ISSN: 2347-4688, Vol. 12, No.(2) 2024, pg. 498-514

Current Agriculture Research Journal

www.agriculturejournal.org

A Review of Attribution of Land Use and Climate change on river hydrology

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Abstract
In recent decades, the world has grappled with an increase in severe floods and recurrent droughts, attributed to both climate change and human interventions. The imperative to balance the burgeoning needs of a growing population with sustainable resource use has accentuated the importance of understanding the interplay between anthropogenic influences and climatic shifts. Evaluating the effects of land use dynamics and the construction of dams is essential to this understanding. This review analyzes 200 peer-reviewed articles focused on climate change, land use dynamics, and the interplay between climate and land use, sourced from Scopus, ScienceDirect, and Web of Science. The majority of these studies investigate the impact of climate and land use changes on river hydrology. By examining a diverse range of models and methodologies, we aim to synthesize current knowledge and identify key trends and gaps in the literature. This review provides a comprehensive overview of how changes in climate and land use are influencing river hydrology, offering insights into both the direct and synergistic effects of these factors on water resources.

Article History
Received: 01 May 2024
Accepted: 13 July 2024

Keywords
Climate Change;
Hydrological Models;
Lulc Change;
River Basin

Introduction

Over the past decades, worldwide shifts in streamflow patterns have been observed, driven by diverse factors such as alterations in meteorological variables (precipitation, solar radiation, temperature, wind) and landscape variables (land use/land cover, topography, soil type). These changes, resulting in either increased or decreased stream flow, have been extensively studied by researchers.[1,2,3,4] The increased frequency of droughts and floods around the world has been strongly correlated with changes in land use and climate.[5,6,7,8] Studies emphasize the impact of altering land use, encompassing urbanization, deforestation, forest management, and agricultural intensification, on catchment hydrology, affecting evapotranspiration, infiltration, groundwater

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Doi: http://dx.doi.org/10.12944/CARJ.12.2.02

recharge, and surface runoff.[9,10,11,12,13] These findings are valuable for flood prediction, soil and water conservation, sediment loss analysis, and biodiversity studies.[14] Climate variability's effects on hydrological regimes involve a coupling between climate and hydrological models, influencing the spatial-temporal patterns of hydrology globally.[15,16,17,18,19]

Recent studies have explored the effects of climate change and changes in land use on river hydrology, considering inputs, outputs, accuracy, complexity, approaches, and spatiotemporal scales. Models are categorized into empirical, conceptual, physically-based, and hybrid models based on data dependence and simulation of physical processes.

Empirical models, relying on existing data without considering hydrological characteristics, offer a simple approach.[20,21,22,23] Conceptual models, combining physical-based and empirical aspects, estimate effects on streamflow generation.[24] Physically-based models, representing actual phenomena through mathematical equations, include well-known models like MIKE SHE, VIC, HEM-HMS, SWMM, SWAT, and Xiangjiang models.[2,25,26,27,28,29,30,31,32,33]

The goal of this review of the literature is to give an extensive overview of earlier research assessing how various models can be used to assess how land use dynamics and climate change affect river hydrology. The analysis categorizes objectives into Land use change (LUC), climate change (CC), and combined land use and climate changes (CLUC), offering insights into their roles in affecting global water balance within river basins. The impact of this literature review lies in its ability to inform and guide policy, enhance water resource management, support climate adaptation, promote sustainable development, and foster international collaboration. This study provides valuable insights that can drive effective actions and strategies to address the pressing challenges of water resource management in a changing climate

Methodology

Identification

In this comprehensive study, we gathered approximately 520 literature articles focusing on the implications of climate change on land use dynamics on river hydrology from various repositories such as Scopes, Science Directory, and Web of Science. These repositories were chosen due to their extensive coverage of scientific publications, high-quality peer-reviewed articles, and relevance to environmental and hydrological research. The initial collection of 520 articles encompassed research from national, global, and local perspectives, providing a broad understanding of the topic across different scales.

Screening

After the initial identification, we proceeded with the screening phase. We removed 55 duplicate articles, resulting in a total of 465 unique articles. Subsequently, we excluded 97 articles that lacked relevant records related to land use and land cover (LULC) and climate results. This exclusion process left us with 368 articles for further assessment

Eligibility

During the eligibility phase, we applied more stringent qualitative criteria to ensure the relevance and quality of the selected studies. Out of the 368 articles, 168 were removed because they did not meet the established qualitative standards for this review. These standards included the robustness of methodologies, the relevance of findings to the review topic, and the clarity of data presentation.

Included

Ultimately, 200 articles were selected for in-depth analysis. Among these, 42 articles focused solely on climate change, 82 on LULC changes, and 76 on the combination of LULC and climate change, as illustrated in Figure 1.

Employing various methodologies, we diligently analyzed these articles and categorized them into three distinct groups based on the specific impacts they explored. Our goal was to analyze and comprehend how each of these influencing elements, both separately and collectively, affected shifts in the patterns of river streamflow.

To achieve this, we adopted a strategic approach to effectively isolate and differentiate the influence of land use dynamics from changes in climate on river hydrology. By thoroughly reviewing each article, we summarized their key findings, methodologies utilized, data sources, and any inherent limitations. This rigorous process enabled us to identify common themes and patterns within each category, providing valuable insights into the complexities of the subject matter. Additionally, we conducted a thorough synthesis of the quantitative data available in the articles. Employing meta-analysis techniques, we synthesized the results to gain a more comprehensive overview of the overall impacts and ensure robust conclusions were drawn from the data. A pivotal aspect of our analysis was the comparison of methodologies employed within each category. Understanding the strengths and weaknesses of the various strategies employed by, researchers made it possible for us to evaluate the validity and dependability of the findings, leading to a more nuanced interpretation of the findings. As we examined each category in-depth, distinct trends and patterns emerged regarding changes in river streamflow magnitude, frequency, and seasonality. These observations provided valuable evidence to support our investigation into the association between land use dynamics and climate change and how they both affect river hydrology.

Crucially, our study considers potential confounding factors, such as alterations in precipitation patterns, land management practices, vegetation cover, and urbanization. By acknowledging and considering these influential factors, we aimed to ensure a comprehensive precise assessment of the effects on the patterns of river streamflow. In the end, our research provides distinct and convincing findings on the independent and combined impacts of land use dynamics and climate change on river hydrology. Our findings emphasize the significance of incorporating these factors into sustainable water resource management strategies. Armed with these valuable insights, we provide informed recommendations for policymakers, land managers, and researchers on adaptation and mitigation measures. By addressing the impacts identified in our study, we aim to contribute to effective strategies for managing and safeguarding river ecosystems in the face of ongoing environmental changes.

