JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 10, ISSUE 03, 2023

Review paper in water Resources application and Rainfall runoff studies using HEC_HMS model and its efficiency

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Received: 28 May 2023 Revised and Accepted: 20 June 2023

Abstract

Water is essential element for human beings as well as echo system development. Population is increasing at rapid rate in developing countries, and climate change, Requirements of water resources is ever increasing. Due to this loss of life and water stress like drought, floods and climate changes in catchment areas, Because of this progress of the country economy and growth rate is reduces in and around the world. To overcome the above effects, water resources planning and management places a major role. For water resources allocation such as domestic supply, agriculture activity, industries, and power supply generations. Remote sensing techniques provided valuable information to water resources Engineer, Hydrologists and decision makers. ArcGis and HEC-HMS software tools plays a major role in data collection and analysis of data, calibration and validation of models ,simulation of models gives useful solution to water resources engineers. The present paper provides useful information of previous studies in Hec-Hms and ArcGis model studies of rainfall -runoff and surface water availability in catchments.

Keywords: HEC-HMS, ArcGis, model studies of rainfall-runoff, Remote sensing techniques.

INTRODUCTION

Hydrologic modeling system designed to simulate the rainfall-runoff processes of dendrite catchment system (HEC-2008). HEC-HMS is widely used in a broad range of hydrologic problems varying from the analysis of large river basin water supply and flood. This study of small urban or natural catchment runoff. HEC-HMS have been used for the studies of water availability, urban drainage, and flow fore casting, future urbanization impact, reservoir spillway design, flood damage reduction, flood plain regulation and system operation.

HEC-HMS (2008) which is one among many watershed models supporting both lumped and distributed model (Madsen 2000). Used to simulate rainfall-runoff correlation, has become a popular and reliable hydraulic model to its capacity -in short time simulation, ease to use and the common method (Arekhi-2012) the less required input parameter, economics in capacity in runoff simulation in un-gauged catchment (Choudhari et al. 2014) and low flow prediction De-silva et al. (2013)

HEC-HMS-model set up two Four main components which are created for developing a HEC-HMS project are basin model manager, Meteorological model manager ,control specification manager, input data(time series, paired data, gridded data). The basin model manager for instance contains the hydrologic elements such as (sub basin, reach, junction, reservoir, diversion, source and sink) and their connectivity that represents the movement of water through the drainage system. Control specification manager are one of the main component of the project and used to control time interval of simulation.

Metrological a component is also the first computational element by means of which precipitation is spatially and temporally distributed over the river basin. The spatial temporal precipitation distribution is accomplished by the inverse distance method and Evapotranspiration computation was carried out using FAO-penman-monteith method.

Hydrological model often requires time-series of precipitation data for estimation basin average rainfall. A time series of flow data often called observed flow (or) observed discharge. This main component inputted all the meteorological data such as rainfall, observed discharge, Evapotranspiration, wind speed, humidity and sun-shine hour etc.

Literature Review

Sintayehu LG [2] this study HEC-HMS 3.5 hydrologic model (with soil moisture Accounting Algorithm) has been used to calibrate (from 1988-2000) and validated (from 2001-2005), the upper Blue Nile river basin(Gilgel, Abay ,Gumera, Ribb and Megech cathment) Methods adopted ArcGis 10.2 was used to delineate the catchment Area. Using HEC-HMS hydrological catchment simulation models, calibration and validation for each catchment. The soil moisture, storage coefficient and the base flow coefficient are the most sensitive parameters for simulation of runoff. The daily Nash and Sutcliffe efficiency and Coefficient of determination R^2 of model performance criterion used to evaluate the model applicability for different catchments. The model well simulated the daily stream flow at the outlet of the catchment; however, there is a slight under and over prediction of the high flows. HEC-HMS model can be used for modeling and projections of future impacts of climate change on runoff for upper

Blue Nile basin, and can be applied to other catchments with similar hydro meteorological and land use characteristics.

