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Surface water assessment availability and potential impacts on Mexico's 757 hydrographic basins for future hydroelectric development

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RESUMEN

Este artículo evalúa la disponibilidad de agua superficial en México en 757 cuencas hidrográficas, organizadas en 37 regiones hidrológicas, proyectando escenarios para 2034. Utilizando la metodología NOM-011-CONAGUA-2015, la disponibilidad se determinó restando el volumen de agua para uso agrícola, urbano o industrial aguas abajo, del volumen de escurrimiento, analizando el clima histórico (1976-2018) y las tendencias de uso del agua. Se encontraron disparidades regionales significativas. Las cuencas del norte, como la HR 8 (Sonora Norte) y 24 (Río Bravo Conchos), enfrentan un estrés hídrico severo, con una disponibilidad tan baja como 0-50 Hm^3 $año^{-1}$. Las regiones del sur, como HR 30 (Grijalva-Usumacinta), tienen una disponibilidad mayor, superior a los 10 000 Hm^3 $año^{-1}$. Las proyecciones para 2034, utilizando la fórmula de Turc y el coeficiente de escurrimiento (Ce), indican que 154 (Turc) y 103 (Ce) cuencas enfrentarán escasez de agua. Se proyecta que las cuencas del noroeste, incluidas HR 9 (Sonora Sur) y HR 25 (San Fernando Soto la Marina), tendrán una disponibilidad inferior a 100 Hm^3 $año^{-1}$, lo que exacerbará el estrés. Se espera que las cuencas del centro-sur, como RH 18 (Balsas) y RH 30, mantengan una alta disponibilidad, superior a 500 Hm^3 $año^{-1}$. El estudio también identificó cuencas adecuadas para el desarrollo hidroeléctrico, centrándose en flujos superiores a 2 m^3 s^{-1} y pendientes superiores al 2%. Sin embargo, las limitaciones ecológicas y legales, como las áreas protegidas y los requisitos de caudal ambiental, limitan el desarrollo, especialmente en RH 30. Estos hallazgos resaltan la necesidad de una gestión integrada del agua para abordar las disparidades regionales, promover la sostenibilidad y mitigar los impactos de la variabilidad climática en los recursos hídricos de México.

ABSTRACT

This study evaluates Mexico's surface water availability across 757 hydrographic basins, organized into 37 hydrological regions, projecting scenarios for 2034. Using NOM-011-CONAGUA-2015 methodology, availability was determined by subtracting downstream commitments from runoff volume, analyzing historical climate (1976-2018) and water use trends. Significant regional disparities exist. Northern basins, like those in HR 8 (Sonora Norte) and 24 (Río Bravo Conchos), face severe water stress, with availability as low as 050 Hm^3/year. Southern regions, such as HR 30 (Grijalva-Usumacinta), have higher availability, exceeding 10 000 Hm^3 $year^{-1}$. Projected scenarios for 2034, using Turc's formula and the runoff coefficient (Rc), indicate 154 (Turc) and 103 (Rc) basins will face water scarcity. Northwest basins, including HR 9 (Sonora South) and 25 (San Fernando Soto la Marina), are projected to have availability below 100 Hm^3 $year^{-1}$, exacerbating stress. South-central basins, like HR 18 (Balsas) and HR 30 are expected to maintain high availability, exceeding 500 Hm^3 $year^{-1}$. The study also identified basins suitable for hydroelectric development, focusing on flows above 2 m^3 s^{-1} and slopes over 2%. However, ecological and legal constraints, like protected areas

and environmental flow requirements, limit development, especially in HR 30. These findings underscore the need for integrated water management to address regional disparities, promote sustainability, and mitigate the impacts of climate variability on Mexico's water resources.

Keywords: water uses, precipitation, surface water availability, temperature, Turc's method.

1. Introduction

Population growth worldwide will bring with it an increasing number of problems regarding drinking water demand and its relationship with availability. According to the water statistics for Mexico in 2019, published by the Comisión Nacional del Agua (National Water Commission, Conagua [2019]), Mexico receives approximately 1 449 471 million cubic meters of water annually through precipitation. Of this total, approximately 72.1% returns to the atmosphere through evapotranspiration, 21.4% flows through rivers and streams, and the remaining 6.4% infiltrates into the subsoil, naturally recharging aquifers. When accounting for cross-border outflows and inflows, Mexico has a 451 584.7 Hm^3 annual renewable freshwater availability (Conagua, 2019).

Surface water availability in Mexico is a critical issue influenced by climatic variability, population growth, and unsustainable water management practices. Studies such as those by Mekonnen and Hoekstra (2016) highlight the global and regional water scarcity challenges, with Mexico facing significant stress due to uneven distribution and overexploitation of surface water resources. López-Morales (2017) provides a comprehensive overview of Mexico's water resources, highlighting that surface water availability is highly seasonal and spatially uneven, with most resources concentrated in the southern regions, while the north of the country faces severe water scarcity. Climate change further complicates this scenario, as highlighted by Magaña et al. (1997), who projected reduced precipitation and increased evaporation rates, thereby threatening the long-term sustainability of surface water. Additionally, Hernández-Espriú et al. (2014) discussed the interplay between surface and groundwater systems, noting that over-reliance on groundwater in regions like Mexico City indirectly impacts surface water availability. Collectively, these studies underscore the urgent need for integrated water management strategies to address Mexico's surface water challenges in the face of the growing demand and climate variability.

Despite these substantial resources, Mexico faces a complex water challenge, including regional imbalances in water availability, basin overexploitation, and increasing demand. The 2030 water agenda (Conagua, 2012) emphasizes these disparities, particularly in critical basins. While regions such as Grijalva-Usumacinta (HR 30) use only a small fraction of their available water, others, like the Lerma and Bravo basins, exceed 100% of their natural surface water availability. This overuse threatens ecosystems and undermines sustainable economic development. Currently, Mexico's national water demand stands at 78 400 Hm^3 annually, of which 11 500 Hm^3 are unsustainably sourced. Projections suggest that, without intervention, this gap could double within the next 20 years. Addressing these challenges requires an integrated water management strategy that not only tackles water scarcity but also considers issues of water quality, governance, and sustainability. These efforts must integrate the interconnected social, economic, and environmental dimensions of water resources. Collaborative action among government agencies, stakeholders, and communities is essential to ensure equitable access to clean water, promote environmental sustainability, and build resilience to future water-related challenges.

This paper examines surface water availability in Mexico across 757 basins, organized into 37 hydrological regions, using the methodology outlined in the Official Mexican Standard NOM-011-CONAGUA-2015 (Semarnat, 2015). It is essential to note that while numerous manuals are available for estimating water availability in a basin, these primarily focus on natural availability or natural runoff. This is distinct from water availability for administrative or legal purposes, as outlined in Silva-Hidalgo et al. (2013). For instance, López-García et al. (2017) conducted a water balance to determine natural availability under climate change scenarios for the Galeana Valley aquifer in the state of Nuevo

León, Mexico. Similarly, Loor (2017) performed a watershed balance in Ecuador, and Ordóñez-Gálvez (2011) presented a methodology to estimate the natural surface water balance in Peru. The United Nations Educational, Scientific and Cultural Organization (UNESCO) incorporated the consumptive use variable (Uc) into the surface water balance of the Valley of Mexico basin, and calculated its water balance variability and uncertainty components (Aparicio-Mijares et al., 2006),

Although most publications focus on the natural water balance, countries such as Chile, Spain, Mexico, and the USA have normative documents for water resource management. These documents are based on the fundamental equation $(dV)(dt)^{-1} = E - S$, which states that the volume change (V) is equal to the inputs (E) minus the outputs (S) of water over a specific period (t) (Aparicio-Mijares et al., 2006). The primary difference lies in the methodology used to estimate the data in the balance equation. Unlike the natural water balance, in the administrative or regulatory balance, consumptive use (Uc) is considered an output (S).

This paper uses a robust methodology to assess average annual surface water availability, quantifying the delta between runoff volume and existing downstream water commitments. Crucially, it extends beyond mere quantification to pinpoint basins exhibiting optimal potential for hydroelectric development by 2034. This is achieved through a meticulous evaluation of topographic characteristics, interwoven with a comprehensive consideration of ecological, social, and infrastructural constraints. By dissecting these multifaceted dynamics, this paper aims to make a significant contribution to a sustainable and resilient water management strategy for Mexico. It seeks to ensure responsible and equitable stewardship of natural resources, while simultaneously illuminating viable pathways for sustainable energy production. Figure 1 illustrates

Fig. 1. Mexican hydrological regions.

Mexico's division into 37 hydrological regions, representing the country's primary watersheds or basins. These regions define water flow dynamics, availability, and catchment boundaries, serving as a critical framework for water resource management, conservation, and infrastructure planning.

2. Methods

As outlined in the Official Mexican Standard NOM-011-CONAGUA-2015 (Semarnat, 2015), which provides specifications and methodology for determining the average annual availability of national waters in Mexico, average surface water availability is estimated using the following equation:

$$D = A_b - R_{xy} \quad (1)$$

where: D is the average annual surface water availability in Hm^3, A_b is the average annual runoff volume downstream in Hm^3, and R_{xy} is the average annual volume committed downstream in Hm^3.

The average runoff volume downstream (A_b) is further calculated using Eq. (2):

$$A_b = A_r + C_p + R_e + I_m - E_x - U_c - E_v - A_v \quad (2)$$

where A_r is the average annual runoff volume from upstream basin; C_p is the average annual natural runoff volume; R_e is the annual returns volume; I_m is the annual import volume; E_x is the annual export volume; U_c is the annual surface water volume extraction (U_{ca}: annual surface water volume extraction through titles currently registered/assigned in the Water Rights Public Registry [REPDA, for its Spanish acronym], U_{cb}: annual surface water volume extraction from titles in the registration process at REPDA, and U_{cc}: annual volume corresponding to reserves and regulated areas); E_v is the average annual evaporation volume in reservoirs and water bodies; and A_v is the average annual storage volume variation in reservoirs (all variables are reported in Hm^3).

Eq. (2) defines A_b as water balance inflows and outflows within a basin. Positive variables represent the water volume entering the basin, while negative variables indicate the water volume leaving it. To calculate water availability, both natural and anthropogenic factors that influence these variables are considered. The behavior of these variables over time was analyzed, and projected values were compared to historical records. The percentage change for each variable was then applied to the latest values published in a 2020 availability study (SINA, 2020).

Hydrological regions in Mexico are composed of multiple hydrological basins, and water availability was calculated both by basin and by hydrological region using Eq. (1). The D value in Eq. (1) was calculated for each hydrological basin. However, the methodology established in NOM-011-CONAGUA-2015 specifies that this calculation must be applied to the entire hydrological region, as it is performed from the downstream basin to the upstream basin. It is important to note that NOM-011-CONAGUA-2015 was designed for its application to a single hydrological basin, which must have a single outlet. In contrast, a hydrological region comprises multiple hydrological basins, and not all hydrological regions in Mexico drain into a single outlet. Many hydrological regions in Mexico have multiple outlets draining into the sea, which does not align with the requirements of NOM-011-CONAGUA-2015.

In this analysis, natural variables include precipitation and temperature, and anthropogenic variables include water usage or consumptive uses (U_c). These inputs are essential for calculating the water balance within a basin (Cp). The methodology to estimate consumptive water uses and the climatological variables required for assessing water availability in Mexico for 2020 and 2034 are detailed below.

2.1 Water use projection

Bonsal et al. (2020) conducted a review analyzing freshwater supply and demand in the Canadian Cordillera, highlighting both historical and future changes in water availability resulting from glacial melt. They found that projected impacts are greater on the seasonality of water flow, with increases in winter and decreases in summer, especially under high-emission scenarios. Southern regions, such as Saskatchewan and Okanagan, will face greater vulnerabilities due to summer water scarcity and growing economic demands. In the north, changes in the landscape, such as permafrost thaw, will impact water quantity and quality. To project future

water use to 2034, we analyzed primary sector water demands like agricultural, industrial, and urban public uses. Trends in production systems, population growth, and economic activity were taken into consideration. Regression analysis was used to obtain these trends and extrapolate them to 2034. The projection used to estimate the value by 2034 is based on historical data from 1976 to 2020. However, it is important to acknowledge that long-term projections are subject to uncertainty due to external factors that may impact the results. Therefore, the presented results should be interpreted as a projection or scenario based on a trend, rather than an exact prediction.

2.1.1 Agricultural sector

Data on planted areas for various crops in irrigation districts and units was sourced from Conagua and the Servicio de Información Agroalimentaria y Pesquera (Agri-Food and Fisheries Information Server, SIAP). Analyzing trends in planted areas by crop type is essential for projecting future water demands.

2.1.2 Urban public sector

Population growth data was obtained from the Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography) (INEGI, 2020) and the Consejo Nacional de Población (National Population Council, Conapo). Trends in population growth were used to project future water demands.

2.1.3 Industrial sector

Data on gross domestic product and production was sourced from INEGI. Trends in economic activity were used to project future water demands.

After calculating water volumes by use and by basin for the years 2020 and 2034, the growth rate between these years was estimated by dividing the volume in 2034 by the volume in 2020 and subtracting $1[(Vol_{2034})(Vol_{2020})^{-1}] - 1$. This growth rate (see Table SI in the supplementary material) of the consumptive use is then applied to the uses included in the 2020 surface water availability studies. It is important to note that the water volume for consumptive uses does not differentiate between surface water and groundwater sources; the primary interest is to estimate the percentage increase or decrease in consumptive uses.

2.2 Historical climate data and projection

2.2.1 Precipitation and temperature

Boulanger et al. (2005) analyzed long-term trends in precipitation within the Paraná-Plata basin. They highlighted a positive increase in the precipitation total index (PTI) from the late 1960s to the early 1980s. They observed a significant increase in precipitation from November to May in southern Brazil and Argentina. Changes in the El Niño-Southern Oscillation (ENSO) characteristics have influenced the variability of precipitation, making it difficult to define robust statistical relationships between ENSO and precipitation in the basin. Additionally, they emphasized the limited usefulness of linear statistical forecast systems for predicting impacts at the local or regional scale.

To analyze the climatic variables of the 757 basins, this work utilized the results of Ramírez-Villa et al. (2022), who obtained precipitation and temperature records from the CLImate COMputing project (Clicom). This database, encompassing 5442 meteorological stations across Mexico, provided the foundational data. They obtained historical precipitation (1976-2018) and temperature data (1976-2015). To ensure data integrity, they implemented a rigorous quality control process, leveraging the CLIMATOL software (v. 3.1) within the R environment. This process incorporated the Paulhus and Kohler (1952) method, addressing anomalous values to facilitate data homogenization and rectify missing data. To address the temporal variability in station operation, Ramírez-Villa et al. (2022) implemented a rigorous data selection process, adhering to World Meteorological Organization guidelines (WMO, 2011) to identify stations with data completeness of at least 80% from 1976 to 2018. Additionally, they calculated the annual accumulated precipitation for each selected station and Thiessen polygons, as stipulated by NOM-011-CONAGUA-2015, to estimate the average rainfall distribution. Polygons corresponding to stations within each basin were extracted, along with their influence areas, enabling the calculation of cumulative annual precipitation per basin (Eq. [3]).

A linear regression model, trained on data from 1976 to 2018, was used by Ramírez-Villa et al. (2022) to project precipitation and temperatures to 2034, employing Excel-based models. Acknowledging the inherent uncertainty of regression models, this

study includes the calculation and presentation of statistical metrics such as R^2 and root mean square error (RMSE), comparing observed historical data with model-generated predictions (shown in Table SI in the supplementary material). These predictions were taken as projections or scenarios due to low R^2 and RMSE values in some basins. For example, in basin 3708 (Sierra Madre), with an average annual rainfall of 461.7 mm, the R^2 value is 0.005. On the other hand, in basin 2305 (La Punta), the R^2 value is 0.435.

$$Cumulative\ annual\ precipitation_{basin} = \frac{\left(\sum_{i=1}^{n} P_i \bullet A_i\right)}{\left(\sum_{i=1}^{n} A_i\right)} \quad (3)$$

where P_i is the annual accumulated precipitation for each meteorological station located within a basin, A_i is the influencing area of the basin, and n is the total polygons number associated with stations surrounding each basin.

To analyze the temperature parameter, a selection process identified 1512 meteorological stations with complete data spanning from 1976 to 2015. This selection was necessary due to a significant reduction in available station data after 2015. A comprehensive data quality assessment was conducted with this robust dataset, followed by the calculation of annual average maximum and minimum temperatures for each station. Subsequently, two interpolations were carried out for each year (maximum and minimum annual temperature) from 1976 to 2015 using Kriging regression. This method generated a mesh with a resolution of 0.05º for the entire Mexican territory. Additionally, an elevation adjustment model was used to improve the quality of the results due to the high correlation between these variables. The temperature average value in each Mexican basin from 1976 to 2015 was obtained using Eq. (4):

$$Temperature_{basin} = \frac{\left(\sum_{i=1}^{n} T_i\right)}{n} \quad (4)$$

where T_i represents the temperature grid points per year located within each basin (in ºC), and n is the total number of polygons located within the basin.

Similar to the procedure for obtaining precipitation projections, temperature projections were obtained. A linear regression Excel model was used for each of the 757 hydrographic basins, utilizing their historical records, to estimate the maximum and minimum annual average temperature values (in ºC) for 2034 (see Table SI in the supplementary material).

