day KBDI index; KBDI_{t-1} - Moisture deficiency (KBDI at t - 1); r—daily rainfall (inch); R – mean annual precipitation (inch) (Alexander, 1990; Taufik et al., 2015; Thanh et al., 2023).

Table 3. Drought classification based on the KBDI (Thanh et al., 2023).

KBDI value	Category
0 - 200	No drought
200 – 400	Possibility of a drought
400 – 600	Occurrence of a drought
600 – 800	Severe drought

3. Results and Discussion

3.1. Model calibration and validation

3.1.1. Thanh Binh station

The simulated flow closely resembles the observations after calibrating the modeled discharge for the 2001-2009 period at Thanh Binh (Figure 4). The goodness-of-fit statistics are as follows: $R = 0.869$, $NSE = 0.640$, $RMSE = 4.911$, $MAE = 2.75$, and $PBIAS = 19.37\%$. However, when applying these calibrated parameters to validate the 2010-2017 period (Figure 5), there is a significant disparity in total discharge, reaching up to 17% (Table 5). This discrepancy can be mitigated by reducing the surface water layer (U_{max} , L_{max}) and the Overland flow runoff coefficient (CQOF), as outlined in Table 4. These adjustments improve the simulation results, resulting in $R = 0.932$, $NSE = 0.749$, $RMSE = 4.144$, $MAE = 2.452$, and $PBIAS = 4.67\%$ (Table 5), indicating a strong fit between the simulated and observed data.

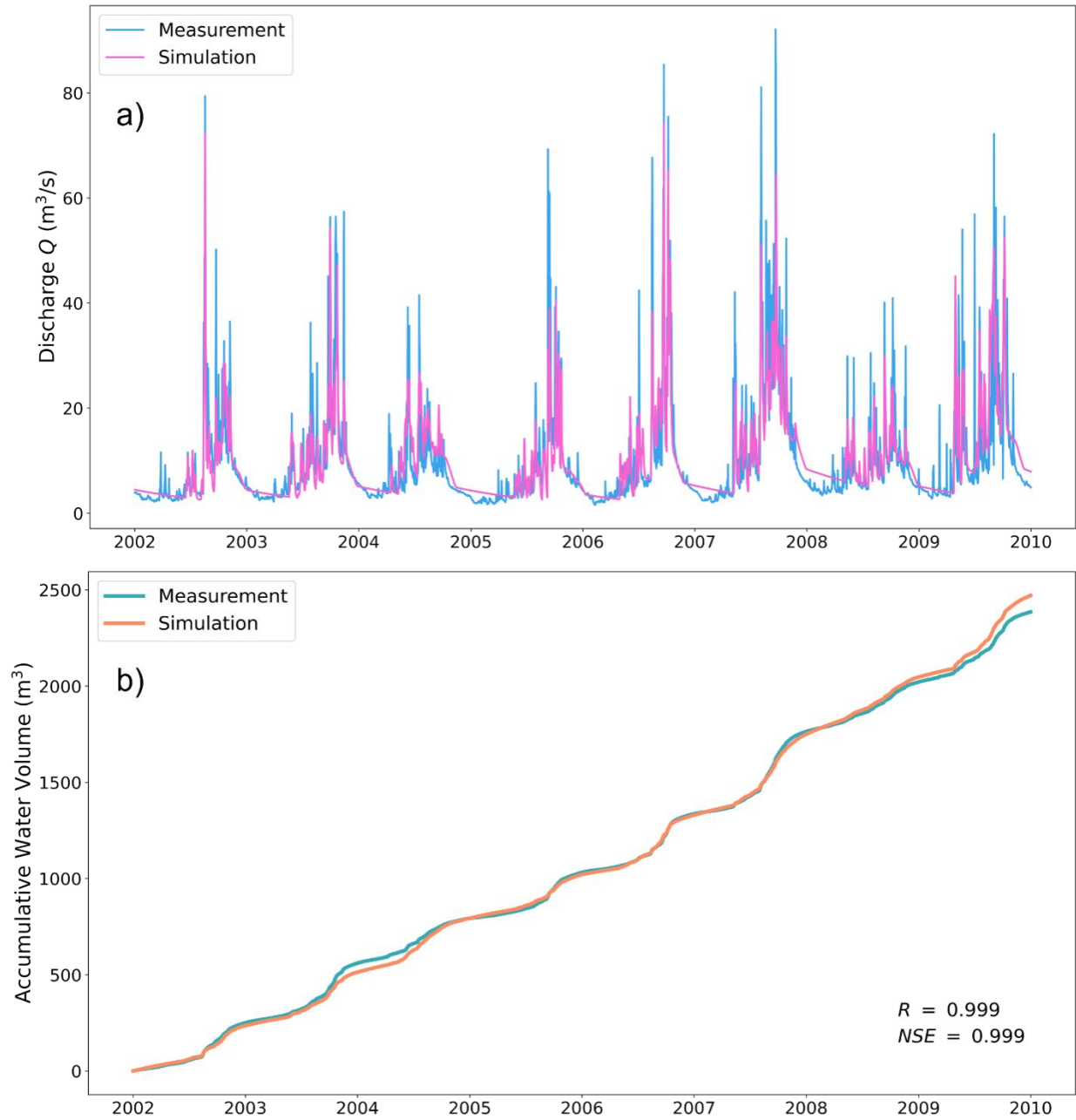


Figure 4. Calibrated discharge (a) and Accumulative Water Volume (b) at Thanh Binh for 2002-2010.

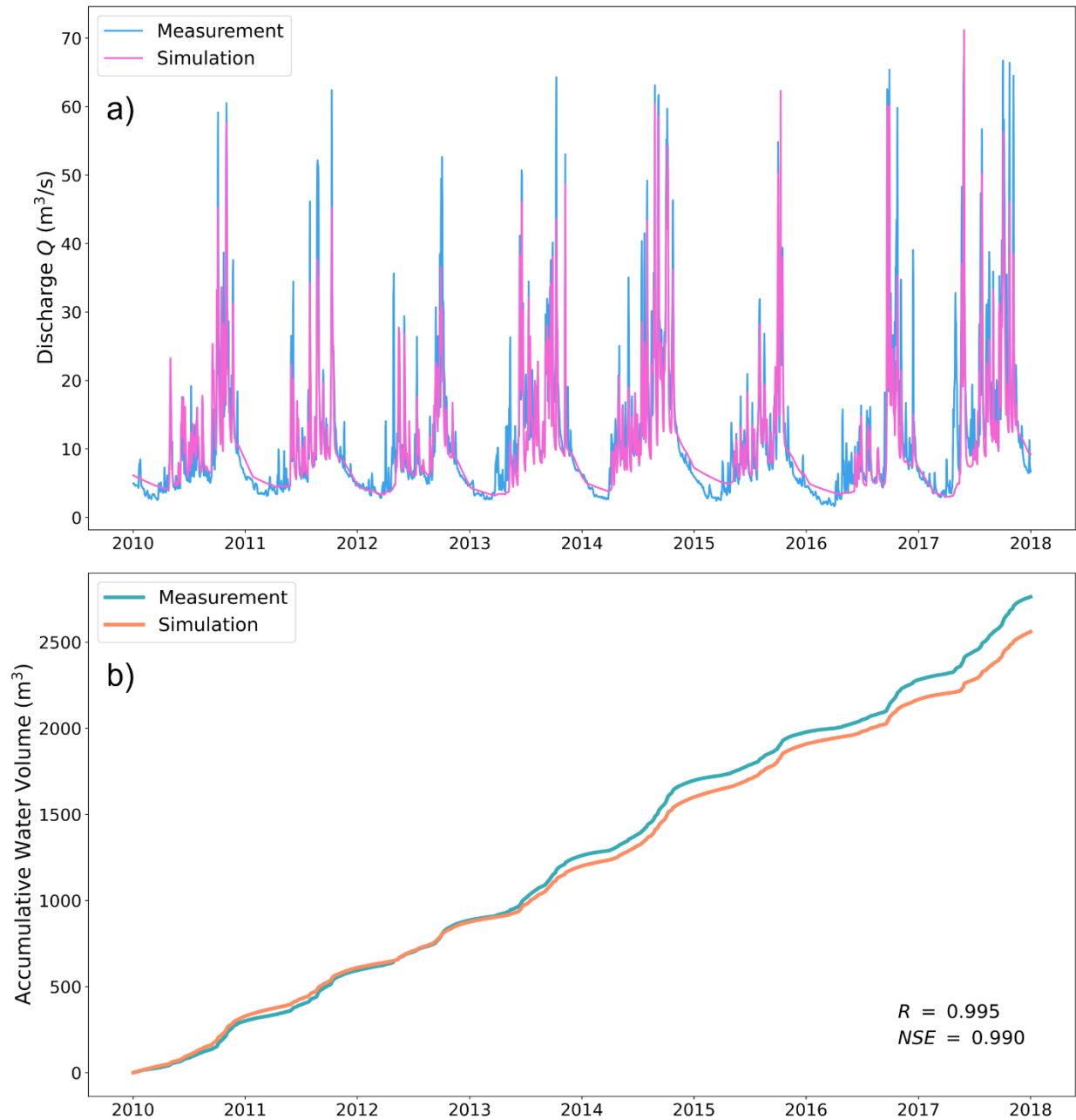


Figure 5. Validated discharge (a) and Accumulative Water Volume (b) at Thanh Binh for 2002-2010.