Arekhi-saleh et al. [3] evaluation of HEC-HMS model in surface runoff simulation, Radmanesh et al (2010), calibrated and evaluate the HEC-HMS model in the yellow river watershed based on rainfall and discharge data. Six rainfalls with their simultaneous floods selected. The results indicate good fit between the peak discharge of simulated and observed hydrograph. All rainfall and evapotranpiration data introduced to model by climate sub model. Methods adopted are calculation of time of concentration (T_c), flow calculation in reaches; models of calculation of loss in HEC-HMS initial and constant loss rate, sensitivity analysis of model parmeters, Green Ampt method deficit and approach loss, Direct runoff method are used.

Fatima Daide et al.[4] studies of hydrologic modeling of the Beht catchment area , by combining the various spatial technology such as Gis,Remote sensing and digital terrain model(DTM).In order to prepare spatial hydrological modeling and flood forecasting. Methodology consists of the first in the automatic extraction of the sub-basin and drainage network. HEC-HMS model used to simulate runoff using extreme daily time services events

Kimhuy sok and Chantha Oeurng [6] the main objective of this work is to apply HEC-HMS model for simulating stream flow and to assess water availability of stung sangker located in Tonelesap Lake Basin. Hydrologic studies on rainfall-runoff have been extensively conducted in many regions around the globe to fulfill various desirable needs with a purpose of effective and proper planning and management water resources for present and future uses.

HEC-HMS conceptual model was used to simulate rainfall runoff in stungsangke catchment in Tonlesaplake basin with daily time step and analysis in monthly time step. The model performance was given by Nash-Sutcliffe Efficiency criteria followed by 0.44 for daily and 0.71 for monthly basis respectively, moreover, the percent bias(PBIAS) for daily and monthly simulation was 4.13% and 3.56%, indicating a satisfactory model fit. The model can suitably used to simulate flow of stung sangke catchment on a continuous time scale particularly monthly basis. The maximum flow volume occurred in October, This case study can be used as

a base line study for future sustainable water resources planning and management strategy in this Tonlesap lake catchment.

Ouedraogo Ismael et al. [7] several river basins across the world have been simulated using hydrological model to understand hydrological processes and availability of water resources. Some of these basins are ungauged. In this study in order to evaluate the hydrological process of Ruiru reservoir for sustainable management. Daily rainfall and monthly evapotranspiration for 5 years (2011-2015) were used for the meteorological inputs. The model evaluation has showed the efficiency of the model to be 0.74 and 0.72 respectively for calibration and the validation indicates that the results of the simulation are satisfactory. The sensitive analysis has showed that the most sensitive parameters are soil storage following ground water storage coefficient and the soil tension storage capacity.

Bhore Sagar et al. [9] surface water and ground water resources potential was evaluated at sub-catchment level using HEC-HMS model. The following methods were applied, dynamic canopy for evapotranspiration, SCS curve number for surface loss, and constant monthly base flow and storage discharge for reservoir consideration. Remote sensing methods were used to evaluate ground water potentials. ArcGis software used for basin model and curve number, maps was prepared using ArcGis for agriculture and non-agriculture demands. For Estimation of resources for present, projected population and agriculture demand. Surface water potentials in sub catchment level spatial databank/Inventory of resources, ground water potential evaluation in catchment area. Developed resources utilization maps/resources potential maps, resources excess/Deficit maps.

Shashi Ranjan et al. [10] research done on punpun river basin HEC-HMS model is used by several researcher to estimate the water potential of the basin through rainfall -runoff modeling. In model daily rainfall and runoff data from the years, 2005 to 2017 were used. Daily, monthly and monsoonal rainfall-runoff model have been developed. The performance of the model has been evaluated, using statistical indices co-efficient of determination (R^2).Nash -Sutcliffe -coefficient (NSE),percent bias (PBIAS) and RMSE-observation, standard deviation ratio (RSR)R^2, NSE values for the model are greater than 0.75, PBIAS is less than 10, which shows very good results from all the models. Except the daily models, in which NSE values are less than 0.75, based on statistical indices, the monthly model performs better then the daily and monsoonal Model.

