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Research paper



A Review on Rainfall Runoff Simulation at Ungauged Catchment

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Abstract

Ungauged catchment occurs when no runoff data are available or when very few ground rain gauges are located in a huge catchment. For these catchments, the parameters to be used in rainfall-runoff models cannot be attained just by adjusting runoff information and thus should be procured by different techniques. Show parameters that require orientation are normally transposed from comparable measured catchments. The rainfall runoff simulation is very important to estimate and predict the flow in ungauged catchment. This investigation reviews ideas to differentiate hydrological comparability for transposing parameters from a gauged to an ungauged catchment. Model parameters that are physically based are generally derived from other information close to the ungauged catchment of intrigue. The primary challenge with rainfall-runoff demonstrating in ungauged catchments is the absence of neighborhood ground precipitation and streamflow information to be utilized in aligning the proposed show parameters. Parameter alignment is useful since adjustment can represent the impacts of hydrological set up in a specific catchment. Since hydrological models are especially reliant on their limit conditions, the alignment practice directed can modify the predispositions of info information utilized. Parameters' adjustment can fundamentally improve the execution of rainfall-runoff models since it included media properties of soil and vegetation which are exceptionally heterogeneous and basically are in every case inadequately known. Alternative methods for ungauged catchments are required which are the subject of this study. This study summarizes the important methods used in an ungauged catchments, discusses the issues of using satellite data as a substitute input to rainfall-runoff models and its comparison with point scale ground data.

Keywords: *Ungauged catchment; rain gauge, satellite, rainfall-runoff model*

1. Introduction

A primary component of the water cycle is streamflow. It is a movement of water in river, channels and sea. The main effect on streamflow is rainfall runoff in watershed. Streamflow is a standout amongst the most basic hydrological factors required for water assets assembling and supervision, and water assets frameworks task together with portions for ecological tributaries. Nonetheless, there are inadequate numbers of deliberation of key variables that can influence the hydrological forms restricts the appropriateness of rainfall runoff models. Runoff will be estimate only at a few locations, and rainfall depths are recorded at some designated locations. Consequently, modeling is an important tool to evaluate the water cycle elements at this ungauged catchment. Rainfall runoff modelling emerged due to lack of technical knowledge on the hydrological regime at the ungauged catchment. Values obtained from rainfall-runoff modeling of ungauged catchments are used in the scheme practices of various water resources engineering structures namely spillways, culverts and embankments. These values are also used in forecasting applications such as flood warning and hydropower task, catchment management uses such as water allocation, climate impact studies and understanding of catchment functioning and response.

Thus, this study aims to review alternative methods for ungauged catchments and proposed to use satellite data as an alternative input. The review of this study can be advantageous for stakeholders specially, to understand the use of rainfall runoff simulation at the ungauged catchment.

2. Ungauged Catchment Method

Stream flow is an important element prior to design of water resources engineering structures since this element is used as a judging factor to ascertain if the region or watershed is practicable for the proposed scheme. Daily stream can be effectively accomplished from attained catchments, however to ungauged catchments, obtaining stream data are challenging in hydrology. For this purpose, numerous methods have been established and applied at different measures of the world.

Ang and Oeurng [1] assessed the pertinence of the Soil and Water Assessment Tool (SWAT) model to feign the streamflow through adjustment and approval for both day by day and month to month premise in one of sub-catchment of Tonle Sap Basin in Cambodia. The outcomes of this examination demonstrated that SWAT model properly performed in gathering the sum and changeability of every day and month to month streamflow hydrograph time series both in adjustment and approval periods. In any case, it gives a sign on the likelihood of model relevance for nearby conditions. SWAT model ought to be utilized to feign month to month

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streamflow in such an ungauged catchment because of information shortage and vulnerability.

