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Author Contributions

S.A. designed the study. M.T. and S.A. performed the analysis, and M.T. wrote the first draft. All the authors contributed to the writing.

Data availability

IMD precipitation data is freely available on the https://imdpune.gov.in/cmpg/Griddata/Rainfall_25_NetCDF.html, ERA5 wind data on https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels?tab=overview, and CMIP6 data on https://esgf-node.llnl.gov/projects/cmip6/. All data analysis codes are available at: "https://github.com/hydromonitoring/MT_SA_Water_Availibilty_github_matlab_codes"

Declaration

Ethics approval and consent to participate: Not applicable for this study**.**

Consent for publication We, the undersigned authors, hereby give our full consent for the publication of the manuscript entitled: "Climate Change-Induced Alterations in Water Budget Components and Water Availability across Indian Dam Catchments" in Climatic Change (Springer) journal.

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Abstract

Dams in India collectively store around 400 BCM of freshwater and play a crucial role in national water security. However, the water available to these reservoirs is increasingly vulnerable to climate change and poorly understood at the dam-catchment scale in a warming climate. In this study, we evaluate changes in potential surface water availability across 5687 Indian dam catchments during the observed period (1951-2022) and the future periods (2031-2065: mid-period; 2066-2100: end-period) using VIC-simulated total runoff. During the observed period, our analysis shows a significant increase (by more than 20%) in potential surface water availability across the majority of dam catchments in Western and Southern India, while a decline of more than 15% in the dams located in the Southern Gangetic Plains and Eastern India. These changes in potential surface water across the majority of dam catchments are associated with systematic shifts in monsoon-season rainfall and rainy days during the recent period (1987-2022), which result in frequent consecutive surplus/deficit years and changes in precipitation partitioned into runoff during recent warming. Consistent with the observations, we find a similar shift in potential surface water availability in the future climate, indicating further increases (decreases) in dam catchments in the Western and Southern (Eastern) regions of India under all four SSP scenarios during the mid- and end of the century. Based on these changes in potential surface, effective water sustainability strategies can be prepared at the dam-catchment scale (such as capacity augmentation of existing dams, inter-basin water transfer) to provide an evidence based prioritize future investments in dam infrastructure in India.

1. Introduction

Water availability plays a vital role in food security, economic growth, and socio-economic development of the densely populated Indian Subcontinent. India's water availability is largely governed by the Summer Monsoon Rainfall, with nearly 70-80% of the annual rainfall occurring during the summer monsoon season (June-September [JJAS; (Gadgil 2003; Rajeevan et al. 2006)]. Consequently, a substantial fraction of the runoff is generated during four monsoon months, making water availability highly seasonal (Dhar and Nandargi 2003; Mishra and Lilhare 2016). To regulate seasonal behaviour and ensure a continuous water availability throughout the year, dams play a crucial role by capturing and storing runoff for agriculture, industry, hydropower generation, and domestic consumption during dry periods (Malhotra 2025). However, substantial spatial and temporal variability has been observed in monsoon-season rainfall over India in recent decades due to increased regional and global warming (Varikoden et al. 2025). Recent studies (Krishnan et al. 2020; Sarkar and Maity 2022; Chaubey and Mall 2023; J. S. and Mishra 2023; Das et al. 2026) reported substantial changes in rainfall patterns and hydroclimatic extremes across the Indian Subcontinent under both observed and

future warming climate. For instance, several studies (Trenberth et al. 2003; Roxy et al. 2017; Mukherjee et al. 2018; Ali et al. 2019; Goyal et al. 2022; Nanditha and Mishra 2022; Pandey et al. 2022; Roulo and Subbarao 2023) suggest an increase in frequency and intensity of extreme precipitation events, which generate a sudden large volume of runoff and cause flooding in India. During the same period, severe drought events are also projected to increase under a warming climate, causing water shortages across several regions in India (Aadhar and Mishra 2020, 2021; Mishra et al. 2021)

These changes in hydroclimatic extremes and frequent wet/dry events have direct implications for the potential water availability and long-term water sustainability of each dam-catchment across India. Since reservoir water storage depends entirely on catchment-specific hydrological processes and runoff generated within each contributing catchment, changes in precipitation, evapotranspiration, and runoff directly translate into changes in dam inflow, dependable yield, and the frequency of deficit and surplus conditions. For instance, previous studies (Mishra and Lilhare 2016; Shah and Mishra 2016) showed that climate change and changes in hydroclimatic extremes have substantially altered the water budget (including evapotranspiration and runoff) and water availability across major Indian river basins. Additionally, rising water demands, combined with erratic monsoon rainfall under climate change, have substantially intensified water stress in India (Vörösmarty et al. 2000; Madhusoodhanan et al. 2016; Mishra et al. 2024a), particularly in regions experiencing groundwater depletion and declining surface water storage. Despite several efforts, previous basin-scale findings (Shah and Mishra 2016; Gowri et al. 2021; Kushwaha et al. 2021) cannot fully capture the heterogeneity of changes in potential water availability across dam catchments that store approximately 400 billion cubic meters (BCM) of water (National Register of Large Dams, 2019). Therefore, assessing changes in hydrological components and potential water availability for each dam-catchment is essential for water security and reliable water resources planning and development in a future warming climate.

Here, we address this gap and examine changes in potential water availability across 5,687 Indian dam catchments during observed and projected future climate conditions [mid-period (2031–2065) and end-period (2066–2100)] under four Shared Socioeconomic Pathways (SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5). Using Variable Infiltration Capacity (VIC)-simulated hydrological components, we quantify changes in potential water availability, monsoon precipitation, rainy days, and other hydrological components for each dam catchment under observed and future climate conditions. By evaluating these changes in each dam catchment, our findings provide comprehensive, quantitative information to support climate-resilient dam operations and effective reservoir or river interlinking, enhance water storage capacity for long-term water resources management, and develop dam catchment-scale adaptation strategies for water scarcity and flood risk across India.