Mohammad Taghi et al.[11] study area of this research is Toroq dam watershed with area of 131.34 Km^2. Average slope of the watershed area 39.12% and its climatic conditions is arid and

semi arid. For simulations of rainfall runoff process and prediction of peak flow HEC-HMS model was employed in this study. The HEC-HMS computer model has a larger number of options such as multi basin watershed, flood damage analysis etc. The soil conservation service (SCS) TR55approach to the determination of interception/infiltration and unit hydrograph well be used. Result indicates the amount of initial loss plays an important role in runoff generation and water balance calculation of the watershed. The average amount of initial for the Rainfall events used in this study is about 0.22S.The result shows that calibration of parameters such as CN and initial loss could considerably improve the outputs of the model

Aniket Rajput et al. [14] used HEC_HMS model for simulation of runoff process in banjar river water shed at Balaghat district of Madhya Pradesh India. The performance of the model is assessed using Nash-Sutcliffe efficiency (NSE), Co-efficient of determination R^2 and percentage error in peak. The model is calibrated and validated, during simulation NSE, PEP and R^2 obtained are 0.792, 4.96% and 0.849 and 0.751, 10.51%, and 0.809 respectively. The developed hydrologic model found to be good fit for the basin area

Munyaneza.O et al.[15] sustainable water resources management analysis are essential in Rwanda to increase or sustain water resources, especially for the agriculture and livestock sectors(UNEP, 2005), However, water resources assessment on the catchment scale is therefore done by the key activity to provide insight into water available for agriculture purposes (Abdulla et al. 2002, Al.Adamat et al. 2010).

HEC-HMS has been successfully applied in many catchments world wide. For example christopher and yung (2001) used HEC-HMS to perform a grid -based hydrologic analysis of a catchment. They compared distributed, semi distributed and lumped models and reasonable contribution of flood observation and runoff volume. Computation methods, the loss method allows computing basin surface runoff, ground water flow and actual evaporation as well as deep percolation out of the basin. Lumping the entire Migina catchment would lead to missing important aspects of some of the sub catchments and subsequently potentially misinforming the planning and decision-making processes. Continuous quality assurance and the control of hydrological and weather data sets recorded at different stations in the entire catchment is of great importance for the feature.

Jamal Ibrahim Mohammed et al. [16] the surface water resources potential assessment requires detailed insights into hydrological process. They mainly focused on the assessment of surface water potential in Dabus sub basin of Ethiopia. HEC-HMS was used to simulate the flow of the sub basin through calibration and validation. The performance of model was assessed by

calibration and validation of gauging stations using relative volume error (D) co efficient of determination (R^2), Nash-Sutcliff Efficiency (NSE) and Performance co-efficient. The HEC-HMS model calibration and validation at three gauging stations in the sub basin shows a good performance at Dabus near Asosa. Which results D=4.9285, R^2=0.91 and NSE=0.89 during calibration stage and D=4.9285, R^2=0.84 and NSE=0.82 during validation. The Dabas sub basin was used for flow simulation to assess surface water resources potential on monthly and annual basis. The results show that high percentage of flows occupied by base flow for sub-basin. Sub -basin has high surface water potential.

Abdessamed DERDOUR et al. [18] the purpose of this study focused on Hec-Hms model is to simulate runoff in semi-arid region of Ainsefra watershed. Ainsefra is one of the Algerian cities, it has been experienced several devastating floods during the past 100 years. Methods used in the analysis frequency storm are applied for the meteorological model. The soil conservation service-curve number (SCS-CN), selected to calculate the loss rate and soil conservation service, unit hydrograph method have been used to simulate the runoff rate. The results shows during calibration and validation, the simulated peak discharges were very close with observed values. Statistical indices values Nash-Sutcliffe efficiency coefficient was 0.95. Which indicates that the hydrological modeling results are satisfactory and suitable for simulation of rainfall-runoff. Analysis of the results indicates simulated peak discharges obtained by Hec-Hms were close with those derived by Gumbel approach. The runoff obtained from frequency storm method will be invaluable for the future study of flood hazard and risk assessment in Ain-sefra city using Hec-Ras. There are number of ungauged rivers located in the semi-arid zone in Algeria. Above methodology could be allowed an acceptable estimation of the runoff in area with similar conditions

Jarugu Anjanee pradha et al. [19] in this study Hec-Hms model is used to simulate the rainfall-runoff process an event based flood modeling. Methods adopted are Green and Amt method for the infiltration process and SCS unit hydrograph for modeling direct runoff is applied. Calibration and validation of the model are done. Nash-sutcliff efficiency is used to check the suitability of the model and taking Nash-sutcliff efficiency as an objective function for the calculation of discharge. These modeling tools that will help water resources managers to find out reasons for floods and change in discharges in stream gauge station. So that they can take necessary steps to mitigate the floods. Land use, land cover on the surface runoff discharges are calculated by basin area, land use, land cover of soil on that particular basin, time-series data all these features are used. These results are significant for better watershed planning, Management

of basins, constructions of Hydraulic structures ,understanding climate changes, calibrating Green and Ampt parameters and simulated runoff hydrographs were generated.