3.1.2. Dai Nga station

Calibrating the MIKE NAM model at Dai Nga during 1990-2000 reveals a good match between the simulated and observed discharge, with the following statistics obtained: $R = 0.915$, $NSE = 0.801$, $RMSE = 7.899$, $MAE = 5.159$, and $PBIAS = 4.42$ (Table 5

and Figure 6). Applying these calibrated parameters over the 2002-2013 period shows an 8% discrepancy in the total discharge. By reducing the surface water layer (Umax, Lmax) and Overland flow runoff coefficient (CQOF), the simulation results improve significantly (Table 4). The error in total discharge is reduced to 4.3%, with the following statistics: R = 0.905, NSE = 0.778, RMSE = 7.950, MAE = 5.420, and PBIAS = 20.55 (Table 5 and Figure 7).

Table 4. Parameters of MIKE NAM model was used following calibration and validation at Thanh Binh and Dai Nga.

Parameter	Definition	Unit	Thanh Binh	Dai Ngai
			Calibration	Calibration
Umax	The maximum water content in the surface storage	mm	48	37
Lmax	The maximum water content in the lower zone storage	mm	264	350
CQOF	Overland flow runoff coefficient	-	0.354	0.468
CKIF	The time constant for routing interflow	hour	865	379
CK12	The time constant for overland flow	hour	28.4	49.8
CKBF	The time constant for routing base flow	hour	4225	1035
TOF	Root zone threshold value for the overland flow	-	0.152	0.984
TIF	Root zone threshold value for interflow	-	0.286	0.46
TG	Root zone threshold value for GW recharge	-	0.669	0.734

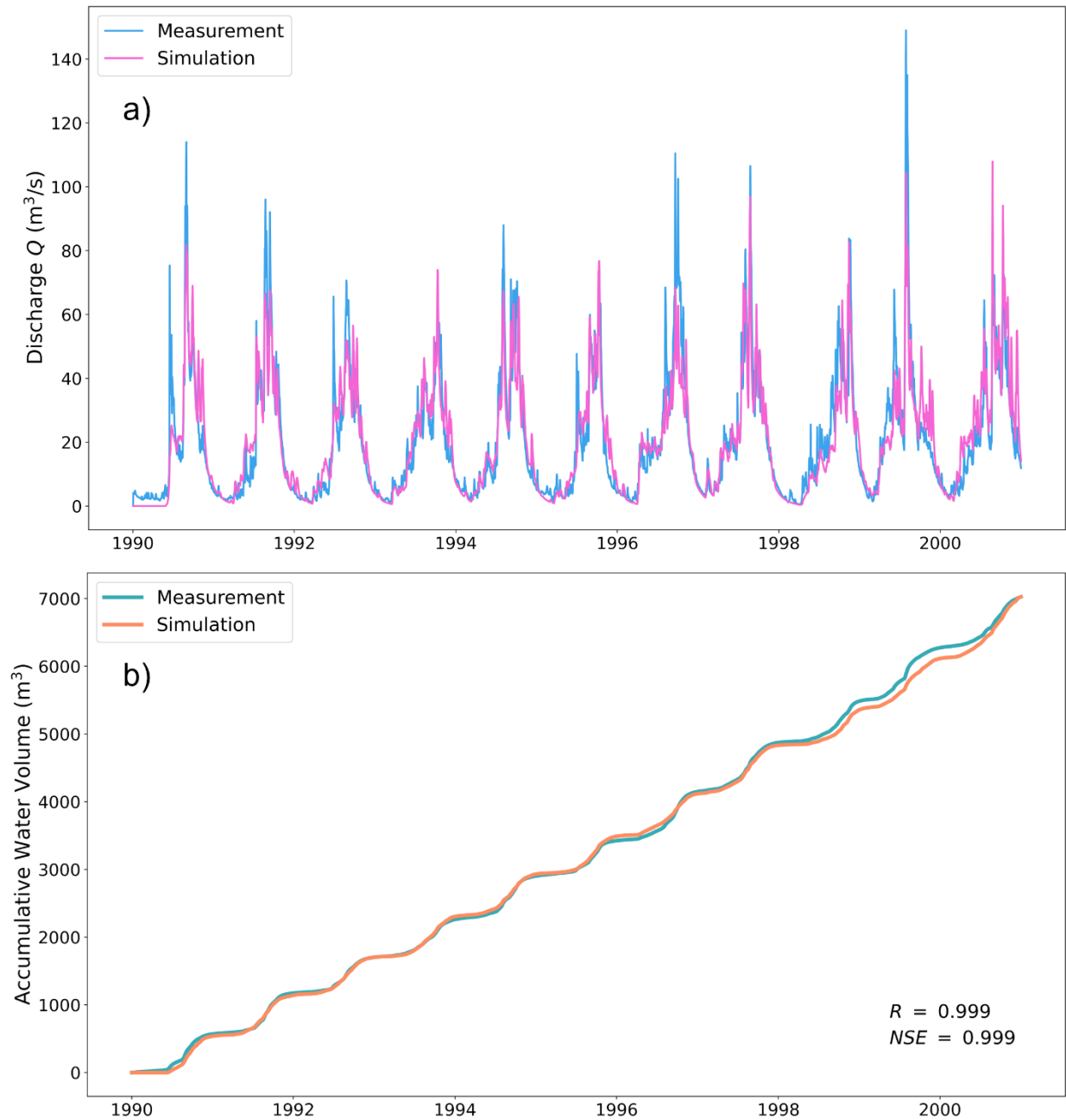


Figure 6. Calibrated discharge (a) and Accumulative Water Volume (b) at Dai Ngai for 1990-2000.