2. Data and Methods

Using the DAM-IN dataset (Tiwari and Aadhar 2025), we obtained the dam locations and delineated catchment boundaries for 5687 dams across India (Figure S1). DAM-IN dataset used 30-m Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM) and the Automatic Outlet Relocation (AOR; Xie et al. 2022) algorithm to delineate the catchment boundary (considering the dam location as the outlet point). Using catchment boundaries, we prepared meteorological data (precipitation, minimum temperature, maximum temperature, and wind speed) for each dam catchment to analyse changes in potential water availability during both the observed and future periods. We obtained daily gridded precipitation, minimum and maximum temperatures from the India Meteorological Department (IMD), and wind speed data from the European Centre for Medium-Range Weather Forecasts Reanalysis (ERA5) for the observed period (1951-2022). IMD developed daily gridded precipitation data at a spatial resolution of 0.25^0 using observations from 6995 stations across India (Pai et al. 2014). However, the minimum and maximum temperature data from the IMD were derived at a spatial resolution of 100 km using 395-gauge stations across India (Srivastava et al. 2009). Further, we regridded the minimum and maximum temperatures to 0.25^0 spatial resolution using the methodology of Marur et al. (2002) and prepared meteorological forcing (precipitation, minimum temperature, maximum temperature, and wind speed) at 0.25^0 spatial resolution for each dam catchment for the period 1951-2022 (Maurer et al. 2002).

In addition to observed data, we obtained precipitation, minimum, and maximum temperature, and wind data from Climate Model Intercomparison Project Phase 6 - Global Climate Models (CMIP6-GCMs; Table S1) for the historical period (1951-2014) and the future period (2015-2100) for the r1i1p1f1 experiment (https://esgf-node.ipsl.upmc.fr/search/cmip6-ipsl/). The twelve GCMs' data collected for the study (Table S1), out of which four GCMs were selected based on their skill in reproducing observed monsoon precipitation over India (Figure S2). We obtained the future data for four shared socioeconomic pathways (SSP) Scenarios (such as SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5) for our analysis. To ensure consistency in spatial resolution with the IMD data, all datasets from CMIP6-GCMs were regridded to 0.25^0 spatial resolution.

Using precipitation, temperature (minimum and maximum), and wind datasets, we constructed meteorological forcing inputs during the observed and future climate for the Variable Infiltration Capacity (VIC; Liang et al. 1994) Model. The VIC model is a macroscale, semi-distributed hydrological model that simulates water and energy fluxes at daily or sub-daily time steps within each grid cell and requires soil and vegetation parameters in addition to meteorological forcing. We derived vegetation parameters from global land cover obtained from the Advanced Very-High Resolution Radiometer (AVHRR) at 1 km spatial resolution (Hansen et al. 2000; Sheffield and Wood 2007) and soil parameters from the Harmonized World Soil Database (HWSD version 1.2) at 0.25^0 resolution. Here, we used calibrated soil parameters for the Indian Subcontinent, as prepared by Shah and Mishra (2016). Shah and Mishra (2016) calibrated soil parameters using observed streamflow data and evaluated model

performance using the Nash-Sutcliffe efficiency (NSE) and other indices (Shah and Mishra 2016). Using the calibrated VIC Model, we simulated hydrological components for each dam catchment using IMD and ERA5 meteorological forcing for the observed period (1951-2022) and using CMIP6-GCMs under different scenarios for the period (1951-2100).

Using meteorological forcing and VIC-simulated hydrological components during the observed period, we estimated changes in potential water availability, precipitation, evapotranspiration, rainy days, and fraction of precipitation partitioned into evapotranspiration and runoff for each dam catchment, considering nonparametric Mann-Kendall (Mann 1945) and Sen's Slope test (Sen 1968). Additionally, we also performed analyses for two sub-periods ([1951-1986; pre-1986] and [1987-2022; post-1986]) to analyze the impact of recent warming on the changes in hydrological components, surface water availability, rainy days (precipitation greater than or equal to 2.5 mm), runoff coefficient (hereafter R/P), and the ratio of evapotranspiration to precipitation (hereafter ET/P). Furthermore, we estimated the frequency of deficit (precipitation anomaly<-10%) and surplus (precipitation anomaly>10%) precipitation, as well as potential water availability, for each dam catchment during the observed period.

Finally, we estimated changes in precipitation, evapotranspiration, potential surface water availability, rainy days, R/P, and ET/P during the mid-period (2031-2065) and the end-period (2066-2100) relative to the historical period (1976-2010) using meteorological forcing and VIC-simulated hydrological components from CMIP6 GCMs. We also estimated changes in the frequency of deficit and surplus monsoon precipitation during the mid- and end-periods to evaluate their implications on potential surface water availability.

3. Results

3.1. Observed Changes in Potential Water Availability across Dam Catchments

First, we evaluated changes (%) in potential surface water availability (defined as monsoon runoff; hereafter, potential water availability) across each dam catchment during the observed period (1951-2022). We found that potential water availability decreased significantly (by more than 15%) across the majority of dams located in the Ganga, Mahanadi, and Brahmaputra river basins (Figure 1). In contrast, dams located in the South coast, Sabarmati, Pennar, and Cauvery river basins exhibited a significant increase (by more than 20%) (Figure 1). Based on changes in potential water availability across India, we further identified a few clusters of dams located in Deccan, Northern, Eastern, Southern, and Western regions of India (displayed in Figure 1b: Black Boxes), which showed substantial change during the period 1951-2022 (Figure 1). Our results showed that dams in the Deccan, North, and East regions experienced a significant decrease in potential water availability during the period 1951-2022. However, potential water availability increased by more than 30% across most dam catchments in the Southern and Western regions between 1951 and 2022 (Figure S3).