These are compared with observed hydrographs. Results shows these computed discharges is more than the observed discharges. There is a difference of 7.7% between over all simulated and observed peak discharge of five calibrated events. Hec-Hms model of extreme events helps in analyzing the flood of that particular area, Analysis of loss parameters using Green and Ampt parameters, transform parameters using SCS unit hydrograph. Maximize the Nash-sutcliffe-efficiency by optimizing Green and Ampt parameters. Calibration done by four events and validation by three events, Calibrated and validated events shows peak discharge is high for simulated events. Calibrated and validated events shows volume is less for simulated events; area is less for simulated events compared to observed events. Validated results shows, the model is reliable as Nash-sutcliffe efficiency is around 0.65-07.

Tu Ngo Anh et al.[20] this research indicates to simulate event-based rainfall-runoff modeling. In this Hec-Hms model data used from a historical flood event in December 2016 and rain fall data from CHIRPS. Statistical index NSE with the value at 0.95, R^2 coefficient reached 0.87, PBIAS being around 0.45 and PFC being at 0.89. This model shows better performance in the rainy season then in the dry season. Hec-Hms model used for operational purposes in weather forecasting and flood warning in river basin in south central coast and Vietnam.

Flow calculations the Muskingum-cunge method has adopted for the flood wave movements across river and correlation between discharge and volume. Total 9 sub-basins constructed to model the precipitation -runoff process of the Laigiang river. This studies shows applicability of satellites precipitation to restore flow data for other basins without rain-gauging and flow stations in vietnam and can apply the results of this study to other basins in the world. The data accuracy of the simulation is highly dependent on the input databases. It is depends on river bed cross-section, density, base flow, ground cover and especially topography that needs to be updated on a large scale. Hec-Hms model used to combine early warning system and water level monitor technologies such as IOT.

Yassine EI Yousfi et al.[21] evaluating the management of water resources in a watershed, discharge data are among the most critical factors that must be considered. Methods used to simulate rainfall-runoff in the Nekkor watershed in Al Hoceima province was simulated by using Gis, Remote sensing and Hec-Hms model. Performance of this model for rain-fall and run off in the watershed was examined. Soil conservation service cure number, loss method used, Model parameters were changed and calibration was performed. Model tests indicates

consistent and satisfactory performance in terms of peak discharges, total flood volume, time of peak discharge and studies indicates overall hydrograph adjustment effects was found. Validation and calibration period determines coefficient R^2 values are 0.73 and 0.71. The root mean square error (RMSE) values shows within acceptable range. During calibration period relative bias (RE) indicates over estimated and an under estimated in validation periods in the peak flows. The model results will help decision makers to manage water resources in this watershed and mitigate flood risk.

Rambabu T et al. [22] Hydrological modeling of a watershed is a function of rainfall kinetics, vegetation cover and land characteristics. The following data is used rainfall, soil and vegetation, surface topography. The morphological parameter like basin shape and stream network also decides the flow direction and its accumulation, runoff volume intensity and peak flow. Precise DEM is used to define the flow direction and stream network at microlevel. Hec-Hms modeling is adopted, these models are used, in which the hydrological response behavior provides the runoff and soil erosion assessment of watersheds under a given flood periods. Remote sensing data is a major input to analysis. The objective finding is sub-watershed contributing more runoff to the flood submergence. To evaluate the peak floods that submerges the lower watershed. Suitable site location for flood control structures in to sub watersheds. Model is calibrated and performance evaluated using the Nash-sutcliff efficiency. Hec-Hms model results indicates that there is correlation between the peak discharge and flood submergence as the flood submergence area is mostly flat with slope less than 1%. As result perennial flooding problem of the Errakalava river suggests the construction of a reservoir at the confluence point of Bineru, Thrupukalava and e Errakalava to mitigate flooding.