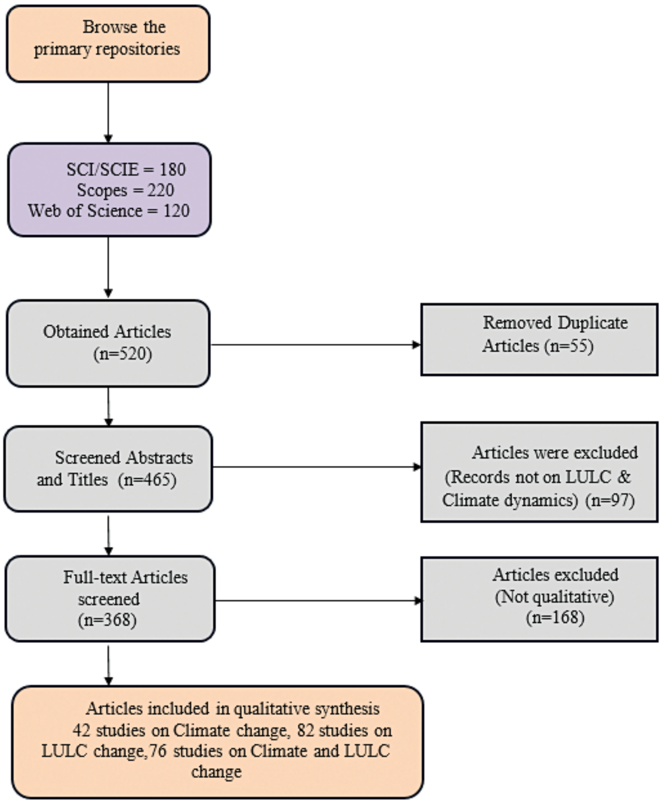

Fig.1: Schema chart for the systematic literature review in the studies

It is important to acknowledge that our study does have limitations, and we have transparently discussed these shortcomings. Nevertheless, we believe our research serves as a crucial foundation for advancing the understanding of the intricate interplay between climate change, land use dynamics, and river hydrology, paving the way for further investigations and policy interventions in this critical field.

Impact of Climate Change and Land use Dynamics on Water Resources

Effect of Climate Change on Water Resources

Changes in temperature and precipitation lead to changes in climate, soil moisture, runoff, water quality, evapotranspiration, wind stress, and ocean properties.[34,35,36,37,38] These lead to Patio-temporal variability of precipitation intensity, the occurrence of natural hazards, and extreme rainfall events influenced by increased flood events. These are affected by economic conditions, ecological processes, environmental policies, and the natural development of ecosystems.[39] To this problem, many researchers have used different models to comprehend the effects of climate change on river hydrology, which is helpful for policymakers as well as for the design and implementation of water resources projects.[40,34,41]

The study's location is the only factor that influences the estimate of how climate change would affect river hydrology. The mean temperature will rise by approximately 1.1 to 6.4 C by 2100, according to the Intergovernmental Panel on Climate Change (IPCC) report (IPCC, 2014).[42] According to the Fifth Intergovernmental Panel on Climate Change (IPCC, 2013),[43] there will be a 2.3–5.5ºC increase in the global mean temperature. This will cause changes in precipitation to lead to increased evapotranspiration, which will have an impact on water supplies. Woldesenbet *et al.* [44] concluded that the Upper Blue Nile basin in Ethiopia saw a 51.3% increase in surface runoff between 1986 and 2010, which was a result of LULC change. Sinha and Eldho *et al.*[45] investigated how LULC dynamics affected streamflow in the Netravati River Basin, India, and found that from 1979 to 2012, discharge rose by 7.88% as a result of LULC dynamics. Givati *et al.*[46] assessed how the Upper Jordan basin's streamflow would be affected by climate change; under RCP 4.5 and RCP 8.5, respectively, streamflow would be reduced by 11% and 16% shortly and by 16% and 44% in the distant future.

According to Hengade & Eldho,[47] the Ashti sub-basin of the Godavari in India had a significant reduction in surface runoff as a result of the basin's decreasing rainfall. Agrawal *et al.*[48] determined that minor variations in climate lead to significant variations in hydrology. Also, they concluded that increases in urbanization temperature, may poes to increased runoff and cause an urban flood. Khoi, and Suetsugi 49 resulted in around 4 to 6% annual streamflow decrease in the future in Be River watershed, in Vietnam's southern area because of future climate scenarios. Vu *et al.*[50] revealed how the Dakbla River Basin's drought was assessed using the SWAT model and standardized runoff index, which led to the occurrence of extreme drought occurrences there following powerful El Nino periods. Using three scenarios of greenhouse gas emissions (A1B, A2, and B), the third Intergovernmental Panel on Climate Change (IPCC) reported on changes in the local hydrology and discovered that the Chao Phraya basin saw an increase in stream flow of about 41.9% as a result of various climate scenarios. Shrestha *et al.*[51] analyzed the effects of climate change on the Nam Ou basin streamflow using downscaled climate data from PRECIS and GCMs, which were used in the SWAT model. They concluded that future climate change will cause the annual simulated streamflow to drop by between 17 to 66%.

Numerous investigations have been carried out to evaluate the climate variability impact on river hydrology using different models[52,53,54,55,56,57] in different river basins such as the Samat watershed[58,59] and Bangpakong River basin 60 of Thailand and Johor, Kelantan, and Bernam River basins of Malaysia[61,62]

Impact of Land use Dynamics on River Hydrology

The hydrological cycle is impacted by land use change, one of the major human activities. Therefore, it is crucial to comprehend the implications of land-use change (also known as "land use science") to decrease the effects of human-environment interactions. One of the main variables affecting anthropogenic activity and changes in the natural environment is land use change (LUC) and it needs to be carefully described to understand the impacts of such changes.[63] LUC encompasses land cover changes because the term refers to alterations that don't involve further human exploitation of the land.[64] LUC has a significant impact on (and is impacted by) world climate change and the ensuing ecological reactions to environmentally friendly growth.[65,66] The majority of the developing nations in the world are going through fast LUC, which is being caused by both population expansion and lifestyle changes that accompany income growth. When there is not enough arable land available, residents may choose an unsuitable plot of land with low agricultural production, which contributes to the geographical patterns of LUC. The difficulties caused by inefficient land use, such as the conversion of inappropriate land to agriculture, which lowers agricultural production and jeopardizes food security, are currently of concern to both society and the government. Landscapes change over time and across space.[67] The International Geosphere-Biosphere Program and the International Human Dimensions Program on Global Environmental Change developed a study plan in 1995 to delve into the possible effects of LUC on ecosystem services and, eventually, socio-economic development. Then, this started to gain popularity as a study topic.[68,69]

By altering hydrological factors such as surface runoff, percolation, lateral flow, and evapotranspiration, the LULC change alters how precipitation becomes runoff.[70] Understanding how land use dynamics affect river basin hydrology is essential for developing an efficient Integrated River Basin Management System (IRBM). This is mostly because different types of land use have different effects on the hydrological components. For instance, urban areas have lower infiltration rates than forest areas, which results in higher surface runoff during heavy precipitation events. Therefore, while maintaining a sufficient water supply, implementing the smart land use plan to control the growth of land within a river system could help lower the risk of water scarcity and flooding. SWAT model use is land use dynamics analysis, which may be used to assess how changes in land use dynamic situations affect the hydrological cycle and water quality. Homdee *et al.*[71] used five hypothetical scenarios to investigate how model findings will react to different changes in land use in the Chi watershed, Thailand: Deforestation, increased farmland, conversion of farmland to rice paddies, conversion of farmland to energy crops, and conversion of farmland to sugarcane plantations. All of the several land-use situations that were simulated had varying effects; for example, the farmland-to-sugarcane plantation scenario significantly showed seasonal evapotranspiration impact but very minor variations in water output.

