DEVELOPMENT OF A FLOOD FORECASTING AND DATA DISSEMINATION SYSTEM FOR KALU RIVER BASIN IN SRI LANKA

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ABSTRACT

Flood hazard is one of the most frequent hazard in Sri Lanka which brings devastating damages. None of the river basins in the country, has effective flood forecasting system. This study focuses on the development of Flood Forecasting System (FFS) and data dissemination system by incorporating improved spatial and temporal resolution of rainfall data. Kalu river basin was chosen due to the reasons that, high rainfall, more frequent flooding and still many people lives in the flood-prone areas of the basin. Since flood forecasting needs forecasted discharge and inundated area, Rainfall Run off Inundation (RRI) model was used to develop FFS in this study. 2014 daily rainfall data was used for calibration and 2013 daily data set was used for validation. Lead-time for this basin was found to be nearly 19.5 hours (based on river discharge traveling time and GSMaP data latency). In order improve spatial and temporal resolution of rainfall data GSMaP was used and for its bias correction, software developed by JAXA was used. In order to determine the minimum number of ground stations (and locations) needed for optimum bias correction, some combinations of ground daily rainfall stations were analyzed. Rainfall stations located along the boundary of the basin gave better results. To disseminate the forecasted data a web based dissemination system was developed using FORTRAN, Gnuplot, JavaScript, Openlayers and HTML. Combined automated system would be used as emergency operation room tool during flood situations.

Keywords: RRI Model, near-real time flood mapping, GSMaP, JavaScript, HTML

INTRODUCTION

Flood occurs due to high intensity rainfall. Since Sri Lanka has many rivers (103 major rivers) with very steep slope and flat lands around river mouth (and sometimes even in upstream) flooding occurs in these flat lands. Kalu river (shown in Figure 1) is affected more severely any other river due to its topographic, rainfall trend (highest annual rainfall) and demographic reasons. Furthermore some studies shows that Rathnapura and Kalutara districts flood damages shows the increasing trend (ADPC, 2016) and around 132,000 people were living in flood prone area of this basin (ADRC, March, 2009).

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At present flood forecasts are made using upstream water levels obtained through telephone and often criticized for inefficiency and ineffectiveness. The objective of this study is to develop a flood forecasting system for Kalu river basin. Possibility of achieving this with ground rainfall data and satellite rainfall data would be considered. Even possibility of dissemination of forecasted information through modern information technology also would be considered. Overall system would enable Irrigation department of Sri Lanka to use this system ***as an operation room tool during flood emergencies*** and might enable the department to implement similar systems in other flood prone basins in Sri Lanka.

Figure 1: Kalu river basin map

DATA AND METHODOLOGY

Flood event of June 1st of 2014 is used for model development and calibration 2013 May and June data were used for validation. Lead time analysis showed that, discharge from most upstream (Ratnapura) takes about 40hrs to reach the most downstream area (Putupaula).However in the case of from tributary (Milakanda) to Putupaula it takes only 24 hours. Rainfall and discharge data sets availability is given in Table 1. In order to validate the flood inundation maps several MODIS and Landsat data sets were tried and due to cloud coverage good results could not be obtained. Finally ALOS data set of 3rd June, 2008 was used for partial validation. Several GSMaP data sets also used for bias correction verification.

Table 1: Data used for calibration and validation

	Daily Data	Hourly Data
Period	2012 to 2014	01/05/2014 to 31/07/2014
No of rain fall stations	18	2
No of Discharge st.	4	4

Although there were several hydrological models available in this study based on the available data and purpose simple RRI model was adopted. RRI model is governed by both continuity and momentum equations (Sayama, 2015) . Using the RRI model FFS was developed by following the methodology indicated in Figure 3. Initially 3 arcsec DEM was tried and due to noise and computational power requirement 15 arcsec DEM was taken for model development. DEM had to be edited (Figure 2) for river path and after sensitivity analysis actual river dimensions also incorporated into the model. Simulation was done from 1st April 2014 to July 31 2014. Sensitivity analysis and calibration were done using the ground rainfall in this period and referred to as

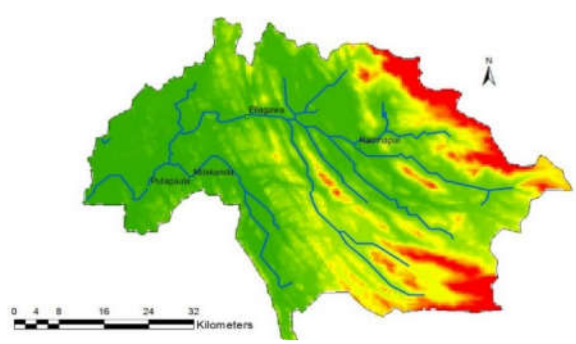

Figure 2: Edited DEM (Changed river path)

the flood period. River width and depth parameters showed high sensitive. Finally it was decided to incorporate the actual river dimensions in order to overcome following problems.