yeshmebet yitbarek Belay et al. [23] hydrologic model studies are used to estimate runoff from rainfall data for the determination of an accurate quantity from a given process. Methods adopted in this studies are HEC-HMS model of the initial and constant, the Green and ampt, and the SCS,CN loss methods were selected as a modeling tool for estimation of runoff in middle Awash Multipurpose dam on the Awash river basin. The Hec-Hms model calibration, and validation done by using meteorological and hydrological data for the year from 2004 to 2008 and 2009 to 2013. Hec-Hms model performance showed the initial and constant Nash-sutcliff NSE-0.73, correlation coefficient R^2=0.75 and RMSE=0.5.

Tripti Dimri et al. [24] developed hydrologic model by considering influence of climate change simulation of stream flows in the Bhagirathi river basin using HEC-HMS model. Model is simulated for single and three year time from 2010 to 2015 included calibration and validation of the model .Result of simulation shows a close relation between observed and simulated data.

Model is assessed using precision standards as the Nash-sutcliff co-efficient (NS), the root mean square error (RMSE), and mean absolute error (MAE) were consider for assessing model precisions.

It is observed that the simulation discharge matches well with the observed discharges after the calibration for both 2010 and 2010-2012.Snowmelt contribution in the basin was found to be nominal with low and constant flows over the winter month frequent fluctuations during extreme rainfall event periods. Peak discharge is obtained during pre-Monsoon month is attributed to the melting of a accumulated snow from winter precipitation the R^2 values are found to be 0.99 and 0.98.during 2010 and 2010-2012.

Patel M.M et al. [25] hydrologic models are simplified, conceptual, representation of part of the hydrological cycle, runoff rates and ground water recharges from rainfall events are key parameters in most water resources development schemes such as storage reservoir of surface water, diversion weirs, flood protection structures and hydropower and irrigation projects.

Hydrological phenomenon is complex, highly non- linear and highly variable in space and time. A Model is required to predict the watershed runoff for the design and management of water resources utilization and flood control projects. Models are classified as event-process models and continuous process models. Event process models are designed to simulate individual events and it emphasis on infiltration and surface runoff .It gives peak discharges and volumes. Continuous process models are designed for long term simulations and it emphasis on all hydrologic process. It simulates drought and water balance.M.M.GT Desilva (et al) describes modeling of event and continuous flow hydrograph with HEC-HMS model. A case study of Kelani river basin Sri Lanka.

Reshmo T et al.[26] describes simulation of event based run-off using HEC-HMS model for Walnut Gulch water shed located in Arizona U.S.A. This model has been applied for 7 rainfall events of sub watershed of Walnut Gulch watershed. The model has calibrated for four rainfall events and validate for three rainfall events. To compute infiltration, rainfall excess conversion of runoff and flow routing methods like Green-Ampt, clerk's unit hydrograph and kinematic wave routing were choosen. It is observed that HEC-HMS model has performed satisfactory for the simulation runoff for the different rainfall events. From the results, it is observed that HEC-HMS model has performed satisfactory for different rainfall events. HEC-HMS successfully

re-produced low flow and thus the model is a useful tool to estimate low flows in advance based on drought forecasts.

Conclusions

HEC-HMS model is designed to simulate the rainfall-runoff process of dendrite watersheds. It is conceptual model supports watershed physical hydrologic process. The model supports both event and continuous hydrologic process modeling. Monthly models are better performance than daily and monsoonal models. Useful tool to estimate low flows in advance based on drought forecast and early warning during extreme rainfall condition in the basin. The model shows good performance the results indicates D=0.006, R^2=0.91 and NSE=0.82 during calibration and D=4.9285, R^2=0.84, and NSE=0.82 during validation. Hec-Hms model in applications of flood control, water Management for medium size basin. It has been found that the HEC-HMS distributed approach simulated daily stream flow satisfactory and it performanence was found to reliable, estimate more desired peak values. Calibrated and validated models can be used to predict, runoff from rainfall for river basin with gauged and ungauged sites in semiarid regions. Rainfall and runoff model useful tool to issue early warning during extreme rainfall condition in the basin.

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