2.3 Water volume per local basin (Cp)

Koshida et al. (2015) examined the impact of climate variability and projected climate change on water availability in Canada. This research, the first in a three-part series, reviewed and compared different approaches to estimating water availability, categorized into three types: climate-based, hydrological, and water supply/demand indicators. Climate-based indicators use variables such as precipitation and evapotranspiration to calculate water balances. Hydrological indicators focus on river flow and runoff. Supply/demand indicators compare the volume of available water with water use. The study provides insights into the current state of water availability estimates in Canada. Water volume per local basin (Cp) is the total water volume that originates within a specific hydrological basin and is available for potential use. This volume is measured in cubic hectometers (Hm^3) and is calculated based on factors such as precipitation, temperature, evaporation, and the basin's physical characteristics. To estimate Cp, three sources were considered:

- Historical Cp: values from the 2020 availability study (Semarnat, 2020).
- Turc's method: this method estimates Cp based on precipitation, temperature, and basin area (Sánchez, 2022).
- The runoff coefficient (Rc) method: this method estimates Cp based on precipitation, basin area, and a runoff coefficient.

Both the Turc's and Rc methods were applied to historical and projected climate data to estimate Cp for the current scenario and the projected 2034 scenario.

2.3.1 Turc's method

This method estimates Cp by calculating the difference between precipitation and actual evapotranspiration (ETR). Eq. (5) demonstrates that ETR is functionally dependent on both annual precipitation and average annual temperature.

$$E = P\text{-}ETR \tag{5}$$

where E is the annual specific runoff, P the annual precipitation, and ETR the actual ETR in the basin (all in mm).

ETR is calculated with the following expression:

If $P > 0.31\ L$ then

$$ETR = (P)\left[\left(0.90 + \left((P)\left(L^{-1}\right)\right)^{2}\right)^{-\frac{1}{2}}\right] \tag{6}$$

where L is obtained as:

$$L = 300 + 25T + 0.05T^{3} \tag{7}$$

where, in turn, P is the annual precipitation (in mm) and T is the average temperature (in ºC).

If $P < 0.31\ L$ then

$$ETR = P \tag{8}$$

Natural runoff average annual volume (Cp, in m^3), is obtained with the expression:

$$Cp = EA \tag{9}$$

where A represents the basin area (in m^2) and E the specific annual runoff (in m).

The volume per basin was calculated with Turc's method, where the most important variables are precipitation and temperature, as well as the area of each basin.

The Cp volume was based on the average precipitation data from 1976 to 2018 and temperature data from 1976 to 2015. Using the same methodology, Cp was also estimated using precipitation and temperature projections for 2034. The percentage change between these values was then determined using Eq. (10):

$$\%\ change = \frac{C_{p_{2034}} - C_{p_{average}}}{Cp_{average}} \tag{10}$$

where *% change* is the percentage of change between an average annual value and that projected for 2034, C_{p2034} is the volume per local basin estimated for 2034 by Turc's method (Hm^3), and *Cp average* is the volume per local basin estimated with average annual climatic values by the Turc's method (Hm^3).

2.3.2 Runoff coefficient (Rc) method

As outlined in NOM-011-CONAGUA-2015, Eq. (11) estimates C_p by the Rc method using a runoff coefficient that depends on land use and soil type. Rc values were either obtained directly from the Conagua database or estimated based on data from similar basins. In this study, land use and soil type were assumed to remain unchanged through 2034.

$$Cp = P \times A \times Rc \tag{11}$$

where Cp is the volume per local basin (m^3), P is the average annual rainfall (m), A is the basin area (m^2), and Rc is the runoff coefficient (dimensionless).

To maintain temporal consistency across our analysis, a percentage change calculation, as defined by Eq. (10), was performed. However, this calculation was specifically applied to the average annual precipitation data spanning from 1976 to 2018. This deliberate restriction of the time period was implemented to ensure uniformity with both the temperature parameter dataset and the projected precipitation values for 2034.

2.4 Water availability by 2034

Three scenarios were considered for estimating surface water availability.

- 2020 availability: Values from the 2020 availability study (Semarnat, 2020).
- 2034 availability (%change using Turc's method): The percentage change calculated using Turc's method was applied to the 2020 Cp value to estimate the corresponding Cp for 2034. Consumptive use (Uc for 2020) was adjusted based on its projected growth rate for 2034. Other variables in Eq. (2), such as R_e, I_m, E_x, E_v, and A_v, were assumed to remain constant.
- 2034 availability (%change using the Rc method): Similarly, the percentage change derived using the Rc method was applied to the 2020 Cp value to calculate the corresponding Cp for 2034. Consumptive use (Uc for 2020) was adjusted based on its projected growth rate for 2034. Other variables in Eq. (2), such as R_e, I_m, E_x, E_v, and A_v, were assumed to remain constant.

Using the values obtained from the availability water document from Semarnat (2020) and the per-

centage changes from the Turc's and Rc methods, the availability of surface water for 2034 was estimated. Eqs. 1 and 2 were applied to compute the two scenarios for 2034 based on the percentage changes from Turc's and Rc. The same growth rate for Uc was used in both methods.

2.5 Identifying sites with hydroelectric potential

Basins characterized by surface water flows greater than or equal to 2 $m^3 s^{-1}$ and slopes exceeding 2% were identified as potential sites for hydroelectric development. Legal and ecological constraints, including protected areas and environmental flow requirements, were considered.

The average annual available water volume was converted to flow rate in cubic meters per second ($m^3 s^{-1}$). Basins with slopes greater than 2% were derived from the slope map at a scale of 1:250 000, published by the Instituto Nacional de Ecología (National Institute of Ecology) (INEGI, n.d.).

3. Results and discussion

3.1 Water use

The agricultural sector is the primary water consumer in Mexico. To ensure sustainable water use, it is crucial to improve water efficiency and adopt sustainable agricultural practices. Water use patterns vary across hydrological regions, requiring region-specific water management strategies. Figure 2 illustrates the significant increases in agricultural water consumption projected for the Balsas, Bravo, Sinaloa, and Nazas-Aguanaval regions. Industrial water use will remain concentrated along the central axis, with increasing demand in northwestern states such as Chihuahua, Sonora, Sinaloa, and Durango. Urban public water use will continue to be highest in basins with large cities. By 2034, the Bajo Atoyac River basin in the Balsas region and the Río Blanco in the Papaloapan region will have the highest extraction volumes, while the Valley of Mexico basin will remain the primary basin for urban public water use. Given the large number of hydrological basins, the results are presented by hydrological regions, which group multiple basins into broader, more manageable categories for analysis.

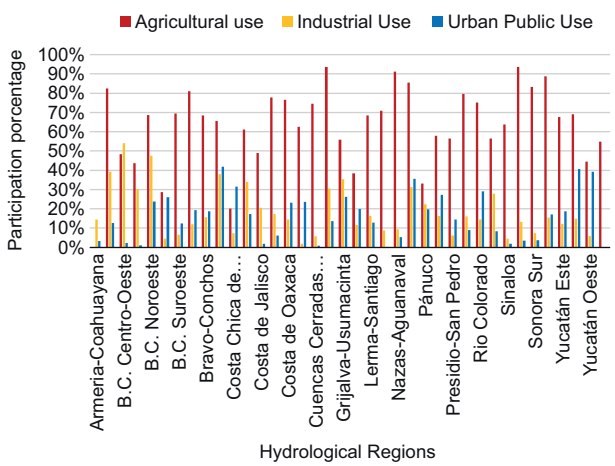

Fig. 2. Participation percentage by consumptive use.

3.2 Climate change impacts

Climate change is expected to have a significant impact on Mexico's water resources. Studies by Boulanger et al. (2005) and Koshida et al. (2015) highlighted the potential consequences of shifting climate patterns on water availability. While long-term climate forecasts inherently carry uncertainty, it is crucial to recognize the potential impacts of climate change on Mexico's water resources. Factors such as altered rainfall patterns, rising temperatures, and increased frequency of extreme weather events could exacerbate water scarcity and disrupt hydrological cycles. Our climatic variable findings are detailed in the following sections.

3.2.1 Precipitation

Precipitation patterns across Mexico exhibit significant regional variability, with the Baja California Peninsula, along with the northwest and north-central regions, experiencing the lowest rainfall, while the southeast region, including Veracruz, Oaxaca, Tabasco, Chiapas, and Campeche, receives the highest precipitation. The projected precipitation for 2034 shows significant regional variability, with some areas projected to experience substantial increases (e.g., Rh 30: +41%) and others facing decreases (e.g., Rh 1, Rh 4, Rh 7: –48%). These changes underscore the need for region-specific water management strategies to address the challenges of water scarcity and flooding. These changes underscore the increasing variability in precipitation patterns, with some regions facing heightened water stress while others experience higher rainfall. Figure 5 illustrates the percentage

change in precipitation between the 1976-2018 average and the projected values for 2034, emphasizing the need for region-specific water management strategies to address these shifts. Additionally, the linear regression model's performance across 757 basins reveals significant disparities, with basins like 1804 (Río Nexapa) showing relatively strong predictive accuracy (R^2 = 0.33 and RMSE = 78.55), while others, such as 2302 (Tepanatepec), 2321 (Coatán), and 3030 (Paredón), exhibit poor performance (R^2 < 0.05, RMSE > 500). These values reinforce what is described in the methodology; the precipitation and temperature values projected for 2034 have a high level of uncertainty, so they are only considered as a scenario (Figs. 3 and 4).

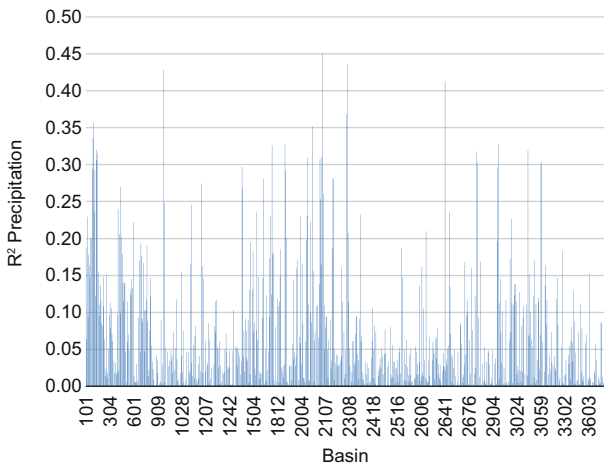

Fig. 3. R^2 values for precipitation linear regression

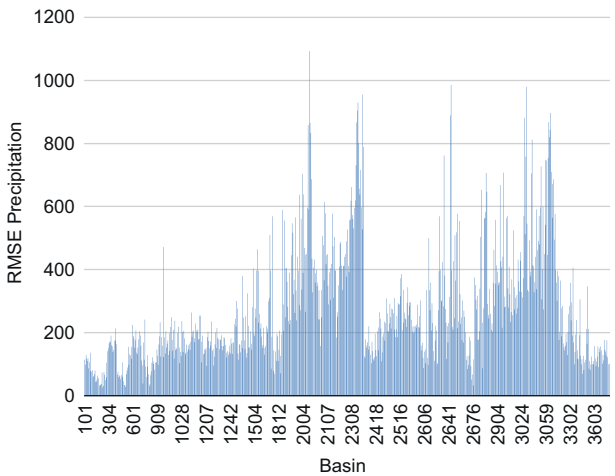

Fig. 4. RMSE values for precipitation linear regression.

3.2.2 Temperature

- In 101 basins, maximum temperatures are projected to decrease slightly by 1% (0.5 ºC).
- In 656 basins, maximum temperatures are projected to increase by 3% (almost 1 ºC).
- Decreases in maximum temperature are concentrated in northern Mexico, Michoacán, coastal Oaxaca, and Campeche, and the southern border with Guatemala.
- Historical minimum temperatures are concentrated in the areas between the Sierra Madre Occidental and the Sierra Madre Oriental, together with Baja California Norte.
- In 299 basins, minimum temperatures are projected to decrease by 3% (–0.4 ºC), while in 458 basins, they are projected to increase by 3% (0.4 ºC).
- Decreases in minimum temperature are observed in northwestern Mexico, particularly in the mountains of Sinaloa, Chihuahua, and Durango.
- Increases in minimum temperature are observed in the Valley of Mexico basin and parts of Campeche.

Similarly, Figures 6 and 7 show the percentage changes in maximum and minimum temperatures, respectively, over the same period.

3.3 Water volume per local basin (Cp)

Turc's and Rc methods were employed to estimate Cp under both historical and projected climate conditions, as well as to calculate the corresponding percentage changes. Turc's method typically results in larger changes in Cp compared to Rc, which accounts solely for variations in precipitation. Figure 8 illustrates the water volume per local basin (Cp), as reported in the study published by Semarnat (2020).

Figure 8 also shows that in 2020, most basins generated a runoff lower than 500 Hm^3 per year, except for the Tarahumara mountains, the Balsas River, and the eastern slopes of the Sierra Madre. The change percentage predicts a decrease in Cp in Baja California Peninsula and northwestern territories, and an increase in the south-central region (Fig. 9). The Rc method shows a less significant change, but also indicates a decrease in Cp in the northwest (Fig. 10).

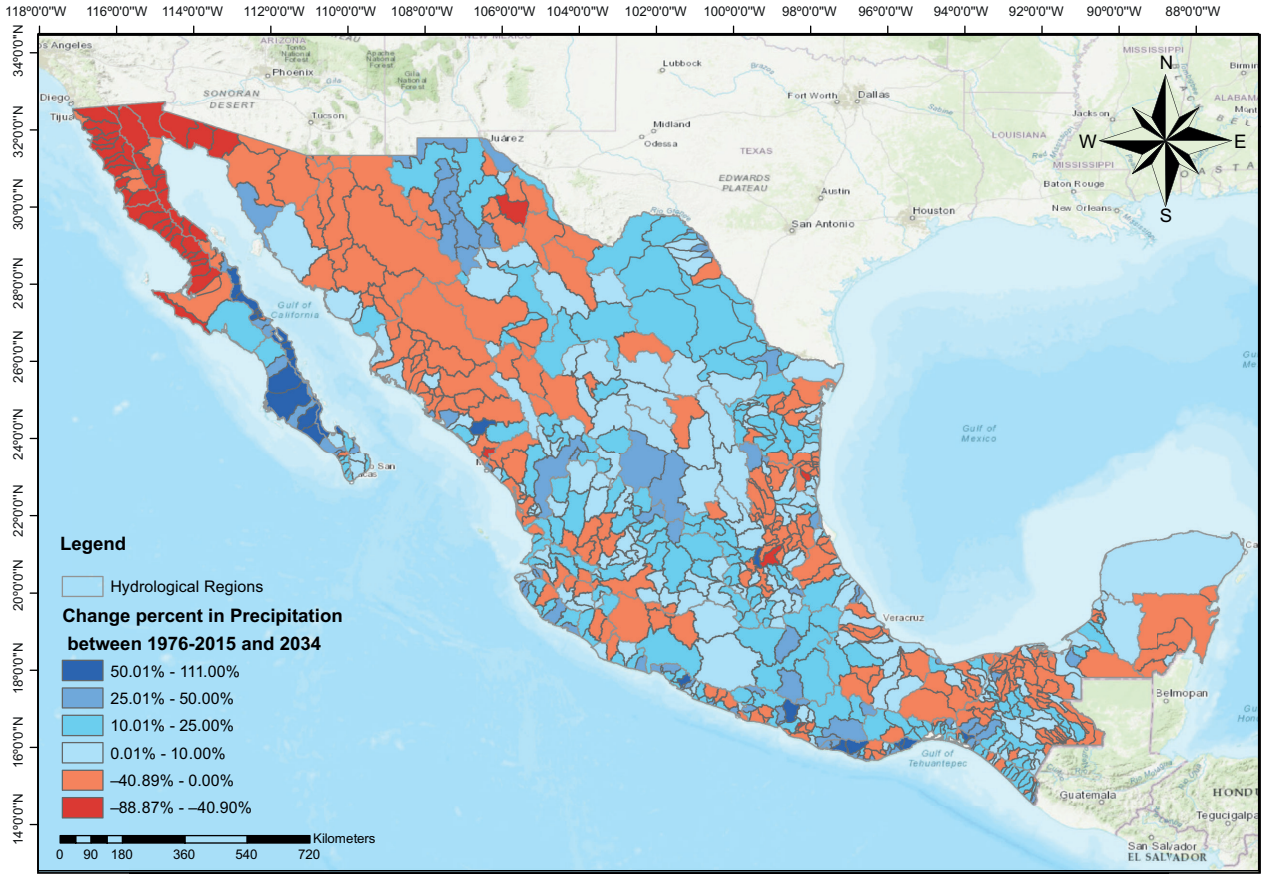

Fig. 5. Change percentage in precipitation between 1976-2018 and 2034.