To further explain the observed changes in potential water availability across Indian dam catchments, we examined changes in monsoon precipitation, evapotranspiration, rainy days, runoff coefficient (R/P), and ratio of ET and P during the period 1951-2022 (Figure 2). We observed that variations in potential water availability were primarily governed by changes in precipitation and rainy days (Figure 2a-b). For instance, dam catchments experiencing increasing (decreasing) rainy days and monsoon precipitation exhibited a corresponding increase (decrease) in potential water availability (Figure 1, 2), highlighting the dominant role of rainy days and monsoon precipitation in controlling runoff generation across dam catchments in the Indian Subcontinent (Figure 2). We also found that rainy days and precipitation play a dominant role in controlling other hydrological components, such as evapotranspiration and the partitioning of precipitation into runoff and evapotranspiration (Figure 2). Dam catchments experiencing increasing (decreasing) rainy days and monsoon precipitation showed corresponding increase (decrease) in evapotranspiration, runoff coefficient, and ET/P ratio (Figure 2).

Next, we evaluated changes in potential water availability and catchment yield during the pre-1986 (1951-1986) and post-1986 (1987-2022) periods to assess the impact of recent observed warming (Figure 3, 4). We found a significant shift in the trend of potential water availability in the majority of dam catchments in India, except for a few dams in the Deccan and East regions (Figure 3). During the pre-1986 period, the majority of dam catchments across India showed a 20-40% decline in potential water availability (Figure 3). However, the declining trend in potential water availability reversed during the recent warming in the post-1986 period (Figure 3), and we observed more than 30% increase in potential water availability across most dams during the post-1986 period (Figure 3). Similar to the previous analysis for the period 1951-2022, these changes in potential water availability between the pre-1986 and post-1986 periods were preliminary due to shifts in rainy days and precipitation (Figure S4). Due to increased rainy days and precipitation during the recent period (1987-2022), we also noticed similar changes in 75% and 50% dependable catchment yields (Figure 4). Our results indicated a more than 20% increase in catchment yield across most dams in the Western and Southern regions and a significant decrease in catchment yield across dams located in the Eastern region during the post-1986 period (Figure 4). Consecutive wet and dry years analysis further suggested that the increase in precipitation and potential water availability over Western and Southern regions during recent warming is linked with an increase in consecutive two and three-year wet years (Figure S5-S10), which results in consecutive two and three-year runoff surpluses across the majority of dam catchments in Western and Southern India during the recent period (Figure S8-S10). Overall, the concurrent increases in monsoon precipitation, rainy days, runoff partitioning, and surplus frequency consistently indicate enhanced potential water availability across most dams in the Indian Subcontinent during the recent period (1987-2022), except for dams located in the eastern region. The dams located in the Eastern region (Mahanadi, Brahmani, and Brahmaputra river basins) show a systematic decline in potential

water availability, driven by consecutive precipitation deficits and declining rainy days in the post-1986 period.

3.2. Changes in Hydrological Components in Future Climate

Observed analysis showed that a substantial shift in precipitation and rainy days during the recent period (1987-2022) has caused an increase in potential water availability across the majority of dam catchments in India, except for dams in Eastern India. To better understand changes in potential water availability under future warming, we evaluated changes in future precipitation, rainy days, evapotranspiration, and the partitioning of precipitation between runoff and evapotranspiration during the mid period (2031-2065) and the end period (2071-2100), which control future water availability. We found that monsoon precipitation and rainy days are projected to increase substantially (more than 20%) across the majority of dams in India under all scenarios, except for dams located in the Eastern region (Mahanadi, Subarnarekha, and Brahmani river basins), particularly in the SSP2-4.5 and SSP3-7.0 scenarios (Figure 5). These increasing changes in rainy days and precipitation under future climate conditions lead to increases in other hydrological variables (such as evapotranspiration and runoff) and partitioning of precipitation into runoff across most dam catchments (Figure S11, S12). For instance, we noticed an increase in runoff coefficient and monsoon evapotranspiration across dams in the Western, Southern, Deccan, and Northern regions of India (Figure S11, S12). Moreover, we found that the substantial increase in monsoon precipitation is projected to occur with frequent consecutive wet years across most dams in India under all SSP scenarios (Figure S13-S15), thereby further decreasing the partitioning of precipitation into evapotranspiration (ET/P) under a warming climate (Figure S11).

Consistent with the observations, we also noticed a declining trend in rainy days and precipitation across dam catchments in the Eastern region (especially in the Mahanadi, Subarnarekha, and Brahmani river basins) during the mid period under the SSP2-4.5 and SSP3-7.0 scenarios (Figure 5). Due to declining precipitation and fewer rainy days over Eastern India, we observed a decline in the runoff coefficient and an increase in ET/P under future climate conditions (Figure S11, S12), with increased frequency of consecutive dry years in the region during warming (Figure S13-S15). Overall, future projections based on CMIP6-GCMs showed that the changing climate will continue to enhance precipitation intensity in the Western, Southern, Deccan, and Northern regions while weakening in the Eastern region of India, indicating a systematic shift toward wetter climatic conditions across the majority of India, except in the Eastern region.

3.3. Future Changes in Potential Water Availability across Dam Catchments

Analysis of hydrological components showed an increase in precipitation and rainy days under future warming across most dam catchments in India (except those in the Eastern region). Due to increased

precipitation and rainy days, potential water availability is projected to increase across most dam catchments in India (Figure 6). For instance, potential water availability is projected to increase substantially by more than 25% across most dams during the end period (2071-2100) under the SSP5-8.5 (Figure 6). Moreover, our results revealed that the majority of dam catchments in India (except the Eastern region) are projected to experience consecutive two to three years of surplus water availability in a warming climate across all scenarios (Figure S16-S18). Under the SSP2-4.5 and SSP3-7.0 scenarios, we found that the potential water availability is projected to decrease in the Eastern region (Mahanadi, Brahmani, and Subarnarekha river basins; Figure 6). Moreover, dams located in the East region (Mahanadi, Subarnarekha, and Brahmani river basins) are projected to experience an increase in frequency of consecutive two- and three-year deficits in potential water availability during the mid-period under SSP2-4.5 and SSP3-7.0 (Figure S17-S18), which results in an increased risk of future drought and water scarcity in the Eastern region during future climate.