1. Formulae (power formulae which represents the river dimensions) assumes that river is expanding as it reaches the sea, whereas actual river remains with fairly constant width in the upstream reach also.
2. Narrow point at Ellagawa cannot be presented in the formulae method.

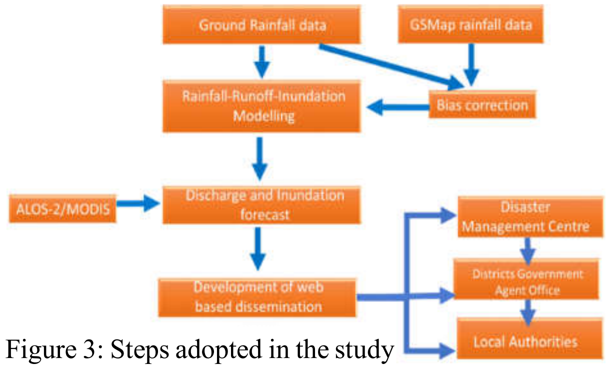

Figure 3: Steps adopted in the study

After incorporation of actual river dimensions and adjustment of rainfall records, calibration was redone. In order to improve hourly data resolution GSMaP was used. However GSMaP has some systematic errors and this had to be corrected. This is called bias Correction. For bias correction JAXA/NTT/ICHARM developed software was used. Normal procedure for dissemination of irrigation department had initiate the alert and pass it to the DMC. Thereafter DMC had to pass the information to other agencies. However since web based dissemination system is available other agencies like local authorities also can access the information directly from this system.

SYSTEM DEVELOPMENT DETAILS

Flood forecast and hazard information is so dynamic and might be updated each hour based on the rainfall data. Therefore this type of dynamic information might need dynamic information dissemination system. Hence web based forecast dissemination system might be the most suitable. Most important advantage of this system is interactive web based maps. Bias corrected GSMaP real-time data was used to run simulation of RRI as specified in methodology flow chart in Figure no 4. In order to make discussion easier system was broken into 5 components. FFS has 5 main components (Figure 4). They are described in the following discussion.

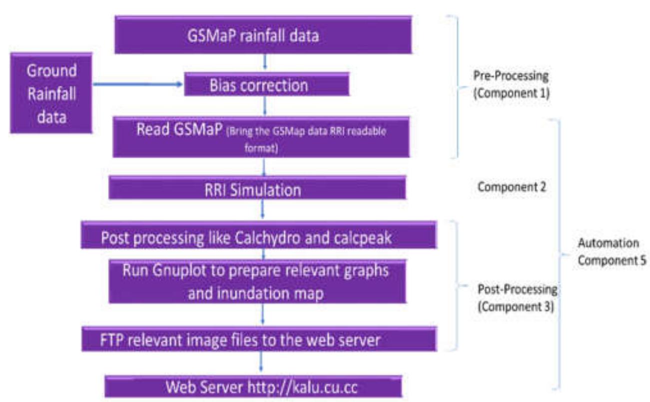

Figure 4 : Flood forecasting and Dissemination system

Pre-processing component of the system details (Component 1)

Since system needs hourly data and hourly rainfall data is sparse GSMaP data was used. First part of GSMaP processing starts with FORTRAN based executable. Based on the input files from GSMaP it rewrite the last hour and number of out files, in RRI control file (RRI_input.txt). Beside this it also modifies certain plot files which would be used as input files for Gnuplot in the rain subfolder in order discharge curves with starting time. Furthermore system would prepare GSMaP rainfall distribution for all 88 points with temporal details.

Post processing (Component 3)

Two important post processing functions were done by FORTRAN based executable. They are,

1. Producing predicted discharge and water level information
2. Automated warning information based on the threshold values given in the location.txt

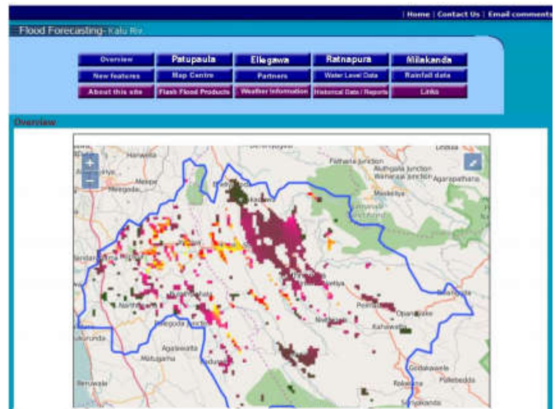

Figure 5: Inundation map produced at runtime

Gnuplot prepares the inundation map at runtime with script as shown in Figure 5. User can set two levels of threshold for each station. Hence based on these threshold value system would raise warning messages in the web site as in the following Figure 6.