Using the SWAT model, Wangpimool *et al.*[72] evaluated streamflow fluctuations from reforestation in the upper Nan River basin, Thailand, based on three scenarios: Range grass and field crops; a better spread forest; and both field crops and distributed forests. They found that during the wet and dry seasons, the first scenario reduced streamflow, the third scenario increased streamflow, and the second scenario showed no discernible effects. Sunandar *et al.*[73] determined the optimal land use management approach to decrease suspended silt without compromising the water supply in the Asaham watershed, Indonesia. They achieve this optimization using a linear program query approach, and several restriction functions based on the present land use conditions. They discovered that by reducing dry land farmland and increasing forest and plantation areas, the perfect situation could be achieved. Tarigan *et al.*[74] measured the minimal forest cover required for Jambi province's watersheds in Indonesia, to ensure adequate ecosystem services for local water supplies. They discovered that protecting at least 30% of the forest canopy was necessary for the watersheds to sustain these ecosystem services. In Indonesia, Prasena and Shrestha,[75] Marhaento *et al.*,[76] and Noda *et al.*[77] assessed the effects of shifting land usage on runoff in the Samin watershed and the upper Citarum watershed, respectively. They concluded that the hydrological cycle will be significantly altered by the changes in land use. Three of the five SWAT studies carried out in the Philippines exclusively focused on evaluating the consequences of land use change. The first study focused on runoff and sediment discharge was examined by Alibuyong *et al.*[78] in the subwatershed of the Manupali River watershed. The SWAT-based land use scenarios indicated that sediment output increased by 200–273%, while runoff volume increased by 3-5%. Similar research by Palao *et al.*[79] in the Layawan watershed found that turning forest land into agricultural land could boost sediment output by up to 106%. Lastly, Boongaling *et al.*[80] evaluated how land use patterns affected the hydrology of the Calumpang watershed in Batangas. The SWAT modeling predicted a 5% and 6% rise in surface runoff and sediment output, respectively, but an 11% decrease in baseflow.

Sinha RK *et al.*[81] used the SWAT model to forecast how changes in land use/land cover (LULC) and climate will affect streamflow. They concluded that LULC changes—specifically, a decrease in grassland and forest areas coupled with an increase in urban and agricultural areas from 2000 to 2050—would lead to increased mean annual streamflow. Conversely, they found that climate changes under RCP 4.5 and RCP 8.5 scenarios would decrease streamflow. Overall, they found that the combined impact of climate variability and LULC change would result in reduced streamflow.

Effect of the Combination of Climate Change and Land use Dynamics on Hydrology

In recent years, few studies have estimated altering in river hydrology due to the Variability of climate and Land Use dynamics using different prototype[s2,82,83,84,85,86,87,88,89] These studies are useful for understanding river hydrology, aiding decision-makers and policymakers in more effective watershed planning. However, these studies vary significantly in methodologies and are quite different from one place to another place, and one model to another model to estimate the impact of altering land use and climate.

For instance, Aboelnour *et al*,[90] used the Mann-Kendall test and SWAT models to discern trends in metrological data and Analyze the impact of land use patterns and climatic variability on stream flow in the Walze Creek watershed. they concluded that the changes in stream flow and baseflow were more affected by urbanization than the alterations in climate and also, observed a decline in the average annual water yield by 25.7%, baseflow by 67.9%, and evapotranspiration by 4.3% acknowledging the combined effects of climate and land use changes. Zhou *et al.*[91] used three quantitative methods, e.i. SWAT model, linear regression, and Climate elasticity to evaluate the impact of LULC dynamics and climate change on streamflow in Dongjiang River Basin, they concluded that around 58% of the alterations in runoff were attributed to climate change, primarily driven by increased annual temperatures. Additionally, around 42% of the runoff changes were ascribed to human activity, mainly the conversion of agricultural and forest land to urban areas. Tan *et al.*[92] evaluated the impact of land use dynamics and climate change, both separately and in conjunction on the Johor River basin's hydrology in Malaysia from 1975 and 2004 using Man-Kendall and Sen's slope tests along with the SWAT model, results showed the coupled effect of land use and climate variability led to increased in annual streamflow by 4.4% and increase in evaporation by 1.2% and also observed that compared to land use dynamics, climate variability had significantly more impact on streamflow and evaporation.

Sayasane *et al.*[93] examined the potential impact of land use patterns and climate change on streamflow in the Nam Xong watershed in the Lao PDR. They employed the PRECIS model to estimate future climate scenarios and utilized the logistic regression method to project the future land use pattern, results showed future streamflow is expected to be reduced by 11.7% to 12.2% in the middle of the watershed, and also overall watershed streamflow is projected to decline by 0.7% to 1.9% over the next 20 years due to the conversion of shrub and woodland into agriculture land.

In Myanmar, Shrestha and Htut 94 examined the combined impact of land use dynamics and projected climatic variability on the hydrology of the Bago River. They used projected climate scenario data from Representative Concentration Pathways (RCP) (RCP4.5 and RCP8.5) for the 2020s, 2050s, and 2080s, along with projected land use generated by the CLUE-S model, results showed the annual streamflow is expected to increase by around 68% in the near term, due to increasing in annual precipitation (30 to 125 mm) and temperature (0.7 – 3 degrees Celsius), and also increased agriculture land, but climate variability has a more significantly influenced on streamflow than land use dynamics. Setyorini *et al.*[95] discovered a slight increase in evapotranspiration, while surface runoff, lateral flow, groundwater, and streamflow were all reduced due to the impact of combined climate variability and land development in the Upper Brantas River basin, Indonesia. In the 3S river basin (Sekong, Sesan, and Srepok), Trang *et al.*[96] assessed the combined effects of land use dynamics and climate change on hydrological fluctuations and nutrient production. They employed two land use and two climate scenarios (RCP 4.5 & RCP 8.5) data from five GCM (General Circulation Model) simulations for the 2030s, 2060s, and 2090s, resulting the yearly streamflow is expected to grow and decrease, respectively, throughout the wet and dry seasons. Kim *et al.*[97] examined the impact of LULC and climate change on river hydrology in the Hoyea River basin, Korea, using sing-type RCP emission scenarios, results revealed that the impact of LULC on runoff was less significant than the climate variability on river hydrology. A few other research on the effects of land use dynamics and climatic variability on water resources and their results are shown in Table 1.

Table. 1: The effect of changing Land Use and climate on River Hydrology

Reference	The primary goal of the research	Hydrological model used	Major findings
Malede, D.A.[98]	Evaluated the integrated and Individual Effect of climate variability and LULC dynamics on Birr watershed's runoff of the Abbay basin in Ethiopia.	SWAT	Increased surface runoff & decreased water yield, baseflow, and ET owing to LULC dynamics like urbanization & growth of agricultural land and the decrease in forest, bushland, and grassland. Increased surface runoff and decreased ET due to both changes in Climate and LULC
Pal SC [99]	Climate change risks and land use practices make India more susceptible to future floods.	Flood susceptibility model	The study's findings show that the amount of rainfall on average each month will rise by roughly 40 to 50 mm by 2100, while 0.071 million square kilometers of natural vegetation will be converted into agricultural and built-up land, and the area affected by catastrophic flood events would grow by up to 122% (0.15 million square kilometers) during the next few decades.
Sharma A[100]	Analyze the impact of climate variability and LULC dynamics on Dharoi River's hydrology and uncertainty in parameters	SSC, SMSC, SWAT	The findings demonstrated that LULCC has less effect on varying parameters in the SWAT model than Climate Change. Therefore, CC is the main factor influencing the Dharoi catchment's streamflow, which increased four times between 2005-2014 compared to 1995-2004.
Li and Fang[101]	Analyzing the effects of climate variability on Mun River's streamflow in Southeast Asia using RCP scenarios	SWAT	Annual average precipitation is projected to increase during the period of 2060s to 2080s and decrease in 2030s under scenarios
Awotwi *et al.*[102]	Assessment of impact on streamflow induced by climate change in Ghana basin, West	SWAT	Under RCP4.5, Annual streamflow decreased and monthly streamflow varied from around -15% to 23%.