Considering future projections of potential water availability across India, there is an urgent need to develop effective adaptation strategies to reduce water scarcity and flood risk at the dam-catchment scale. The spatially divergent changes in potential water availability identified in this study can be helpful in climate-resilient dam infrastructure planning. Moreover, with increased future water demand for irrigation, domestic and industrial water supply under a warming climate (Sharma et al. 2019; Singh et al. 2026), capacity augmentation of existing reservoirs and inter-basin water transfer can be planned effectively based on the changes in potential water availability and frequency of consecutive wet or dry events. Dams experiencing increased potential water availability in observed and future warming are of high importance for upgrading storage capacity to buffer against emerging supply surpluses. Moreover, our dam-catchment-scale analysis provides an evidence base to prioritise future investments in dam infrastructure development, maintenance, and operations.

4. Discussion and Conclusions

To fulfil the water requirements of a population of around 1.4 billion, India has developed one of the world's largest dam infrastructures in recent decades, comprising more than 5700 dams with a gross storage capacity of around 400 BCM. However, the reliability of water availability in these dam infrastructure systems is increasingly vulnerable to intensifying climate variability and hydroclimatic extremes under a warming climate (Mishra et al. 2024b). While previous studies largely focused on basin-scale hydrologic variability (Mishra and Lilhare 2016; Shah and Mishra 2016; Bharat and Mishra 2021; Kushwaha et al. 2021), our study provided a detailed assessment of potential water availability for each dam across the Indian subcontinent under both observed and projected future climate conditions and demonstrated that climate-driven changes exhibit substantial heterogeneity at the dam scale. Our results showed that potential water availability has substantially increased across most dams

in the Western and Southern regions (Sabarmati, Cauvery, and several peninsular basins) of India during the observed period. In contrast, we observed a decline in potential water availability across most dams in the Eastern region (especially Brahmani and Subarnarekha river basins) during the period 1951-2022.

Across the Indian subcontinent, total runoff is associated with precipitation variability in monsoon-dominated basins, and even a moderate increase in rainfall frequency can amplify runoff responses (Mishra and Lilhare 2016; Müller et al. 2021). Consistent with previous studies, our analysis suggested that increases (decreases) in potential water availability are primarily associated with increases (decreases) in monsoon precipitation and rainy days. Changes in monsoon precipitation characteristics translated into changes in potential water availability across individual dams, which have substantially reversed during the recent period 1987-2022 across the India subcontinent. During the period 1987-2022, shifts in precipitation patterns have led to a significant increase in monsoon precipitation and rainy days across most dams in the Western, Southern, Deccan, and northern regions. Moreover, the risk of consecutive two- and three-year dry periods has decreased in these regions, resulting in increased potential water availability. On the other hand, the eastern region (covering the Brahmani, Subarnarekha, and Brahmaputra river basins), which received increasing precipitation during the pre-1986 period, has now shifted to declining precipitation during the recent period (1987-2022). The recent decline in precipitation and rainy days over the eastern region has resulted in a deficit in potential water availability during the recent observed warming. The decline in precipitation and potential water availability deficits, accompanied by an increase in consecutive two to three-year deficit events during the post-1986 period, indicate a transition toward drier conditions across the eastern regions.

Consistent with the observations, future analyses showed similar changes in hydrological components and potential water availability across India using CMIP6-GCMs. We found that precipitation and rainy days are projected to increase in the majority of dam catchments in India (except in the Eastern region) during both the mid- and end-periods across all scenarios (especially under SSP5-8.5), indicating a systematic shift toward wetter climatic conditions and increased potential water availability. In the Eastern region of India, we observed a declining trend in precipitation and rainy days with increasing frequency of consecutive dry years, which results in a decrease in future potential water availability across the majority of dams located in the Mahanadi, Subarnarekha, and Brahmani river basins during the mid period under the SSP2-4.5 and SSP3-7.0 scenarios. Future changes in the potential water availability are particularly important for reservoir systems, which are critical for storage reliability (Espanmanesh et al. 2024) in the densely populated and agriculturally driven Indian subcontinent. Moreover, projected changes in potential water availability can be utilised to address drought and flood management challenges at the dam-catchment scale in a warming climate.

Collectively, the consistent change in potential water availability, precipitation, rainy days, partitioning ratios, and deficit-surplus frequency suggests a systematic shift in dam-catchment-scale hydrological

behaviour under changing climatic conditions. These shifts have direct implications for reservoir storage and long-term water planning. Therefore, incorporating climate-informed risk assessment into reservoir storage planning strategies may be necessary to ensure long-term regional water sustainability. Furthermore, our analysis provides a scientific basis for effective planning of future regional water transfers and for enhancing dam-specific storage capacity, which can support irrigation expansion, drought and flood preparedness, and long-term climate adaptation of India's water infrastructure. Our study can also serve as a robust framework for understanding climate-driven changes in potential water availability under observed and future climate conditions, and supports the development of climate-resilient water storage management and long-term water-resource planning.