Tegegne and Kim [2] proposed new method called catchment runoff-response similarity (CRRS), in the perspective of lessening the hydrologic procedure prescient vulnerability and to take care of the issue of the key properties perceptible proof that support hydrologic likeness. The CRRS has two stages: 1) the regularly utilized regionalization method is connected near provisionally transpose the adjusted model parameter from gauged to ungauged catchments and 2) the runoff reaction of each littler depicted sub catchments of the checked and ungauged catchments are acquired in light of the parameter esteem processed in the initial step. The comparative sub catchments of the gauged and ungauged catchments are then distinguished in view of their overflow reaction likeness. The researchers conclude that, the runoff prescient vulnerability in the ungauged catchments of the two examination catchments was altogether decreased by the CRRS approach. In this way, the proposed approach can be utilized as an elective strategy for overflow forecast at the ungauged catchments around the world.

Xu et al., [3] proposed a precise way to deal with the challenge, and the approach incorporates field review, precipitation information gathering, recurrence investigation, establishment of hardware in the examination region, and numerical demonstrating. A hydrological demonstrate, TOPMODEL, was utilized to mimic streamflow process, to align the model parameters, a rain check was setup in the catchment and water level sensor was introduced at a control cross-area of the Lai Chi Wo river in January 2015. The recorded precipitation and overflow information were utilized to adjust the model parameters. This investigation uncovered that the severities of precipitation and overflow extremes are not reliable but rather objectively related.

Kha, et.al., [4] investigated the inflow prediction practice that assimilates real-time apprising systems by incessant optimization process of MIKE NAM to stipulate a suitable parameter set to forecast time. The proposed forecasting area of Ho Ho basin was verified. This zone faced insufficiency of past records for model calibration and validation. Analyses on the forecast results used transferred parameters obtained from calibrated parameter values at Hoa Duyet. It was found that outcomes obtained from the adapted parameters at the proposed process exhibited truthful prediction, which will improve decision making.

Abimbola, Wenninger, Venneker, and Mittelstet [5] investigated streamflow qualities of ungauged catchments in Rwanda by utilizing a regionalization approach in view of atmosphere similitude and stepwise different relapse examination. One climatic homogeneous locale was recognized and datasets of nine gauge stations and general accessible catchment qualities were utilized to create non-changed and log-changed relapse models. Aftereffects of this investigation demonstrate that atmosphere, physiography and land cover emphatically impact the hydrology of catchments in Rwanda. Utilizing leaves one cross-approval, the log-changed models were found to foresee the stream parameters all the more appropriately.

Yamanaka and Ma [6] proposed and test a novel approach for foreseeing runoff from inadequately gauge catchments utilizing a base complex model aligned with isotope information alone (i.e., without watched release information). The model is made out of two water-stores (soil water and groundwater) and considers their availability to overflow as far as both water and isotope spending plans. Monte Carlo recreation uncovered a solid intelligence between show execution in isotope reenactment and overflow forecast, exhibiting that the utilization of isotopes as unique intermediaries of adjustment targets helps dependably oblige display parameters. The outcomes show that this approach can fill in as a ground-breaking device for expectation of runoff hydrographs, especially for catchments in which the stage release relationship is profoundly factor.

Ragettli, Zhou, Wang, Liu, and Guo [7] evaluated a novel procedure for hydrologic parameter regionalization in view of choice tree learning approaches. Choice tree learning is a prescient demonstrating approach utilized in insights, information mining and machine learning. The scientists utilize this method in blend with the hydrological display Precipitation Runoff Modeling System (PRMS-OMS) to propose a technique for how to parameterize existing measured catchments surge occasions and sum up the parameters and model way to deal with ungauged catchments of China. The classification and regression trees (CART) produced in the investigation group parameter exchanges of comparative execution and afterward investigate the data substance of accessible catchment descriptors to clarify fruitful or fizzled parameter exchanges.

