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Hydrological modelling in a data-scarce semi-arid catchment: Assessing urbanisation impacts on runoff in Bouskoura, Morocco

Sara Salih*, Chakiri Said, Chekkouch Hajar,
Sliman Hitouri, Mohamed Sadiki

University Ibn Tofail, Faculty of Sciences, Campus Universitaire B.P. 242, 14000, Kénitra, Morocco

* Corresponding author

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Abstract: Urbanisation is a major driver of hydrological change, particularly in semi-arid regions where data scarcity limits the calibration of hydrological models. This study addresses the challenge of modelling hydrological responses in the ungauged Bouskoura catchment (Morocco), which has experienced rapid urban growth over recent decades. We combined land-use maps from 2017 and 2021, developed from Sentinel imagery and classified with Support Vector Machine (SVM) algorithms (κ = 0.99), with demographic projections to 2030 and applied the HEC-HMS hydrological model with the SCS-CN method to assess changes in runoff dynamics. Results show that the runoff coefficient increased from 69.11 in 2017 to 72.06 in 2021, with projections reaching 77.56 by 2030. Peak discharges followed the same trend, rising from 28.4 $m^3 \cdot s^{-1}$ in 2017 to 42.1 $m^3 \cdot s^{-1}$ in 2021 and up to 92.9 $m^3 \cdot s^{-1}$ in 2030, indicating an alarming escalation of flood risk under continued urban expansion. While the absence of observed streamflow data prevents calibration, the comparative scenario-based framework applied here provides reproducible insights into hydrological shifts in data-scarce semi-arid basins. These findings highlight the urgent need to integrate stormwater management and sustainable land-use planning in peri-urban areas of Casablanca and, more broadly, demonstrate the applicability of remote sensing and model-based approaches for ungauged catchments facing rapid urbanisation.

Keywords: Bouskoura watershed, flood risk, Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS), runoff coefficient, semi-arid basin, ungauged catchment, urbanisation

INTRODUCTION

Urbanisation has become one of the most significant drivers of change in hydrological processes across watersheds worldwide. The expansion of impervious surfaces such as concrete and asphalt reduces soil infiltration capacity, increases surface runoff, accelerates peak discharge, and elevates the risk of urban flooding (Booth and Jackson, 1997; Shuster *et al.*, 2005; Andrieu *et al.*, 2013). In highly developed urban catchments, up to 90% of stormwater is transformed into direct runoff (Sheng, 2009). These changes are particularly critical in semi-arid environments, where water scarcity and extreme rainfall events amplify vulnerability to flooding.

In Morocco, the Casablanca region, including the Bouskoura watershed, has experienced intense urban growth in recent decades (Bahi *et al.*, 2016). Rapid land-use transformations have significantly altered hydrological responses in peri-urban catchments, threatening both infrastructure and ecological balance. Yet, despite these pressures, limited research has provided quantitative, model-based assessments of recent land-use dynamics and their hydrological consequences in this region. This gap is particularly evident for ungauged basins, where the absence of observed discharge data constrains calibration and validation, making modelling approaches essential for understanding urbanisation impacts (Dawod, Mirza and Al-Ghamdi, 2011; Banasik *et al.*, 2014).

This study aims to address these gaps by assessing the impact of urbanisation on runoff dynamics in the Bouskoura catchment, a semi-arid peri-urban watershed experiencing rapid expansion. Specifically, it investigates how land-cover changes between 2017 and 2021, and projected development to 2030, influence runoff coefficients and peak discharges. To achieve this, we used the soil conservation service curve number (SCS-CN) method embedded in the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) model, applied in a comparative scenario-based framework suitable for ungauged basins. By combining remote sensing data, hydrological modelling, and demographic projections, this work contributes to a better understanding of flood risks in semi-arid peri-urban contexts and supports the design of sustainable stormwater management strategies in data-scarce environments.

MATERIALS AND METHODS

STUDY AREA

The Bouskoura watershed is located along Morocco's Atlantic coast, south of Casablanca, and covers approximately 255 km^2 (Fig. 1). The region experiences a hot-summer Mediterranean climate (Csa) with semi-arid steppe climate (BSh) influences, as reported by Climate Data (no date), with an average annual rainfall of about 317 mm. The topography consists of gentle hills and alluvial plains, combining agricultural land, urban areas, and natural vegetation. Notable landmarks within the watershed include the suburbs of Casablanca, the Bouskoura forest, Mohammed V International Airport, and surrounding farmland.