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Figures

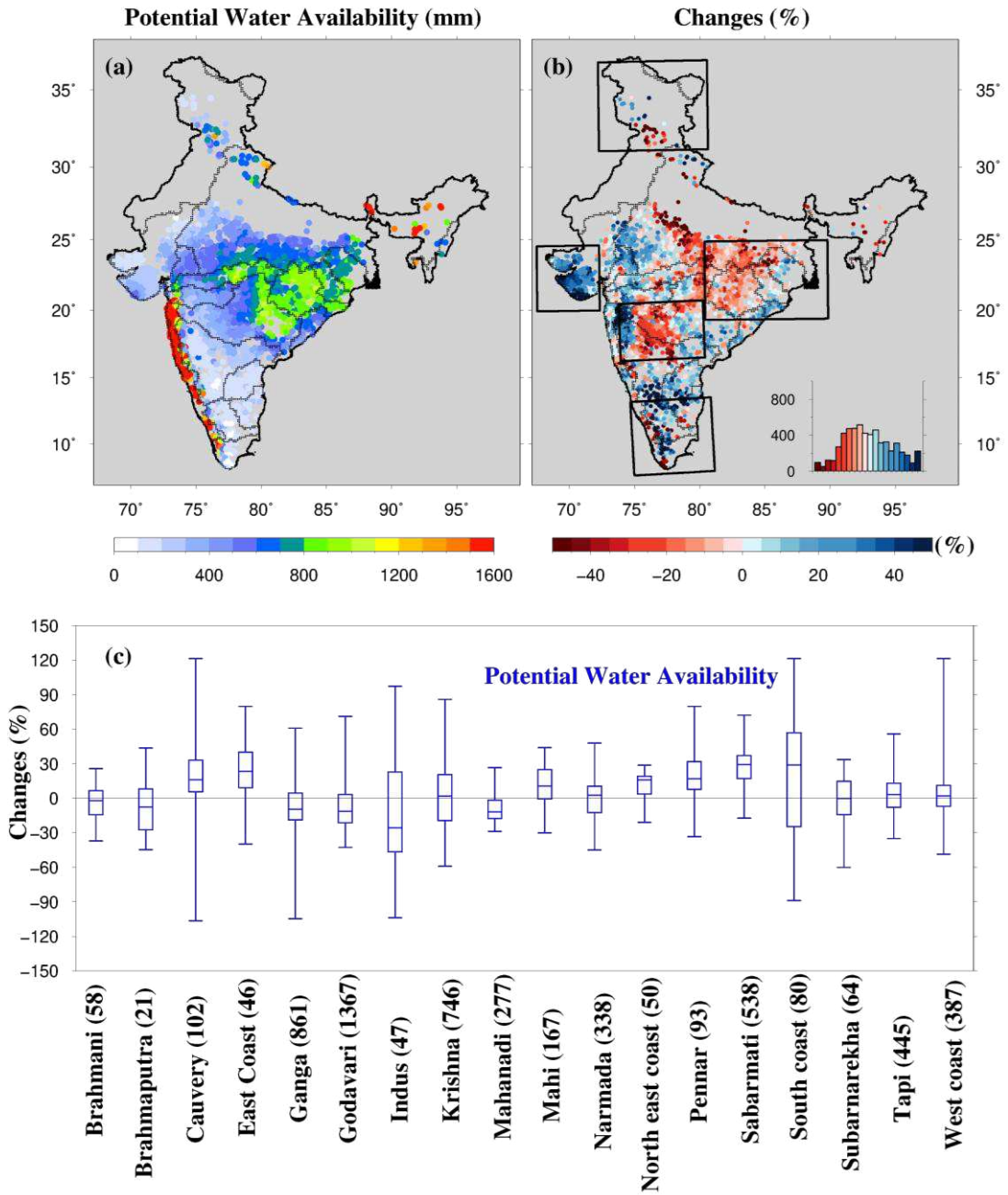

Potential Water Availability (mm)
Changes (%)
(a)
(b)
35°
30°
25°
20°
15°
10°
70°
75°
80°
85°
90°
95°
800
400
0
0
400
800
1200
1600
−40
−20
0
20
40
(%)
(c)
Potential Water Availability
Changes (%)
150
120
90
60
30
0
−30
−60
−90
−120
−150
Brahmani (58)
Brahmaputra (21)
Cauvery (102)
East Coast (46)
Ganga (861)
Godavari (1367)
Indus (47)
Krishna (746)
Mahanadi (277)
Mahi (167)
Narmada (338)
North east coast (50)
Pennar (93)
Sabarmati (538)
South coast (80)
Subarnarekha (64)
Tapi (445)
West coast (387)

Figure 1: **Observed changes in monsoon runoff across each dam catchment during the period 1951-2022.** (a) Monsoon potential water availability (mm) during the observed period (1951-2022), (b) changes (%) in monsoon runoff, and (c) Box and whisker plots (showing the minimum, 25th percentile, median, 75th percentile, and maximum values) of changes (%) in monsoon potential water availability over the dam catchments present across major river basins in India. The numbers shown along the river basins indicate the number of dams in each basin. The histogram in panels (b) refers to the number of dams in each bin or category, where the x-axis represents the changes (%) in the monsoon potential water availability, and the y-axis represents the number of dam catchments. The black boxes in panel (b) refer to a few selected representative regions.