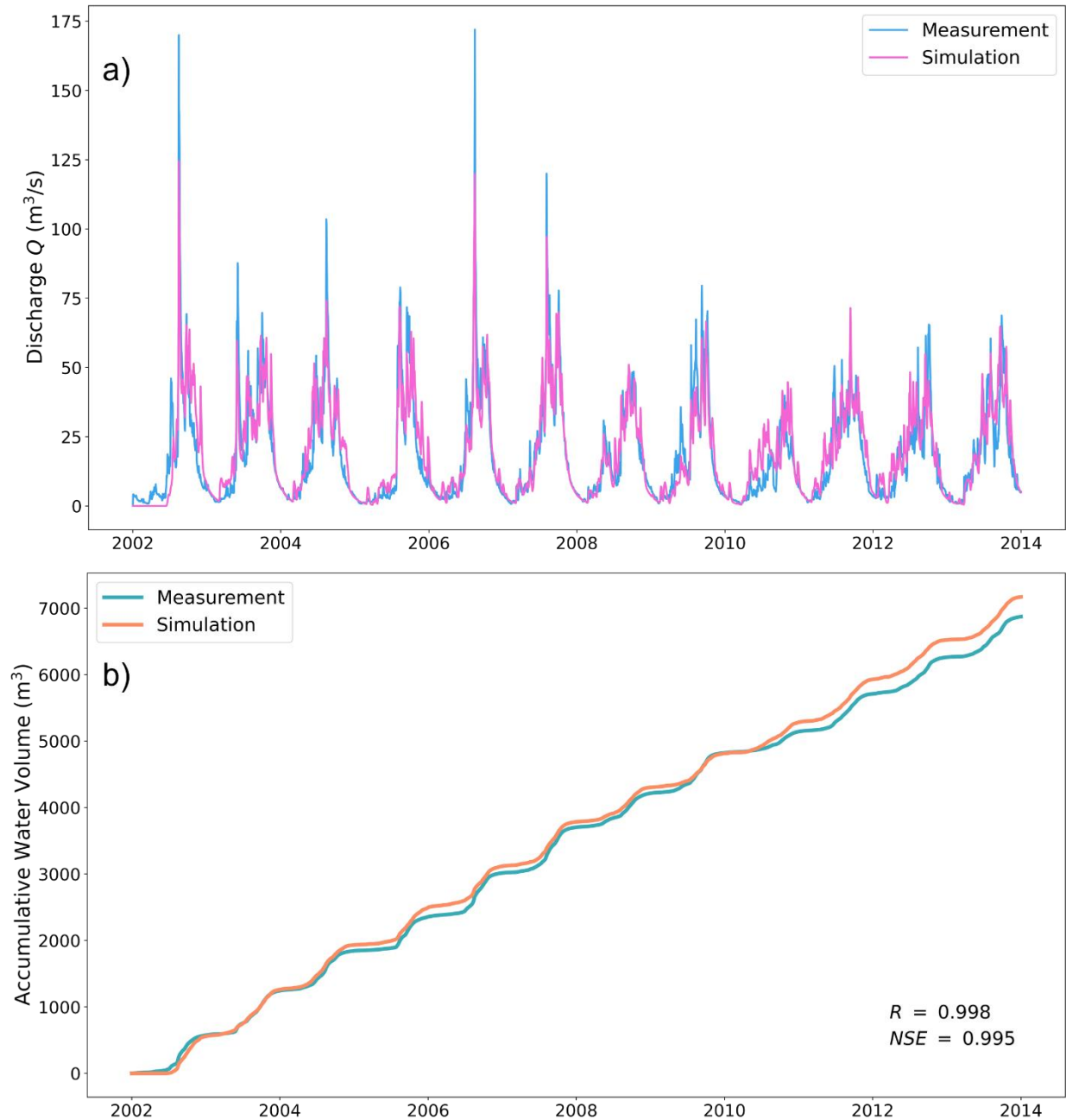


Figure 7. Validated discharge (a) and Accumulative Water Volume (b) at Dai Ngai for 2002-2014.

The calibration and model validation results for the two hydrological stations indicate significant changes regarding water flow in recent years. The water concentration in the watershed has become faster due to substantial alterations in land cover, such as a reduction in forested areas.

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Table 5. MIKE-NAM model performance results.

No	Indices	Thanh Binh		Dai Nga	
		Calibration (2002 – 2010)	Validation (2010 - 2018)	Calibration (1990 – 2000)	Validation (2002 - 2014)
1	R	0.869	0.932	0.915	0.905
2	NSE	0.640	0.749	0.801	0.778
3	RMSE	4.911	4.144	7.899	7.950
4	MAE	2.775	2.452	5.159	5.420
5	PBIAS (%)	19.37	4.67	4.42	20.55

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385 3.2. Potential water resources of Lam Dong province under climate change

386 The results indicate that the total water volume within Lam Dong in the base period
 387 is quite high and the concentration in rainy months from June to October. However, when
 388 considering the influence of climate change, the total water volume increases during the
 389 rainy season (September and October) and slightly decreases during the dry season
 390 (March and April) (Figure 8). However, this trend varies across different river basins. The
 391 most substantial decrease in water volume is observed in the RCP 8.5 scenario for the Da
 392 Dang and Da Nhim River basins, potentially leading to more severe drought conditions
 393 in the future for areas like Di Linh, Duc Trong, and Don Duong (refer to Table 6).
 394 Specifically, Da Nhim experiences the most significant reduction, with a decrease of
 395 approximately 221.7 million m³ from the baseline period (1986-2005) to the period 2016-
 396 2035 under the RCP 8.5 scenario, dropping from 1720.6 million m³ to 1498.9 million m³.

397 The Lam Dong's climate change assessment reveals that reduced rainfall in the
 398 future will profoundly affect the province's agricultural activities. Compared to the
 399 period between 1984 and 2016, the rainy season from 2016 to 2035 is expected to start one
 400 month earlier and end one month sooner. Consequently, during the 2016-2035 period, the
 401 province will face significant water shortages towards the end of November (the
 402 beginning of the dry season) and less water scarcity in April compared to previous years

(a reversal from the situation before 2010) (Figure 8). As a result, there won't be water shortages during the summer and autumn, but there is a high risk of water shortage during the winter-spring crop.

Table 6. Projections of potential water resources to different river basins under two climate change scenarios.

River basin	Area (km ²)	Total water volume (million m ³)		
		Base period (1986 – 2005)	RCP 4.5 (2016 – 2035)	RCP 8.5 (2016 – 2035)
Krong No	2753.42	1383.3	1464.0	1515.8
Da Dang	1191.67	1003.7	872.0	809.0
Da Nhim	2145.98	1720.6	1590.8	1498.9
Thuong Dong Nai 1	2855.19	1004.2	1058.9	1058.1
Thuong Dong Nai 2	3276.09	5769.1	4847.4	4853.8
La Nga	1318.09	1373.5	1474.0	1419.2
Luy – Cai Phan Thiet	557.148	245.3	270.8	239.2
Total	14,097.61	12,499.7	11,577.8	11,393.9

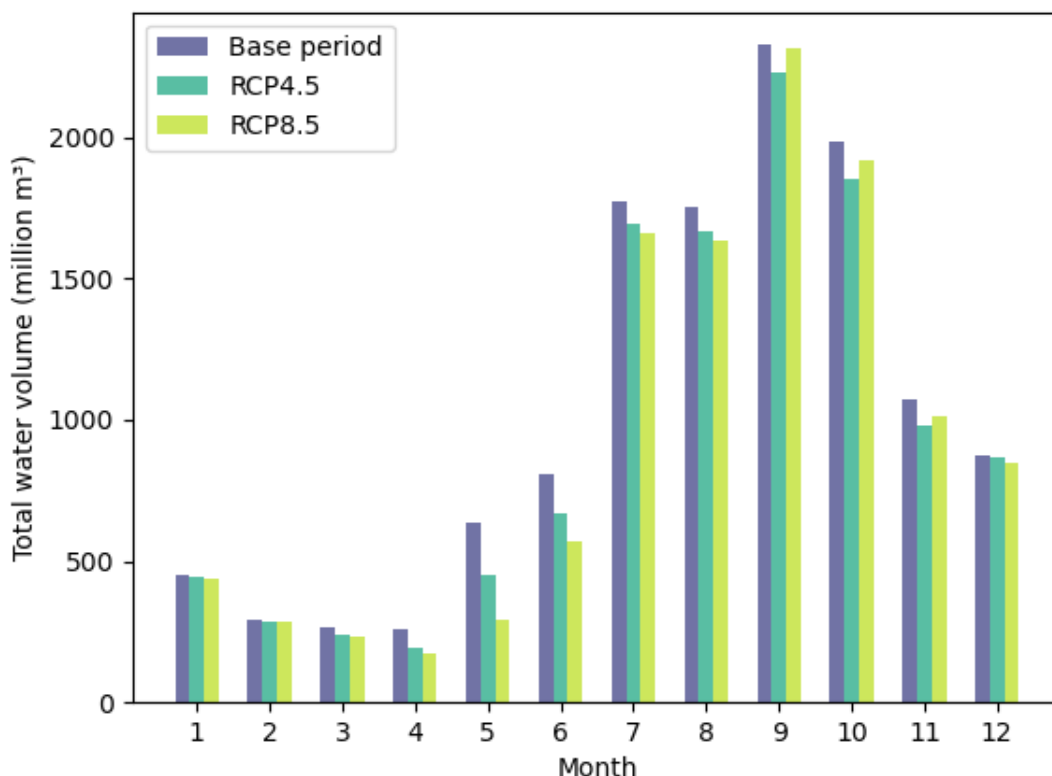


Figure 8. Projections of the water resource potential in Lam Dong province for the baseline period and under two different climate change scenarios

3.3. Water balance assessment

3.3.1. Water balance based on SC1.1 scenario

Figure 9 displays the results of the water balance calculation for the SC1.1 scenario (P=50%). The results reveal an overall water deficit of 85.58 million m³ in Lam Dong province (Table 10 - Appendices), with Thuong Dong Nai 1 accounting for 26.3 million m³, which is 30.7% of the total water deficit in Lam Dong province. Water shortages occur predominantly from December to May, with a supply-to-demand ratio ranging from 80% to 86%. The total water deficit in the La Nga River basin is 25.3 million m³, constituting 29.6% of the province's total water deficit, with a supply-to-demand ratio of 81% to 88%. As for the Da Dang, Thuong Dong Nai 2, Da Nhim, and Krong No river basins, they generally meet water demands adequately, with a supply of 90% to 100%.