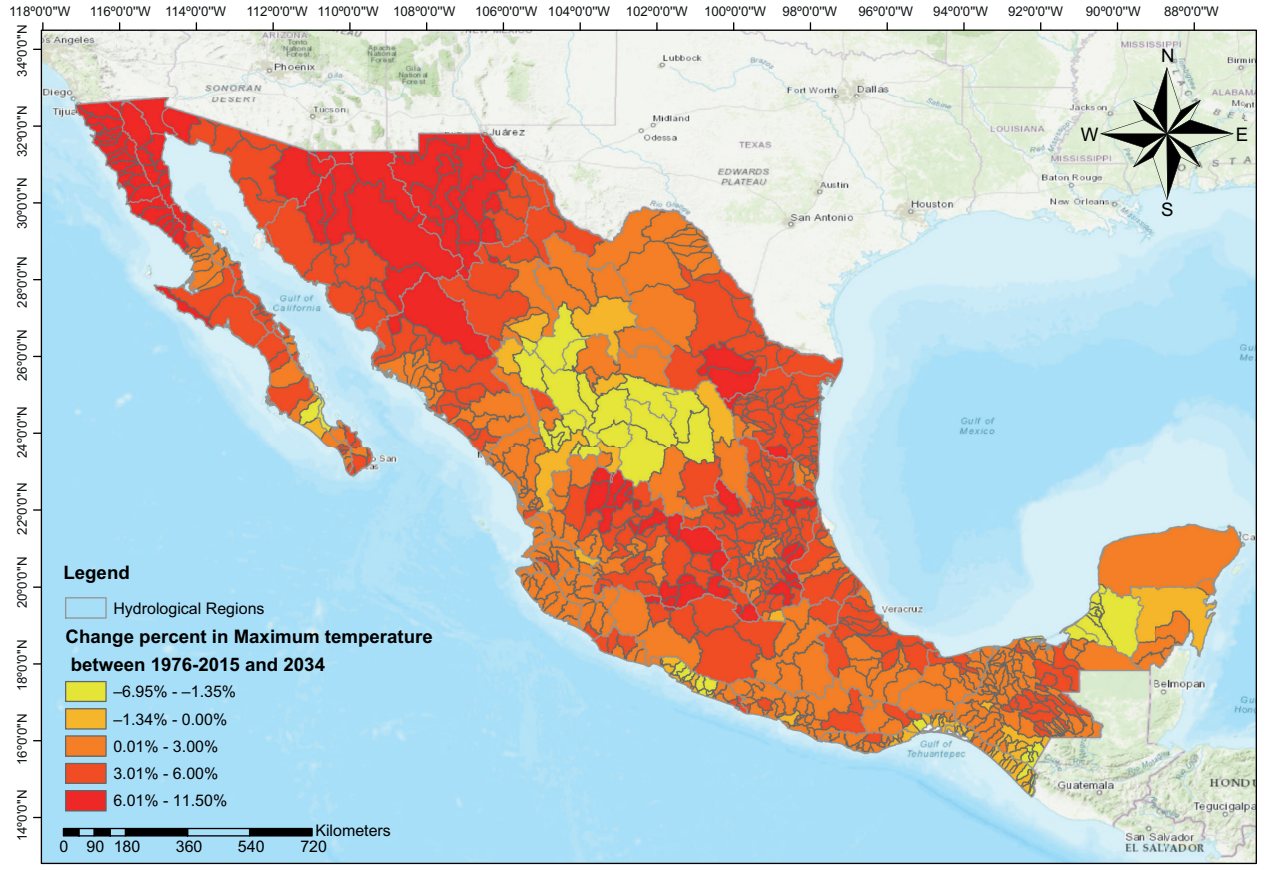

Fig. 6. Change percentage in maximum temperature between 1976-2015 and 2034.

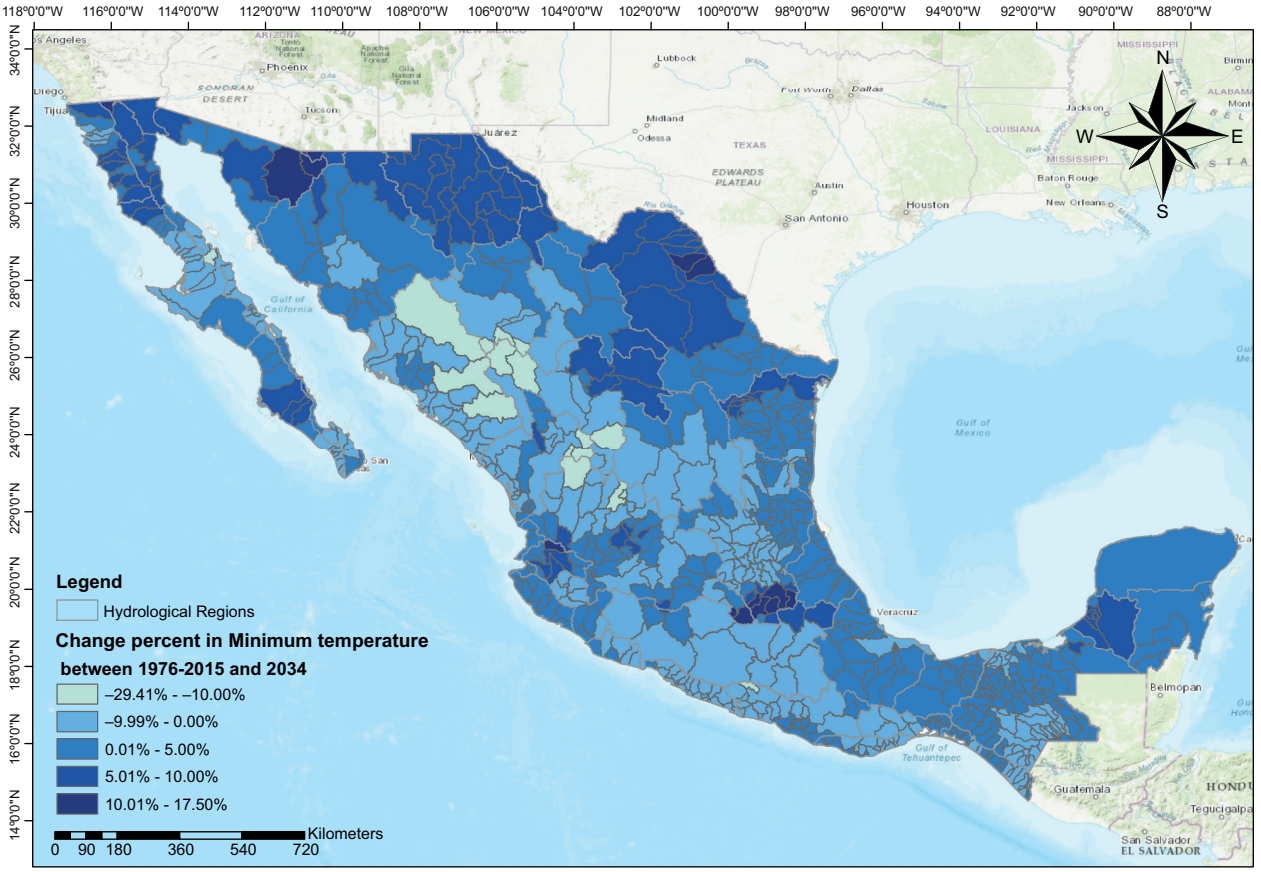

Fig. 7. Change percentage in minimum temperature between 1976-2015 and 2034.

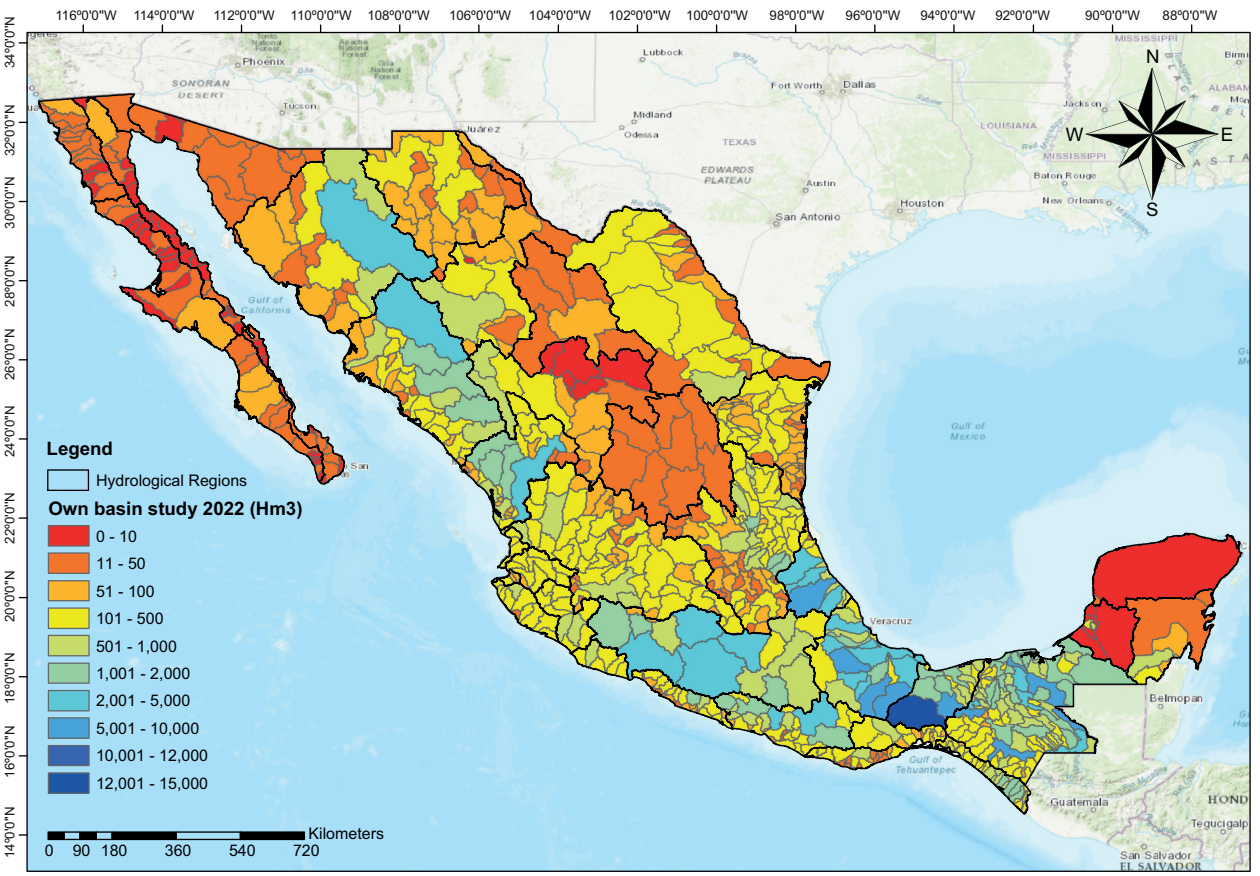

Fig. 8. Water volume local basin (Semarnat, 2020).

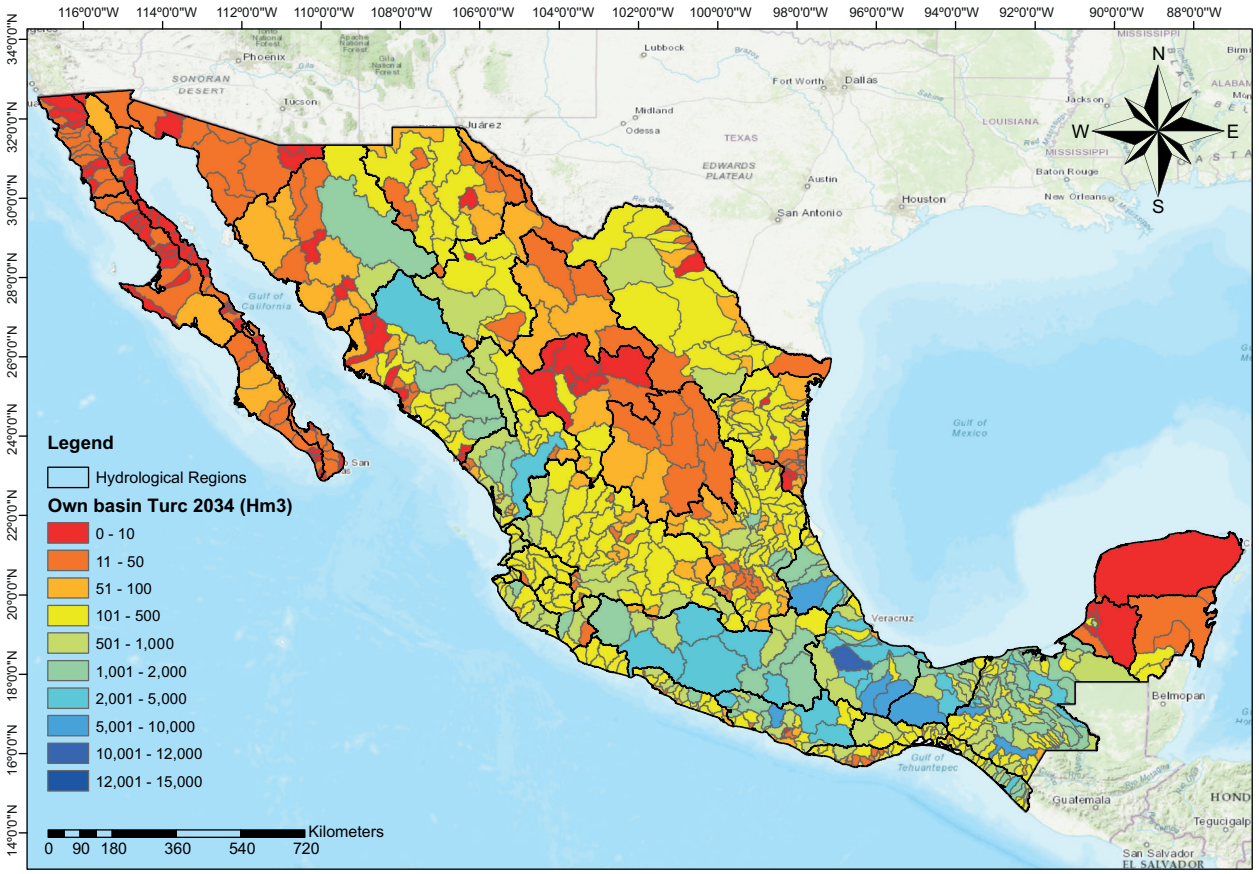

Fig. 9. Water volume per local basin by 2034, estimated with Turc's method.

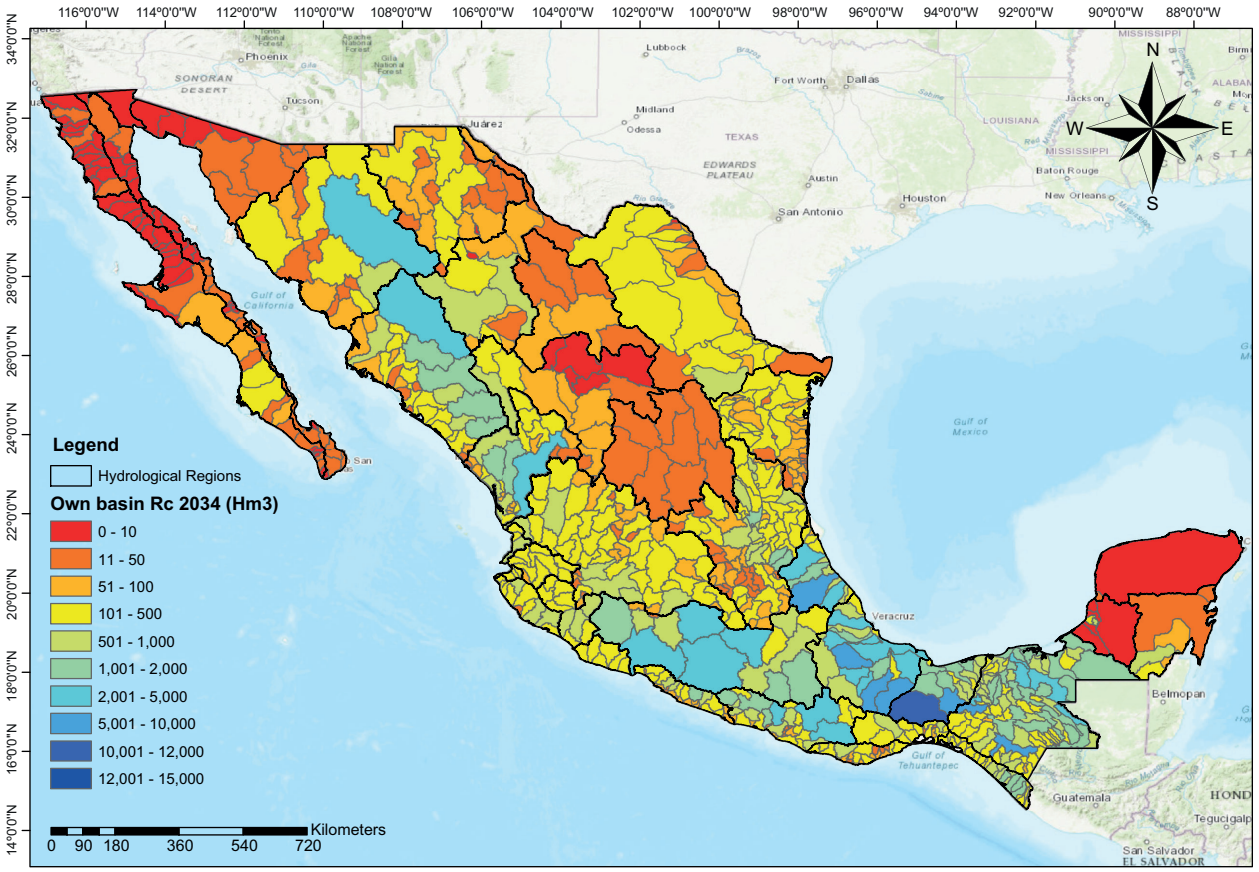

Fig. 10. Water volume per local basin by 2034, estimated with the RC method.

3.4 Water availability

For 2020, basins without water availability were primarily concentrated in the following hydrological regions: 8 Sonora Norte, 9 Sonora Sur, 24 Río Bravo Conchos, 12 Lerma, and 18 Balsas, as well as basin 3405 Río Santa María 1 together with several basins in the southwestern area of hydrological region 25 San Fernando Soto la Marina. Figure 11 shows surface water availability for 2020, as published by Semarnat (2020).

In the 2034 scenario, using Turc's method, projections show 154 basins (25%) without availability, 266 basins (36%) with availability (but less than 100 Hm^3), and 337 basins (38%) with more than 100 Hm^3. For the 2034 projection, using the percentage change calculated by Turc's method (Fig. 12), basins without availability are expected to be concentrated in the northwest of the country and Rh 29 Coatzacoalcos, with additional scattered basins without availability distributed throughout the national territory. Figure 12 displays the surface water availability projected for 2034, calculated using Turc's method.