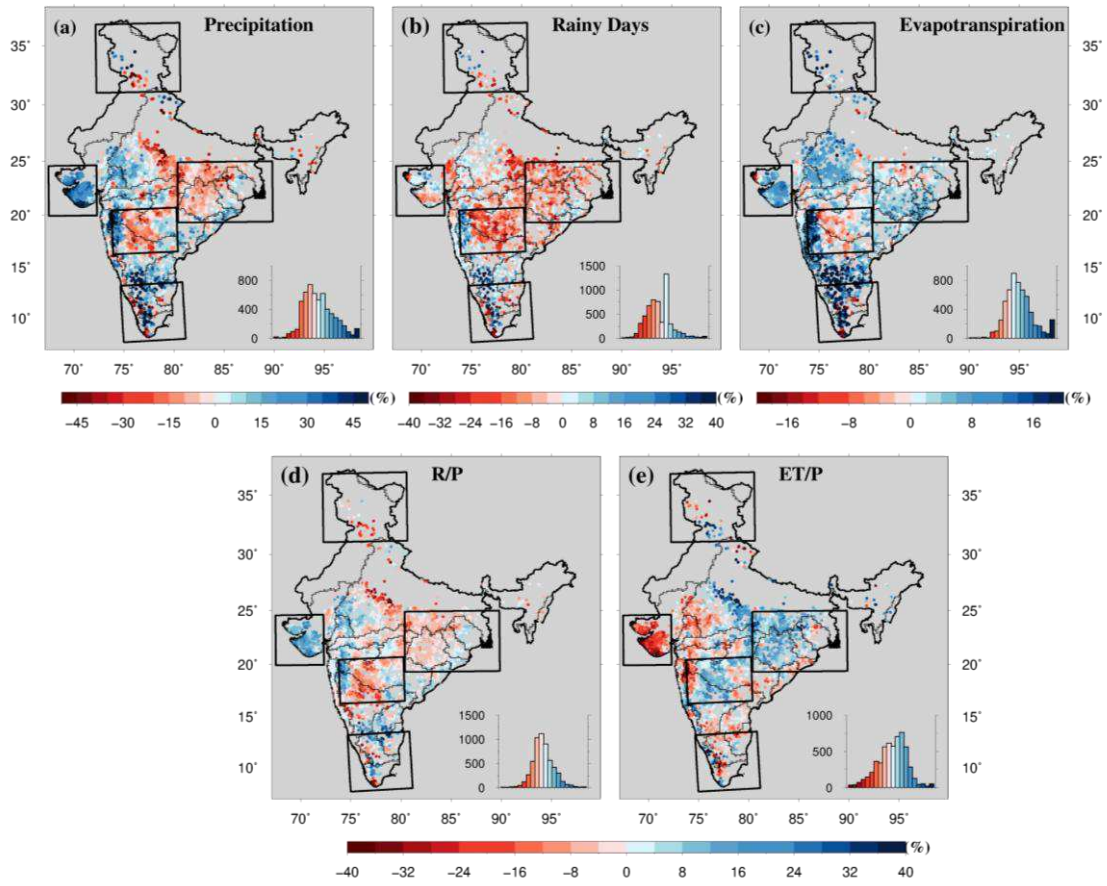


Figure 2: Changes (%) in monsoon precipitation, rainy days, evapotranspiration, R/P, and ET/P during the period 1951-2022. (a) changes (%) in monsoon precipitation, (b) changes (%) in monsoon rainy days, (c) changes (%) in monsoon evapotranspiration, (d) changes (%) in monsoon R/P, and (e) changes (%) in ET/P. The histogram in the panels shows the number of dams in each bin or category, where the x-axis represents the changes (%) and the y-axis represents the number of dam catchments. The black boxes in the panels indicate a few selected representative regions.

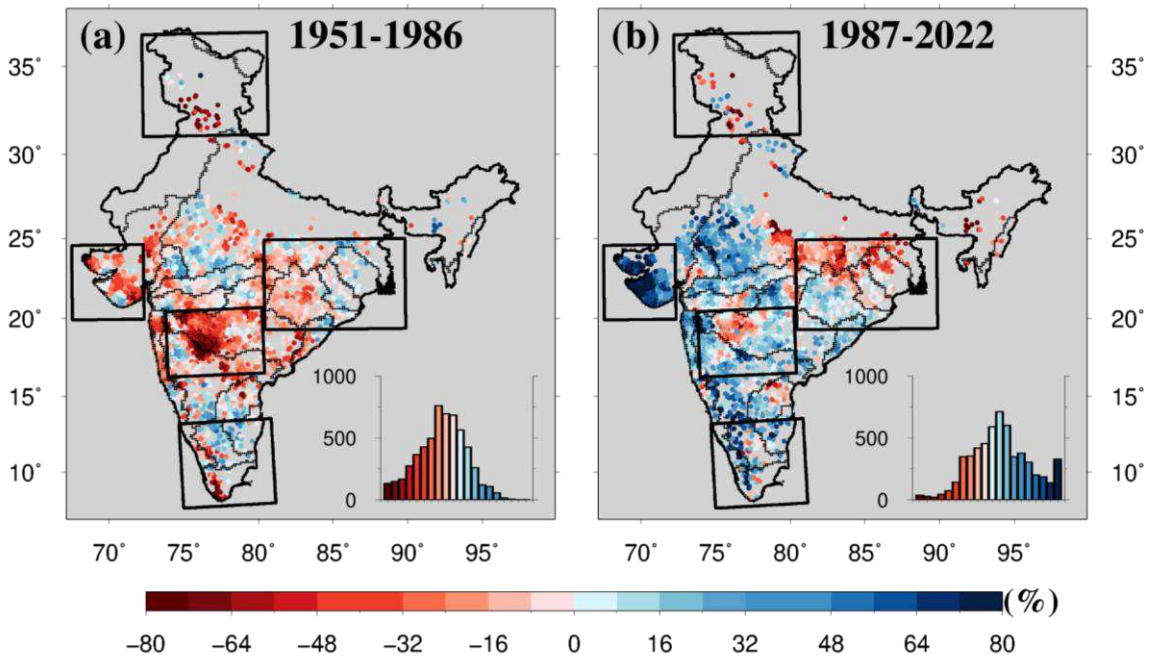
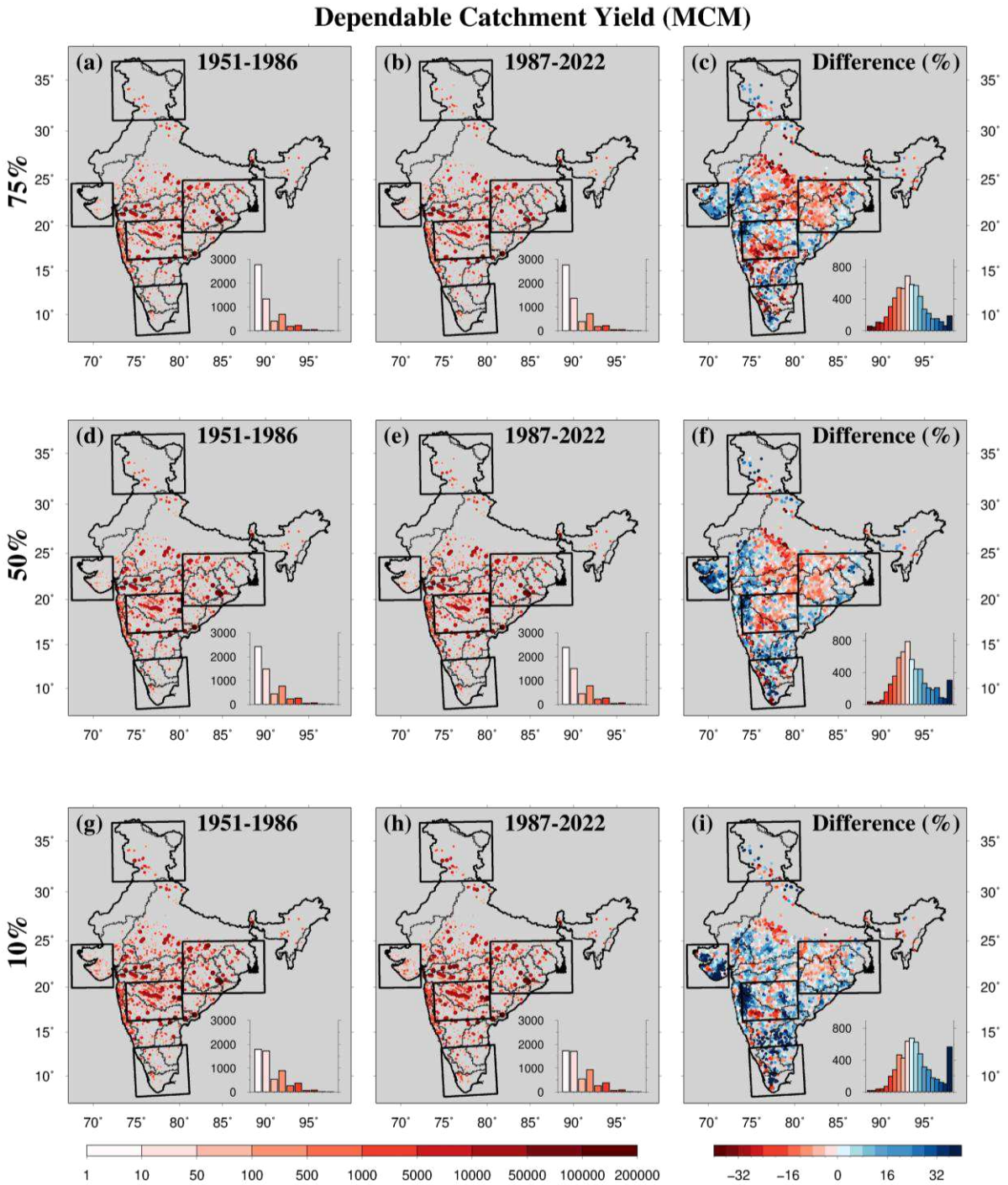