142.2 million m³. Thuong Dong Nai 1 and the La Nga River basin have the most significant water deficits, amounting to 36.7 million m³ and 28.7 million m³, respectively. The supply-to-demand ratio varies from 72% to 84% in these areas and is primarily concentrated in agricultural areas of Duc Trong, Lam Ha, and Di Linh districts (Figure 11). For this scenario, Da Dang and Da Nhim have supply-to-demand ratios ranging from 89% to 94%. Meanwhile, Thuong Dong Nai 2 faces a total water deficit of 28.3 million m³ and a supply-to-demand ratio between 86% and 88% (Table 10 - Appendices). Comparing this scenario with the previous two scenarios, in the SC1.3 scenario, Thuong Dong Nai 2 exhibits a lower supply-to-demand ratio, falling by 4% to 6% compared to demand.

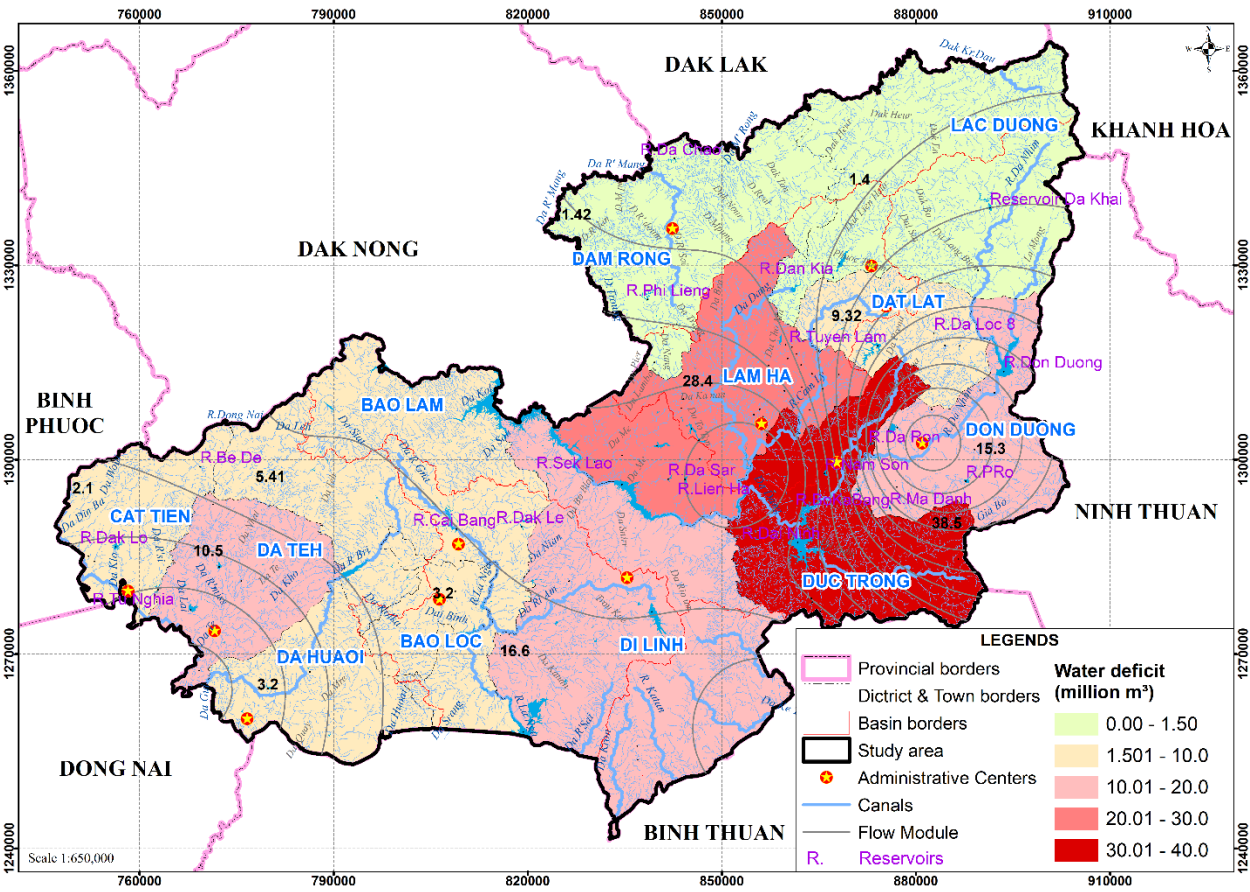


Figure 11. Spatial variability in the magnitude of the water deficit in Lam Dong province based on the SC1.3 scenario.

3.3.4. Water balance based on SC2 scenario

In scenario SC2, which considers an altered water inflow to the river basins as projected by the RCP 8.5 GHG emission scenarios, the total water deficit for the entire province is 127.3 million m³. All the river basins experience water shortages, and most have supply-to-demand ratios below 90% compared to previous scenarios. Thuong Dong Nai 1 has the most significant water deficit, with 41.5 million m³, accounting for 32.6% of the total water deficit in the province. The supply-to-demand ratio in this region ranges from 70% to 75%, with water shortages mainly concentrated in the dry season from January to April. The total water deficits in the La Nga and Thuong Dong Nai 2 river basins are 26.9 and 22.4 million m³, respectively, making up 21.2% and 17.5% of the province's total water deficit ([Table 10 - Appendices](#)). The supply-to-demand ratio in these areas ranges from 80% to 88%, and water shortages are concentrated primarily in Di Linh, Da Teh, and Cat Tien and partly in Da Huoi and Bao Lam districts ([Figure 12](#)). The remaining river basins, including Da Nhim, Da Dang, and Krong No, have relatively low water deficits, with supply-to-demand ratios ranging from 92% to 100% compared to water demand. As evident in scenario SC2, when impacted by climate change, the water shortage rates are higher compared to scenario SC1. However, the water deficit increasing by approximately 30% is a significant concern for agriculture and other activities in the region.

