Nepalese Engineers Association, Japan (NEAJ)

Newsletter

Volume 1, Issue 1

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Nepalese Engineers Association, Japan (NEAJ)

January 2015

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EDITORIAL

The publication committee of NEAJ presents its first volume and first issue of NEAJ Newsletter. This issue reports on recent activities of NEAJ and also includes technical papers. The editorial and publication committee would like to thank all of those who have contributed in their own ways to make this issue possible.

We hope that you will enjoy reading this issue.

Thank you!

With Best Regards,

Guest Editor
Badri Shrestha

Publication Committee
Pawan Kumar Bhattarai
Khagendra Belbase
Sapana Poudel

President's Message

I am very pleased to write my few words for first issue of NEAJ Newsletter. This is the first publication of the newly restructured organization NEAJ. This issue includes activities of NEAJ and some technical papers from various fields. I would like to thanks all colleagues, specially our editorial and publication committee to prepare it.

The NEAJ is an organization of Nepalese engineers established to facilitate mutual cooperation and support for the professional welfare and development among Nepalese engineers residing in Japan and to effectively contribute and play the role of Nepalese engineers community for the development of the country. Formerly, Nepalese engineers residing in Japan established Nepal Engineers Association-Japan Center (NEA-JC) on March 24, 2003 according to Act-13(2) of the Nepal Engineers' Association (NEA) constitution (3rd amendment). The general assembly members officially dissolved NEA-JC and established the newly restructured organization "Nepalese Engineers Association, Japan (NEAJ)" through general assembly meeting held from 19 April 2014 to 25 June 2014. The new restructured organization NEAJ was established on 25 June 2014. The first executive committee, have formally assumed office of the tenure from 1 August 2014.

We, the executive committee, are trying our best to strengthen newly born NEAJ and to achieve its objectives. This publication of newsletter is definitely a symbol of progress for NEAJ. I am fully confident that this will help strengthening Nepalese engineers community for the development of the country and make our activities more vibrant. I hope that the publication of NEAJ newsletter will get continuity in the future with the support from all NEAJ colleagues.

Thank you

Best Regards
Badri Bhakta Shrestha
President, NEAJ

NEAJ Newsletter
Volume 1, Issue 1

Contents

Activity Reports

Skype Discussion Meeting on Natural Disaster Mitigation: Engineering Approach

A "**Skype Discussion Meeting on Natural Disaster Mitigation: Engineering Approach**" was organized on 31st August 2014 (13:30 – 15:30). The main agenda of the meeting was discussion on possible application of engineering technologies for natural disaster mitigation in Nepal. The main discussion point and ideas are summarized as below.

Discussion and Ideas:

(1) Er. Chandi Subedi briefly explained about possible application of IT solutions for disaster mitigation and management in context of Nepal including introduction of Raspberry PI, challenges and further actions to implement a pilot project for disaster mitigation in Nepal. Er Chandi also mentioned that Raspberry PI can put in riverbed and detect temperature, river water level, flow velocity, or some other geological vibration and these data can be transmitted via IP to local government or other central monitoring body and alert the inhabitants before the disaster. This technology also could be useful for landslide monitoring and issuing the warning.

(2) Er. Dr. Ved Kafle shared hand-on experience with Raspberry Pi kit and pointed that the sensors and communication modules would incur additional monetary and battery-power.

> ***Raspberry Pi** is a computing board that includes a CPU, 256 or 512 MB memory, SD card for storage, USB and serial slots. It doesn't include any sensors or radio communication units. It runs Raspbian (Linux like) OS over which TCP/IP communication protocols and applications can be implemented easily. WiFi or Zigbee (e.g. XBee) radio modules, and different sensor modules (eg. location, temperature, pressure, humidity, light) can be attached easily through the serial slots. (Source: Er. Ved Kafle)*

(3) For practical application of Raspberry Pi technology for landslide monitoring and early warning system, it was discussed to implement prototype project at first for checking reliability of this technology for landslide monitoring and issuing early warning.

(4) Collaboration with geotechnical engineers is also necessary to implement landslide mitigation project in Nepal.

(5) For sustainable implementation of pilot project and also for regular monitoring, participation of local community would be better option. To overcome socio-economic problem, it would be better to provide some application to community and collect data from users.

(6) Collaboration is also necessary with other IT experts/professional, particularly for data transmission.