From a geological standpoint, the basin lies at the edge of the Berrechid plain, dominated by Silurian and Devonian shales with interbedded quartzites. These formations generate a rugged relief known locally as "sokhrate". The downstream areas, including Anfa and Oasis, are composed of Miocene sandy marls. The substrate is largely impermeable and is overlain by a shallow soil layer ranging from 20 cm on slopes to approximately 1 m in valley bottoms, suggesting limited infiltration and groundwater storage capacity (Hasnaoui *et al.*, 2015).

DATA USED

Land use

Land-use maps for 2017 and 2021 were produced using the Google Earth Engine platform and a supervised classification method based on the Support Vector Machine (SVM) algorithm. The SVM algorithm is a machine-learning technique that identifies the optimal decision boundaries between distinct land-cover classes by maximising the margin between them. This approach is particularly effective in handling complex and high-dimensional datasets, such as satellite imagery. The accuracy of the classification was evaluated using a confusion matrix, which resulted in a κ index of 99%, indicating an exceptionally high level of agreement. The final maps classified various land-cover types, including built-up areas, trees, crops, rangeland, bare ground, and water.

Land use in the Bouskoura watershed changed between 2017 and 2021 (Fig. 2). Comparison of the two maps shows a clear increase in urban areas, particularly in the southern and central parts of the watershed. Urban areas increased by 30.08%. This expansion appears to have occurred at the expense of agricultural land and natural vegetation, reflecting rapid urban growth in the area. Vegetation areas experienced a 19.03% decrease, while bare soil slightly declined by 3.70%. The largest relative change was observed in water bodies, which expanded by 380.56%, although this high percentage is mainly due to the small initial water surface in 2017. Meanwhile, dense vegetation increased by 13.91%, indicating some localised reforestation or natural regrowth.

In 2017, the landscape was mostly covered by green spaces such as cultivated fields and pastures. By 2021, a significant portion of these areas had been replaced with urban infrastructure, suggesting a noticeable increase in impervious surfaces such as roads and buildings. This change was probably influenced by factors such as population growth and the pressure of urban expansion.