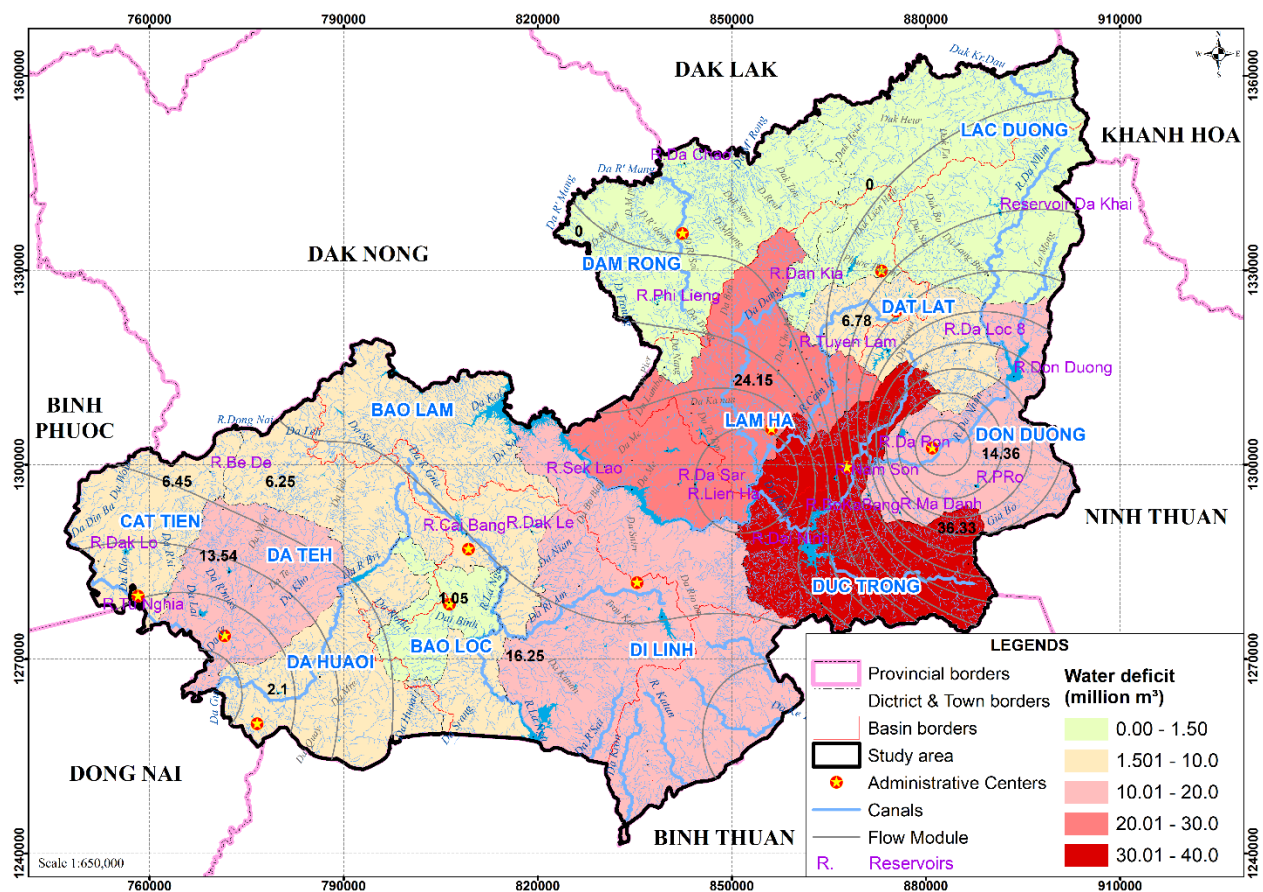


Figure 12. Projected water deficit in 2025 of Lam Dong province under the impact of climate change.

483

484 3.4. Assess drought duration, severity, and intensity

485 3.4.1. *Abnormally dry conditions*

486 [Figure 13](#) depicts the changing of drought across different spatial locations during
487 winter-spring crop in Lam Dong province when experiencing abnormally dry conditions.
488 In years with water inflow to the reservoirs (19 reservoirs), an initial water volume of
489 approximately 137 million m³ is available at the onset of spring, coupled with a total
490 seasonal rainfall exceeding 249 mm ([Table 11 - Appendices](#)). These are the years when
491 drought is absent, and the water supply meets the demand. Water resources have been
492 replenished since the beginning of the season, ensuring a year-round water supply for
493 domestic and agricultural purposes for the population. However, localized drought
494 events may still affect small reservoirs and there are months when the reservoir water
495 levels only meet 30-40% of the irrigation requirements.

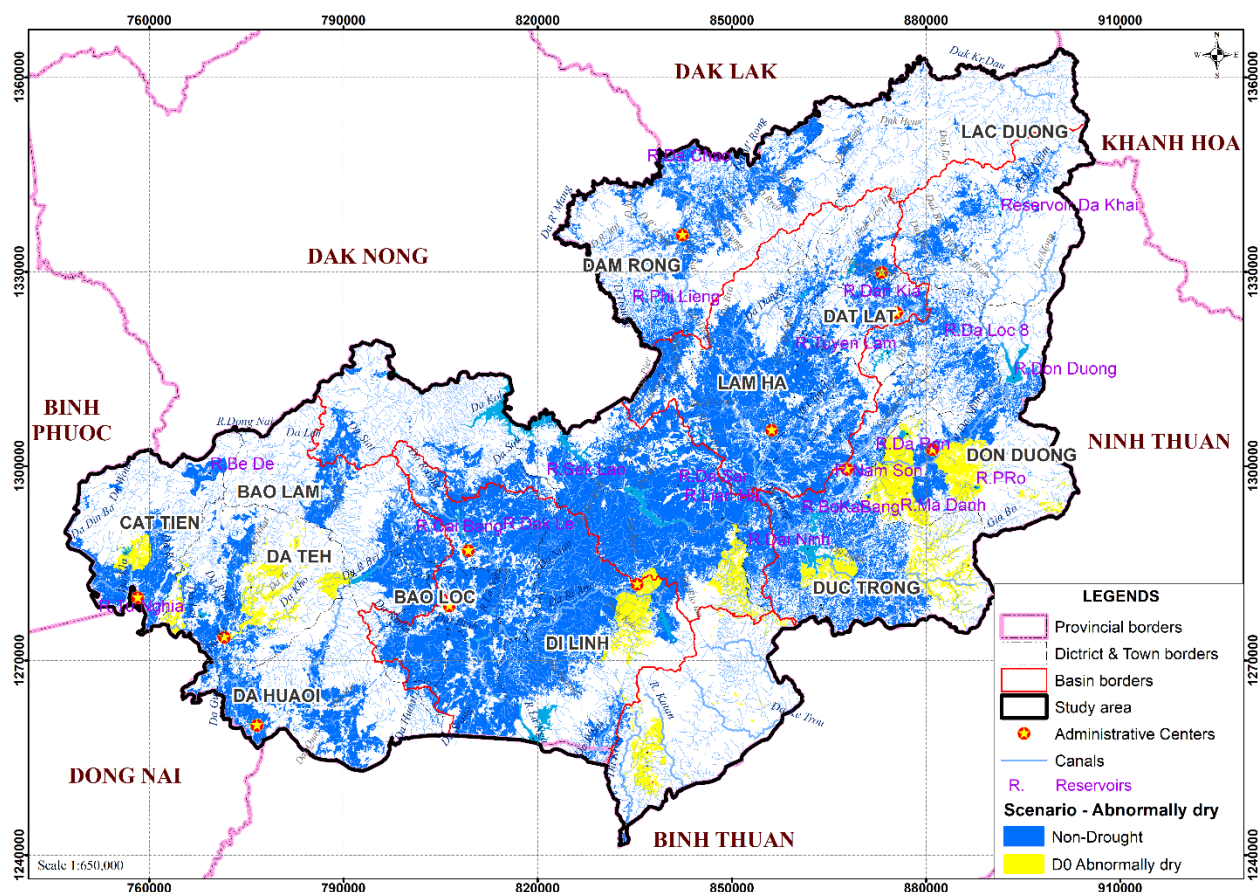


Figure 13. Regions expected to encounter abnormally dry conditions during the winter-spring period.

3.4.2. Moderate drought conditions

For moderate drought conditions, the initial water volume entering the reservoirs in winter-spring crop is approximately 125 million m³, and the total seasonal rainfall is less than 153 mm (Tabel A5 - Appendices), occurring during abnormally dry to moderate drought years. Water resources meet 85% of the water demand. However, there are still months when reservoir water levels only satisfy 30-40% of the irrigation needs. In some reservoirs, abnormally dry conditions appeared, such as Proh Lake, where water shortage occurred at the beginning of the winter-spring crop, leading to abnormally dry and moderate drought conditions from February to April. Nevertheless, the water supply during the growing season meets irrigation requirements. In regions beyond the reach of

522 of the water demand. This dire situation might require reducing the cultivated area.
523 Several reservoirs at the beginning of the season only meet less than 25% of the irrigation
524 needs, leading to immediate water scarcity concerns, as observed in Ma Danh and Bo Ka
525 Bang reservoirs ([Figure 15](#)). Proh reservoir, with an initial water volume meeting only
526 65% of the requirements, experiences drought conditions from February to April. Water
527 levels are sufficient for December and January but reach moderate to severe drought
528 during the mentioned months. In areas beyond the reach of the hydro-irrigation
529 infrastructure, water availability ensures 82% coverage of the irrigation area during the
530 growing season. Water scarcity remains a significant concern in highland areas such as
531 Da Teh, Don Duong, and Di Linh. While larger reservoirs like Ka La and Da Teh can
532 guarantee water supply for both production and domestic use, most small reservoirs
533 experience abnormally dry to severe drought from January to April.