Figure 13 shows the surface water availability for 2034, calculated using the Rc method. Additionally, Figure 14 illustrates the comparative behavior of water availability between 2020 and the projected scenarios for 2034. These figures collectively provide a comprehensive comparison of the results obtained in this study with the official water availability data published by the Mexican government, as well as the projected scenarios based on the applied methodologies. Similarly, projections with the runoff coefficient method (Fig. 13) show that basins without availability will also be concentrated in the northwest of the country, though to a lesser extent. Additional affected areas include Rh 30 Grijalva-Usumacinta, 18 Balsas, and 35 Mapimí. With the Rc method, in the 2034 scenario, there are 103 basins without

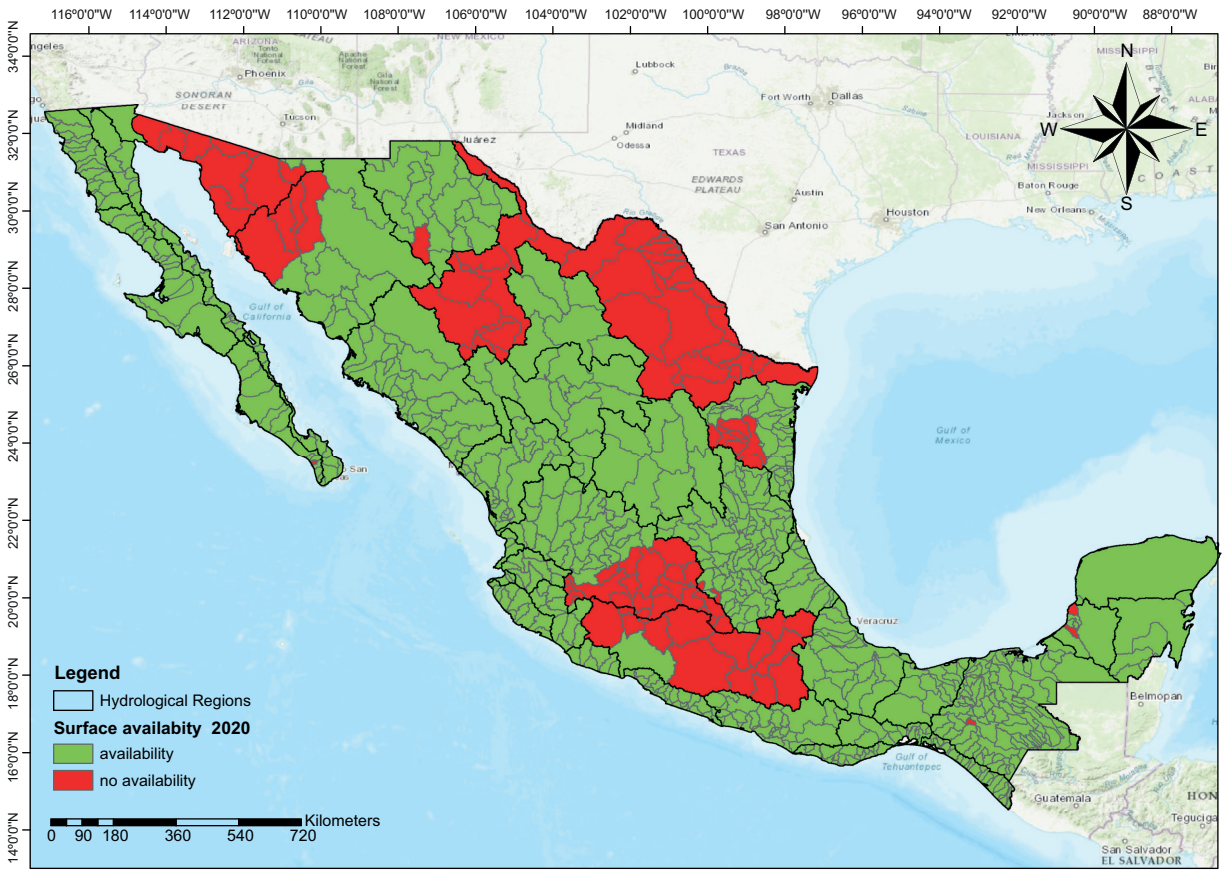

Fig. 11. Surface water availability in 2020 (Semarnat, 2020).

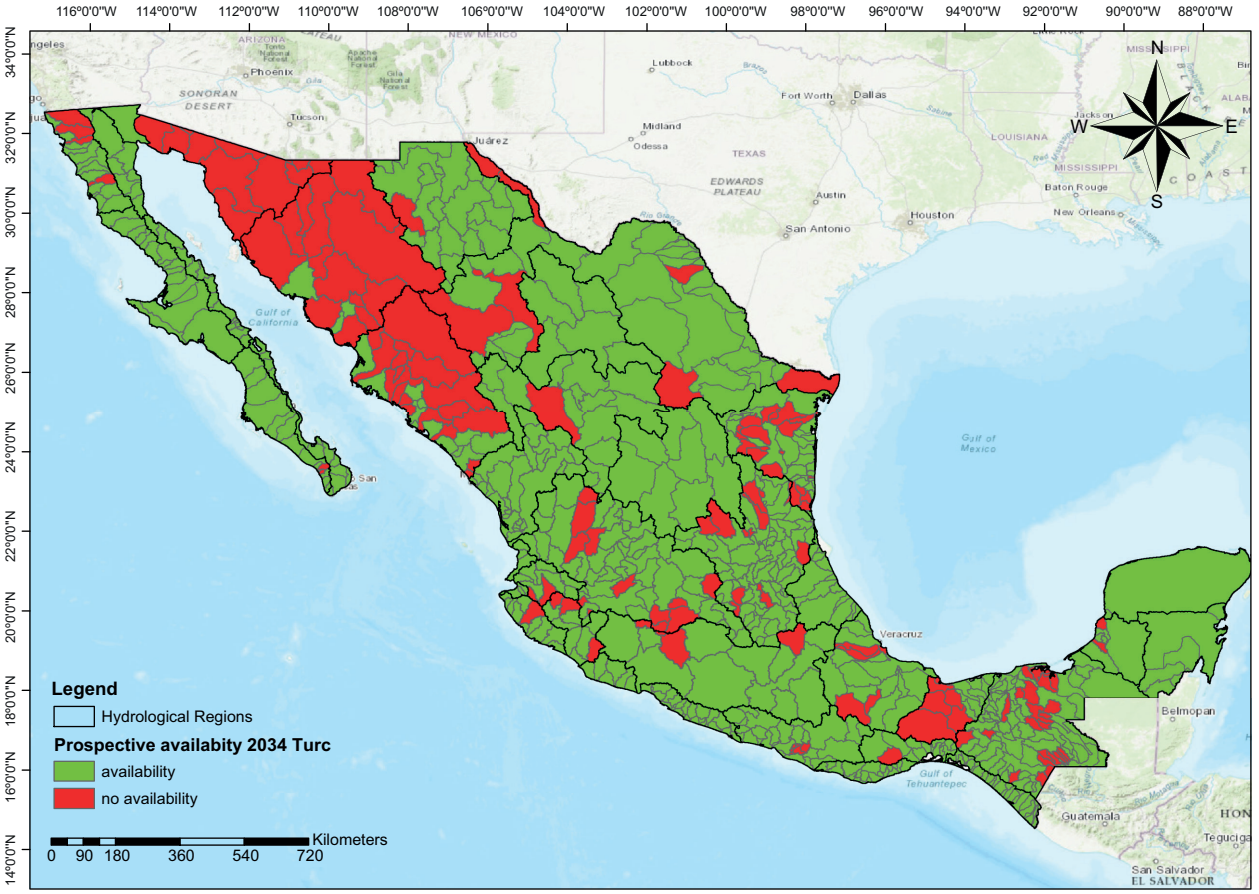

Fig. 12. Surface water availability by 2034, estimated with Turc's method.

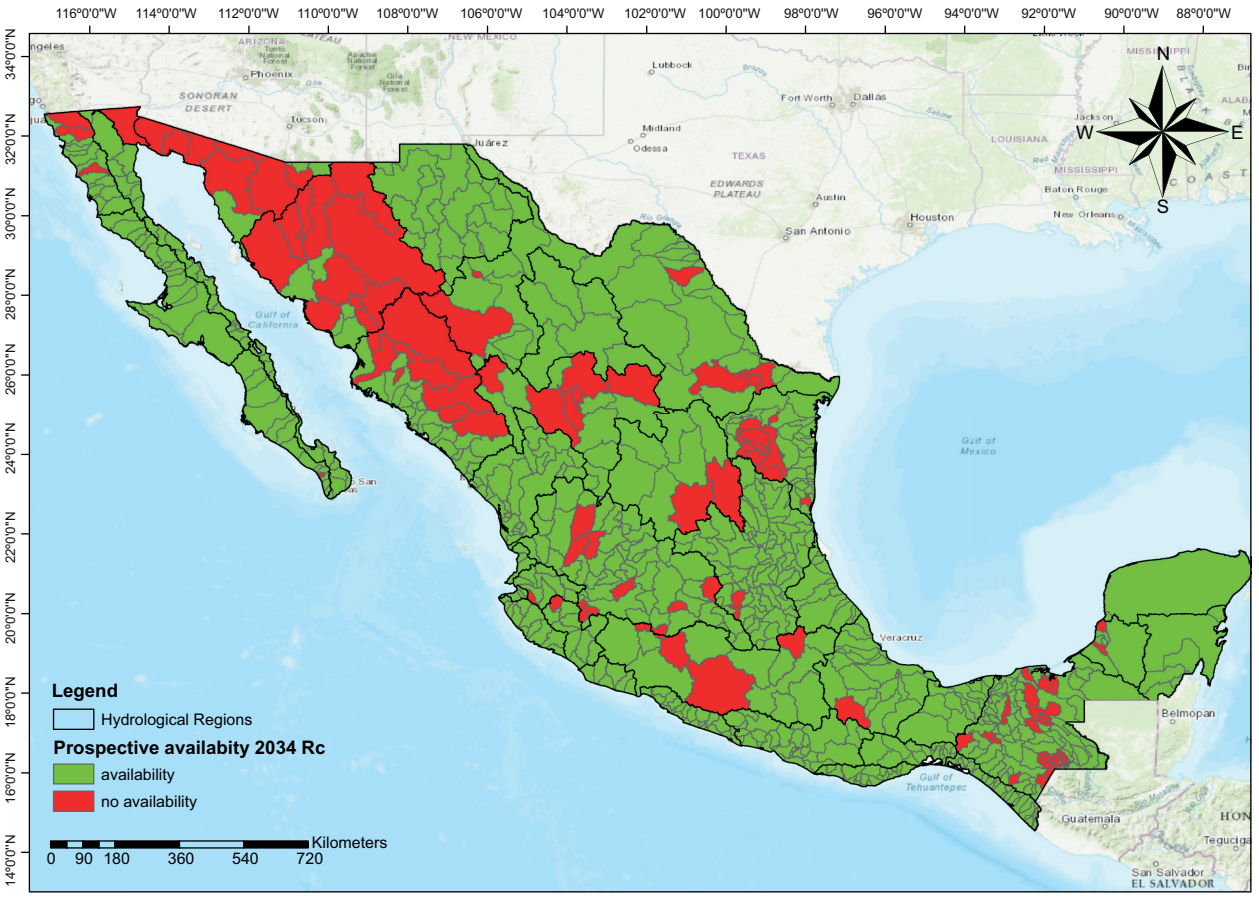

Fig. 13 Surface water availability by 2034, estimated with the Rc method.

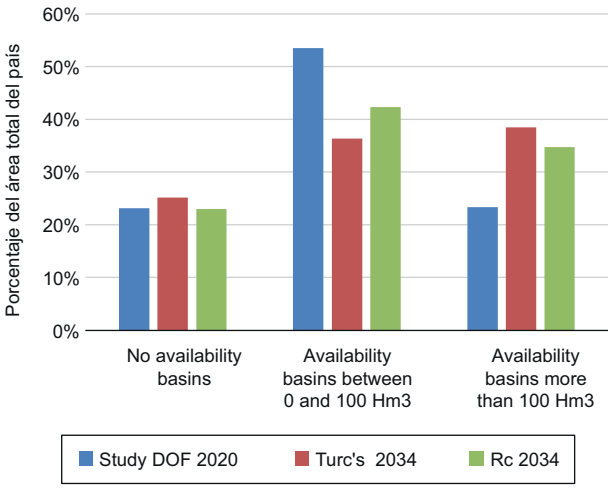

Fig. 14. Percentage of basins with and without availability of surface water for each scenario analyzed.

availability (23%), 334 basins (42%) with availability (but less than 100 Hm^3) and 320 basins (35%) with more than 100 Hm^3.

Figure 14 graphically contrasts the calculated results with the 2020 water availability data published by Semarnat (2020), providing a clearer understanding of trends and variations. The basins without availability, as reported in the 2020 study, increase slightly when the estimated percentage changes derived from the Turc's and Rc methods are applied. In both scenarios, the number of basins with availability of less than 100 Hm^3 decreases, while the number of basins with availability exceeding 100 Hm^3 increases. Nationwide, the total number of basins without availability rose significantly from 91 in 2020 to 154 when applying the percentage change from Turc's method and to 103 when using the Rc method.

3.6 Hydropower potential

To identify potential sites for hydropower development, basins with surface water availability (*D*) exceeding 2 m $^3s^{-1}$ and slopes greater than 2% were considered. Additionally, downstream flow (*AB*), as defined in NOM-011-CONAGUA-2015, was utilized to pinpoint basins suitable for further analysis. This approach enables the identification of sites with hydroelectric potential, which can accommodate either large dams or smaller infrastructure, such as pipelines running parallel to the riverbeds. Figures 15 and 16 present the results of the calculations, employing each previously mentioned method, based on the scenery's water availability for 2034.

Figure 17 offers a comprehensive visual representation of the intricate relationships between hydrological regions, projected water availability for 2034, and ecologically critical areas. To assess the potential impacts of water availability on sensitive ecosystems, this study incorporated existing designations of ecologically critical areas, including Protected National Areas (ANPs, for their acronym in Spanish), Ramsar wetlands, and Important Bird Conservation Areas (AICAs, for their acronym in Spanish). The AB 2034 analysis, utilizing Turc's method (as depicted in Fig. 12), identified basins with sufficient water flow to meet future demands, while also revealing the highest number of basins projected to experience water scarcity by 2034. These results were then overlaid with a map of protected areas, encompassing NPAs, Ramsar wetlands, and AICAs, emphasizing the imperative need for sustainable infrastructure planning. This integrated approach, facilitated by the calculations and development shown in Figure 17, provides a crucial tool for understanding the intersection of water resources and ecological preservation.

3.7 Key recommendations

- Infrastructure prioritization: Focusing on regions with projected water availability exceeding 2 $m^3 s^{-1}$, especially in hydrological regions such as HR 12, HR 25, HR 26, HR 30, and HR 31.
- Protecting critical ecosystems: Avoiding or minimizing the impact of infrastructure projects on Ramsar wetlands, ANPs, and AICAs to safeguard biodiversity.
- Adaptive water management: Implementing strategies to address challenges posed by climate variability and anthropogenic pressures, ensuring resilience in water resource management.

Reconciling the potential and restrictions in HR 30: Apparent abundant water resources in Hydrological Region 30 (HR 30), encompassing the Grijalva-Usumacinta basin, coupled with the strict limitations on hydroelectric development along the Santo Domingo River, highlight the intricate equilibrium required in water resource management. This scenario vividly illustrates the dual mandates of energy

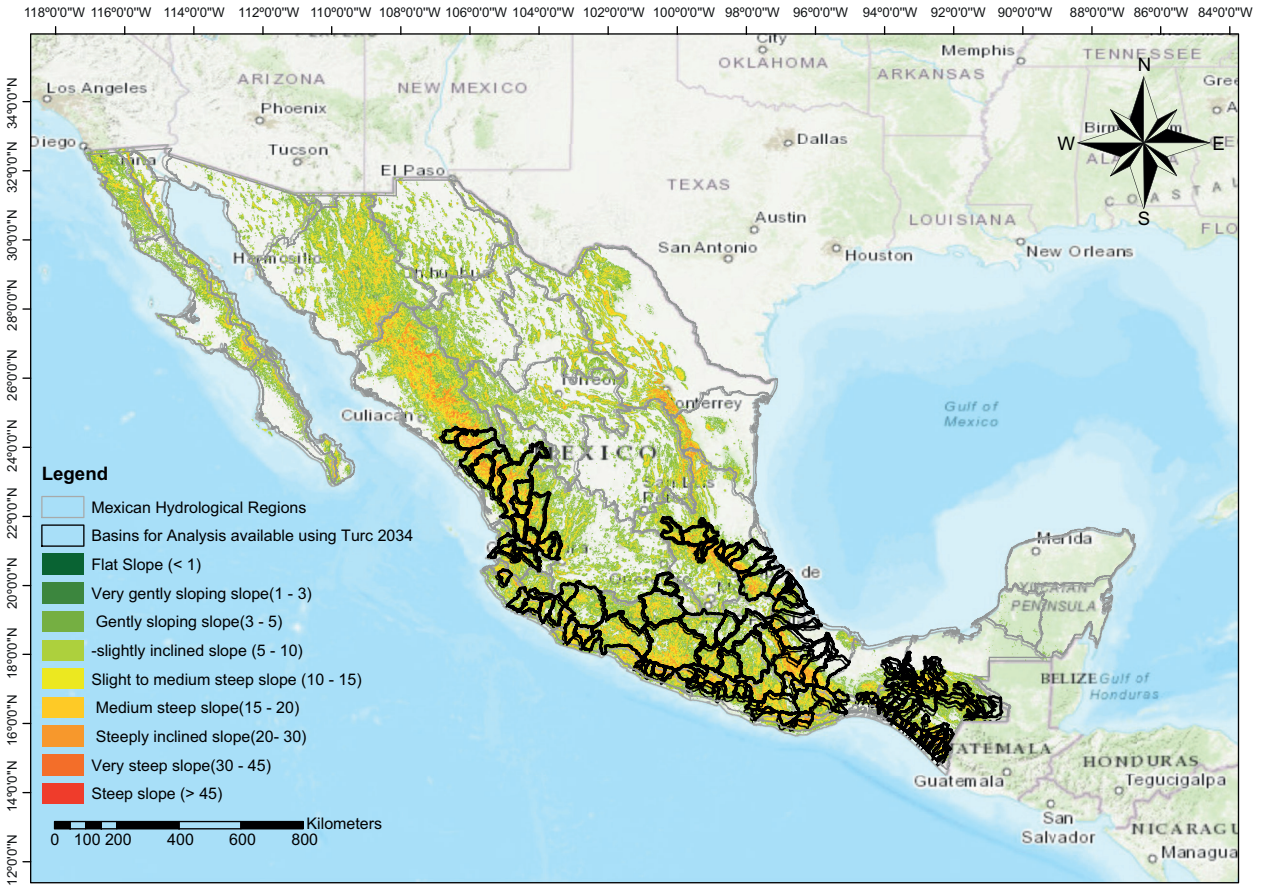

Fig. 15. Map of basins with available flow greater than 2 $m^3 s^{-1}$ by 2034, estimated with Turc's method.