Gumindoga et. al., [8] determined runoff contributions from ungauged sub catchments. The researcher demonstrated the measured Marimba and Mukuvisi sub catchments by including the adjustment of the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS). The parameters transferred to the ungauged sub catchments were once simulated using streamflow of eight ungauged sub catchments complete the incorporation of GIS_and remote_sensing practices. The model succeeded to feign the overall runoff capacity plus highest_runoff for six years-historical. In this investigation, the simulated parameters for gauged sub catchments were effectively transmitted to six ungauged sub catchments. Simulation on runoff capacities for ungauged sub catchments remains beneficial for water assets management and design.

F et. al., [9] studied the use of Prediction at Ungauged Basin (PUB) Method in defining the water accessibility of ungagged catchments inside Sta. Lucia Watershed. This study proposed a technique that can assist the standardization of watersheds with no rain gauges or programmed water level devices. This process is known as_GIS Map Correlation (GMC) technique which utilized base_maps and digital_elevation_models to related the physical or geographical characteristics of watersheds and determine its correlations. In assessing the accurateness of the development, the study simulated a precipitation occurrence inside the similar catchment and relates the specific discharge with past data. The investigation found that the proposed strategy demonstrated a solid match in the correlation directed. This proved that GMC Method is effective to be used in standardization of ungauged catchments.

Khaddor, et. al., [10] evaluated a rainfall-runoff model using modern simulation tools, namely the Hydrologic model as well as Remote Sensing technic and Geographical Information System software (ArcGIS, HEC-GeoHMS). The study aims to forecast the design at peak. The results showed that the SCS-24 Type I storm represents the best distribution to simulate rainfall-runoff event at each return interval, since during the same storm event, it is the most related to the observed sudden rainfall at the neighboring gauged watershed called Kalaya.

Swain and Patra [11] studied a relative valuation of three conventional streamflow regionalization methods namely Inverse Distance Weightage (IDW), Kriging, and global mean which depends on spatial proximity between amongst giver plus beneficiary catchments. This study focuses on the closeness of estimated catchments nearby the ungauged catchment which are more cooperative than resemblance amongst catchments relating to its properties. Relapse and physical comparability approach created practically identical outcomes, and the model proficiency is satisfactory.

Iskender and Sajikumar [12] attempted to relate the execution of Soil and Water Assessment Tool (SWAT) and Geomorphologic instantaneous unit hydrograph (GIUH) modeling to forecast a superficial runoff for the instance of occasion displaying utilizing sub day by day precipitation and overflow. In view of model execution correlation, it is discovered that reliably better outcomes obtained from the GIUH models. Conversely, refinements in the outcomes are necessary since inconsistency happened between the duplicated stream and the genuine stream. Nevertheless, additional clarifications are essential for less exact execution of the suggest-

ed model for example absence of hourly precipitation and runoff information.

Abdul Razaq et al. [13] developed a set of multivariate linear and exponential models to predict streamflow in ungauged catchments at the east coast of Peninsular Malaysia. The model predicted streamflow at ungauged catchments with reasonable accuracy. The R2adj values for the best models are of the order 82.5 to 96%. The best is selected to suit a particular flow matrix. However, the logarithmic transformed data at resulting exponential function suggested a higher predictive power except for very low flow where multiple linear equations proved to be healthier. It is therefore expected that the practice used in the study can be utilized at other tropical areas in predictions of streamflow at ungauged river basins.

Swain et. al., [14] developed a Geographic Unit Hydrograph (GUH) for Koel River basin for estimate of flood hydrograph and verified the accurateness of the proposed GIUH method. Based on assessment of the derivative GUH with experiential Unit Hydrograph (UH), plainly the suggested method is appropriate and effective for determination of UH. The attained GUH at dynamic flow velocity of around 0.90 m/s exhibited nearer covenant to Synthetic Unit Hydrograph (SUH) derivative from Central Water Commission (CWC) method. Since, CWC approach is liberated of climate parameters and geomorphological attributes therefore, the subsequent UH could obligate advanced computational inaccuracies. Consequently, the GUH founded method will be better than the CWC approach.