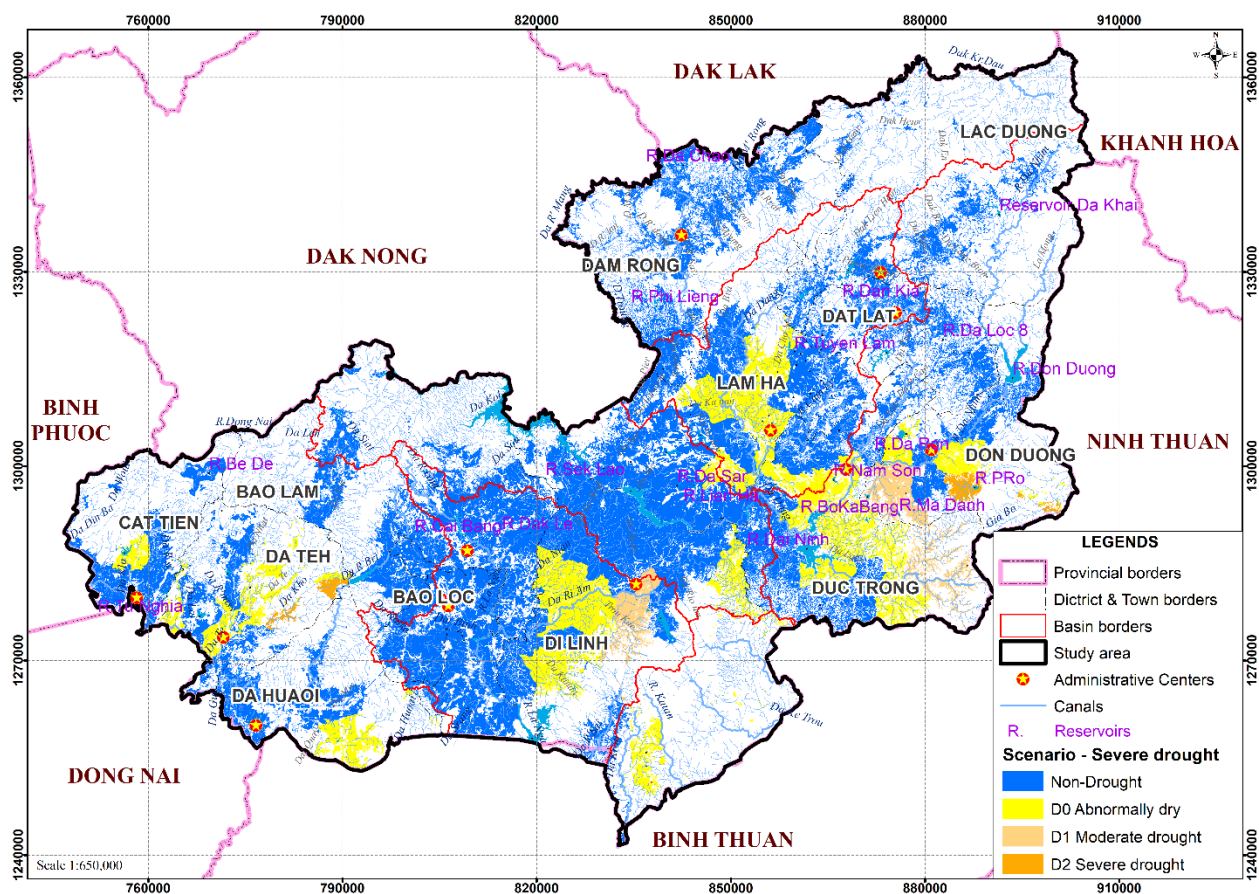


Figure 15. Regions expected to encounter severe drought conditions during the winter-spring period.

3.4.4. Extreme drought conditions

With $P = 95\%$, the initial water supply to the 19 reservoirs at the beginning of the winter-spring crop is approximately 100 million m^3 , accompanied by a total for moderate drought conditions, the initial water volume entering the winter-spring reservoirs in the winter-spring crop is approximately 125 million m^3 rainfall of less than 59 mm (Tabel A5 - Appendices). Water resources meet only about 75% of the water demand. At the start of the season, water scarcity becomes evident in reservoirs such as Lien Ha, Ma Danh, and Bo Ka Bang (Figure 16). Most reservoirs can barely meet water demand during the first two months of the winter-spring season (December and January). From February to April, the severity of drought conditions escalates to moderate and then to severe levels.

In the extreme drought scenario, the seasonal rainfall is exceptionally low, causing small reservoirs to reach critically low water levels by the end of March, with only 33.1 million m³ remaining. Da Teh reservoir's initial water volume meets only 70% of the water demand. In regions beyond the reach of the hydro-irrigation infrastructure, water availability ensures 78% coverage of the irrigation area during the growing season. However, severe drought affects highland areas such as Da Teh, Don Duong, and Di Linh. Based on the forecast results regarding the timing of drought events and the projected water resources, extreme drought could affect more than 54,000 hectares of cultivated land. Some reservoirs can only supply less than 20% of the irrigation requirements at the beginning of the season.

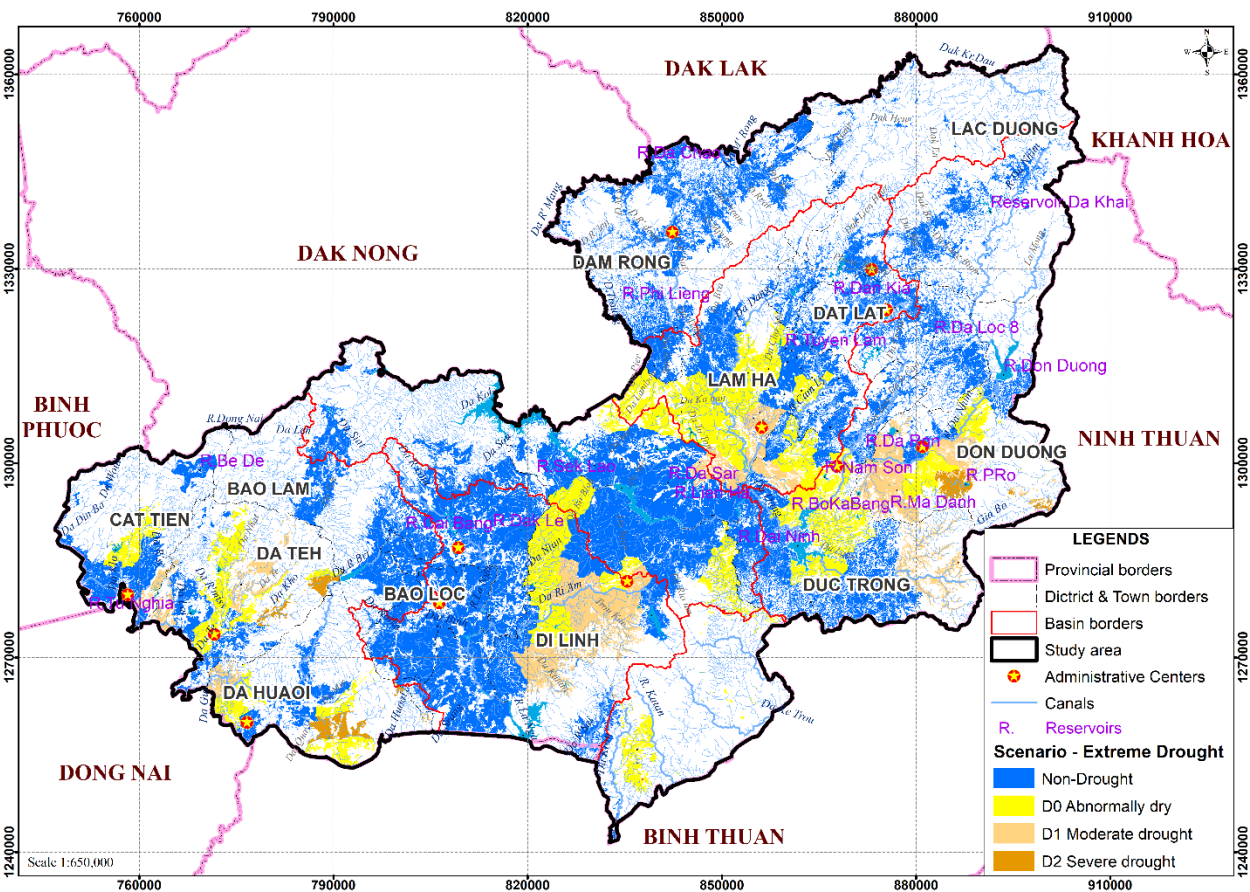


Figure 16. Regions expected to encounter severe extreme conditions during the winter-spring period.