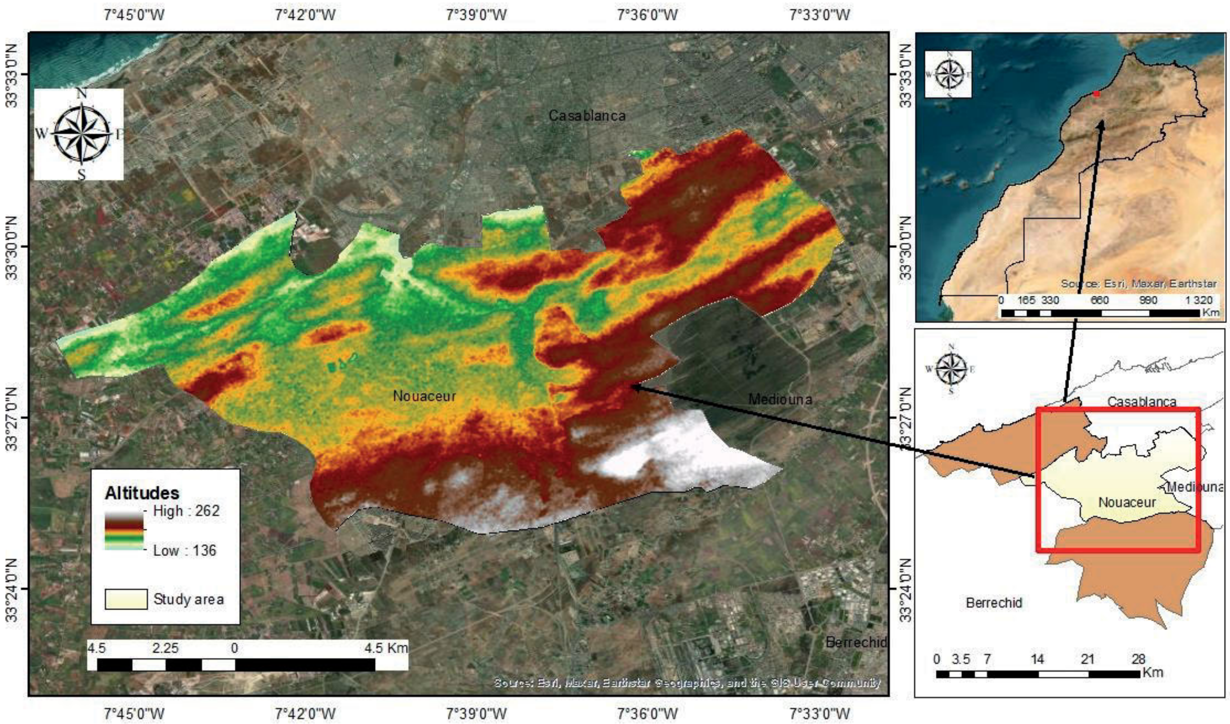

Fig. 1. Location map – Bouskoura; source: own elaboration based on Google Earth and ArcGIS

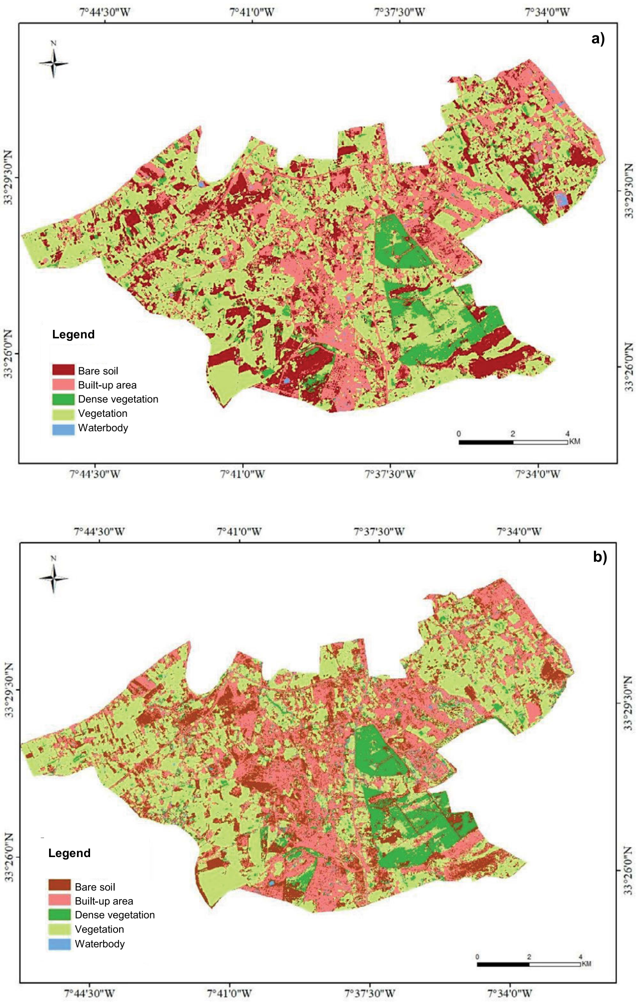

Fig. 2. Land use map of the Bouskoura watershed in: a) 2017, b) 2021; source: own elaboration

From a hydrological point of view, reducing vegetated areas means that less water infiltrates the ground, which leads to more runoff. This could increase the risk of flooding and affect the watershed's hydrological response, which is consistent with the slight rise in runoff coefficients and discharge levels between 2017 and 2021. These changes point to the need for land-management strategies that support urban growth while also protecting the watershed's natural hydrological functions.

To better illustrate land-use dynamics, a summary table of land-use transitions between 2017 and 2021 was added (Tab. 1). This approach highlights the dominant conversions towards urban areas relevant to hydrological modelling.

Hydrological data

Hourly rainfall data over a 10-year period (2014–2024) were collected from the Casablanca Mohamed V Airport station (Fr.: La Gare de l'Aéroport Mohammed V – GMMN), located approximately 11 km southeast of the Bouskoura watershed. This station, situated at an elevation of 59 m, is considered the most representative for the study area, contributing over 55% to the temperature and dew point data used in hydrological estimations (ABHBC, 2022). The rainfall data were processed and statistically adjusted using HYFRANPLUS software to compute return periods and synthetic design storms for hydrological simulation (Fig. 3).