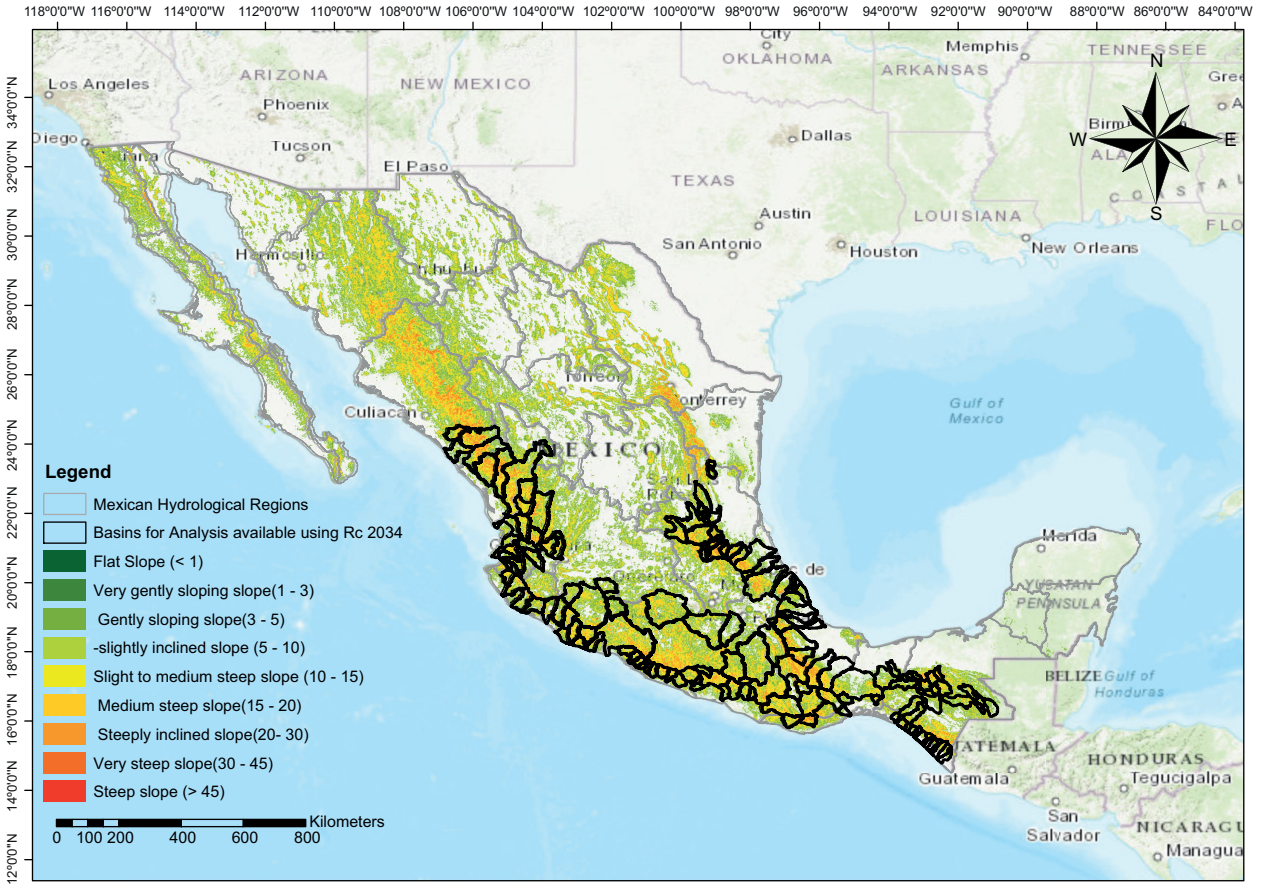

Fig. 16. Map of basins with available flow greater than 2 $m^3 s^{-1}$ by 2034, estimated with the Rc method.

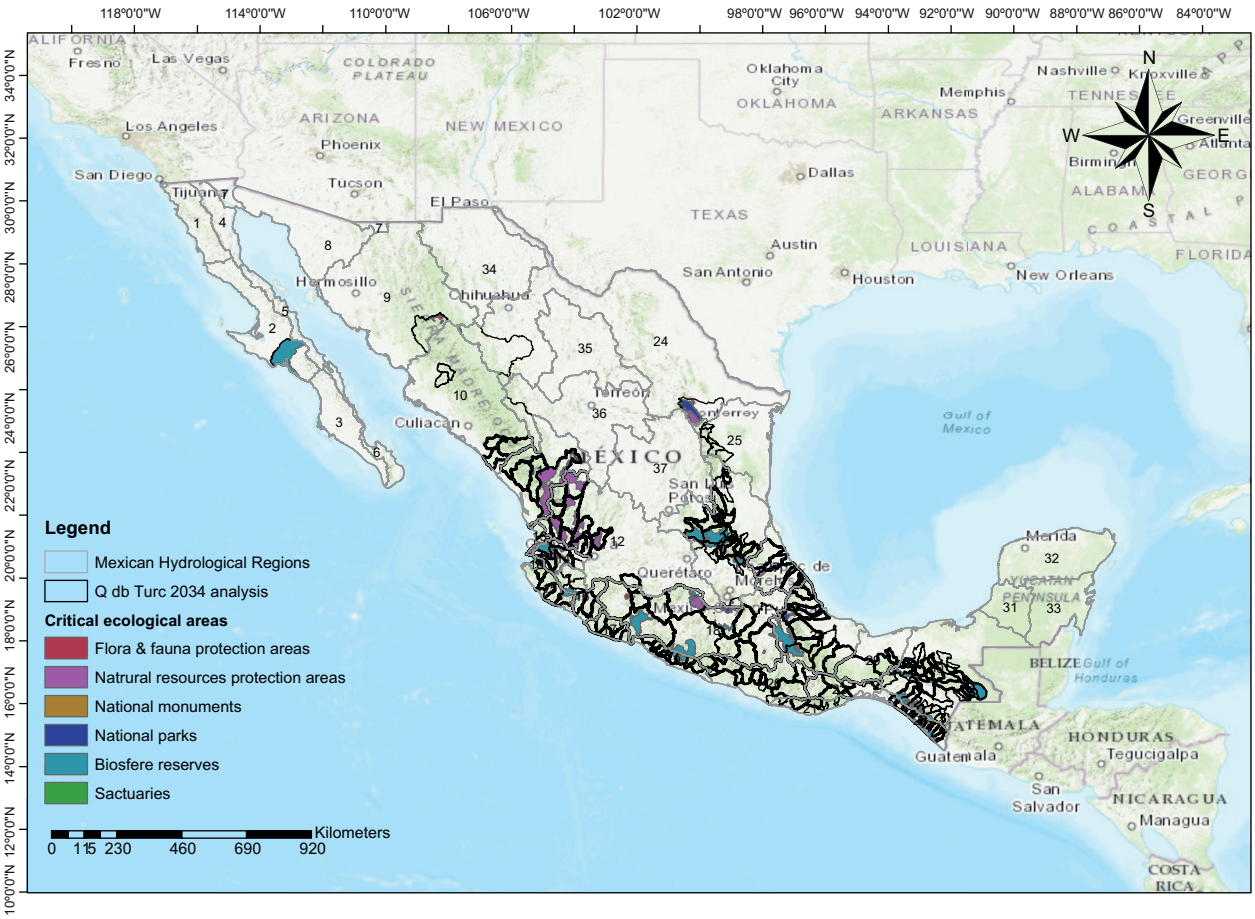

Fig. 17. Relationship between hydrological regions, projected water availability (using Turc's method) by 2034, and critical ecological areas.

generation and ecological preservation. While HR 30 exhibits the volumetric capacity to meet projected future water demands, it simultaneously represents one of Mexico's most ecologically sensitive and significant areas. Consequently, a nuanced strategy that prioritizes both sustainable energy solutions and the protection of critical ecosystems, is essential. The proposed Santo Domingo hydroelectric project within HR 30 was halted by the Secretaría de Medio Ambiente y Recursos Naturales (Secretariat of Environment and Natural Resources, Semarnat) due to its potential ecological and social repercussions, demonstrating the government's commitment to prioritizing ecological connectivity and biodiversity conservation over energy development. This decision embodies a broader strategic framework aimed at:

- Ensuring ecological flows: Maintaining sufficient water flow to sustain local biodiversity and essential ecosystem services.
- Mitigating social conflict: Respecting indigenous rights and addressing community opposition to large-scale infrastructure projects.
- Upholding conservation commitments: Adhering to national and international legal frameworks that promote sustainable development.

By effectively balancing these imperatives, sustainable infrastructure planning can unlock the potential of regions like HR 30 while safeguarding Mexico's vital ecosystems. This integrated approach fosters responsible resource management and ensures the ecological integrity of the nation's hydrological basins.

4. Conclusions

In this work, the results of the analysis of historical precipitation and temperatures conducted by Ramírez-Villa et al. (2020) and their projection to 2034, based on a linear behavior, were utilized. The growth rates of water volume in agricultural, industrial, and urban public consumptive uses were analyzed. Using two equations (Turc's and Rc), the volume per local basin (Cp) was estimated and applied in Eqs. 1 and 2, to calculate the available volume of surface water by 2034. Subsequently, the basins with the possibility of developing hydroelectric projects were identified.

R^2 and RMSE values obtained from the linear regression applied to historical precipitation and temperature data provide results with a low probability of occurrence through 2034; however, they can be considered a scenario or an average value. On the other hand, if these trends in rainfall and temperature behavior, as well as water use behavior, continue, surface water availability scenarios can be obtained through 2034.

The results of this work enable a first analysis of the surface water resources available in 2020 and their scenarios by 2034. For example, according to the Semarnat (2020) study, 321 953.36 Hm^3 of water are generated in Mexico by natural runoff (Cp), and 192 022.94 Hm^3 are extracted for consumptive uses (60%). There is sufficient water in the country, but the problem arises when the analysis is carried out by hydrological region. In 2020, the natural runoff in the north was 81 095.08 Hm^3, with a Uc of 78 830.86 Hm^3 (97.2%). In the rest of the regions (south), the natural runoff was 240 858.28 Hm^3 and the Uc of 113 192.08 Hm^3 (47%). That is, in the north, almost 100% of surface water is consumed for different purposes, resulting in severe water stress.

The northern regions experience severe water stress, characterized by high local basin (Cp) values and consumptive use (Uc). The substantial exploitation of available surface water across various sectors intensifies pressure on already scarce resources.

The southern regions, which face significant barriers to infrastructure development, exhibit lower water utilization rates. These challenges include irregular precipitation patterns, limited investment, environmental constraints, social resistance, and the recognition of indigenous rights. Furthermore, limited hydropower potential necessitates the exploration of alternative energy sources. Developing hydropower infrastructure presents a significant challenge, demanding a careful equilibrium between energy generation and ecological and social considerations. Southeastern basins, like the Usumacinta and Grijalva, exhibit substantial hydropower potential, yet they also face considerable hurdles.

Legal requirements for ecological flows, as demonstrated by the environmental flow decrees for the Usumacinta River, frequently clash with hydropower operational demands. Furthermore, indigenous rights and local opposition create additional complexities for the implementation of infrastructure. Achieving sustainable hydropower development requires a commitment to prioritizing biodiversity conservation, respecting indigenous rights, and ensuring equitable distribution of resources. This approach aims to harmonize energy needs with the preservation of vital ecosystems and the well-being of local communities. This paper underscores the urgent need for stronger regulatory interventions to combat illegal surface water extraction and restore ecological balance. Strict enforcement of ecological flow requirements in perennial channels is crucial for protecting ecosystems. The remaining flows should be allocated for consumptive uses, prioritizing human consumption and essential agriculture.

In conclusion, Mexico faces complex challenges in managing its water resources and meeting its energy demands. However, proactive and integrated measures that prioritize sustainability, equity, and resilience can overcome these obstacles. By embracing innovative solutions and fostering the responsible use of natural resources, Mexico can secure long-term environmental health and equitable access to resources for all its regions.

Acknowledgments

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Nacional de Ciencia y Tecnología (Conacyt) (currently Secretaría de Ciencias, Humanidades, Tecnología e Innovación).

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Supplementary material

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
101	0.19	113.99	0.54	0.76	0.03	0.67	0.117
102	0.06	97.71	0.55	0.79	0.01	0.74	0.050
103	0.23	128.80	0.47	0.70	0.00	0.68	0.196
104	0.09	117.45	0.44	0.71	0.01	0.61	0.133
105	0.18	110.18	0.51	0.62	0.00	0.58	0.199
106	0.16	118.61	0.46	0.66	0.00	0.59	0.174
107	0.15	86.69	0.46	0.66	0.00	0.62	0.201
108	0.20	106.79	0.42	0.66	0.02	0.67	0.200
109	0.20	136.65	0.36	0.71	0.04	0.65	0.201
110	0.29	78.08	0.42	0.62	0.05	0.63	0.200
111	0.34	76.14	0.50	0.59	0.07	0.63	0.186
112	0.36	80.51	0.54	0.48	0.02	0.53	0.188
113	0.24	60.28	0.59	0.64	0.08	0.58	0.174
114	0.29	62.09	0.56	0.49	0.05	0.56	0.200
115	0.12	68.44	0.60	0.59	0.06	0.62	0.202
116	0.32	80.12	0.51	0.81	0.08	0.58	0.202
201	0.31	43.73	0.48	0.95	0.08	0.67	0.203
202	0.32	44.97	0.50	1.19	0.06	0.66	0.203
203	0.15	50.70	0.49	1.03	0.02	0.59	0.203
204	0.09	63.75	0.46	0.97	0.01	0.54	0.203
205	0.11	56.75	0.42	0.90	0.00	0.48	0.203
206	0.14	31.78	0.44	0.88	0.00	0.60	0.203
207	0.12	33.50	0.35	0.65	0.03	0.62	0.203
208	0.09	35.64	0.16	0.64	0.01	0.63	0.203
209	0.08	38.01	0.04	0.66	0.12	0.48	0.203
210	0.15	73.93	0.06	0.65	0.16	0.51	0.203
211	0.11	26.61	0.08	0.64	0.16	0.67	0.203
212	0.06	32.05	0.06	0.55	0.07	0.66	0.236
213	0.01	74.21	0.03	0.63	0.03	0.67	0.175
214	0.02	66.38	0.33	0.56	0.01	0.64	0.195
215	0.15	50.62	0.51	0.59	0.04	0.69	0.169
216	0.01	58.70	0.51	0.58	0.00	0.56	0.404
301	0.02	104.90	0.37	0.59	0.00	0.73	0.656
302	0.05	141.39	0.36	0.73	0.06	0.83	0.657
303	0.10	150.00	0.23	0.62	0.08	0.80	0.318
304	0.11	166.04	0.33	0.52	0.17	0.83	0.268
305	0.08	170.55	0.03	0.58	0.16	0.70	0.283
306	0.11	170.52	0.06	0.63	0.14	0.67	0.227
307	0.07	190.32	0.02	0.55	0.07	0.67	0.223
308	0.06	160.42	0.29	0.49	0.00	0.63	0.258
309	0.00	156.44	0.40	0.44	0.13	0.65	0.222
310	0.03	139.17	0.33	0.56	0.03	0.72	0.225
311	0.02	144.76	0.33	0.44	0.06	0.69	0.401
312	0.03	174.63	0.27	0.34	0.10	0.62	0.330
313	0.02	174.52	0.09	0.37	0.04	0.62	0.222
314	0.02	212.99	0.36	0.43	0.01	0.69	0.180
315	0.10	163.26	0.36	0.43	0.03	0.65	0.257
401	0.24	67.71	0.43	0.89	0.14	0.65	0.663
402	0.02	76.26	0.37	0.76	0.12	0.55	0.668
403	0.21	58.75	0.33	0.89	0.04	0.58	0.654