	Africa using RCP 4.5 & 8.5 scenarios		Conversely, under RCP8.5, annual streamflow increased & monthly streamflow varied from approximately -24% to 24%
Lopes *et al.*[103]	Analyzing the effects of changes in land use on the river hydrology, southern Brazilian Amazon	SWAT	Surface runoff increased as a result of increased agricultural land & decreased forest land
Getachew *et al.*[104]	Evaluated the effect of changing LULC and climate on streamflow in Ethiopia's Lake Tana basin under RCP scenarios	SWAT & IPEAT	Increased ET, streamflow, and Baseflow due to significantly increased cropland and urban areas and also around 25% precipitation increased due to climate variability
Kibii *et al.*[105]	Examining how the Kaptagat watershed's river streamflow is impacted by land development and climate change	SWAT	Rainfall, baseflow, and streamflow all decreased due to changes in land use, including the decline in forest cover and an increase in urbanization.
Wang *et al.*[106]	Urbanization's impact on the Yitong River Basin's hydrology	SWAT	The reduction of forest land by 11.7% and significant changes in wetlands and bare sands as decreased caused stream flow to increase.
Araza *et al.*[107]	Changes in streamflow that are likely to occur as a result of changes in LULC and climate, and the risk they pose to the Philippines' Abuan watershed's water resources	SWAT	Reduced streamflow, precipitation, groundwater recharge, and ET due to the effect of climate variability and LULC trend
Kumar and Bhattacharjya[108]	Using GIS, SWAT & HEC-HMS models were evaluated in the Bhagirathi-Alkhnanda River basin in India	SWAT and HEC-HMS	The models underestimate peak discharge but SWAT outperforms HEC-HMS in the test
Puno *et al.*[109]	Evaluated the effect of climate variability and LULC trend in Muleta Watershed’s hydrology, Philippines	SWAT	Increased surface runoff and decreased replenishment of groundwater owing to modification in LUCL, such as a 10% reduction in forest cover and a drop in rainfall as a result of the combination of LULC and climatic variability
Pokhrel [110]	Analyzing the effect of LULC dynamics on sediment yield and streamflow of Bagmati River basin, Kathmandu, Nepal	SWAT	Increased streamflow by 27% and decreased streamflow by 25% due to increased built-up land by 6% from the forest, scrub, agricultural land
Woldesenbet *et al.* [111]	Examination of the impact of LULC dynamics on the Upper Blue River Nile Basin’s Hydrology, Ethiopia.	SWAT	Increasing the wet-season flow decre-ases the scrubland and increases the cultivation land causing to surface run -off increase, while decreasing dry-season flow lowers the groundwater component.
Briones *et al.*[112]	In Palico Watershed, Analysing the impact of LULC changes on river hydrology, Philippines	SWAT	Reducing grassland and forest cover enhanced surface runoff but decreased groundwater recharge and baseflow. Conversely, increasing forest cover

			and grassland increased baseflow while decreasing streamflow.
Zhang L *et al*[113]	Analyzing of Climate variability and Land use dynamics on Heihe River Hydrology, China	Dyna-CLUE and Markov chain	ET increased & Stream flow decreased due to Land use change but increased streamflow and ET by Climate change only
Ayeni *et al.* [114]	Examining the effects of climate variability on southwestern Nigeria's surface water resources	C-CAM	Decreased forest land caused to stream flow increase.
Fujihara *et al*[115]	Evaluated the impacts of climate variability on streamflow of the Seyhan River Basin in Turkey using downscaled data	Hydro-BEAM	Climate change leading to decreased annual runoff of around 55%
Davis Todd *et al.*[116]	The evaluation of the impact of changes in climate by the transformation of Landscape on water resources	VIC	Increased streamflow and baseflow owing to the conjunction impact of land use dynamics and climate variability but significant influence of LULC than climate
Wang[117]	Quantitative Methods and Applications in GIS	Integrated GIS	LULC dynamics cause Increased flood peak of around 20% in 100 years
Chen *et al.*[118]	Assessment of the effect of climate variability and land use pattern on the Suomo Basin's hydrology	CHARM, SWAT	Owing to LULC dynamics and climate trends, 20% and 60-80% changes in runoff, respectively
Belay *et al*,[119]	Evaluation of the impact of separate and combined LULC/ Climate changes in Muga watershed	CA Markov, SWAT	Increased surface runoff and decreased lateral flow, groundwater flow, and evapotranspiration in present and future scenarios than baseline due to LULC dynamics
Arfasa *et al*,[120]	In West Africa, examination of the impact of LULC and climate change on irrigation water resources	Systematic Review	Agriculture land and urban land increased by 11.7% and 140% and decreased forestland by 24.6% from 1997 to 2018 causing to decreased water balance

Conclusion

The literature review scrutinized around 200 research papers on the evaluation of the effect of LULC dynamics and climate trends on river streamflow. In this regard, the review has demonstrated that recent research and past decades have shown changes in streamflow may be simulated using different models. The literature review has revealed substantial insights into the effect of land use land cover dynamics and climate change, both independently and in conjunction on river hydrology, which helps maintain proper water management.. Most of the research scholars employed various models for the evaluation of the influence of LULC dynamics and climate variability on stream flow. These models included a variety of methodologies such as hydrological, empirical, and evapotranspiration models. The synthesis of these studies highlights both consensus and divergence in findings across different models and methodologies. Many studies agree that approximately 80%, concur that climate change substantially affects river hydrology. This impact is primarily through alterations in temperature, precipitation patterns, and evapotranspiration rates. For instance, studies by the Intergovernmental Panel on Climate Change (IPCC) and Woldesenbet *et al.* indicate a consistent rise in temperature and variability in precipitation, leading to increased evapotranspiration and altered streamflow patterns. Around 75% of the studies reviewed agree that changes in land use, particularly urbanization and agricultural expansion, significantly influence hydrological components such as surface runoff, baseflow, and evapotranspiration. For instance, Sinha and Eldho's investigation into the Netravati River Basin and Sunandar *et al.*'s work on the Asaham watershed consistently found that agricultural expansion leads to increased runoff and sediment yield. The extent of these impacts can vary. For example, while Boongaling *et al.* noted only a modest increase in surface runoff in the Calumpang watershed, Malede *et al.* reported substantial changes in water yield and baseflow due to significant LULC changes in the Birr watershed. Many studies have been carried out that take extreme events into account, such as the consequences of negative anthropogenic impacts. An integrated modeling approach is valuable for assessing how changes in land use may affect water resources, according to a recent study. In the publications reviewed, a recommendation emerged suggesting the integration of a spatially explicit land-use simulation model with a hydrological model as a pragmatic approach to evaluate the combined impacts of land-use change and climate change on surface water dynamics. Because of the variable reactions to LULC changes, a site-specific investigation is required to fully understand their consequences. For this type of research, a variety of factors, including LULC, the climate, the landscape, and the soil's physical characteristics, must be assessed. The outcomes underscore the necessity for integrating diverse models to comprehensively evaluate changes in surface water dynamics.

Acknowledgement

The Government of India under the schemes of the Inspire Faculty Award and the Early Career Research Award held by Dr.Maheswaran is gratefully acknowledged.

Funding Sources

The financial assistance provided by the Department of Science and Technology (DST), Government of India GRANT no - IFA12-ENG-28.

Conflict of Interest

The authors declared no conflict of interest.