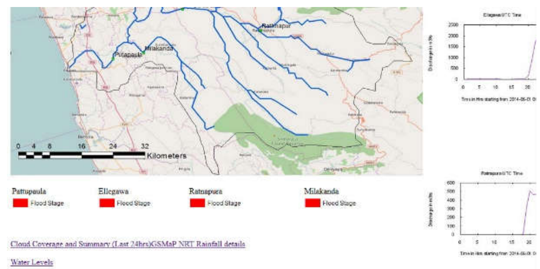

Figure 6: Warnings issued by the system

Web technologies (Component 4)

Openlayers, JavaScript, HTML and KML were used. Inundation map is based on openlayers and gives the user ability to dynamic zoom and panning of the map. Demo is available on the internet site http://kalu.cu.cc. DOS based automation script was also developed. Therefore if the system is able to retrieve the DIAS data web site would be updated hourly automatically.

Directory structure and automation (component 5)

Directory structure of the system designed in fixed manner so that automated script can execute each processes and transfer the relevant files to other processes. Therefore it is a must to keep the sub folders name as it is.

RESULTS

All these simulations were done for the period of April 1st to July31st of 2014 using ground rainfall

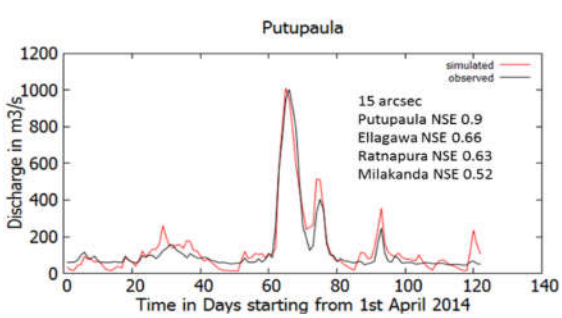

Figure 7: RRI simulation on 15 arcsec DEM

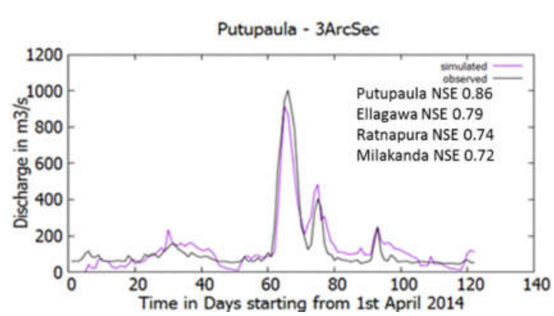

Figure 8:RRI simulation on 3 arcsec DEM

data from Irrigation Department. Initial calibration was not good. However after incorporation of actual river dimensions into RRI and a shift in the daily data was corrected recalibration results were good Nash Sutcliffe Efficiency (NSE) 0.91 and Root Mean Square Error (RMSE) 56 at Putupaula .For validation 2013 data was used (NSE 0.67 and RMSE 72). Similarly 3 arcsec DEM model also was developed and same calibration parameters were applied.

However First model (15 arcsec- Figure 7) gave good performance mainly Putupaula and other station showed lesser NSE. Second model (3 arcsec –Figure 8) showed similar performance for all four station and showed better average NSE. In order validate the inundation MODIS, Landsat and ALOS data were tried. MODIS and Landsat were covered with clouds and could not get proper inundation maps. However ALOS data for 2008 June 3rd flood event gave partial inundated area of Kalu river basin

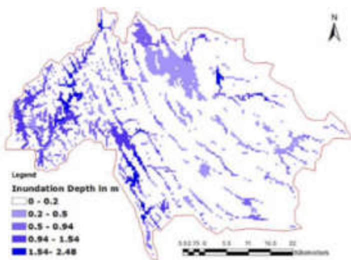

Figure 9:Inundation Map produced from 15arcsec simulation for the flood period of 2014