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
404	0.10	65.23	0.33	0.59	0.08	0.41	0.628
405	0.27	61.28	0.42	0.58	0.07	0.46	0.441
406	0.20	52.96	0.39	0.61	0.13	0.46	0.203
407	0.18	65.96	0.40	0.90	0.12	0.44	0.203
408	0.14	106.05	0.53	0.59	0.09	0.78	0.202
501	0.12	59.71	0.38	1.03	0.03	0.47	0.203
502	0.14	45.82	0.36	0.80	0.00	0.54	0.203
503	0.14	34.47	0.35	0.70	0.01	0.53	0.203
504	0.05	34.15	0.16	0.58	0.15	0.45	0.203
505	0.01	28.14	0.14	0.46	0.31	0.50	0.203
506	0.06	69.06	0.23	0.46	0.25	0.63	0.203
507	0.11	79.43	0.31	0.53	0.18	0.62	0.203
508	0.07	89.67	0.33	0.80	0.04	0.60	0.320
509	0.05	155.57	0.31	0.73	0.08	0.55	0.088
510	0.00	98.54	0.32	0.43	0.08	0.53	0.321
511	0.13	132.03	0.36	0.45	0.13	0.56	0.326
512	0.12	128.01	0.41	0.51	0.11	0.53	0.645
513	0.14	117.05	0.43	0.51	0.14	0.55	0.053
514	0.13	154.57	0.46	0.55	0.04	0.55	0.056
515	0.22	224.00	0.32	0.51	0.03	0.61	0.089
601	0.01	189.34	0.53	0.58	0.00	0.70	0.447
602	0.01	182.49	0.40	0.50	0.00	0.62	0.378
603	0.01	152.03	0.56	0.39	0.00	0.64	0.171
604	0.01	175.47	0.22	0.35	0.04	0.62	0.213
605	0.03	207.01	0.43	0.35	0.27	0.61	0.281
606	0.01	136.81	0.32	0.52	0.13	0.54	0.285
607	0.00	131.74	0.20	0.54	0.01	0.58	0.438
608	0.09	152.31	0.00	0.90	0.00	0.55	0.229
609	0.17	179.07	0.09	0.65	0.05	0.65	0.262
610	0.05	205.02	0.01	1.15	0.21	0.63	0.661
611	0.19	190.41	0.30	0.53	0.09	0.66	0.692
612	0.18	159.22	0.10	0.51	0.05	0.65	0.660
613	0.09	112.22	0.10	0.61	0.00	0.65	0.661
614	0.09	96.70	0.27	0.63	0.01	0.61	0.483
701	0.17	39.20	0.45	0.86	0.12	0.59	0.280
702	0.10	169.26	0.49	0.77	0.20	0.77	0.300
703	0.05	113.97	0.57	1.03	0.14	0.67	0.905
704	0.10	241.85	0.56	0.62	0.36	0.51	0.174
801	0.12	91.45	0.43	0.53	0.13	0.35	0.017
802	0.19	59.57	0.38	0.54	0.09	0.35	0.072
803	0.09	129.35	0.57	0.61	0.39	0.39	0.339
804	0.01	92.64	0.58	0.50	0.39	0.46	–0.102
805	0.02	68.13	0.35	0.51	0.19	0.37	–0.243
806	0.08	30.95	0.48	0.63	0.16	0.53	0.510
807	0.12	36.15	0.43	0.60	0.13	0.37	0.408
808	0.15	65.07	0.44	0.56	0.10	0.36	0.300
809	0.05	77.81	0.39	0.55	0.12	0.41	0.072
901	0.03	104.53	0.56	0.57	0.09	0.38	0.601
902	0.02	122.08	0.47	0.73	0.13	0.41	0.458

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
903	0.01	100.77	0.53	0.68	0.12	0.41	0.379
904	0.00	109.34	0.44	0.55	0.14	0.44	0.019
905	0.00	81.66	0.49	0.40	0.00	0.45	0.481
906	0.00	104.44	0.30	0.59	0.00	0.49	0.590
907	0.04	107.27	0.59	0.76	0.09	0.46	0.421
908	0.02	146.05	0.58	0.60	0.02	0.49	0.059
909	0.04	126.68	0.47	0.55	0.00	0.40	0.449
910	0.00	98.40	0.31	0.52	0.02	0.52	0.060
911	0.00	162.45	0.36	0.60	0.08	0.42	0.449
912	0.00	188.91	0.48	0.63	0.13	0.52	–0.046
913	0.01	233.12	0.44	0.68	0.01	0.39	0.492
914	0.09	124.05	0.36	0.60	0.09	0.34	0.449
915	0.00	185.58	0.37	0.72	0.00	0.37	0.495
916	0.03	158.70	0.54	0.54	0.06	0.47	–0.063
1001	0.43	471.47	0.16	0.27	0.28	0.61	0.150
1002	0.01	122.72	0.36	0.54	0.18	0.66	–0.117
1003	0.25	184.87	0.25	0.41	0.15	0.68	0.358
1004	0.05	134.36	0.17	0.49	0.14	0.71	0.626
1005	0.00	204.94	0.09	0.38	0.00	0.51	0.017
1006	0.00	152.16	0.08	0.43	0.02	0.52	–0.131
1007	0.05	164.48	0.06	0.45	0.30	0.51	0.013
1008	0.00	174.42	0.25	0.41	0.22	0.63	–0.235
1009	0.03	129.33	0.33	0.46	0.51	0.43	0.210
1010	0.03	198.63	0.38	0.41	0.36	0.52	0.209
1011	0.00	142.55	0.42	0.36	0.13	0.58	0.038
1012	0.05	217.49	0.45	0.54	0.28	0.43	0.131
1013	0.04	248.35	0.49	0.41	0.20	0.35	–0.013
1014	0.04	177.45	0.60	0.43	0.14	0.41	0.551
1015	0.02	142.62	0.43	0.51	0.12	0.39	–0.094
1016	0.07	209.44	0.17	0.36	0.14	0.60	0.154
1017	0.00	117.48	0.36	0.50	0.17	0.67	0.106
1018	0.02	237.25	0.33	0.39	0.30	0.43	0.342
1019	0.05	145.11	0.34	0.47	0.12	0.38	0.125
1020	0.12	152.67	0.16	0.47	0.01	0.52	0.282
1021	0.04	147.42	0.13	0.43	0.00	0.50	–0.049
1022	0.01	198.27	0.21	0.39	0.06	0.51	0.213
1023	0.01	218.90	0.30	0.51	0.03	0.56	–0.012
1024	0.00	152.07	0.46	0.52	0.03	0.48	–0.149
1025	0.00	102.78	0.21	0.51	0.01	0.56	–0.128
1026	0.02	139.46	0.07	0.45	0.03	0.53	–0.271
1027	0.04	126.51	0.21	0.54	0.00	0.52	–0.045
1028	0.15	237.21	0.45	0.51	0.12	0.61	–0.113
1029	0.02	201.95	0.36	0.39	0.20	0.69	–0.331
1030	0.08	138.61	0.41	0.54	0.03	0.57	–0.012
1101	0.00	206.05	0.04	0.63	0.04	0.82	0.437
1102	0.00	181.65	0.10	0.64	0.03	0.83	0.145
1103	0.00	137.00	0.06	1.41	0.02	0.60	0.158
1104	0.01	131.21	0.20	0.93	0.06	0.60	–0.191
1105	0.05	162.48	0.01	0.87	0.02	0.62	0.164

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
1106	0.00	140.52	0.10	0.75	0.02	0.66	0.177
1107	0.00	160.23	0.30	0.80	0.03	0.63	–0.186
1108	0.05	147.11	0.24	1.00	0.03	0.62	–0.034
1109	0.02	164.88	0.16	0.44	0.32	0.58	–0.178
1110	0.02	145.02	0.03	0.55	0.29	0.55	–0.096
1111	0.17	171.18	0.02	0.57	0.21	0.55	0.173
1112	0.25	264.09	0.00	0.50	0.09	0.67	0.142
1113	0.03	186.84	0.45	0.44	0.01	0.64	0.240
1114	0.01	203.03	0.05	0.60	0.08	0.71	0.612
1115	0.06	207.17	0.00	0.72	0.06	0.80	0.540
1116	0.01	182.03	0.12	0.45	0.03	0.65	0.452
1117	0.07	170.06	0.02	0.55	0.13	0.73	0.182
1118	0.08	228.94	0.04	0.44	0.00	0.71	0.126
1119	0.00	207.05	0.20	0.56	0.01	0.83	0.191
1120	0.01	201.93	0.26	0.41	0.00	0.58	0.416
1121	0.01	211.26	0.30	0.45	0.00	0.58	0.417
1122	0.03	178.50	0.25	0.43	0.00	0.55	0.425
1123	0.01	179.54	0.40	0.45	0.01	0.63	0.216
1124	0.04	254.38	0.06	0.57	0.13	0.73	0.133
1125	0.02	254.47	0.01	0.70	0.08	0.83	0.162
1126	0.00	171.52	0.20	0.55	0.01	0.80	0.405
1201	0.27	106.13	0.53	0.45	0.40	0.36	0.064
1202	0.16	190.93	0.47	0.56	0.18	0.38	–0.057
1203	0.02	131.57	0.22	0.45	0.00	0.31	–0.085
1204	0.15	133.69	0.26	0.37	0.00	0.41	–0.026
1205	0.00	147.93	0.44	0.42	0.02	0.37	–0.053
1206	0.02	145.44	0.51	0.45	0.01	0.46	–0.230
1207	0.06	151.61	0.51	0.51	0.00	0.37	0.263
1208	0.00	94.53	0.41	0.49	0.00	0.39	0.188
1209	0.03	185.38	0.32	0.50	0.01	0.38	–0.028
1210	0.03	203.22	0.56	0.47	0.02	0.48	–0.235
1211	0.09	173.65	0.11	0.50	0.03	0.53	–0.045
1212	0.00	150.24	0.51	0.37	0.07	0.41	0.375
1213	0.06	159.23	0.23	0.39	0.01	0.41	–0.143
1214	0.01	171.84	0.01	0.40	0.05	0.60	–0.010
1215	0.02	235.95	0.33	0.38	0.01	0.52	0.042
1216	0.00	142.10	0.38	0.38	0.05	0.50	0.670
1217	0.00	147.45	0.43	0.39	0.00	0.54	0.157
1218	0.00	96.33	0.57	0.41	0.16	0.38	0.534
1219	0.03	124.69	0.68	0.50	0.05	0.42	0.121
1220	0.08	162.28	0.27	0.52	0.14	0.52	0.067
1221	0.07	200.89	0.43	0.49	0.09	0.49	0.202
1222	0.11	151.27	0.36	0.57	0.00	0.47	0.145
1223	0.12	214.76	0.34	0.56	0.04	0.47	0.248
1224	0.05	183.06	0.32	0.56	0.11	0.53	0.089
1225	0.05	178.21	0.39	0.72	0.04	0.58	0.133
1226	0.03	147.50	0.35	0.78	0.13	0.58	0.042
1227	0.06	178.00	0.40	0.79	0.03	0.51	0.075
1228	0.00	177.62	0.44	0.83	0.20	0.61	0.085

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
1229	0.03	192.43	0.11	0.55	0.10	0.54	0.058
1230	0.01	157.89	0.13	0.51	0.01	0.52	0.043
1231	0.00	143.89	0.29	0.73	0.08	0.56	0.112
1232	0.02	157.39	0.27	0.46	0.01	0.53	0.159
1233	0.02	185.88	0.41	0.48	0.32	0.61	0.029
1234	0.02	181.88	0.36	0.52	0.28	0.62	–0.038
1235	0.05	161.54	0.32	0.58	0.05	0.59	0.456
1236	0.00	121.98	0.35	0.60	0.02	0.59	0.315
1237	0.07	136.75	0.23	0.44	0.00	0.49	0.233
1238	0.05	141.71	0.16	0.57	0.01	0.58	0.209
1239	0.02	129.69	0.17	0.59	0.00	0.56	0.355
1240	0.03	138.08	0.00	0.64	0.07	0.63	0.359
1241	0.02	158.19	0.38	0.60	0.18	0.70	–0.114
1242	0.05	134.18	0.48	0.62	0.05	0.67	0.979
1243	0.00	182.26	0.47	0.66	0.02	0.57	0.049
1244	0.00	165.12	0.48	0.61	0.14	0.63	–0.010
1245	0.00	132.52	0.36	0.63	0.00	0.61	0.269
1246	0.00	168.14	0.12	0.54	0.20	0.60	0.041
1247	0.05	168.90	0.24	0.58	0.09	0.54	0.194
1248	0.10	227.00	0.09	0.45	0.21	0.55	0.172
1249	0.00	243.75	0.19	0.44	0.13	0.51	0.322
1250	0.00	218.78	0.00	0.52	0.20	0.77	0.413
1251	0.05	300.90	0.07	0.46	0.02	0.54	0.373
1252	0.05	276.58	0.18	0.44	0.03	0.57	0.249
1253	0.03	133.78	0.06	0.59	0.07	0.50	0.365
1254	0.05	114.59	0.12	0.59	0.08	0.45	0.124
1255	0.05	163.12	0.22	0.48	0.04	0.56	0.342
1256	0.00	161.63	0.27	0.39	0.09	0.46	0.352
1257	0.04	138.25	0.33	0.37	0.09	0.46	0.289
1258	0.02	175.06	0.28	0.44	0.02	0.49	0.276
1301	0.03	379.58	0.08	0.47	0.04	0.58	0.244
1302	0.30	150.94	0.32	0.41	0.01	0.69	0.473
1303	0.27	248.28	0.29	0.43	0.00	0.65	0.259
1304	0.04	175.76	0.21	0.43	0.03	0.58	0.171
1305	0.08	147.64	0.03	0.49	0.05	0.60	0.094
1306	0.02	252.62	0.30	0.41	0.01	0.71	0.762
1401	0.09	121.05	0.01	0.54	0.13	0.56	0.618
1402	0.04	134.76	0.02	0.55	0.06	0.51	0.618
1403	0.08	324.52	0.01	0.50	0.44	0.72	0.231
1404	0.03	221.26	0.17	0.37	0.23	0.53	0.361
1405	0.09	153.00	0.01	0.44	0.44	0.62	0.395
1406	0.00	153.67	0.10	0.41	0.17	0.68	0.246
1407	0.13	204.46	0.21	0.36	0.04	0.61	0.361
1408	0.02	165.04	0.33	0.40	0.17	0.60	0.374
1409	0.19	146.75	0.15	0.40	0.03	0.65	0.235
1501	0.00	281.59	0.26	0.41	0.03	0.74	0.857
1502	0.13	403.74	0.16	0.41	0.07	0.76	0.858
1503	0.18	196.61	0.13	0.42	0.09	0.74	0.556
1504	0.07	189.38	0.02	0.41	0.01	0.65	0.545
1505	0.09	276.04	0.06	0.49	0.17	0.78	0.604

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
1506	0.02	247.79	0.05	0.44	0.09	0.64	0.758
1507	0.01	397.81	0.00	0.44	0.10	0.78	0.849
1508	0.08	463.66	0.01	0.51	0.05	0.67	0.857
1509	0.24	396.59	0.01	0.59	0.02	0.80	0.781
1510	0.06	231.39	0.07	0.57	0.01	0.86	0.177
1511	0.15	259.47	0.13	0.43	0.05	0.87	0.103
1601	0.01	213.40	0.05	0.45	0.00	0.51	0.325
1602	0.02	229.19	0.13	0.41	0.02	0.55	0.267
1603	0.02	187.72	0.12	0.43	0.09	0.53	0.338
1604	0.02	152.02	0.30	0.31	0.01	0.56	0.316
1605	0.00	161.22	0.14	0.42	0.00	0.70	0.218
1606	0.09	215.89	0.12	0.32	0.05	0.67	0.158
1607	0.15	130.94	0.18	0.48	0.02	0.48	0.341
1608	0.28	150.77	0.05	0.39	0.02	0.64	0.386
1609	0.00	158.02	0.12	0.38	0.07	0.62	0.181
1610	0.05	220.11	0.39	0.56	0.11	0.63	0.052
1701	0.01	213.09	0.40	0.44	0.04	0.58	0.491
1702	0.12	199.72	0.46	0.33	0.02	0.55	0.651
1703	0.02	299.68	0.33	0.43	0.00	0.54	0.554
1704	0.00	310.04	0.34	0.36	0.04	0.53	0.377
1705	0.05	509.45	0.26	0.39	0.01	0.53	0.165
1706	0.17	396.24	0.18	0.44	0.00	0.53	–0.102
1801	0.09	86.25	0.09	0.41	0.16	0.43	0.080
1802	0.23	187.14	0.44	0.39	0.07	0.49	0.118
1803	0.12	569.24	0.01	0.21	0.45	0.43	0.074
1804	0.33	78.55	0.11	0.30	0.07	0.49	0.249
1805	0.18	144.40	0.08	0.30	0.07	0.56	0.297
1806	0.18	69.42	0.02	0.44	0.22	0.39	0.379
1807	0.01	140.67	0.51	0.49	0.01	0.39	0.035
1808	0.00	110.73	0.35	0.33	0.45	0.51	0.213
1809	0.08	195.97	0.52	0.39	0.10	0.44	0.177
1810	0.00	187.83	0.53	0.55	0.00	0.53	0.661
1811	0.01	110.08	0.28	0.38	0.03	0.52	0.143
1812	0.12	146.11	0.07	0.35	0.05	0.46	0.094
1813	0.11	206.42	0.56	0.39	0.02	0.41	0.351
1814	0.01	126.44	0.66	0.42	0.13	0.38	0.697
1815	0.11	71.28	0.32	0.44	0.06	0.49	0.356
1901	0.15	194.27	0.10	0.41	0.00	0.49	–0.239
1902	0.19	589.09	0.00	0.42	0.12	0.55	–0.271
1903	0.03	289.55	0.05	0.42	0.00	0.46	–0.264
1904	0.02	205.72	0.00	0.39	0.08	0.41	–0.249
1905	0.03	555.66	0.10	0.39	0.29	0.50	–0.269
1906	0.01	249.44	0.00	0.40	0.03	0.42	–0.026
1907	0.03	405.05	0.01	0.38	0.08	0.40	–0.041
1908	0.33	404.51	0.12	0.39	0.35	0.41	–0.174
1909	0.29	361.23	0.06	0.36	0.38	0.42	–0.224
1910	0.20	281.98	0.01	0.38	0.12	0.43	–0.106
1911	0.01	236.69	0.01	0.39	0.09	0.42	–0.266
1912	0.01	390.10	0.03	0.45	0.37	0.40	–0.270
1913	0.00	226.82	0.02	0.58	0.05	0.38	–0.223