Authors' Contributions

Data curation, Formal analysis, S.S.; Funding acquisition, Investigation, R.M., Methodology Design - S.S., Writing—original draft, S.S., Writing—review & editing, R.M., K.K.B. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

All the data are available from the corresponding author by request

References

1. Singh RK., Jain MK., Gupta V. Impact of climate change on runoff regime of the Godavari River in India. Sustain Water Resour Manag. 2022;8:69. https://doi.org/10.1007/s40899-021-00558-0
2. Setti S., Maheswaran R., Radha D., Sridhar V., Asce M., Barik KK., Narasimham ML. Attribution of Hydrologic Changes in a Tropical River Basin to Rainfall Variability and Land-Use Change: Case Study from India. J Hydrol Eng. 2020;25:1–15. doi:10.1061/(ASCE)HE.1943-5584.0001937.
3. Booij MJ., Schipper TC., Marhaento H. Attributing changes in streamflow to land use and climate change for 472 catchments in Australia and the United States. Water. 2019;11(5):1059. https://doi.org/10.3390/w11051059
4. Wang H., Stephenson SR. Quantifying the impacts of climate change and land use/cover change on runoff in the lower Connecticut River Basin. Hydrological processes. 2018;32(9):1301-1312. https://doi.org/10.1002/hyp.11509
5. Samaniego L., Thober S., Kumar R., Wanders N., Rakovec O., Pan M., Zink M., Sheffield J., Wood EF., Marx A. Anthropogenic warming exacerbates European soil moisture droughts. Nat Clim Change. 2018;8(5):421-426. https://doi.org/10.1038/s41558-018-0138-5.

6. Dai A. Increasing drought under global warming in observations and models. Nat Clim Change. 2013;3(1):52-58. https://doi.org/10.1038/nclimate1633.
7. Rogger M. Land-use change impacts on floods at the catchment scale—Challenges and opportunities for future research. Water Resour Res. 2017;53(7):5209–5219. https://doi.org/10.1002/2017WR020723.
8. Hirabayashi Y., Mahendran R., Koirala S., Konoshima L., Yamazaki D., Watanabe S., Kim H., Kanae S. Global flood risk under climate change. Nat Clim Change. 2013;3(9):816-821. https://doi.org/10.1038/nclimate1911.
9. Gashaw T., Tulu T., Argaw M., Worqlul AW. Modeling the hydrological impacts of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. Sci Total Environ. 2018;619-620:1394-1408. https://doi.org/10.1016/j.scitotenv.2017.11.191.
10. Kidane W., Bogale G. Effect of land use land cover dynamics on the hydrological response of watershed: A case study of Tekeze Dam watershed northern Ethiopia. J Soil Water Conserv Res. 2017;5(1):1-16. https://doi.org/10.1016/j.iswcr.2017.03.002
11. Niraula R., Meixner T., Norman LM. Determining the importance of model calibration for forecasting absolute/relative changes in streamflow from LULC and climate changes. J Hydrol. 2015;522:439-451. https://doi.org/10.1016/j.jhydrol.2015.01.007.
12. Wang W., Shao Q., Yang T., Peng S., Xing W., Sun F. Quantitative assessment of the impact of climate variability and human activities on runoff changes: A case study in four catchments of the Haihe River Basin China. Hydrol Process. 2013;27(8):1158-1174. https://doi.org /10.1002/hyp.9299
13. Seong CH., Sridhar V. Hydroclimatic variability and change in the Chesapeake Bay watershed. J Water Clim Change. 2017;8(2):254–273. https://doi.org/10.2166/wcc.2016.008
14. Thanapakpawin P., Richey J., Thomas D., Rodda S., Campbell B., Logsdon M. Effects of land use change on the hydrologic regime of the Mae Chaem River Basin, NW Thailand. J Hydrol. 2007;334(1–2):215-230. https://doi.org/10.1016/j.jhydrol.2006.10.012
15. Jin X., Sridhar V. Impacts of climate change on hydrology and water resources in the Boise and Spokane River Basins. J Am Water Resour Assoc. 2012;48(2):197-220. https://doi.org/10.1111/j.1752-1688.2011.00605.x.
16. Ghosh S., Das D., Kao SC., Ganguly AR. Lack of uniform trends but increasing spatial variability in observed Indian rainfall extremes. Nat Clim Change. 2012;2(2):86-91. https://doi.org/10.1038/nclimate1327.
17. Sridhar V., Jin X., Jaksa WT. Explaining the hydro climatic variability and change in the Salmon River Basin. Clim Dyn. 2013;40(7–8):1921–1937. https://doi.org/10.1007/s00382-012-1467-0
18. Paul S., Ghosh S., Mathew M., Devanand A., Karmakar S., Niyogi D. Increased spatial variability and intensification of extreme monsoon rainfall due to urbanization. Sci Rep. 2018;8(1):1–10. https://doi.org/10.1038/s41598-018-22322-9.
19. Surinaidu L., Amarasinghe U., Maheswaran R., Nandan MJ. Assessment of long-term hydrogeological changes and plausible solutions to manage hydrological extremes in the transnational Ganga River basin. h2oj, 2020; 3(1), 457–480.
20. Guo F., Lenoir J., Bonebrake TC. Land-use change interacts with climate to determine elevational species redistribution. Nat Commun. 2018;9(1):1-7. https://doi.org/10.1038/s41467-018-03786-9
21. Dey P., Mishra A. Separating the impacts of climate change and human activities on streamflow: A review of methodologies and critical assumptions. J Hydrol. 2017;548:278-290. https://doi.org/10.1016/j.jhydrol.2017.03.014.
22. Tomer MD., Schilling KE. A simple approach to distinguish land-use and climate-change effects on watershed hydrology. J Hydrol. 2009;376(1–2):24-33. https://doi.org/10.1016/j.jhydrol.2009.07.029.
23. Wei X., Zhang M. Quantifying streamflow change caused by forest disturbance at a large spatial scale: A single watershed study. Water Resour Res. 2010;46(12):1–15. https://doi.org/10.1029/2010WR009250.
24. Bergström S. The HBV model. In: Singh VP (ed) Computer Models of Watershed Hydrology, Water Resources Publications,

Highlands Ranch, Colorado, USA, 1995; 443-476.