Table 1. Net changes in land use/land cover between 2017 and 2021

Land use/land cover type	Area change (ha)	Trend
Water	+2.74	increase
Vegetation	−12.78	decrease
Dense vegetation	+1.42	increase
Built-up	+9.77	increase
Bare soil	−1.15	decrease

Source: own elaboration.

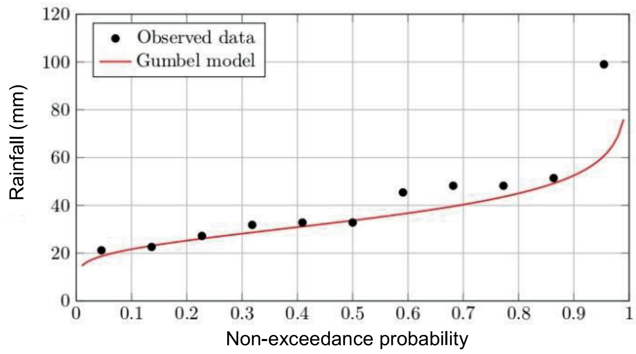

Fig. 3. Gumbel distribution fitted to observed rainfall data using the method of moments. The model is used to estimate extreme flood quantiles and return periods; source: own study

These precipitation inputs were later used in HEC-HMS to simulate runoff response under different land-use scenarios (2017, 2021, and projected 2030). For consistency, the same rainfall event was used in all scenarios, with land use and *CN* values as the only variables.

Demographic data

Demographic projections play a key role in estimating the future evolution of urbanisation and its effects on runoff, making it possible to anticipate the challenges associated with water resource management (Grimm *et al.*, 2008). In 2017, the population of Bouskoura was 102,036. In 2021, it reached 152,397 inhabitants (HCP, 2017), an increase of 21% in four years. In 2030, the projected population is 211,888, almost double the 2017 value (HCP, 2017) (+68% over 13 years) – Figure 4.

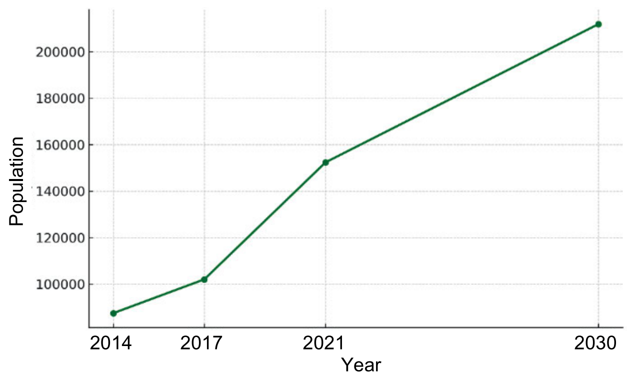

Fig. 4. Demographic trends in Bouskoura between 2014 and 2030; source: own elaboration based on: HCP (2017)

Average annual growth between 2014 and 2030 can be estimated at around 4–5%, reflecting rapid urbanisation. Population growth often leads to increased demand for new residential and commercial buildings, as well as infrastructure such as roads and public services. This growth can increase the amount of sealed surface area, which in turn increases run-off.

ESTIMATION OF RUNOFF USING THE CURVE NUMBER METHOD

The estimation of surface runoff was carried out using the curve number (CN) method, developed by the USDA Soil Conservation Service (SCS) and detailed in USDA (1986). This empirical method is widely used in hydrology to relate land cover and soil characteristics to runoff potential, particularly in the context of urban development.

Land use maps for the years 2017 and 2021 were obtained through supervised classification of satellite imagery using Google Earth Engine. These maps were then exported to ArcGIS, where the surface area of each land use class was calculated. Standard *CN* values were assigned to each class according to SCS guidelines, with adjustments made based on local context and literature.

Due to the lack of detailed Hydrological Soil Group (HSG) data in the study area, *CN* values were assigned based on general land-use descriptions under average antecedent moisture conditions (AMC II). The standard *CN* values used in this study are presented in Table 2. Equivalent curve number (*CN*eq) values were calculated using Equation (1):

$$CN\text{eq} = \frac{CN_1A_1 + CN_2A_2 + \ldots + CN_nA_n}{A_1 + A_2 + \ldots A_n} \tag{1}$$

where: *CN* = curve number, A = area.