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
1914	0.03	240.67	0.00	0.58	0.07	0.35	–0.243
1915	0.03	445.79	0.10	0.66	0.31	0.37	–0.266
1916	0.00	546.82	0.03	0.58	0.02	0.38	–0.096
1917	0.03	517.59	0.09	0.67	0.02	0.35	–0.261
1918	0.01	321.57	0.20	0.91	0.24	0.34	–0.272
1919	0.06	367.68	0.09	0.61	0.01	0.38	–0.179
1920	0.14	262.09	0.01	0.52	0.00	0.40	–0.204
1921	0.04	565.18	0.00	0.49	0.34	0.19	–0.214
1922	0.05	333.83	0.00	0.53	0.00	0.41	–0.147
1923	0.03	239.66	0.09	0.48	0.04	0.36	–0.245
1924	0.04	440.98	0.20	0.37	0.36	0.19	–0.244
1925	0.16	395.93	0.33	0.51	0.03	0.24	–0.117
1926	0.17	287.78	0.36	0.45	0.23	0.25	0.094
1927	0.00	636.65	0.31	0.49	0.39	0.21	0.384
1928	0.01	271.79	0.53	0.31	0.27	0.29	0.389
2001	0.07	561.51	0.11	0.39	0.54	0.23	0.575
2002	0.23	336.09	0.16	0.33	0.64	0.28	0.114
2003	0.06	703.82	0.30	0.26	0.60	0.33	0.344
2004	0.03	389.57	0.10	0.68	0.41	0.24	0.417
2005	0.17	637.99	0.35	0.42	0.37	0.27	0.592
2006	0.08	468.86	0.52	0.36	0.28	0.36	0.467
2007	0.01	266.66	0.37	0.44	0.26	0.40	0.463
2008	0.01	446.10	0.39	0.49	0.39	0.35	0.514
2009	0.01	450.45	0.12	0.61	0.08	0.41	0.243
2010	0.06	596.09	0.05	0.69	0.05	0.42	0.516
2011	0.20	857.83	0.02	0.71	0.14	0.40	0.537
2012	0.23	590.80	0.00	1.24	0.01	0.43	0.491
2013	0.31	1092.96	0.04	0.65	0.20	0.42	0.372
2014	0.11	865.86	0.05	0.58	0.23	0.51	0.120
2015	0.01	833.98	0.00	0.64	0.00	0.46	–0.029
2016	0.01	686.05	0.01	0.62	0.04	0.44	0.514
2017	0.22	434.28	0.00	0.69	0.00	0.44	0.650
2018	0.10	327.73	0.00	0.70	0.02	0.45	0.565
2019	0.09	405.38	0.02	0.63	0.00	0.47	0.236
2020	0.35	431.94	0.00	0.67	0.00	0.45	0.438
2021	0.16	358.65	0.00	0.69	0.01	0.47	0.429
2022	0.01	388.46	0.00	0.71	0.02	0.46	0.469
2023	0.06	401.20	0.00	0.75	0.01	0.46	0.588
2024	0.07	347.38	0.03	0.65	0.01	0.42	0.332
2025	0.00	358.40	0.01	0.69	0.04	0.48	0.393
2026	0.11	243.00	0.01	0.77	0.02	0.47	0.472
2027	0.00	334.03	0.00	1.05	0.02	0.47	0.659
2028	0.11	241.66	0.20	0.37	0.00	0.41	–0.100
2029	0.07	157.53	0.18	0.47	0.01	0.45	–0.092
2030	0.14	248.38	0.13	0.48	0.01	0.41	–0.058
2031	0.31	336.05	0.21	0.52	0.00	0.44	–0.064
2032	0.25	506.88	0.08	0.59	0.01	0.43	0.276
2101	0.16	478.03	0.05	0.57	0.03	0.46	0.192
2102	0.31	366.21	0.16	0.53	0.00	0.44	0.376
2103	0.45	614.99	0.13	0.50	0.01	0.48	0.318

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
2104	0.26	578.84	0.18	0.49	0.00	0.43	0.210
2105	0.11	417.41	0.09	0.55	0.01	0.46	0.395
2106	0.05	445.65	0.19	0.49	0.00	0.48	0.313
2107	0.08	448.98	0.10	0.54	0.00	0.46	0.404
2108	0.09	348.51	0.17	0.49	0.00	0.49	0.303
2109	0.09	290.30	0.08	0.55	0.00	0.46	0.380
2110	0.05	391.39	0.31	0.42	0.10	0.57	0.040
2111	0.01	404.57	0.02	0.59	0.00	0.59	0.496
2112	0.06	303.19	0.08	0.55	0.00	0.55	0.271
2113	0.00	418.83	0.04	0.55	0.03	0.59	0.633
2114	0.09	577.16	0.01	0.61	0.02	0.60	0.714
2115	0.02	473.78	0.02	0.74	0.07	0.61	0.900
2116	0.03	310.53	0.00	0.66	0.02	0.60	0.797
2117	0.19	504.05	0.00	0.79	0.04	0.59	0.937
2118	0.28	398.66	0.00	0.75	0.06	0.59	0.803
2119	0.28	396.53	0.02	0.84	0.05	0.63	0.484
2201	0.05	184.54	0.00	0.57	0.02	0.40	0.015
2202	0.01	250.01	0.14	0.66	0.05	0.47	0.858
2203	0.03	265.27	0.42	0.50	0.01	0.39	1.661
2204	0.04	350.30	0.00	0.55	0.06	0.55	1.410
2205	0.03	409.36	0.35	0.58	0.02	0.58	0.648
2206	0.04	482.30	0.08	0.83	0.01	0.60	4.947
2207	0.03	487.33	0.00	0.61	0.01	0.82	5.147
2208	0.00	413.72	0.04	0.69	0.18	0.75	0.699
2209	0.03	401.64	0.00	0.86	0.06	1.07	4.612
2210	0.03	335.04	0.01	0.77	0.05	0.85	0.824
2211	0.16	410.40	0.01	0.65	0.13	0.68	0.696
2212	0.04	412.17	0.01	0.68	0.05	0.84	0.887
2213	0.11	439.93	0.04	0.58	0.06	0.57	0.926
2214	0.00	449.16	0.00	0.58	0.03	0.51	0.616
2215	0.07	377.51	0.02	0.65	0.02	0.56	0.695
2301	0.01	489.65	0.05	0.65	0.00	0.66	0.832
2302	0.02	527.38	0.02	0.57	0.01	0.65	0.400
2303	0.05	411.56	0.03	0.60	0.00	0.61	0.443
2304	0.37	391.79	0.01	0.54	0.02	0.53	–0.038
2305	0.44	556.10	0.00	0.55	0.02	0.36	0.067
2306	0.21	559.31	0.00	0.57	0.01	0.44	0.053
2307	0.11	618.41	0.02	0.49	0.00	0.33	0.037
2308	0.05	661.43	0.02	0.50	0.02	0.33	0.032
2309	0.03	572.28	0.01	0.49	0.00	0.31	0.030
2310	0.00	560.04	0.00	0.44	0.00	0.36	0.026
2311	0.01	530.72	0.00	0.42	0.00	0.35	0.030
2312	0.02	595.63	0.00	0.44	0.00	0.34	0.047
2313	0.06	619.86	0.02	0.46	0.02	0.36	0.101
2314	0.06	730.91	0.01	0.39	0.00	0.33	0.149
2315	0.03	866.27	0.00	0.44	0.00	0.26	0.149
2316	0.03	904.36	0.00	0.46	0.00	0.24	0.149
2317	0.07	929.52	0.02	0.43	0.05	0.26	0.144
2318	0.09	801.11	0.07	0.43	0.03	0.28	0.138
2319	0.09	656.21	0.34	0.37	0.16	0.33	0.141

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
2320	0.04	638.27	0.03	0.38	0.12	0.39	0.143
2321	0.01	716.56	0.08	0.35	0.15	0.38	0.113
2322	0.03	597.89	0.01	0.36	0.00	0.39	0.138
2323	0.09	954.73	0.31	0.35	0.08	0.43	0.136
2324	0.23	527.62	0.24	0.41	0.00	0.39	–0.140
2325	0.06	788.39	0.43	0.30	0.13	0.47	–0.086
2401	0.07	124.81	0.36	0.76	0.15	0.59	0.205
2402	0.01	121.04	0.23	0.82	0.13	0.48	0.352
2403	0.02	178.84	0.00	0.51	0.37	0.37	0.191
2404	0.01	152.45	0.20	0.65	0.47	0.41	–0.487
2405	0.00	159.86	0.01	0.48	0.24	0.44	–0.080
2406	0.03	170.48	0.02	0.52	0.14	0.44	0.264
2407	0.00	146.01	0.12	0.50	0.49	0.37	0.243
2408	0.02	220.53	0.23	0.51	0.13	0.49	0.349
2409	0.03	157.26	0.11	0.93	0.00	0.44	–0.273
2410	0.00	130.32	0.24	0.75	0.08	0.51	0.010
2411	0.02	102.90	0.17	0.80	0.09	0.63	0.419
2412	0.00	171.57	0.29	0.66	0.00	0.47	0.310
2413	0.01	141.59	0.30	0.70	0.03	0.43	0.331
2414	0.01	116.38	0.11	0.88	0.06	0.66	0.648
2415	0.04	111.69	0.07	1.03	0.08	0.66	0.556
2416	0.06	121.84	0.06	1.15	0.22	0.60	0.712
2417	0.11	197.32	0.03	1.18	0.32	0.58	0.710
2418	0.05	144.77	0.03	1.24	0.32	0.58	0.246
2419	0.01	125.55	0.02	1.27	0.32	0.58	2.062
2420	0.08	204.66	0.02	1.23	0.35	0.54	2.811
2421	0.00	143.66	0.01	1.34	0.36	0.55	0.710
2422	0.07	216.37	0.01	1.32	0.39	0.54	0.726
2423	0.00	265.27	0.00	1.48	0.41	0.54	0.646
2424	0.00	244.55	0.01	1.41	0.44	0.55	0.524
2425	0.01	213.61	0.16	1.34	0.33	0.55	0.506
2426	0.02	109.21	0.05	1.32	0.19	0.53	0.568
2427	0.03	138.11	0.05	1.22	0.21	0.44	0.308
2428	0.04	187.00	0.27	1.17	0.21	0.56	0.729
2429	0.02	197.67	0.28	1.13	0.13	0.66	0.281
2430	0.05	235.81	0.25	1.23	0.07	0.65	0.281
2431	0.00	174.97	0.16	0.80	0.10	0.41	0.180
2432	0.04	230.53	0.30	0.86	0.14	0.55	0.154
2433	0.02	308.17	0.39	0.65	0.11	0.45	0.265
2434	0.04	261.41	0.17	1.19	0.16	0.64	0.264
2435	0.08	206.06	0.19	1.12	0.15	0.66	0.571
2436	0.04	203.42	0.24	1.09	0.16	0.68	4.444
2437	0.00	228.74	0.27	1.02	0.20	0.66	0.556
2501	0.00	291.96	0.13	1.10	0.27	0.59	0.316
2502	0.03	249.36	0.12	1.01	0.11	0.60	0.263
2503	0.03	212.98	0.04	0.98	0.01	0.61	0.450
2504	0.00	276.52	0.14	1.09	0.14	0.55	0.410
2505	0.00	273.51	0.10	1.10	0.02	0.67	0.337
2506	0.08	261.33	0.20	1.06	0.08	0.62	0.223
2507	0.01	309.73	0.22	1.07	0.08	0.58	0.262

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
2508	0.01	209.48	0.32	1.06	0.12	0.61	0.260
2509	0.06	186.30	0.22	1.01	0.07	0.59	0.223
2510	0.01	211.08	0.20	1.06	0.03	0.67	0.293
2511	0.03	252.99	0.15	1.09	0.04	0.64	–0.433
2512	0.03	186.54	0.31	0.87	0.00	0.62	0.344
2513	0.00	293.81	0.39	0.88	0.01	0.62	–0.284
2514	0.02	290.00	0.42	0.81	0.01	0.58	0.365
2515	0.03	289.26	0.36	0.78	0.01	0.55	0.365
2516	0.04	315.61	0.34	0.76	0.01	0.70	0.383
2517	0.01	372.80	0.35	0.72	0.01	0.59	0.491
2518	0.01	385.80	0.37	0.69	0.02	0.56	0.508
2519	0.05	206.51	0.26	0.81	0.00	0.57	0.360
2520	0.05	231.10	0.21	0.77	0.00	0.55	0.493
2521	0.02	334.86	0.32	0.63	0.01	0.55	0.503
2522	0.19	263.60	0.07	0.69	0.00	0.52	0.408
2523	0.00	245.81	0.21	0.67	0.00	0.52	0.501
2524	0.15	242.87	0.08	0.87	0.00	0.52	0.470
2525	0.00	217.48	0.36	0.79	0.01	0.51	0.483
2526	0.01	294.70	0.34	0.62	0.02	0.55	0.515
2527	0.05	343.54	0.55	0.72	0.03	0.51	0.177
2528	0.03	255.65	0.26	0.84	0.14	0.46	0.396
2529	0.01	284.41	0.16	0.73	0.22	0.57	0.332
2530	0.06	296.41	0.18	0.91	0.24	0.57	0.327
2531	0.03	297.33	0.17	0.86	0.25	0.62	0.349
2532	0.01	240.67	0.09	1.06	0.23	0.59	0.300
2533	0.01	203.08	0.11	1.06	0.19	0.59	0.309
2534	0.04	218.90	0.13	1.16	0.23	0.60	0.328
2535	0.01	197.69	0.22	1.11	0.28	0.64	0.366
2536	0.05	220.99	0.12	1.32	0.15	0.53	0.101
2537	0.01	202.67	0.14	1.20	0.20	0.65	0.193
2538	0.00	220.06	0.11	0.97	0.09	0.59	0.205
2539	0.01	225.55	0.20	0.95	0.21	0.65	0.014
2540	0.00	216.08	0.25	1.03	0.23	0.70	0.056
2541	0.01	288.70	0.24	1.05	0.16	0.66	0.044
2542	0.01	218.04	0.19	0.89	0.10	0.70	0.248
2543	0.05	215.53	0.26	1.03	0.10	0.67	0.361
2544	0.05	253.20	0.22	0.84	0.06	0.69	0.364
2545	0.02	301.96	0.33	0.93	0.03	0.66	0.365
2601	0.03	158.69	0.09	0.29	0.03	0.47	–0.005
2602	0.02	143.92	0.17	0.46	0.09	0.45	0.092
2603	0.14	167.79	0.33	0.47	0.02	0.45	0.275
2604	0.03	120.23	0.33	0.45	0.00	0.50	0.240
2605	0.01	88.08	0.24	0.39	0.00	0.57	0.144
2606	0.01	140.82	0.26	0.37	0.02	0.49	0.330
2607	0.16	147.69	0.39	0.41	0.08	0.43	0.264
2608	0.02	102.55	0.46	0.47	0.02	0.42	0.198
2609	0.01	335.83	0.36	0.62	0.00	0.44	0.114
2610	0.11	120.14	0.18	0.65	0.03	0.48	0.166
2611	0.04	97.84	0.14	0.44	0.03	0.45	0.322
2612	0.01	500.32	0.26	0.65	0.07	0.40	0.307

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
2613	0.21	334.06	0.08	0.53	0.13	0.45	0.260
2614	0.01	271.39	0.45	0.67	0.01	0.32	0.305
2615	0.00	358.36	0.46	0.61	0.01	0.35	0.288
2616	0.01	207.07	0.47	0.68	0.04	0.40	0.426
2617	0.03	294.02	0.29	0.79	0.00	0.38	0.339
2618	0.07	230.01	0.37	0.90	0.03	0.37	0.419
2619	0.01	141.18	0.28	0.71	0.01	0.32	–0.074
2620	0.00	110.89	0.40	0.75	0.01	0.33	1.779
2621	0.00	175.01	0.34	0.78	0.04	0.38	0.882
2622	0.03	221.65	0.14	0.55	0.00	0.38	0.361
2623	0.06	206.38	0.11	0.68	0.00	0.39	0.218
2624	0.05	99.01	0.27	0.66	0.05	0.46	0.245
2625	0.04	105.01	0.41	0.60	0.14	0.38	0.178
2626	0.01	270.68	0.32	0.77	0.25	0.38	0.338
2627	0.06	395.09	0.26	0.81	0.06	0.36	0.233
2628	0.04	569.39	0.22	0.84	0.01	0.40	0.403
2629	0.07	398.59	0.21	0.91	0.01	0.39	0.443
2630	0.08	300.06	0.21	0.72	0.00	0.38	0.541
2631	0.03	302.67	0.17	0.79	0.04	0.47	0.688
2632	0.02	424.88	0.22	1.04	0.09	0.45	0.316
2633	0.01	283.22	0.31	0.97	0.12	0.46	2.575
2634	0.03	761.47	0.12	1.01	0.03	0.49	0.405
2635	0.01	381.35	0.13	1.05	0.07	0.46	1.066
2636	0.00	275.02	0.21	1.04	0.15	0.44	3.258
2637	0.02	231.83	0.34	0.61	0.20	0.50	0.256
2638	0.03	117.19	0.30	0.42	0.05	0.48	0.378
2639	0.04	220.11	0.20	0.41	0.27	0.44	0.392
2640	0.03	168.45	0.10	0.39	0.07	0.54	0.332
2641	0.41	229.98	0.05	0.36	0.14	0.48	0.242
2642	0.02	313.28	0.13	0.54	0.17	0.44	0.222
2643	0.04	889.29	0.21	0.79	0.09	0.40	0.328
2644	0.03	985.14	0.24	0.85	0.17	0.37	0.398
2645	0.05	397.82	0.15	1.03	0.02	0.40	0.589
2646	0.06	218.40	0.27	1.04	0.08	0.38	0.675
2647	0.24	209.94	0.12	0.84	0.00	0.45	0.731
2648	0.13	426.77	0.27	0.95	0.11	0.53	0.297
2649	0.07	246.36	0.23	0.93	0.01	0.58	0.282
2650	0.01	508.76	0.16	0.95	0.06	0.51	0.656
2651	0.04	364.88	0.24	0.79	0.00	0.46	0.783
2652	0.04	517.80	0.20	0.79	0.00	0.51	0.110
2653	0.00	577.68	0.25	0.77	0.02	0.51	0.228
2654	0.02	214.11	0.23	0.83	0.00	0.53	0.047
2655	0.05	235.56	0.13	0.97	0.04	0.52	1.033
2656	0.01	553.62	0.26	0.85	0.06	0.47	2.042
2657	0.00	321.82	0.21	0.86	0.00	0.53	1.291
2658	0.00	227.36	0.47	0.87	0.04	0.62	0.334
2659	0.01	248.37	0.23	0.95	0.12	0.47	3.332
2660	0.05	175.85	0.34	0.91	0.05	0.35	0.599
2661	0.00	301.53	0.30	1.13	0.05	0.41	0.499
2662	0.00	169.17	0.42	0.90	0.09	0.43	1.162