25. Surinaidu L., Muthuwatta L., Amarasinghe UA., Jain SK., Ghosh NC., Kumar S., Singh S. Reviving the Ganges Water Machine: Accelerating surface water and groundwater interactions in the Ramganga sub-basin. Journal of Hydrology, 2016; 540, 207–219. https://doi.org/10.1016/j.jhydrol.2016.06.025
26. Surinaidu L. Quantifying stream flows and groundwater response under the climate and land use change through integrated hydrological modeling in a South Indian River basin. Water Security, 2022; 17, 100129. https://doi.org/10.1016/j.wasec.2022.100129
27. Ehtiat, M., Jamshid Mousavi, S. & Srinivasan, R. Groundwater Modeling Under Variable Operating Conditions Using SWAT, MODFLOW and MT3DMS: a Catchment Scale Approach to Water Resources Management. Water Resour Manage, 2018; 32, 1631–1649. https://doi.org/10.1007/s11269-017-1895-z
28. Guo J., Su XL., Singh VP., Jin JM. Impacts of climate and land use/cover change on streamflow using SWAT and a separation method for the Xiying River Basin in northwestern China.” Water, 2016; 8 (5): 1–14. https://doi.org/10.3390/w8050192.
29. Wang W., Hao Q; Yang T; Peng S; Xing W; Sun F. Quantitative assessment of the impact of climate variability and human activities on runoff changes: A case study in four catchments of the Haihe River Basin China. Hydrol. Process, 2013; 27 (8): 1158–1174. https://doi.org /10.1002/hyp.9299.
30. Mengistu D T; Sorteberg A. Sensitivity of SWAT simulated streamflow to climatic changes within the Eastern Nile River Basin. Hydrol. Earth Syst. Sci. 2012; 16 (2): 391–407. https://doi.org/10.5194/hess-16-391-2012.
31. Fiseha BM., Setegn SG., Melesse AM., Volpi E., Fiori A. Hydrological analysis of the Upper Tiber River Basin central Italy: A catchment modeling approach. Hydrol. Processes, 2012; 27 (16): 2339–2351. https://doi.org/10.1002/hyp.9234.
32. Srinivasan R., Zhang X., Arnold J. “SWAT ungauged: Hydro logical budget and crop yield predictions in the Upper Mississippi River Basin.” J. Trans. ASABE, 2010; 53 (5): 1533–1546. https://doi.org/10.13031/2013.34903.
33. Asres MT., Awulachew SB. SWAT-based runoff and sediment yield modeling: a case study of the Gumera watershed in the Blue Nile basin. Ecohydrology & Hydrobiology. 2010 Jan 1;10(2-4):191-9.
34. Teng J., Chiew FHS., Timbal B., Wang Y., Vaze J., Wang B. Assessment of an analog downscaling method for modeling climate change impacts on runoff. J. Hydrol, 2012; 472–473, 111–125. https://doi.org/10.1016/j.jhydrol.2012.09.024.
35. Jones DA., Wang W., Fawcett R. High-quality spatial climate data-sets for Australia. Aust. Meteorol. Oceanogr. J, 2009; 58, 233.
36. Najjar RG., Pyke CR., Adams MB., Breitburg D., Hershner C., Kemp M., Howarth R., Mulholland MR., Paolisso M., Secor D., Sellner K., Wardrop D., Wood R. Potential Climate-Change Impacts on the Chesapeake Bay. Estuarine, Coastal and Shelf Science, 2010; 86(1):1–20. doi: 10.1016/j.ecss.2009.09.026.
37. Parry ML. Climate change impacts, adaptation, and vulnerability: Working group II contribution to the fourth assessment report of the IPCC. Cambridge University Press; 2007.
38. Walling DE. The sediment delivery problem. Journal of hydrology. 1983 Aug 1;65(1-3):209-37.
39. Pachauri RK., Allen MR., Barros VR., Broome J., Cramer W., Christ R., Church JA., Clarke L., Dahe Q., Dasgupta P., Dubash NK. Climate change 2014: synthesis report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Ipcc; 2014.
40. Liu J., Zhang Q., Singh VP., Shi P. Contribution of multiple climatic variables and human activities to streamflow changes across China. Journal of Hydrology. 2017 Feb 1;545:145-62.
41. Masih I, Uhlenbrook S, Maskey S, Smakhtin V. Streamflow trends and climate linkages in the Zagros Mountains, Iran. Climatic Change. 2011 Jan;104(2):317-38.
42. IPCC. (2014). Climate Change 2014 Synthesis Report. Contribution of Working

Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

43. Climate Change 2013: The Physical Science Basis. Cambridge: IPCC, Cambridge University Press, 2013.
44. Woldesenbet TA., Elagib NA., Ribbe L., Heinrich J. Hydrological responses to land use/cover changes in the source region of the Upper Blue Nile Basin, Ethiopia. Sci Total Environ. 2017;575:724–741.
45. Sinha RK, Eldho TI. Effects of historical and projected land use/cover change on runoff and sediment yield in the Netravati river basin, Western Ghats, India. Environmental earth sciences. 2018 Feb;77:1-9.
46. Givati A, Thirel G, Rosenfeld D, Paz D. Climate change impacts on streamflow at the upper Jordan River based on an ensemble of regional climate models. Journal of Hydrology: Regional Studies. 2019 Feb 1;21:92-109.
47. Hengade N, Eldho TI. Assessment of LULC and climate change on the hydrology of Ashti Catchment, India using the VIC model. Journal of Earth System Science. 2016 Dec;125:1623-34.
48. Agarwal A., Babel M. S. & Maskey S. 2014 Analysis of future precipitation in the Koshi river basin, Nepal. Journal of Hydrology 513, 422–434. https://doi.org/10.1016/j.jhydrol.2014.03.047.
49. Khoi D. N. & Suetsugi T. 2014 Impact des changements climatiques et de l'utilisation des terres sur les processus hydrologiques et la production de sédiments-étude de cas du bassin versant de la rivière Be, Vietnam. Hydrological Sciences Journal 59 (5), 1095–1108. https://doi.org/10.1080/02626667.2013.819433.
50. Vu, M.T.; Raghavan, V.S.; Liong, S.Y. Ensemble climate projection for a hydro-meteorological drought over a river basin in central highland, Vietnam. KSCE J. Civ. Eng. 2015, 19, 427–433.
51. Shrestha, B.; Babel, M.S.; Maskey, S.; van Griensven, A.; Uhlenbrook, S.; Green, A.; Akkharath, I. Impact of climate change on sediment yield in the Mekong River basin: A case study of the Nam Ou basin, Lao PDR. Hydrol. Earth Syst. Sci. 2013, 17, 1–20.
52. Hengade N, Eldho TI, Ghosh S. Climate change impact assessment of a river basin using CMIP5 climate models and the VIC hydrological model. Hydrological Sciences Journal. 2018 Mar 12;63(4):596-614.
53. Mudbhatkal A, Raikar RV, Venkatesh B, Mahesha A. Impacts of climate change on varied river-flow regimes of southern India. Journal of Hydrologic Engineering. 2017 Sep 1;22(9):05017017.
54. Wijesekara GN. An integrated modeling system to simulate the impact of land-use changes on hydrological processes in the Elbow River watershed in Southern Alberta (Doctoral dissertation, University of Calgary).
55. Chawla I, Mujumdar PP. Isolating the impacts of land use and climate change on streamflow. Hydrology and Earth System Sciences. 2015 Aug 24;19(8):3633-51.
56. Das, J. and Umamahesh, N.V., 2016. Downscaling monsoon rainfall over river Godavari Basin under different climate change scenarios. Water Resources Management, 30, 5575– 5587. doi:10.1007/s11269-016-1549-6
57. Wagner, P.D., Reichenau, T.G., Kumar, S., Schneider, K., 2015. Development of a new downscaling method for hydrologic assessment of climate change impacts in data-scarce regions and its application in the Western Ghats, India. Reg. Environ. Chang. 15 (3), 435–447. http://dx.doi.org/10.1007/s10113-013-0481-z.
58. Graiprab, P.; Pongput, K.; Tangtham, N.; Gassman, P.W. Hydrologic evaluation and e ect of climate change on the at Samat watershed, northeastern region, Thailand. Int. Agric. Eng. J. 2010, 19, 12–22.
59. Molle F (2007) Scales and power in river basin management: the Chao Phraya River in Thailand. Geogr J 173(4):358–373
60. Okwala, T., Shrestha, S., Ghimire, S., Mohanasundaram, S. and Datta, A., 2020. Assessment of climate change impacts on water balance and hydrological extremes in Bang Pakong-Prachin Buri river basin, Thailand. Environmental Research, 186, p.109544.
61. Tan, M.L., Ibrahim, A.L., Yusop, Z., Duan, Z. and Ling, L., 2015. Impacts of land-use and climate variability on hydrological