Figure 3: Changes (%) in monsoon potential water availability across the dams during the pre-1986 period (1951-1986), and post-1986 period (1987-2022). (a, b) Changes (%) in monsoon potential water availability for each dam catchment during the 1951-1986 and 1987-2022 periods. The histograms in the panels show the number of dams in each bin or category, with the x-axis representing changes (%) in potential water availability. The y-axis represents the number of dam catchments. The black boxes in the panels indicate a few selected representative regions.



458

459 **Figure 4: Dependable monsoon catchment yield (75%, 50%, 10%) in million cubic meters**
460 **(MCM) across the dams during the pre-1986 period (1951-1986) and the post-1986 period (1987-**
461 **2022).** (a,b) 75% dependable monsoon catchment yield during the period 1951-1986 and 1987-2022.
462 (c) Difference (%) in 75% dependable monsoon catchment yield during the post-1986 and pre-1986
463 periods [panel b-panel a]. (d-f and g-i) Similar to a-c but for 50% and 10% dependable monsoon
464 catchment yield. The histogram in the panels shows the number of dams in each bin or category, where
465 the x-axis represents the dependable monsoon catchment yield (75% [panels a-b], 50% [panels d-e],
466 10% [panels g-h]) as well as the difference in dependable monsoon catchment yield (75% [panel c],

50% [panel f], 10% [panel i]). The y-axis represents the number of dam catchments. The black boxes in the panels indicate a few selected representative regions.