Table 2. Curve number (*CN*) values for different land use and soil types

Land use/soil type	Description	*CN* value (0–100)
Forest land	dense forest with natural soil, undisturbed	55–70
Grassland	natural grasslands, tall grasses	60–80
Cultivated land (agricultural)	annual crops, tilled land	70–85
Bare soil	bare, dry soil without vegetation	80–90
Rangeland (grazing land)	pastures or lightly cultivated land	70–80
Urban areas	highly impervious urban areas (buildings, roads, etc.)	85–98
Industrial areas	industrial zones or infrastructure	90–98
Water (water bodies)	bodies of water such as rivers, lakes	100

Source: own elaboration based on: USDA (1986).

HYDROLOGICAL SIMULATION WITH HEC-HMS

To simulate the hydrological behaviour of the Bouskoura catchment, the Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) software was used. HEC-HMS is widely recognised for its ability to model rainfall-runoff processes in urban and semi-urban catchments, particularly in the absence of observed streamflow data.

The model was selected for its compatibility with the SCS-CN method and its suitability for ungauged basins. The simulation framework included the following elements:

- precipitation data from the Casablanca Mohamed V meteorological station (GMMN) at an hourly resolution;
- use of the SCS-CN method to estimate infiltration losses;
- initial abstraction and antecedent moisture conditions set to average (AMC II);
- a constant rainfall event (from 2017) applied to all years (2017, 2021, and the 2030 projection) to isolate land-use effects;
- only the *CN* value was modified for each scenario, based on the corresponding land use data.

Due to the absence of observed discharge data at the outlet of the Bouskoura watershed, no calibration or validation of the HEC-HMS model could be performed. This represents a significant limitation of the study, as absolute predictions cannot be ensured. Consequently, the results are interpreted in a comparative and scenario-based framework (2017, 2021, and projected 2030). Such an approach is commonly applied in ungauged semi-arid catchments, where discharge measurements are rarely available, and has been shown to provide valuable insights into the relative impacts of land-use change on runoff dynamics (Dawod, Mirza and Al-Ghamdi, 2011; Banasik *et al*., 2014). Despite this limitation, the model remains a useful tool for understanding how urbanisation alters hydrological responses.

RESULTS AND DISCUSSION

RESULTS

Equivalent curve numbers

Each soil type was listed along with its corresponding *CN* value and the *CN*eq for the area covered by that type (Tab. 3). When applying models such as the SCS-CN, the choice of *CN* values is often influenced by prior tests or statistical adjustments to ensure the most accurate results. Generally, higher *CN* values are selected to represent areas with more runoff, such as those with more impervious surfaces or less vegetated conditions typically found in urbanised areas.

Applying Equation (1) showed that the *CN* values increased from 69.11 in 2017 to 72.06 in 2021. This change is due to an increase in built-up areas from 32.48 ha in 2017 to 42.25 ha in 2021, reflecting increasing urbanisation. Arable land decreased from 67.17 ha to 54.39 ha, indicating a likely conversion of agricultural land to built-up areas. A slight decrease in bare land could also be attributed to urban expansion.

Comparative analysis of simulation results

The hydrographs simulated for 2017 and 2021 were compared to assess the impact of urban growth on runoff behaviour. The increase in *CN* values due to urban expansion resulted in higher

Table 3. Calculation of equivalent curve numbers in 2017 and 2021

Type of soil	Area (ha)	*CN*	*CN*eq
2017			
Water	0.72	100	72.45
Vegetation (cultivated land)	67.17	55	3,694.88
Dense vegetation (forest land)	10.21	45	459.85
Built-up (urban areas)	32.48	90	2,923.35
Bare soil	31.12	85	2645.84
***CN*eq**			69.11
2021			
Water	3.46	100	346.71
Vegetation (cultivated land)	54.39	55	2991.96
Dense vegetation (forest land)	11.63	45	523.41
Built-up (urban areas)	42.25	90	3803.11
Bare soil	29.97	85	2548.09
***CN*eq**			72.06

Explanations: *CN* = curve number, *CN*eq = equivalent curve number.
Source: own elaboration.

peak discharges and total runoff volumes, confirming that urbanisation intensifies the hydrological response of the basin.