components in the Johor River basin, Malaysia. Hydrological Sciences Journal, 60(5), pp.873-889.
62. Tan, M.L., Samat, N., Chan, N.W. and Roy, R., 2018. Hydro-meteorological assessment of three GPM satellite precipitation products in the Kelantan River Basin, Malaysia. Remote Sensing, 10(7), p.1011.
63. Mendoza-González, M., M. Martínez, D. Lithgow, O. Pérez-Maqueo, and P. Simonin, (2012). Land use change and its effects on the value of ecosystem services along the coast of the Gulf of Mexico. Ecological Economics, vol. 82, pp. 23–32
64. Ellis, E.C., Kaplan, J.O., Fuller, D.Q., Vavrus, S., Klein Goldewijk, K., Verburg, P.H., 2013. Used planet: A global history. Proceedings of the National Academy of Sciences 110, 7978–7985. https://doi.org/10.1073/pnas.1217241110
65. Kawy, W.A. and Belal, A.A., 2011. GIS to assess the environmental sensitivity for desertification in soil adjacent to El-Manzala Lake, East of Nile Delta, Egypt.
66. Janssen, R., Van Herwijnen, M., Stewart, T.J. and Aerts, J.C., 2008. Multiobjective decision support for land-use planning. Environment and Planning B: Planning and design, 35(4), pp.740-756.
67. Scholte, S.S., Van Teeffelen, A.J. and Verburg, P.H., 2015. Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. Ecological economics, 114, pp.67-78.
68. Li, J., Zhang, C. and Zhu, S., 2021. Relative contributions of climate and land-use change to ecosystem services in arid inland basins. Journal of Cleaner Production, 298, p.126844.
69. Singh, H., 2014. A Study on Socio-Economic Status of Scheduled Caste People of Kangra. Asian Journal of Multidisciplinary Studies, 2(12), p.119.
70. Sajikumar, N., Remya, R.S., 2015. Impact of land cover and land use change on runoff characteristics. J. Environ. Manag. 161, 460–468. https://doi.org/10.1016/j.jenvman.2014.12.041.
71. Homdee, T.; Pongput, K.; Kanae, S. Impacts of land cover changes on hydrologic responses: A case study of Chi River basin, Thailand. Annu. J. Hydraul. Eng. 2011, 55, S31–S36. [CrossRef]
72. Wangpimool, W.; Pongput, K.; Tangtham, N.; Prachansri, S.; Gassman, P.W. The impact of para rubber expansion on streamflow and other water balance components of the Nam Loei River basin, Thailand. Water 2017, 9, 1. [CrossRef]
73. Sunandar, A.D.; Suhendang, E.; Hendrayanto; Jaya, I.N.S.; Marimin. Land use optimization in Asahan watershed with linear programming and SWAT model. Int. J. Sci. Basic Appl. Res. 2014, 18, 63–78.
74. Tarigan, S.D.; Sunarti; Wiegand, K.; Dislich, C.; Slamet, B.; Heinonen, J.; Meyer, K. Mitigation options for improving the ecosystem function of water flow regulation in a watershed with the rapid expansion of oil palm plantations. Sustain. Water Qual. Ecol. 2016, 8, 4–13. [CrossRef]
75. Prasena, A.; Shrestha, D.B.P. Assessing the effects of land use change on runoff in Bedog sub-watershed Yogyakarta. Indonesia. J. Geogr. 2013, 45, 48–61.
76. Marhaento, H.; Booij, M.J.; Rientjes, T.H.M.; Hoekstra, A.Y. Attribution of changes in the water balance of a tropical catchment to land use change using the SWAT model. Hydrol. Process. 2017, 31, 2029–2040. [CrossRef]
77. Noda, K.; Yoshida, K.; Shirakawa, H.; Surahman, U.; Oki, K. E ect of land use change driven by economic growth on sedimentation in river reach in Southeast Asia—A case study in upper Citarum river basin. J. Agric. Meteorol. 2017, 73, 22–30. [CrossRef]
78. Alibuyong, N.R.; Ella, V.B.; Reyes, M.R.; Srinivasan, R.; Heatwole, C.; Dillaha, T. Predicting the effects of land use change on runoff and sediment yield in Manupali River subwatersheds using the SWAT model. Int. Agric. Eng. J. 2009, 18, 15–25.
79. Palao, L.K.M.; Dorado, M.M.; Anit, K.P.A.; Lasco, R.D. Using the Soil and Water Assessment Tool (SWAT) to assess material transfer in the Layawan watershed, Mindanao, Philippines and its implications on payment for ecosystem services. J. Sustain. Dev. 2013, 6, 73–88. [CrossRef]
80. Boongaling, C.G.K.; Faustino-Eslava,

D.V.; Lansigan, F.P. Modeling land use change impacts on hydrology and the use of landscape metrics as tools for watershed management: The case of an ungauged catchment in the Philippines. Land Use Policy 2018, 72, 116–128. [CrossRef]

81. Sinha, R.K.; Eldho, T.I.; Subimal, G. Assessing the impacts of land cover and climate on runoff and sediment yield of a river basin. Hydrol. Sci. J. 2020, 65, 2097–2115.

82. Anand, J., A. K. Gosain, and R. Khosa. 2018. "Prediction of land use changes based on land change modeler and attribution of changes in the water balance of Ganga Basin to land use." Sci. Total Environ. 644 (Dec): 503–519. https://doi.org/10.1016/j.scitotenv.2018.07.017.

83. Pokhrel BK (2018) Impact of land use change on flow and sediment yields in the Khokana Outlet of the Bagmati River, Kathmandu, Nepal. Hydrology, 5(2), 22. https://doi.org/10.3390/hydrology5020022

84. Marhaento, H., 2016. GIS-based analysis for assessing landslide and drought hazards in the corridor of Mt. Merapi and Mt. Merbabu National Park, Indonesia. Geoplanning: Journal of Geomatics and Planning, 3(1), pp.15-22.

85. Zhang, Nan Z, Xu Y, Li S (2016) Hydrological impacts of land use change and climate variability in the headwater region of the Heihe River Basin, Northwest China. PloS One, 11(6), e0158394.

86. Aich, V., S. Liersch, T. Vetter, J. Andersson, E. N. Müller, and F. F. Hattermann. 2015. "Climate or land use?—Attribution of changes in river flooding in the Sahel Zone." J. Water. 7 (6): 2796–2820.

87. Nie, W., Y. Yuan, W. Kepner, M. S. Nash, M. Jackson, and C. Erickson. 2011. "Assessing impacts of land use and landcover changes on hydrology for the upper San Pedro watershed." J. Hydrol. 407 (1–4): 105–114. https://doi.org/10.1016/j.jhydrol.2011.07.012.

88. Wang, B., S. Y. Yim, J. Y. Lee, J. Liu, and K. J. Ha. 2014a. "Future change of Asian-Australian monsoon under RCP 4.5 anthropogenic warming scenario." Clim. Dyn. 42 (1–2): 83–100. https://doi.org/10.1007/s00382-013-1769-x.

89. Wang, W., Q. Shao, T. Yang, S. Peng, W. Xing, and F. Sun. 2013. "Quantitative assessment of the impact of climate variability and human activities on runoff changes: A case study in four catchments of the Haihe River Basin China." Hydrol. Process 27 (8): 1158–1174. https://doi.org /10.1002/hyp.9299.

90. Aboelnour, M., Gitau, M.W. and Engel, B.A., 2020. A comparison of streamflow and baseflow responses to land-use change and the variation in climate parameters using SWAT. Water, 12(1), p.191.

91. Zhou, Y., Lai, C., Wang, Z., Chen, X., Zeng, Z., Chen, J. and Bai, X., 2018. Quantitative evaluation of the impact of climate change and human activity on runoff change in the Dongjiang River Basin, China. Water, 10(5), p.571.

92. Tan ML, Ibrahim AL, Yusop Z, Duan Z, Ling L (2015) Impacts of land-use and climate variability on hydrological components in the Johor River basin, Malaysia. Hydrological Sciences Journal, 60(5), 873–889.