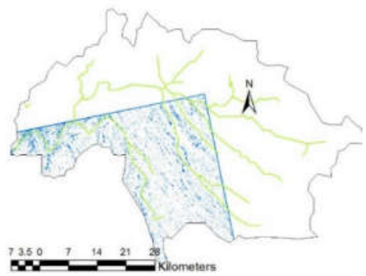

Figure 10:Inundation area retrieved from ALOS 2008 June3rd data set in blue colour

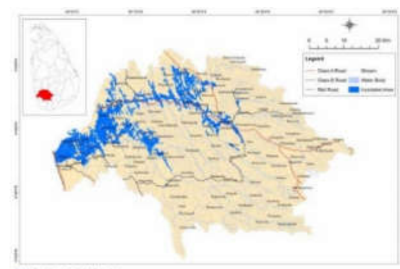

Figure 11 : DMC Sri Lanka report on hazards in 2012 inundation map (DMC, December 2012)

(Figure 10). However DMC published inundation Map (Figure 11) also been compared.

GSMaP bias correction

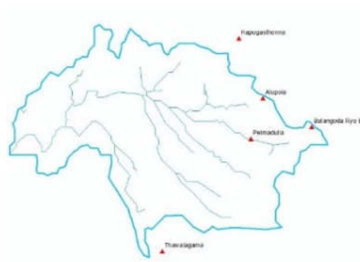

Figure 12: Group 1

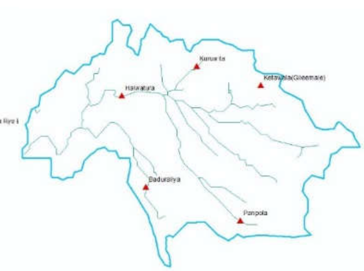

Figure 13: Group 2

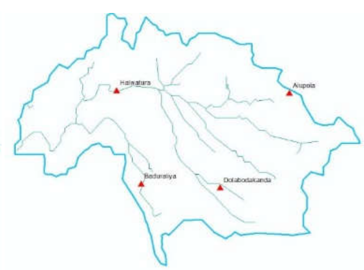

Figure 14: Group3

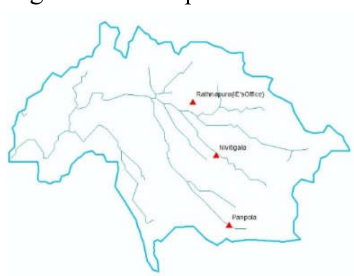

Figure 15: Group 4

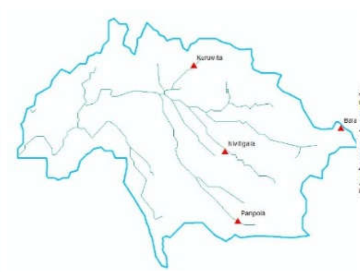

Figure 16: Group 5

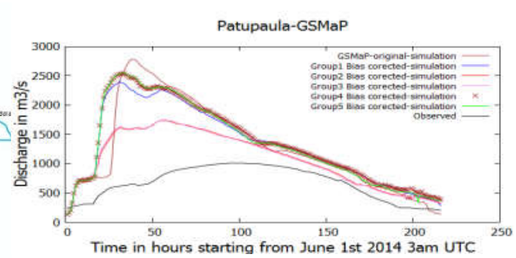

Figure 17: Comparison 5 group combination

As the hourly data for bias correction is from automated gauges it is necessary to decide the minimum number of stations and location of the gauges to get the optimum bias correction. For this five groups combinations were tried. It was found that gauges located along the boundary gave better bias correction (Figure 13 and 14).

DISCUSSION

Sensitivity analysis showed that river dimensions plays important role in model output. For flood inundation validation satellite data was used. Since Landsat and MODIS data during the flood period concerned were mostly covered with cloud, as a final resort 2008 June 3rd ALOS SAR image and DMC published map was used for validation. During initial analysis of bias correction parameter's sensitivity analysis grouping does not work well for this basin. This may be due to the small catchment area. To determine minimum number of the stations required for optimum bias correction, 5 combinations of 18 ground stations were used. Basins located around the basin boundary yielded good result. Based on the basin area, minimum number could be decided. For development of the web based dissemination system, DOS based scripting was used, since DOS based computers are most common in irrigation department. Automation script would run as windows/DOS services for every hour and web site would be updated automatically on hourly interval.

RECOMMENDATION

Although due to the noise in the 3 arcsec 15 arcsec was used in this study. 3 arcsec model could be used for forecasting if accurate DEM and enough computational power is available. Dissemination system could be further improved by incorporating SMS and email alerts. Development of simple web integrated RRI model as described in this paper, for flood prone basins might enable the stakeholders of the basin to do better flood management.

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