These findings highlight the critical need for integrated urban planning and stormwater management strategies to mitigate the adverse effects of land cover change on hydrology.

Trends in runoff coefficients

The curve number (*CN*) increased from 69.11 to 72.06 between 2017 and 2021, indicating that the potential for surface runoff increased markedly. This trend corresponds to the growth of impermeable surfaces, which expanded by over 10 ha during this period.

Although the increase in *CN* may seem limited, it indicates a reduction in infiltration capacity and a corresponding increase in surface runoff, potentially leading to higher peak discharge and reduced groundwater recharge during precipitation events (Fletcher, Andrieu and Hamel, 2013).

This evolution is typical of peri-urban areas undergoing unregulated urban expansion, as highlighted in similar studies across North African basins (Hasnaoui *et al*., 2015), where urban sprawl has been shown to degrade the natural hydrological response.

Analysis of curve number development based on demographic trends

The increase in *CN* reflects the progressive replacement of permeable surfaces by urban land uses, leading to reduced infiltration and enhanced surface runoff. Although moderate, this increase reflects a reduction in infiltration and an increase in runoff. Moreover, it can be used as an indicator of future development.

Urbanisation projections can be modelled using different approaches (linear, exponential, sigmoid, etc.). This study chose a linear projection to simplify the analysis and avoid introducing uncertainties associated with more complex models requiring additional data. Although a linear projection was adopted for simplicity and data availability, it should be noted that urban growth and population increase do not necessarily translate proportionally into impervious surface expansion, which introduces additional uncertainty into future *CN* estimates. The development of catchment areas due to urbanisation generally follows a linear or exponential trend, depending on the dynamics of urban development and land-use planning policies (Fletcher, Andrieu and Hamel, 2013).

Between 2021 and 2030, the population is expected to increase by 39%. Extrapolating the impact of this increase on *CN*:
- a 21% increase in the population between 2017 and 2021 increased the CN by 2.5;
- with a 39% increase in the population between 2021 and 2030, the increase in *CN* could be proportional:

$$\Delta CN = 2.5\frac{39}{21} = 5.8 \tag{2}$$

Projection: $CN_{2030} = CN_{2021} + \Delta CN = 77.9 + 0.15 = 77.54$.

Thus, by 2030, *CN* is projected to reach 77.54, indicating a further reduction in infiltration and an increase in runoff, which could elevate flood risks in the watershed.

Variation in simulated discharge

The hydrological simulations performed using HEC-HMS revealed a marked increase in peak discharge over the study period:
- 4 $m^3 \cdot s^{-1}$ in 2017;
- 8 $m^3 \cdot s^{-1}$ in 2021;
- 9 $m^3 \cdot s^{-1}$ projected for 2030.

This tripling of peak discharge over 13 years highlights the sensitivity of runoff response to land-use changes, even in the absence of major changes in rainfall input. Such findings align with the literature, where increases in *CN* of just 5–10 points have been linked to exponential increases in discharge peaks and flood volumes (USDA, 1986; Fletcher, Andrieu and Hamel, 2013).

From a water resources management perspective, this trend underlines the need for urban drainage planning, especially in rapidly urbanising basins like Bouskoura. Without adequate mitigation strategies (e.g., green infrastructure, infiltration basins), the increased runoff may overwhelm existing drainage systems, elevate flood risks, and exacerbate soil erosion and water quality degradation.

The evolution of peak discharge and runoff volume in the Bouskoura watershed between 2017, 2021, and the 2030 projection is illustrated in Figures 5 and 6. The results indicate that urbanisation not only increases peak discharge but also significantly modifies the temporal distribution of runoff.

The intensification of impervious surfaces accelerates the runoff process, leading to earlier peak times and an increase in total discharge volume. These changes are reflected in the steepening of the hydrographs, indicating more intense and rapid flood responses – factors that raise the likelihood of flash floods.

Additionally, the prolonged runoff duration observed under more urbanised conditions suggests reduced infiltration capacity, emphasising the growing need for sustainable stormwater management practices in future urban development strategies.