93. Sayasane, R.; Kawasaki, A.; Shrestha, S.; Takamatsu, M. Assessment of potential impacts of climate and land use changes on stream flow: A case study of the Nam Xong watershed in Lao PDR. J. Water Clim. Chang. 2016, 7, 184–197. [CrossRef]

94. Shrestha S, Htut AY (2016) Land use and climate change impacts on the hydrology of the Bago River basin, Myanmar. Environmental Modeling and Assessment, 21(6), 819–833. https://doi.org/10.1007/s10666-016-9524-y

95. Setyorini, A.; Khare, D.; Pingale, S.M. Simulating the impact of land use/land cover change and climate variability on watershed hydrology in the upper Brantas basin, Indonesia. Appl. Geomat. 2017, 9, 191–204. [CrossRef]

96. Trang, N.T.T.; Shrestha, S.; Shrestha, M.; Datta, A.; Kawasaki, A. Evaluating the impacts of climate and land-use change on the hydrology and nutrient yield in a transboundary river basin: A case study in the 3S river basin (Sekong, Sesan, and Srepok). Sci. Environ. 2017, 576, 586–598. [CrossRef]

97. Kim, J., Choi, J., Choi, C. and Park, S., 2013. Impacts of changes in climate and land use/land cover under IPCC RCP scenarios on streamflow in the Hoeya River Basin, Korea.

Science of the Total Environment, 452, pp.181-195.

98. Malede DA, Alamirew T, Andualem TG (2023) Integrated and Individual Impacts of Land Use Land Cover and Climate Changes on Hydrological Flows over Birr River Watershed, Abbay Basin, Ethiopia. Water, 15(1), 166.
99. Pal SC, Chowdhuri I, Das B, Chakrabortty R, Roy P, Saha A, Shit M (2022) Threats of climate change and land use patterns enhance the susceptibility of future floods in India. Journal of Environmental Management, 305, 114317. https://doi.org/10.1016/j.jenvman.2021.114317.
100. Sharma A, Patel PL, Sharma PJ (2022) Influence of climate and land-use changes on the sensitivity of SWAT model parameters and water availability in a semi-arid river basin. CATENA, 215, 106298. https://doi.org/10.1016/j.catena.2022.106298
101. Li, C., Fang, H., 2021. Assessment of climate change impacts on the streamflow for the Mun River in the Mekong Basin, Southeast Asia: using SWAT model. Catena 201. https://doi.org/10.1016/j.catena.2021.105199.
102. Awotwi, A., Annor, T., Anornu, G.K., Quaye-Ballard, J.A., Agyekum, J., Ampadu, B., Nti, I.K., Gyampo, M.A., Boakye, E., 2021. Climate change impact on streamflow in a tropical basin of Ghana, West Africa. J. Hydrol.: Reg. Stud. https://doi.org/10.1016/j.ejrh.2021.100805.
103. Lopes, T.R., Zolin, C.A., Mingoti, R., Vendrusculo, L.G., Almeida, F.T.D., Souza, A.P.D., Oliveira, R.F.D., Paulino, J., Uliana, E.M., 2021. Hydrological regime, water availability, and land use/land cover change impact on the water balance in a large agriculture basin in the Southern Brazilian Amazon. J. S. Am. Earth Sci. 108 (103224) https://doi.org/10.1016/j.jsames.2021.10322.
104. Getachew, B., Manjunatha, B.R., Bhat, H.G., 2021. Modeling projected impacts of climate and land use/land cover changes on hydrological responses in the Lake Tana Basin, upper Blue Nile River Basin, Ethiopia. J. Hydrol. 595 https://doi.org/10.1016/j.jhydrol.2021.125974.
105. Kibii, J.K., Kipkorir, E.C., Kosgei, J.R., 2021. Application of soil and water assessment tool (SWAT) to evaluate the impact of land use and climate variability on the Kaptagat catchment river discharge. Sustainability (Switzerland) 13 (4), 1–19. https://doi.org/10.3390/su13041802.
106. Wang, H., Zhang, S., Li, X., Wang, B., 2021. Hydrological effect of urbanization in Yitong River Basin. Fresenius Environ. Bull. 30 (2), 1318–1325.
107. Araza, A., Perez, M., Cruz, R.V., Aggabao, L.F., Soyosa, E., 2021. Probable streamflow changes and its associated risk to the water resources of Abuan watershed, Philippines caused by climate change and land use changes. Stochastic. Environ. Res. Risk Assessment. 32 (2), 389–404. https://doi.org/10.1007/s00477-020-01953-3.
108. Kumar, D., Bhattacharjya, R.K., 2020. Evaluating two GIS-based semi-distributed hydrological models in the Bhagirathi-Alkhnanda River catchment in India. Water Policy 22 (6), 991–1014. https://doi.org/10.2166/wp.2020.159.
109. Puno, R.C.C., Puno, G.R., Talisay, B.A.M., 2019. Hydrologic responses of watershed assessment to land cover and climate change using soil and water assessment tool model. Global J. Environ. Sci. Manag. 5 (1), 71–82. https://doi.org/10.22034/ gjesm.2019.01.06.
110. Pokhrel BK (2018) Impact of land use change on flow and sediment yields in the Khokana Outlet of the Bagmati River, Kathmandu, Nepal. Hydrology, 5(2), 22. https://doi.org/10.3390/hydrology5020022
111. Woldesenbet TA, Elagib NA, Ribbe L, Heinrich J (2017) Hydrological responses to land use/cover changes in the source region of the Upper Blue Nile Basin, Ethiopia. Science of The Total Environment, 575, 724–741.
112. Briones, R.U.; Ella, V.B.; Bantayan, N.C. Hydrologic impact evaluation of land use and land cover change in Palico watershed, Batangas, Philippines using the swat model. J. Environ. Sci. Manag. 2016, 19, 96–107
113. Zhang, Nan Z, Xu Y, Li S (2016) Hydrological impacts of land use change and climate variability in the headwater region of the Heihe River Basin, Northwest China. PloS One, 11(6), e0158394.
114. Ayeni AO, Kapangaziwiri E, Soneye ASO, Engelbrecht FA (2015) Assessing the impact

of global changes on the surface water resources of southwestern Nigeria. Hydrology Science Journal, 60(11), 1956–1971.

115. Fujihara, Y., Tanaka, K., Watanabe, T., Nagano, T. and Kojiri, T., 2008. Assessing the impacts of climate change on the water resources of the Seyhan River Basin in Turkey: Use of dynamically downscaled data for hydrologic simulations. Journal of Hydrology, 353(1-2), pp.33-48.
116. Davis Todd CE, Goss AM, Tripathy D, Harbor JM (2007) The effects of landscape transformation in a changing climate on local water resources. Physical Geography, 28(1), 21–36. https://doi.org/10.2747/0272-3646.28.1.21
117. Wang F (2006) Quantitative methods and applications in GIS. CRC Press.
118. Chen, J., Li, X. & Zhang, M. Simulating the impacts of climate variation and land-cover changes on basin hydrology: A case study of the Suomo basin. Sci. China Ser. D-Earth Sci. 48, 1501–1509 (2005). https://doi.org/10.1360/03yd0269.
119. Belay, T., & Mengistu, D. A. (2024). Modeling hydrological characteristics based on land use/land cover and climate changes in Muga watershed, Abay River Basin, Ethiopia. Cogent Food & Agriculture, 10(1). https://doi.org/10.1080/23311932.2024.2319935
120. Arfasa, G. F., Owusu-Sekyere, E., & Doke, D. A. (2023). Past and future land use/land cover, and climate change impacts on environmental sustainability in Vea catchment, Ghana. Geocarto International, 38(1). https://doi.org/10.1080/10106049.2023.2289458