Nruthya and Srinivas [15] investigated the efficiency of provincial Flow Duration Curve (FDC) technique and territory extent strategy to appraise figure of streamflow at ungauged sites along Mahanadi river basin, India. The two procedures used weighted general day by day streamflow standards seeing the weights of geological closeness and regions of the selected destinations. Results demonstrated that territorial FDC strategy that fused zone based weights created uplifted outcomes when contrasted with other joined techniques and weights estimated in the examination. Traditionalist routine with regards to utilizing just source site require not be always intense. It is in like manner seen to be better when two source destinations are considered. Broadened look into is fundamental at other stream bowls to toughen the conclusions drawn from this examination.

Mamun et. al., [16] presented an update and interpretation of regionalization method for the research area. The work was anticipated to provide a brief computational method to foresee and guesstimate the overflow peaks of numerous return periods for ungauged catchment area. The conditions created showed exceptionally righteous estimations of assurance. The advanced territorial overflow conditions possible are relied upon to give great estimation to overflow guess. Thusly, overflows of various outline periods can be accomplished, with the direct possible time and slightest uses, using the regionalized strategy.

Accurateness of prediction on IUH/UH using Geomorphologic instan-taneous unit hydrograph (GIUH) prototypes fundamentally is contingent on the approximation utilized for dynamic parameter velocity. Kirpich formula and rate relations remain unconventionally used to estimate time of attentiveness for a watershed. An investigation by Jotish et. al., [17] demonstrated that joint empirical formulae creates a new beneficial joining to evaluate the dynamic parameter rate for a watershed. The new procedure can be utilized at checked watershed to evaluate dynamic parameter rate. The prototypical is pragmatic to an ungauged watershed at Barak bowl, in India. The investigation begins that, the recommended technique can offer exact valuation for dynamic parameter rate and practice with GIUH approach; it improved the forecast on top qualities. The proposed technique is unobtrusive and conveys approximations of dynamic parameter rate for checked watershed and is valuable for ungauged watersheds.

Lim and Lye [18] studied a regionalization method to give valuable outcomes that can be used to estimate scheme floods for non-tidal influenced ungauged basins in Sarawak. Thus, an applied regional flood estimation technique for Sarawak, Malaysia, was demonstrated which utilized techniques in regional flood frequency investigation. The assortment of suitable frequency scattering was showed based on an suitable arithmetic test. With due respect to the constraints discussed, the regional flood frequency outcomes can be practical to non-tidal subjective ungauged basins in Sarawak located inside or in proximity of a recognized homogeneous region.

Hammouri and El-naqa [19] evaluated HEC-HMS rainfall-runoff prototypical to forecast superficial runoff occurred at Wadi Madoneh basin as an outcome of numerous configuration storms. The model was directed against genuine spillover occasions. The managed display produced new parameter gauges for the basin. The stream evaluation chart amongst repeated and real streams demonstrated that the adjusted model fits the genuine overflow information. The stream residuals between the genuine and the reproduced information were achieved. The results demonstrated that the model isn't biased at over anticipating or under estimating the repeated overflow.

Table 1: Summary of methods used at ungauged catchment.

No.	Authors, year, country	Technique/ Method/ Model used	Input Parameter	Outcomes
1	Ang and Oeurng 2018 Cambodia	Soil and Water Assessment Tool (SWAT), Geographic Information Systems (GIS)	DEM, soil type, land use, daily and monthly rainfall	The SWAT model ought to be utilized to reproduce month to month streamflow in such an ungauged catchment like the Stung Pursat catchment because of information shortage and vulnerability.
2	Tegegne and Kim 2018 Korea	Catchment runoff-response similarity (CRRS) and Soil and Water Assessment Tool (SWAT)	DEM, Soil use, land use, rainfall, temperature	The proposed approach can be utilized as an elective technique for spillover expectation in the ungauged bowls around the world.
3	Xu, Chen, Peart, Ng, Hau and Law 2018 China	Systematic approach for ungauged catchments, TOPMODEL,Generalized Likelihood Uncertainty Estimation (GLUE)	DEM, Soil use, land use, rainfall, Flood records	This investigation uncovered that the severities of precipitation and overflow extremes are not predictable but rather objectively related.
4	Kha, Nhu, and Anh 2018 Vietnam	MIKE NAM	Hourly rainfall data of flood event,	The outcomes demonstrated that the parameters of MIKE NAM model can enhance the adequacy of inflow determining for an information undermined zone.
5	Abimbola, Wenninger, Venneker, and Mittelstet	GIS tools and FAO Local Climate Estimator (New_LocClim)	Mean annual rainfall, DEM, Streamflow records	These models can be utilized for evaluating the stream parameters in ungauged catchments in Rwanda and the procedure can be