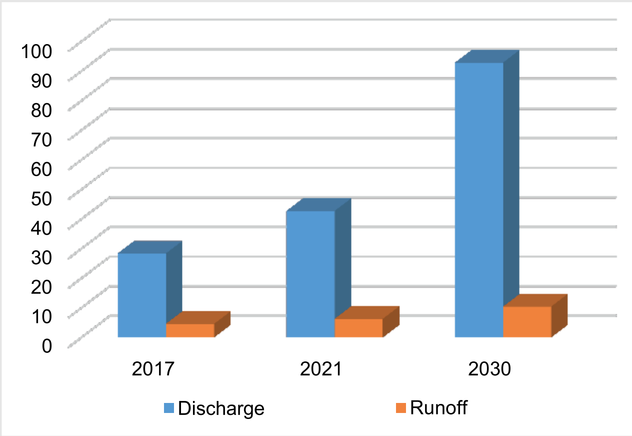

Fig. 5. Comparison of peak discharge ($m^3 \cdot s^{-1}$) and runoff volume (m^3) for different scenarios; source: own study

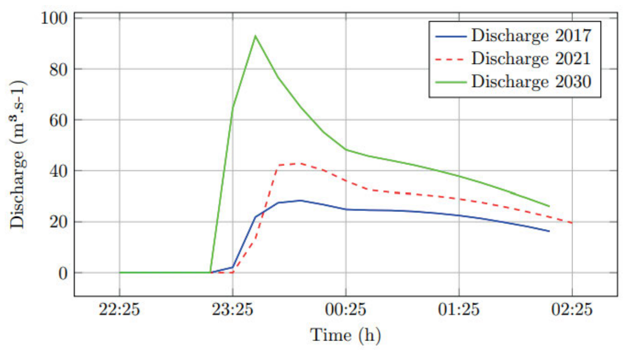

Fig. 6. Comparison of discharge in 2017, 2021, and 2030; source: own study

DISCUSSION

Several limitations must be acknowledged in this study.

First, the absence of observed discharge data prevented the calibration and validation of the hydrological model. Consequently, the simulations presented are scenario-based and are intended to highlight relative variations in hydrological response, rather than provide exact discharge estimates.

Second, the projection of future *CN* values was based on a linear relationship with population growth, assuming a proportional increase in impervious surfaces. While this approach offers a simplified representation of urban dynamics, it may not capture the **complexities of land-use evolution**, which can be influenced by regulatory policies, socioeconomic factors, or land-use planning strategies.

Moreover, the model does not explicitly consider several parameters that can significantly affect runoff, such as soil compaction, slope variability, vegetation density, or potential changes in precipitation patterns due to climate variability.

Despite these limitations, the methodology applied enables a preliminary assessment of urbanisation impacts on runoff and supports the identification of potential future hydrological risks in the Bouskoura catchment. These findings may serve as a basis for further studies involving more detailed data and calibrated models.

The results of this study clearly indicate a progressive increase in runoff discharges in the Bouskoura watershed from 2017 to 2030, highlighting the significant hydrological impact of urbanisation. Simulated peak flows increased from 28.4 $m^3 \cdot s^{-1}$ in 2017 to 42.8 $m^3 \cdot s^{-1}$ in 2021 (a 50% rise) and are projected to reach 92.9 $m^3 \cdot s^{-1}$ by 2030, representing a dramatic increase of 119% compared to 2021.

This increase correlates with a rise in the runoff coefficient (expressed in *CN*), which reflects the expansion of impervious surfaces such as roads and buildings and the consequent reduction in infiltration capacity. The transformation of agricultural and vegetated land into built-up areas is the main driver of this trend, consistent with findings reported in other rapidly urbanising watersheds (Brabec, Schulte and Richards, 2002; Walsh *et al.*, 2005).

Several studies have documented similar impacts of urbanisation on hydrological responses. For example, Brabec, Schulte and Richards (2002) showed that urbanisation increases impervious cover, leading to higher runoff volumes and peak discharge, thereby intensifying flood risks. Walsh *et al.* (2005) emphasised that urban land-use changes often result in increased runoff, reduced groundwater recharge, and altered stream flow regimes. Similarly, Jiao *et al.* (2021) found significant increases in peak discharge linked to urban sprawl in Chinese watersheds, highlighting the importance of land-use planning to mitigate hydrological impacts.