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
2663	0.09	270.14	0.25	1.24	0.05	0.41	0.622
2664	0.08	249.96	0.51	0.75	0.07	0.47	0.245
2665	0.06	201.71	0.05	0.64	0.08	0.40	–0.066
2666	0.01	112.94	0.00	0.61	0.21	0.42	0.048
2667	0.00	124.97	0.16	0.43	0.13	0.48	0.155
2668	0.02	84.03	0.30	0.50	0.21	0.41	0.001
2669	0.03	97.82	0.20	0.40	0.44	0.43	0.070
2670	0.17	127.48	0.32	0.39	0.42	0.40	0.046
2671	0.04	186.70	0.39	0.40	0.28	0.49	0.100
2672	0.09	175.15	0.19	0.34	0.11	0.53	0.086
2673	0.12	94.77	0.01	0.33	0.01	0.53	0.192
2674	0.10	50.72	0.37	0.43	0.10	0.45	0.246
2675	0.00	67.40	0.16	0.44	0.00	0.43	0.233
2676	0.00	115.07	0.10	0.55	0.00	0.53	–0.024
2677	0.06	32.11	0.19	0.45	0.00	0.52	0.130
2701	0.02	374.67	0.32	0.85	0.10	0.38	0.595
2702	0.00	351.95	0.28	0.83	0.09	0.34	0.464
2703	0.16	305.14	0.29	1.02	0.08	0.44	0.637
2704	0.08	273.72	0.29	0.86	0.11	0.37	0.619
2705	0.00	317.24	0.15	0.77	0.08	0.34	0.032
2706	0.00	176.94	0.23	0.64	0.05	0.33	0.190
2707	0.02	178.05	0.14	0.45	0.04	0.32	0.170
2708	0.12	204.85	0.27	0.34	0.04	0.43	0.277
2709	0.03	339.68	0.32	0.57	0.20	0.39	0.169
2710	0.32	504.09	0.32	0.74	0.09	0.40	0.104
2711	0.30	653.22	0.31	0.69	0.08	0.42	0.033
2712	0.00	231.27	0.16	0.69	0.03	0.39	0.086
2801	0.09	86.63	0.15	0.42	0.12	0.45	0.256
2802	0.01	277.87	0.15	0.47	0.00	0.57	–0.050
2803	0.00	563.27	0.24	0.47	0.02	0.32	–0.023
2804	0.17	562.86	0.22	0.43	0.02	0.48	0.418
2805	0.00	583.06	0.18	0.41	0.00	0.29	–0.086
2806	0.00	706.12	0.16	0.72	0.04	0.49	0.252
2807	0.03	646.43	0.12	0.86	0.07	0.49	0.125
2808	0.01	291.30	0.36	0.39	0.12	0.41	0.167
2809	0.01	256.42	0.42	0.55	0.02	0.30	–0.352
2810	0.05	245.57	0.19	0.55	0.00	0.39	–0.532
2811	0.00	338.94	0.27	0.77	0.02	0.43	0.112
2812	0.03	260.52	0.44	0.36	0.00	0.35	0.126
2813	0.01	210.01	0.26	0.47	0.00	0.36	0.179
2814	0.00	229.41	0.45	0.46	0.00	0.35	0.181
2815	0.05	203.20	0.38	0.41	0.02	0.37	0.396
2816	0.05	357.90	0.34	0.39	0.07	0.42	0.180
2817	0.03	462.22	0.21	0.43	0.00	0.38	0.455
2818	0.00	284.73	0.27	0.55	0.01	0.37	0.196
2901	0.00	557.89	0.06	0.66	0.08	0.26	0.417
2902	0.01	355.26	0.08	0.62	0.13	0.29	0.195
2903	0.05	413.68	0.08	0.57	0.15	0.28	–0.090
2904	0.00	394.02	0.08	0.77	0.06	0.26	0.338
2905	0.00	350.46	0.22	0.50	0.10	0.28	–0.055

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
2906	0.00	359.29	0.22	0.51	0.08	0.26	0.306
2907	0.03	359.20	0.05	0.59	0.00	0.27	0.350
2908	0.04	668.03	0.13	0.57	0.02	0.26	0.451
2909	0.00	426.31	0.09	0.58	0.00	0.31	0.233
2910	0.20	407.06	0.24	0.51	0.11	0.50	0.576
2911	0.30	215.15	0.21	0.39	0.22	0.25	–0.029
2912	0.33	440.38	0.10	0.41	0.24	0.39	0.128
2913	0.01	707.16	0.25	0.44	0.13	0.29	–0.045
2914	0.11	281.71	0.44	0.49	0.07	0.27	0.049
2915	0.15	314.34	0.48	0.50	0.03	0.23	0.127
3001	0.07	282.60	0.01	0.45	0.13	0.26	0.132
3002	0.03	563.40	0.01	0.33	0.11	0.31	0.086
3003	0.10	570.41	0.12	0.40	0.14	0.38	0.042
3004	0.00	341.02	0.16	0.48	0.16	0.36	0.063
3005	0.03	279.48	0.00	0.38	0.00	0.29	–0.038
3006	0.00	409.93	0.11	0.48	0.04	0.41	–0.021
3007	0.00	322.21	0.27	0.48	0.06	0.35	0.131
3008	0.12	233.70	0.01	0.35	0.02	0.37	1.746
3009	0.00	265.43	0.04	0.39	0.10	0.38	–0.105
3010	0.00	368.76	0.01	0.34	0.02	0.39	0.108
3011	0.00	255.33	0.07	0.39	0.00	0.35	–0.036
3012	0.01	524.23	0.00	0.36	0.00	0.35	–0.039
3013	0.06	273.23	0.01	0.34	0.01	0.36	0.057
3014	0.17	343.85	0.489	0.65	0.01	0.28	–0.070
3015	0.07	310.46	0.02	0.48	0.05	0.36	0.106
3016	0.23	260.01	0.14	0.45	0.02	0.37	–0.137
3017	0.11	319.44	0.18	0.41	0.00	0.36	–0.084
3018	0.00	277.64	0.10	0.38	0.02	0.33	–0.095
3019	0.11	432.19	0.10	0.44	0.03	0.25	–0.075
3020	0.14	362.55	0.07	0.55	0.11	0.37	–0.041
3021	0.12	329.95	0.00	0.60	0.19	0.34	–0.226
3022	0.14	428.39	0.01	0.56	0.13	0.43	–0.263
3023	0.11	455.81	0.01	0.46	0.00	0.24	–0.223
3024	0.02	329.52	0.00	0.45	0.20	0.36	–0.244
3025	0.03	312.48	0.00	0.44	0.09	0.27	–0.256
3026	0.00	372.78	0.01	0.47	0.08	0.28	–0.230
3027	0.02	570.39	0.05	0.55	0.01	0.25	–0.199
3028	0.13	881.12	0.08	0.55	0.01	0.24	0.011
3029	0.02	511.97	0.02	0.51	0.08	0.25	–0.181
3030	0.01	757.67	0.07	0.61	0.04	0.29	0.064
3031	0.08	979.38	0.08	0.57	0.06	0.24	0.019
3032	0.02	545.70	0.04	0.58	0.03	0.28	0.203
3033	0.09	335.56	0.08	0.58	0.01	0.28	0.134
3034	0.11	331.05	0.13	0.55	0.02	0.31	0.117
3035	0.00	492.91	0.03	0.55	0.01	0.29	0.202
3036	0.02	378.82	0.02	0.55	0.02	0.26	0.146
3037	0.00	393.41	0.06	0.60	0.02	0.30	0.162
3038	0.11	704.61	0.36	0.44	0.12	0.33	0.013
3039	0.01	812.35	0.41	0.51	0.01	0.25	–0.002
3040	0.32	414.05	0.38	0.47	0.03	0.25	–0.020

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
3041	0.07	409.05	0.23	0.62	0.21	0.26	0.039
3042	0.15	328.32	0.37	0.39	0.08	0.26	0.099
3043	0.07	360.45	0.37	0.46	0.05	0.29	0.088
3044	0.10	440.59	0.27	0.41	0.12	0.30	0.022
3045	0.00	591.36	0.15	0.42	0.14	0.30	0.057
3046	0.06	337.41	0.17	0.56	0.18	0.22	0.005
3047	0.05	461.35	0.19	0.48	0.03	0.33	0.129
3048	0.12	491.52	0.18	0.50	0.07	0.30	0.081
3049	0.01	570.27	0.10	0.52	0.02	0.47	0.094
3050	0.17	480.28	0.20	0.62	0.03	0.24	0.054
3051	0.00	597.60	0.13	0.62	0.02	0.29	0.076
3052	0.11	727.27	0.02	0.59	0.00	0.27	0.092
3053	0.01	305.56	0.28	0.53	0.00	0.32	0.099
3054	0.04	400.99	0.29	0.43	0.07	0.37	0.165
3055	0.11	601.75	0.23	0.54	0.03	0.24	0.024
3056	0.12	273.07	0.20	0.48	0.24	0.37	0.125
3057	0.02	448.64	0.30	0.56	0.21	0.39	0.142
3058	0.07	541.24	0.25	0.40	0.01	0.25	0.075
3059	0.30	747.97	0.00	0.46	0.00	0.43	0.035
3060	0.30	746.22	0.02	0.46	0.01	0.40	0.008
3061	0.00	447.23	0.29	0.46	0.00	0.25	0.019
3062	0.06	754.35	0.14	0.44	0.00	0.28	0.016
3063	0.00	868.58	0.07	0.39	0.00	0.36	0.118
3064	0.02	819.52	0.10	0.33	0.09	0.27	0.149
3065	0.14	843.12	0.07	0.33	0.11	0.29	0.149
3066	0.16	896.09	0.08	0.36	0.21	0.30	0.149
3067	0.08	710.15	0.12	0.45	0.24	0.31	0.147
3068	0.12	671.06	0.07	0.49	0.00	0.45	0.106
3069	0.00	564.61	0.43	0.66	0.20	0.27	0.329
3070	0.02	686.97	0.10	0.42	0.04	0.49	–0.006
3071	0.00	494.66	0.32	0.50	0.05	0.23	0.018
3072	0.04	576.78	0.38	0.39	0.16	0.41	0.038
3073	0.02	398.24	0.37	0.40	0.12	0.43	0.120
3074	0.07	359.30	0.15	0.44	0.00	0.31	0.107
3075	0.03	301.16	0.21	0.49	0.08	0.40	0.035
3076	0.00	396.16	0.13	0.57	0.00	0.35	0.160
3077	0.03	379.10	0.27	0.47	0.13	0.40	0.188
3078	0.00	177.51	0.11	0.39	0.40	0.32	1.164
3079	0.04	202.63	0.00	0.37	0.43	0.29	0.452
3080	0.02	365.33	0.39	0.41	0.27	0.33	0.349
3081	0.02	276.91	0.08	0.56	0.00	0.37	0.884
3082	0.12	188.65	0.11	0.44	0.43	0.26	–0.020
3083	0.15	284.60	0.25	0.44	0.37	0.27	0.323
3101	0.08	166.17	0.41	0.71	0.58	0.55	–0.045
3102	0.00	154.41	0.40	0.55	0.52	0.52	0.143
3103	0.01	144.49	0.31	0.50	0.23	0.62	0.189
3104	0.01	159.31	0.39	0.55	0.48	0.54	0.055
3105	0.00	196.64	0.19	0.50	0.44	0.51	0.270
3106	0.05	169.32	0.38	0.59	0.58	0.49	–0.016
3107	0.18	129.39	0.23	0.49	0.55	0.39	–0.020

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
3201	0.01	201.70	0.00	0.53	0.09	0.52	0.324
3202	0.00	258.86	0.18	0.57	0.05	0.67	0.325
3301	0.01	285.24	0.02	0.37	0.24	0.63	0.239
3302	0.00	357.73	0.20	0.46	0.20	0.37	–0.288
3303	0.02	239.61	0.09	0.33	0.28	0.31	0.464
3304	0.04	295.38	0.01	0.65	0.14	0.72	0.545
3305	0.00	190.83	0.02	0.59	0.16	0.45	0.682
3306	0.00	406.44	0.03	0.63	0.08	0.52	1.388
3401	0.04	168.56	0.54	0.74	0.04	0.51	0.140
3402	0.03	98.89	0.51	0.76	0.13	0.47	0.223
3403	0.05	138.91	0.50	0.76	0.16	0.52	0.224
3404	0.01	194.70	0.51	0.75	0.01	0.52	–0.092
3405	0.06	239.97	0.39	0.68	0.04	0.46	0.126
3406	0.08	143.65	0.46	0.72	0.12	0.50	0.446
3407	0.06	118.29	0.47	0.73	0.16	0.51	0.240
3408	0.03	115.73	0.41	0.73	0.18	0.56	0.140
3409	0.13	192.29	0.42	0.73	0.13	0.47	0.330
3410	0.09	305.71	0.38	0.71	0.05	0.46	0.195
3411	0.05	126.28	0.37	0.72	0.14	0.53	0.015
3412	0.00	100.03	0.34	0.77	0.14	0.59	0.077
3413	0.00	115.55	0.39	0.73	0.15	0.56	0.085
3414	0.01	69.23	0.30	0.77	0.12	0.46	0.165
3415	0.01	126.10	0.24	0.87	0.12	0.48	0.697
3416	0.07	81.71	0.26	0.78	0.12	0.56	0.363
3417	0.00	105.39	0.34	0.78	0.12	0.51	0.062
3418	0.00	114.11	0.25	0.78	0.12	0.51	0.344
3419	0.11	211.36	0.31	0.73	0.08	0.46	0.299
3420	0.02	165.27	0.28	0.73	0.09	0.48	0.358
3421	0.08	346.19	0.32	0.64	0.02	0.41	0.301
3422	0.01	211.38	0.36	0.61	0.01	0.46	0.317
3501	0.01	86.16	0.01	1.01	0.21	0.43	0.015
3502	0.01	110.29	0.00	0.89	0.01	0.46	0.103
3503	0.00	81.93	0.02	0.91	0.01	0.59	0.457
3504	0.06	98.87	0.10	0.92	0.00	0.57	0.246
3505	0.00	123.99	0.08	0.90	0.01	0.51	0.193
3506	0.07	100.61	0.11	0.52	0.10	0.41	0.127
3601	0.00	99.55	0.00	0.53	0.53	0.38	0.121
3602	0.01	110.68	0.06	0.59	0.09	0.47	0.057
3603	0.01	157.12	0.13	0.69	0.30	0.44	0.010
3604	0.15	118.59	0.04	0.85	0.00	0.68	–0.164
3605	0.01	94.28	0.08	0.94	0.02	0.60	–0.173
3606	0.01	108.69	0.04	1.08	0.04	0.53	0.053
3607	0.00	123.55	0.00	1.03	0.14	0.42	0.156
3608	0.01	156.70	0.14	0.87	0.01	0.43	–0.015
3609	0.00	90.33	0.00	1.02	0.31	0.49	0.093
3610	0.00	150.72	0.39	1.12	0.05	0.63	–0.133
3611	0.02	138.55	0.02	0.55	0.10	0.59	0.020
3612	0.02	156.25	0.02	0.56	0.09	0.56	0.482
3613	0.06	144.05	0.10	0.46	0.28	0.61	0.193
3614	0.00	102.09	0.24	0.82	0.00	0.57	–0.138

Table SI.

Basin	R2 for precipitation	RMSE for precipitation	R2 for maximum temperature	RMSE for maximum temperature	R2 for minimum temperature	RMSE for minimum temperature	2020-2034 growth rate of consumptive uses
3615	0.03	128.69	0.00	1.04	0.24	0.51	–0.058
3616	0.00	111.35	0.14	0.62	0.26	0.61	0.087
3701	0.01	177.44	0.00	0.71	0.06	0.38	0.458
3702	0.01	146.96	0.04	0.66	0.03	0.52	0.355
3703	0.00	140.57	0.15	0.64	0.05	0.47	0.337
3704	0.00	128.37	0.33	0.71	0.01	0.65	0.148
3705	0.09	175.68	0.05	0.58	0.08	0.63	0.242
3706	0.09	121.60	0.09	0.73	0.18	0.55	0.319
3707	0.01	98.90	0.20	0.72	0.05	0.47	0.136
3708	0.00	102.03	0.07	0.70	0.07	0.38	0.487