The results of the KBDI calculations for Phu My, Lam Ha district, from 2009 to 2020, reveal that droughts typically occur from late January to mid-May. Severe drought conditions (KBDI index > 600) are more likely to happen in March and April. From 2009 to 2020, there were six instances of relatively severe meteorological droughts (KBDI index > 600, lasting for two consecutive months) in the dry seasons of 2010, 2014, 2015, 2016, 2018, and 2020. The calculation of the KBDI drought index for the 2015-2016 dry season shows that droughts were not uniform across the region in space and time. Due to the prolonged period of hot and dry weather and the influence of El Nino, drought conditions began in late January and persisted until May 2016. The KBDI index continuously exceeded 600 throughout the entire region for two months (from March to April 2016), indicating the severity of the drought if there were no water management infrastructure in place. The northern areas of Lam Dong province (including Dam Rong, Lam Ha, and Bao Lam districts) experienced an earlier onset and conclusion of the drought. In contrast, the central and southeastern regions bordering the South-Central region had a longer drought duration than the northern areas.

Drought severity hinges on the initial water source, seasonal rainfall, and reservoir forecasts. Water balance calculations in Lam Dong pinpoint the root cause of water scarcity, namely, an imbalance between water supply and demand during dry periods. A deeper issue is significantly reducing forested areas acting as natural water reservoirs. In Lam Dong province, characterized by hilly terrain and fragmented topography, the end of the rainy season swiftly dries soil as forests recede, leading to reduced river flow and ensuing water scarcity for agriculture and daily needs. Water sources meet usage needs in abnormally dry conditions, predominantly affecting Don Duong and Di Linh. Water sources fulfill 85% of the demand in moderate drought, but some reservoirs may face shortages for months. Effective water resource management remains essential to ensure sustainability and development, even in years with sufficient water. Severe

drought leads to a significant decline in initial water sources and low rainfall, risking drying small reservoirs and reducing water supply to less than 20% of irrigation needs. High-altitude areas like Da Teh, Don Duong, and Di Linh often face severe drought and need special attention regarding water supply. Forecasting drought timing and severity is crucial in water resource and agricultural planning, encompassing water conservation, quality management, and efficient resource use. Drought remains a challenge even with adequate initial water and rainfall. Constructing efficient water storage and distribution infrastructure is vital to minimize drought's impact on communities and agriculture. Localized droughts in some small reservoirs underscore the need for improved management and maintenance of smaller water sources. Research and measures to protect and restore these sources are vital to prevent significant water shortages.

The study has demonstrated the feasibility and potential application of the MIKE HYDRO BASIN model and the KDBI drought index in evaluating water resource management in Lam Dong. The findings of the research clarify the effectiveness of KDBI, as evidenced by previous studies in areas such as Binh Thuan province of Vietnam (Thanh et al., 2023), the Greater Mekong sub-region (Hosoya & Takeuchi, 2012), and Indonesia (Darmawan et al., 2014; Shofiyati et al., 2014). These results provide crucial information to stakeholders, ranging from farmers to water resource management agencies, enabling them to plan and organize more effectively for crop cultivation under forecasted drought conditions and establish optimal irrigation plans. Additionally, the study supports water management agencies in identifying water supply needs and capabilities, thereby enhancing water resource infrastructure and raising awareness about future investments in water infrastructure. These findings serve as a basis for improving drought monitoring and surveillance in Lam Dong and serve as an example for similar studies in other regions affected by drought and water scarcity.

However, limitations and uncertainties persist in this research. While it has successfully simulated drought conditions and water availability in Lam Dong, the scientific complexity leaves room for further research, especially in the context of climate change and Lam Dong's water requirements. Regarding numerical models, most parameters are challenging to measure directly or may have measurement errors, necessitating estimation through model calibration procedures ([Carrera et al., 2005](#); [Doherty, 2015](#)). In this context, the statistic R is utilized as a crucial metric to assess the model's capability in handling real-time hydrological data. R indicates the model's ability to accurately predict long-term outcomes through observation and simulation of flow dynamics. Results from the calibration phase at Thanh Binh and Dai Nga stations, with R values of 0.869 and 0.915 respectively, provide evidence of the correlation between observed and predicted data. During the validation process, the MIKE-NAM rainfall runoff module achieved R values of 0.932 and 0.905 respectively, underscoring the accuracy and effectiveness of the model. However, data collection and methodology inaccuracies may lead to deviations from actual measurements. Model calibration is a complex process that demands precise adjustment of key parameters within the MIKE-NAM module. Among the nine parameters in the MIKE-NAM module, specific parameters like Umax, Lmax, CQOF, CKIF, and CKBF are particularly sensitive in determining the model's outcomes, highlighting their significance ([Keerthy et al., 2024](#); [Teshome et al., 2020](#)). Besides, minimizing result uncertainty is crucial when using models for hypothetical scenarios or future forecasts ([Herrera et al., 2022](#)). Moreover, this study exclusively concentrated on the Keetch-Byram Drought Index (KBDI). Subsequent research endeavors will incorporate a diverse set of drought indices, encompassing the Normalized Difference Vegetation Index (NDVI), Precipitation-Evapotranspiration Index (SPEI), Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), and integrate artificial intelligence for more advanced calculations of future drought scenarios.

4. Conclusion

In this paper, drought in Lam Dong province was approached through two scenarios: the current state (SC1) and considering the impact of climate change (SC2) based on the RCP 4.5 and 8.5, where greenhouse gas (GHG) emissions continue to rise throughout the 21st century. The study has successfully employed the MIKE NAM and MIKE-HYDRO basin models, which are considered reliable due to their alignment with actual data from weather stations and other validating data sources. At the Thanh Binh station, the model achieved strong correlations $R = 0.932$ and performance metrics including $NSE = 0.749$, $RMSE = 4.144$, $MAE = 2.452$, and $PBIAS = 4.67\%$. Similarly, at the Dai Ngai station, the model exhibited significant correlations $R = 0.905$ along with $NSE = 0.778$, $RMSE = 7.950$, $MAE = 5.420$, and $PBIAS = 20.55\%$. Simulation under scenarios SC1 and SC2 revealed varying degrees of drought susceptibility across the province. Notably, districts such as Di Linh, Don Duong, and Da Teh consistently showed higher vulnerability to severe droughts compared to other regions. The study also demonstrated that water demand for the winter-spring crop can be fully met under abnormally dry conditions. Still, this percentage decreases to 85%, 80%, and below 75% for moderate, severe, and extreme droughts, respectively. Additionally, the water balance calculations have shown that improving future infrastructure (SC2) can enhance water resource management and fulfill irrigation needs. This forms the foundation for the development and expansion of water resource management strategies in Lam Dong, ensuring stability in agricultural production and facilitating crop adaptation to changing water resources under climate change.

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Availability of data and material: Not applicable

Declarations

Ethical responsibilities of Authors: All authors have read, understood, and have complied as applicable with the statement on “Ethical responsibilities of Authors” as found in the Instructions for Authors. The authors approved the manuscript, and there are no ethical issues to declare.

Consent to participate: The authors have agreed on the manuscript, and there are no issues to disclose.

Consent for publication: The authors have no issues on this matter and agreed to publish the content of the paper.

Competing interests: The authors declare no competing interests.