The variation in flow increase rates between the periods 2017–2021 (+50%) and 2021–2030 (+119%) may be explained by several factors:

- **urban development patterns**: some newly urbanised areas still include permeable surfaces (e.g., parks, green spaces) that help mitigate runoff increases by promoting infiltration (Singh Bhadauria and Singh, 2025; Sudhir Singh Bhadauria and Akhilesh Singh, 2025);
- **assumption of constant rainfall:** the simulations assume steady precipitation over time, isolating land-use changes as the sole driver of flow variations; in reality, climate variability can further influence hydrological responses (Blöschl *et al.*, 2013).

The absence of calibration data constitutes a limitation, but the comparative trends identified are robust and consistent with studies conducted in other semi-arid ungauged catchments (Dawod, Mirza and Al-Ghamdi, 2011; Banasik *et al.*, 2014). The sharp increase in peak flows between 2017 and 2030 highlights the urgent need to incorporate hydrological considerations into urban planning in Bouskoura. Furthermore, reliance on uniform rainfall scenarios introduces uncertainties; future research should explore multiple storm events and conduct sensitivity analyses of *CN* values and rainfall intensity to improve predictive reliability.

While urbanisation clearly drives increased runoff and peak flows, other hydrological processes such as infiltration, soil moisture dynamics, and temporary water storage significantly influence basin responses. Future work should incorporate these factors and utilise observed flow data for model calibration to improve prediction accuracy.

CONCLUSIONS

Urbanisation significantly modifies watershed hydrology by increasing impervious surfaces, reducing infiltration, and enhancing flood potential. In the Bouskoura catchment, hydrological modelling conducted under data-scarce conditions indicates a steady rise in the runoff coefficient, from 69.11 in 2017 to 77.56 in 2030, and a substantial increase in peak discharge from 28.4 to 92.9 $m^3 \cdot s^{-1}$.

These findings provide valuable quantitative insights into the evolving runoff dynamics of a semi-arid, peri-urban watershed despite the absence of observed streamflow data. By combining remote sensing and hydrological modelling, this study offers a methodological framework for assessing urbanisation impacts in ungauged catchments. The comparative analysis across 2017, 2021, and 2030 highlights temporal changes in runoff under increasing urban expansion, providing a basis for understanding hydrological responses in semi-arid, data-limited environments.

The results have practical implications for urban planning and flood management. Decision-makers in the Casablanca region may consider stormwater management strategies, including green infrastructure, retention basins, and permeable surfaces, to mitigate future flood risks. Peak discharge projections should be integrated into drainage design and urban development planning to enhance resilience in rapidly urbanising peri-urban areas such as Bouskoura.

Nevertheless, the study acknowledges limitations inherent to data-scarce contexts. The lack of observed streamflow prevented formal calibration of the HEC-HMS model; a comparative approach with consistent rainfall inputs was adopted to ensure relative consistency across scenarios. Consequently, the absolute values should be interpreted cautiously, while the trends and relative changes remain informative. Due to the strong sensitivity of runoff estimates to *CN* values, the projected peak discharge for 2030 remains subject to significant uncertainty and should be interpreted primarily in a qualitative and comparative sense. More rigorous quantification of uncertainty would be necessary to support precise infrastructure investment decisions. Future research could include sensitivity analyses exploring a range of *CN* values, which would provide intervals of runoff estimates rather than single values, improving the robustness and interpretation of the results.

In summary, this research advances understanding of urbanisation-induced hydrological changes in semi-arid, ungauged catchments, demonstrating that meaningful insights can be derived even under data scarcity. It provides actionable knowledge for planners and policymakers, emphasising the importance of proactive adaptation strategies to reduce urban flood risk in rapidly developing areas like Bouskoura.

AUTHOR CONTRIBUTIONS

1st Author (68%): study design, data collection, statistical analysis, data interpretation, manuscript preparation, literature search. 2nd Author (6%): data interpretation. 3rd Author (6%): data interpretation. 4th Author (15%): statistical analysis, manuscript preparation. 5th Author (5%): literature search.

CONFLICT OF INTERESTS

All authors declare no conflict of interests.

INSTITUTIONAL REVIEW BOARD STATEMENT

This study did not involve humans or animals. Ethical review and approval were therefore not required.

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