	2017 Rwanda			connected in some other locale, as long as adequate and great quality streamflow information is accessible.
6	Yamanaka and Ma 2017 Japan	Exponential tank model, JMA Radar-AMeDAS (Automated Meteorological Data Acquisition System), Monte Carlo simulations	Rainfall, River flow, Meteorological data	Isotope adjustment helps dependably compel display parameters, and that this approach is valuable for spillover expectation in inadequately measured bowls, for example, the investigation bowl, where riverbed distortions habitually happen.
7	Ragettli, Zhou, Wang, Liu, & Guo 2017 China	Classification and regression trees (CART), Precipitation Runoff Modeling System (PRMS/OMS)	DEM, Land use, Terrain, Hydro climatic characteristics, Drainage characteristics	Truck regionalization idea is especially appropriate for usage in meagerly checked and geographically complex conditions where a nearness based regionalization idea isn't pertinent
8	Gumindoga, Rwasoka, Nhapi, and Dube 2017 Zimbabwe	HEC-HMS	Rainfall, Evapotranspiration, Runoff, Rating curve, DEM, Land use/cover and soil data	The computer-generated parameters for the gauged sub catchments were effectively transferred to six the ungauged sub catchment in view of the NSE. Restoration of overflow volumes for the ungauged sub catchments is helpful for water assets arranging and management.
9	F, A, and Fibor 2017 Philippines	GIS Map Correlation (GMC), Arc GIS, HEC HMS	land cover maps, hydrologic cycle, DEM, Rainfall, River flow	The actual discharge and the simulated peak discharge shows the same value, which is 0.3 m^3/s. The outcomes showed that the Nash-Sutcliffe is satisfactory, Percent Bias was very good and RSR was satisfactory. The standards indicate that the simulated data had a precise fit compared to the real data.
10	Khaddor, Achab, Soumali, and Alaoui 2017 Morocco	ArcGIS, HEC-GeoHMS	DEM, Rainfall, River flow	Results obtained from this simulation provide exploitable information for protection against floods and for the design of hydraulic structures along the boukhalef watershed.
11	Swain and Patra 2017 India	Soil and Water Assessment Tool (SWAT), Regionalization methods.	Mean annual rainfall, daily streamflow, Land use and soil database, DEM	The similar investigation uncovers Kriging and IDW created more noteworthy outcomes in tenure NSE, RSR, PBIAS and PPTS than the other did regionalization strategies.
12	Iskender and Sajikumar 2016 India	Soil and Water Assessment Tool (SWAT), Geomorphologic instantaneous unit hydrograph (GIUH)	DEM, soil type, land use, rainfall weather (temperature, solar radiation, relative humidity and wind speed) and river discharge data to establish the water balance.	The execution of the models, it is start that dependably results are acquired for the GIUH models. Alternately, refinements in the results are vital since irregularity happened between the repeated stream and the genuine stream. There are a few outside explanations behind the less exact sanctioning of the model for water-sheds, for example, absence of hourly precipitation and spillover information.
13	Abdul Razaq, Ismail, Heryansyah, Awan, Alamgir, Hadi Pour 2015 Malaysia	Multivariate Statistical	Streamflow, Rainfall, Geomorphologic and geographic, Soil Characteristics, Land Use / Land Cover	The model is found to predict streamflow in ungauged catchments with reasonable accuracy. The R2adj for the best models are of the order of 82.5 to 96%.Study can be used in other tropical regions for predictions of streamflow in ungauged river basins.
14	Swain, Jha, and Patra India 2015	Geomorphologic instantaneous unit hydrograph (GIUH)	Drainage area, basin shape, and ground slope, physical characteristics, channel characteristics, average annual rainfall	Based on the appraisal of the determined GUH with reasonable UH, obviously the proposed approach is suitable and successful for the plunge of UH. Help the designers for truthful estimate of the surge hydrograph and additionally for the demonstrating of polluting influences transport. Strategy is financially saving and very exact for deciding the GUH and surge hydrograph for any ungauged catchment.
15	Nruthya and Srinivas 2015 India	Regional flow duration curve method	Streamflow records,	Results demonstrated that regional FDC strategy that fused territory based weights created increased outcomes when contrasted with other joined strategies and weights estimated in the examination
16	A. Mamun, Hashim, Amir 2012 Malaysia	Regionalization Technique	Mean Annual Rainfall, Flood frequency region, Topographical Maps	The equations developed indicated very worthy coefficients of determination. Provide good approximation for flood estimation.
17	Jotish, Parthasarathi, Nazrin, and Konsam	Geomorphologic instantaneous unit hydrograph	DEM	Exactness of the UH anticipated utilizing GIUH technique in a general sense relies