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Appendices

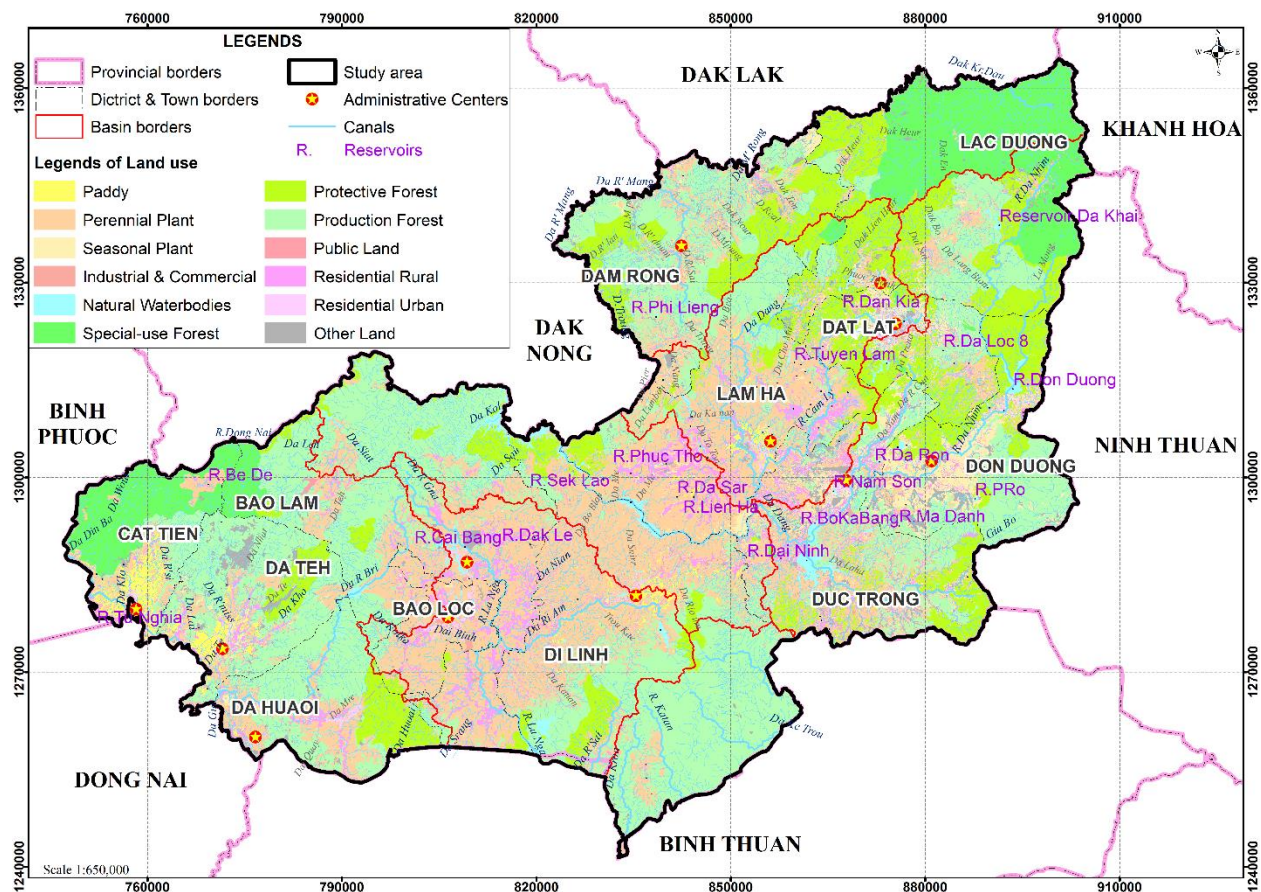


Figure A1: Land use map of the study area.

11	79.5	84.3	87.9	91.2	95.7	102	95.4	99.9	102.9
12	81.53	86.18	90.21	95.48	99.82	106.64	105.71	111.6	113.77
Average	91.02	94.19	97.42	102.89	106.35	113.64	109.55	114.19	116.85

876

877 Table 8. Drought scenarios according to rainfall frequency.

Case	Precipitation frequency	Drought category
Excess water	< 50%	Non-drought
Water scarcity	From 50% to 75%	Abnormally dry
	From 75% to 85%	Moderate drought
	From 85% to 95%	Severe drought
	Over 95%	Extreme drought

878

879 Table 9. Changes in average annual temperature and rainfall in 2016 - 2035 compared to
880 1986 – 2005 (MONRE, 2016).

Season	Temperature (°C)		Rainfall (%)	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Winter (December – February)	0.8 (0.4 – 1.3)	0.9 (0.6 – 1.3)	32.5 (-4.6 – 69.7)	19.9 (-29.2 – 63.3)
Spring (March – May)	0.7 (0.4 – 1.1)	0.9 (0.6 – 1.3)	3.1 (-1.6 – 8.2)	-8.7 (-18.8 – 1.9)
Summer (July – August)	0.7 (0.4 – 1.1)	0.9 (0.6 – 1.3)	3.8 (-0.2 – 7.7)	7.2 (2.2 – 12.5)
Autumn (September – November)	0.7 (0.4 – 1.1)	0.8 (0.5 – 1.2)	0.0 (-6.2 – 6.3)	5.2 (-2.7 – 13.5)

881 Table 10. The water supply capacity of the studied river basin for different precipitation
882 scenarios.

River basin	SC1.1 (P=50%)			SC1.2 (P=85%)			SC1.3 (P=90%)			SC2		
	Water use (10⁶ m³)	Water supply (10⁶ m³)	Deficit discharge (10⁶ m³)	Water use (10⁶ m³)	Water supply (10⁶ m³)	Deficit discharge (10⁶ m³)	Water use (10⁶ m³)	Water supply (10⁶ m³)	Deficit discharge (10⁶ m³)	Water use (10⁶ m³)	Water supply (10⁶ m³)	Deficit discharge (10⁶ m³)
Krong No	90,4	90,4	0	90,4	90,4	0	90,4	89,0	1,5	78,8	78,8	0,0
Da Dang	203,1	187,2	15,8	203,1	188,9	14,1	203,1	190,2	12,9	180,4	180,4	0,0
Da Nhim	266,13	266,13	0,00	266,13	266,13	0,00	266,13	250,80	15,32	242,92	223,82	19,10

Thuong Dong Nai 1	193,55	167,28	26,27	193,55	157,33	36,22	193,55	156,81	36,74	167,99	126,53	41,46
Thuong Dong Nai 2	238,8	227,4	11,4	238,8	225,5	13,3	238,8	210,5	28,3	187,8	165,4	22,4
La Nga	178,3	152,9	25,3	178,3	154,8	23,4	178,3	149,6	28,7	167,6	140,7	26,9
Luy – Cai Phan Thiet	60,5	53,76	6,69	60,5	45,83	14,62	60,5	41,64	18,81	53,8	36,34	17,44
Total deficit discharge			85,58			101,75			142,17			127,25
883												

884

Table 11. The results calculated water sources for winter-spring crops.

Reservoirs	Location	Capacity (million m³)	Scenario Responsiveness in winter-spring crop											
			Abnormally dry			Moderate drought			Severe drought			Extreme drought		
			Head crop (million m³)	End crop (million m³)	Ratio (%)	Head crop (million m³)	End crop (million m³)	Ratio (%)	Head crop (million m³)	End crop (million m³)	Ratio (%)	Head crop (million m³)	End crop (million m³)	Ratio (%)
Dak Lo	Cat Tien	13.63	13.40	4.096	100%	12.47	3.28	100%	9.53	2.98	98%	8.86	2.71	96%
Phuoc Trung	Cat Tien	3.18	3.18	0.768	100%	2.96	0.61	100%	2.75	0.56	98%	2.20	0.51	85%
Tuyen Lam	Da Lat	27.85	27.40	15.592	100%	25.48	12.47	100%	23.70	11.35	100%	22.04	10.33	100%
Loc Thang Dak	Bao Lam	5.49	5.58	2,68	100%	5.19	2.14	100%	4.83	1.95	100%	4.49	1.78	100%
Long Thuong	Bao Lam	11.67	11.57	7.48	100%	10.76	5.98	100%	10.01	5.45	100%	9.31	4.96	100%
Da Ron	Don Duong	5.83	4.46	1.464	100%	4.15	1.17	100%	3.86	1.07	100%	3.59	0.97	100%
Proh	Don Duong	3.22	3.19	0.168	100%	2.96	0.13	89%	2.76	0.12	87%	2.56	0.00	75%
BoKaBang	Don Duong	1.11	1.00	0.08	100%	0,93	0.06	95%	0.86	0.00	89%	0.80	0.00	76%
Ma Danh	Don Duong	0.39	0.35	0,016	100%	0.33	0.01	86%	0.30	0.00	85%	0.28	0.00	78%
Lien Ha	Lam Ha	1.49	1.48	0.016	100%	1.37	0.01	100%	1.28	0.00	90%	1.19	0.00	85%
Phuc Tho	Lam Ha	2.93	2.92	1.904	100%	2.72	1.52	100%	2.53	1.39	100%	2.35	1.26	100%
Thon 1 Phuc Tho	Lam Ha	0.87	0.87	0.4	100%	0.81	0.32	100%	0.75	0.29	98%	0.70	0.26	85%
Thon 3 Tan Thanh	Lam Ha	1.56	1.60	0.704	100%	1.49	0.56	100%	1.39	0.51	97%	1.29	0.47	84%
Ka La	Di Linh	18.89	18.62	6.256	100%	17.32	5.00	100%	16.11	4.55	100%	14.98	4.14	100%
Da Li Ong	Da Huoai	1.18	1.17	0.688	100%	1.09	0.55	100%	1.01	0.50	100%	0.94	0.46	100%
Da Ham	Da Teh	6.4	6.19	1.144	100%	5.75	0.92	100%	5.35	0.00	92%	4.98	0.00	88%

885