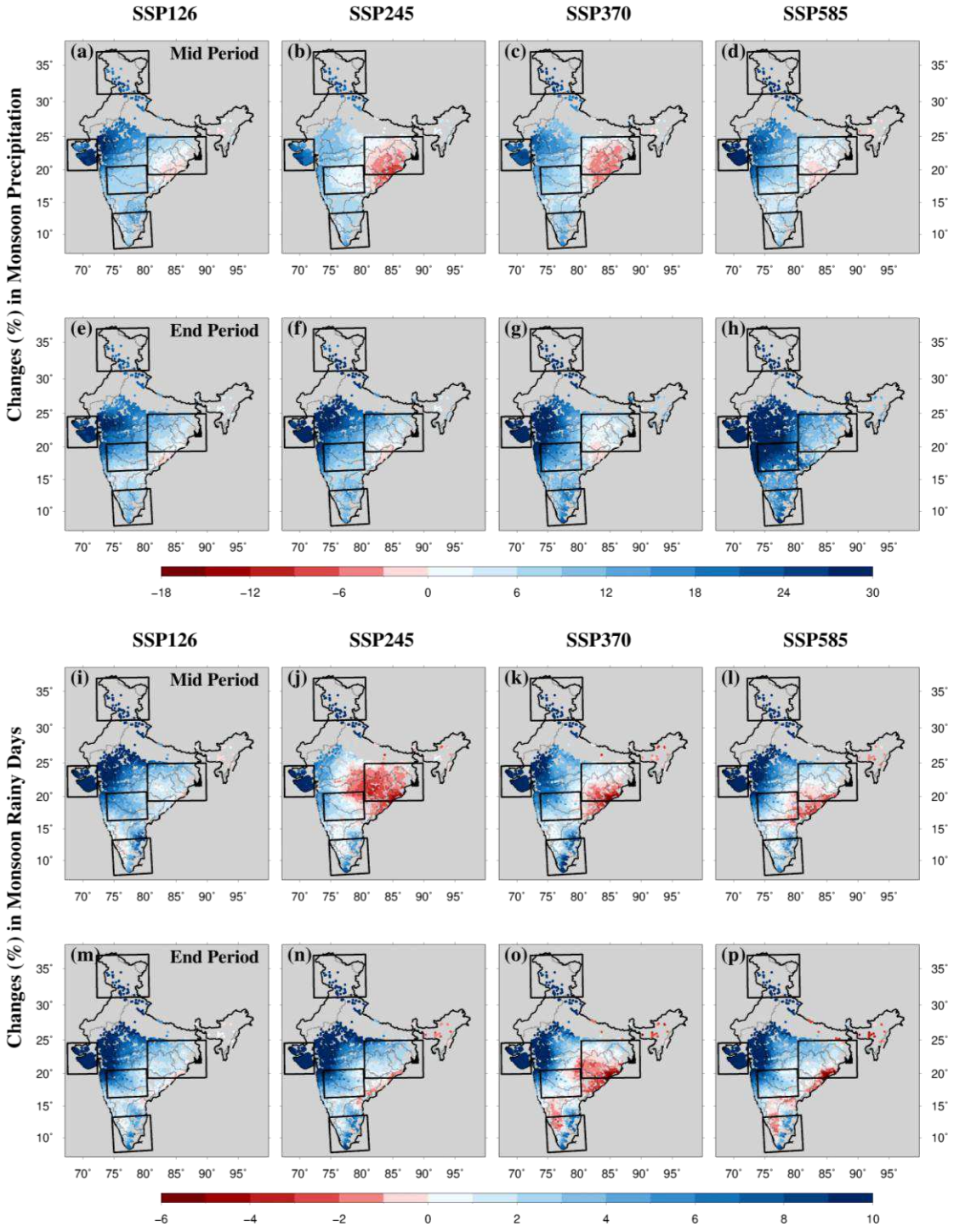


Figure 5: Changes (%) in monsoon precipitation and rainy days across the dams during the mid-period (2031-2065) and end-period (2066-2100) across all SSP scenarios. (a-d) Changes (%) in monsoon precipitation in SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 during the mid-period. (e-h)

Changes (%) in monsoon precipitation in SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 during the end-period. (i-l) Changes (%) in monsoon rainy days in SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 during the mid-period. (m-p) Changes (%) in monsoon rainy days in SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 during the end-period. The black boxes in the panels indicate a few selected representative regions.

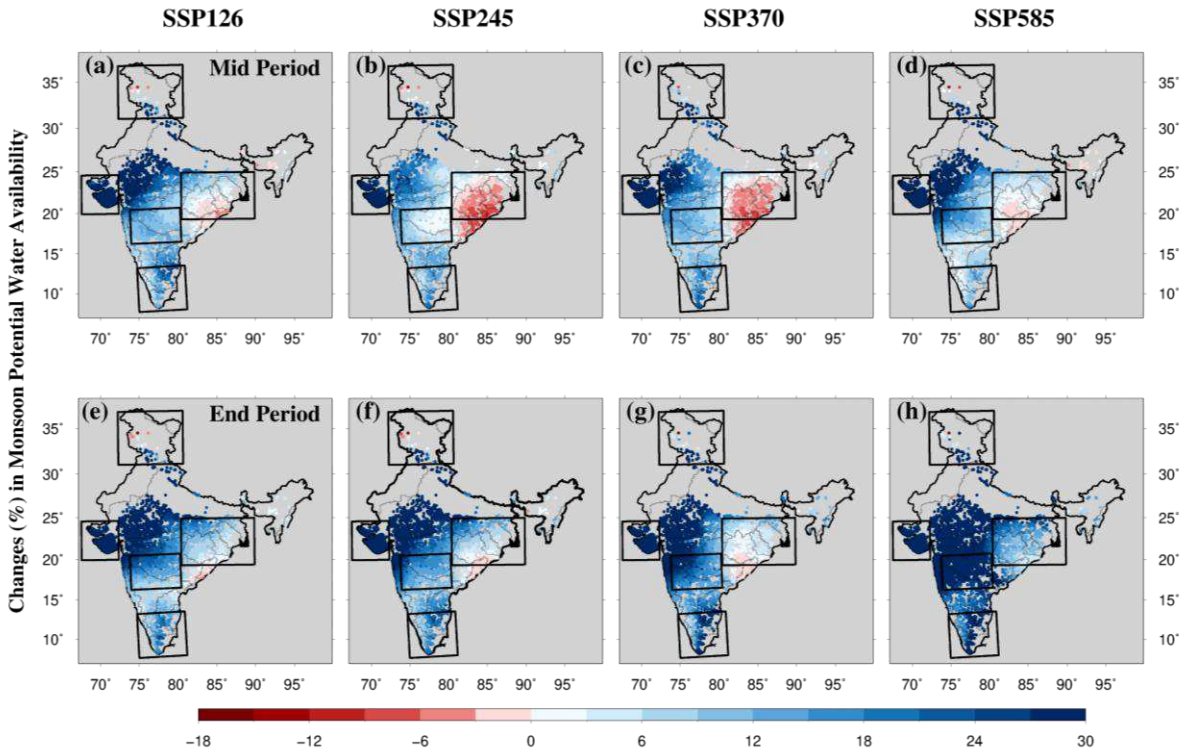


Figure 6: Changes (%) in monsoon potential water availability across the dams during the mid-period (2031-2065) and end-period (2066-2100) across all SSP scenarios. (a-d) Changes (%) in monsoon potential water availability in SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 during the mid-period. (e-h) Changes (%) in monsoon potential water availability in SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 during the end-period. The black boxes in the panels indicate a few selected representative regions.

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