	Victor 2011 India	(GIUH), GIS		upon the gauge utilized for dynamic parameter rate. The present method giving appraisal of dynamic parameter rate based on effectively assessable watershed parameters is unassuming and is important for ungauged watersheds.
18	Lim and Lye 2009 Malaysia	Index-flood estimation procedure based on L-moments.	Streamflow, Rainfall, DEM, Flood frequency region	The regional flood regularity results can be useful to non-tidally prejudiced ungauged basins in Sarawak deceitful within or in vicinity of an identified homogeneous region. The technique can be implemented for other regions delivered that sufficient flood records are accessible.
19	Hammouri and El-naqa 2007 Jordan	Geographic Information Systems (GIS) and the Hydrologic Modeling System (HMS) of the Hydrologic Engineering Center (HEC).	Precipitation, Digital Elevation Model (DEM)	The flow assessment graph between simulated and actual flows shows how the regulated model fits the observed overflow information, and the stream residuals between the watched and the mimicked information were achieved. The results demonstrate that the prototypical isn't one-sided in finished anticipating or under foreseeing the simulated spillover.

3. Discussion

Gathering stream flow data at ungauged catchments is still a challenge in hydrology. For this purposed, numerous methods have been established and applied at different parts of the world. Based on the review conducted, it is found that the proposed models have successfully achieved to feign total runoff volume and peak runoff at certain period. The fit of the models was tested using Nash-Sutcliffe, Percent Bias (PBIAS) and RMSE-observation Standard Deviation Ratio (RSR) showed a respectable fit with respect to the actual data. It provided exploitable information for protection against floods and for the design of hydraulic structures. The models are not biased in over predicting or under predicting the simulated runoff [1], [2], [8], [9], [10] and [19].

Consistently high performance results are obtained from GIUH models as compared to SWAT models used by [11], [12], [14] and [17]. The method used for simulation at ungauged catchment of different sites varies. Each technique delivers various advantages and weaknesses for example time consumption, tool and accuracy. It is along these lines, critical to pick a powerful strategy so as to achieve the most attractive outcomes

4. Conclusion

This study reviews various concepts to identify hydrological similarity in order to transpose parameters from a gauged to an ungauged catchment.

In ungauged catchments, no runoff data are accessible to calibrate the model parameters, thus unconventional approaches are required. This study has revised a few techniques that depend on the kind of parameters, adjustment parameters related with a specific model, or physically based parameters with some criticalness outside of the model utilized. Adjustment parameters are ideally transposed from comparable, measured catchments inside a similar area.

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