Research grant to assist the Masters level thesis

Nepalese Engineers Association, Japan (NEAJ) has decided to provide research grant from President Fund of NEAJ to assist the Masters Level Thesis of the students of engineering studying in academic institute in Nepal. The call on application for research grant to assist the Masters level thesis was announced and it is currently in selection process. The detail information about the grant support is available at following NEAJ website.

http://www.neajc.org/2014/11/21/call-for-research-grant-to-assist-the-masters-level-thesis/

Organization of 8th NEAJ Symposium on Current and Future Technologies

The 8th "NEAJ symposium on Current and Future Technologies" is going to be organized in **TOKYO on January 25 (Sunday), 2015**. Presentations are invited from Nepalese and non-Nepalese academics, researchers, experts and students. Presentations by working people in different Japanese companies are also encouraged to share their ideas and experiences.
The basic aim of this symposium is to provide a common platform for students, researchers and people working in different kinds of industries to share their findings, knowledge and experiences. By doing so, we can help in transferring technologies, experiences, ideas to different Nepalese friends and ultimately to our home country.

Date, Time and Venue:

January 25, 2015 (Sunday)

10:00 A.M to 5:00 P.M.

Interactive Dinner: 5:30 P.M to 7:30 P.M.

Venue: Seminar A (4th floor, room number 406), Engineering building Number 1

Hongo Campus, the University of Tokyo

Bunkyo-ku, Tokyo, 113-8656, Japan

The detail information is available at
http://www.neajc.org/2014/11/29/8thneajsymposium/

Further inquiries: neajsymposium@gmail.com

Other Activities:

- **NEAJ Sub-committees were formed.**
- **Designing of NEAJ Logo: The NEAJ logo was designed.**
- **The new group mailing system of NEAJ was created.**
- **The NEAJ bank account has been opened.**
- **The NEAJ home page was updated.**
- **The NEAJ membership list is updating.**
- **The NEAJ membership application form is prepared.**

Information/Notice

To all NEAJ Colleagues,
If you have not yet joined NEAJ mailing system, please contact us to join NEAJ group mail system as soon as possible.

For Membership Application of NEAJ:
http://www.neajc.org/membershipapp/
or
Contact us by email at: neajapan2014@gmail.com

Technical Papers

DECISION SUPPORT SYSTEM FOR SUSTAINABLE WATER RESOURCES MANAGEMENT

B. K. Mishra, United Nations University – Institute for the Advanced Study of Sustainability, Tokyo, Japan
S. Herath, United Nations University – Institute for the Advanced Study of Sustainability, Tokyo, Japan
D.S. Sampath, Department of Civil Engineering, University of Peradeniya, Sri Lanka
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Abstract: The ancient irrigation tank systems in Sri Lanka have been playing a crucial role for agricultural water supply. These systems also constitute one of the richest sources of wetland biodiversity in the country. In recent years, these tanks are found to be less effective due to increasing water demands for irrigation, climate change, variability and several others. A key issue with these ancient tanks is seasonality and duration of water retention. Several structural and non-structural measures are being made to tackle the problems of water shortage. Deduru Oya reservoir Project, under construction, will supply irrigation water to existing farm area under village tank systems as well as new farm area through a network of canals. Water supply and demand situations were tested for normal and drought climatic scenarios. Water Evaluation And Planning (WEAP) was applied to test the water shortage along the left bank canal irrigation systems. The results pointed out that tanks will get dried in some months in drought year if the farmers are allowed to withdraw water conventionally (i.e. farmers are free to withdraw water as they wish). Simulations of the WEAP model suggested that there will not be any irrigation water scarcity for some changes in usual withdrawal. Additionally, water levels will not get very low during the dry season and many tanks will not dry out resulting little loss of biodiversity.

Keywords: Decision support systems, Irrigation water requirement, Water evaluation and planning.

INTRODUCTION

Optimal use of water resources is highly important for the sustainable future. Many emerging and developing countries lack adequate supply of water for irrigation and other uses due to inefficient infrastructural and allocation arrangements. Potential conflicts arising from competing demands of complex water resource systems require a holistic approach to address the various components of water management. The planning of water resource systems brings together an array of technical tools and expertise along with parties of varied interests and priorities.

This research aims to enhance resilience of rural community by integrating traditional (ancient tanks) and modern (reservoir) agricultural systems using water and evaluation planning (WEAP) tool, a decision support system [1,2], to evaluate water supplies and demands in Deduru river reservoir project system, Sri Lanka. Deduru river reservoir project is aimed to exploit the Deduru basin water resources in improving crop intensities of existing agricultural lands under tank irrigation systems and developing new agricultural lands in the Deduru and adjacent Mee river basins in view of enhancing productivity. Additionally, the project needs to ensure enough water for hydropower and environmental uses. Overall objective of this study is to develop and test water balance at monthly time scale under different supply and demand management scenarios.

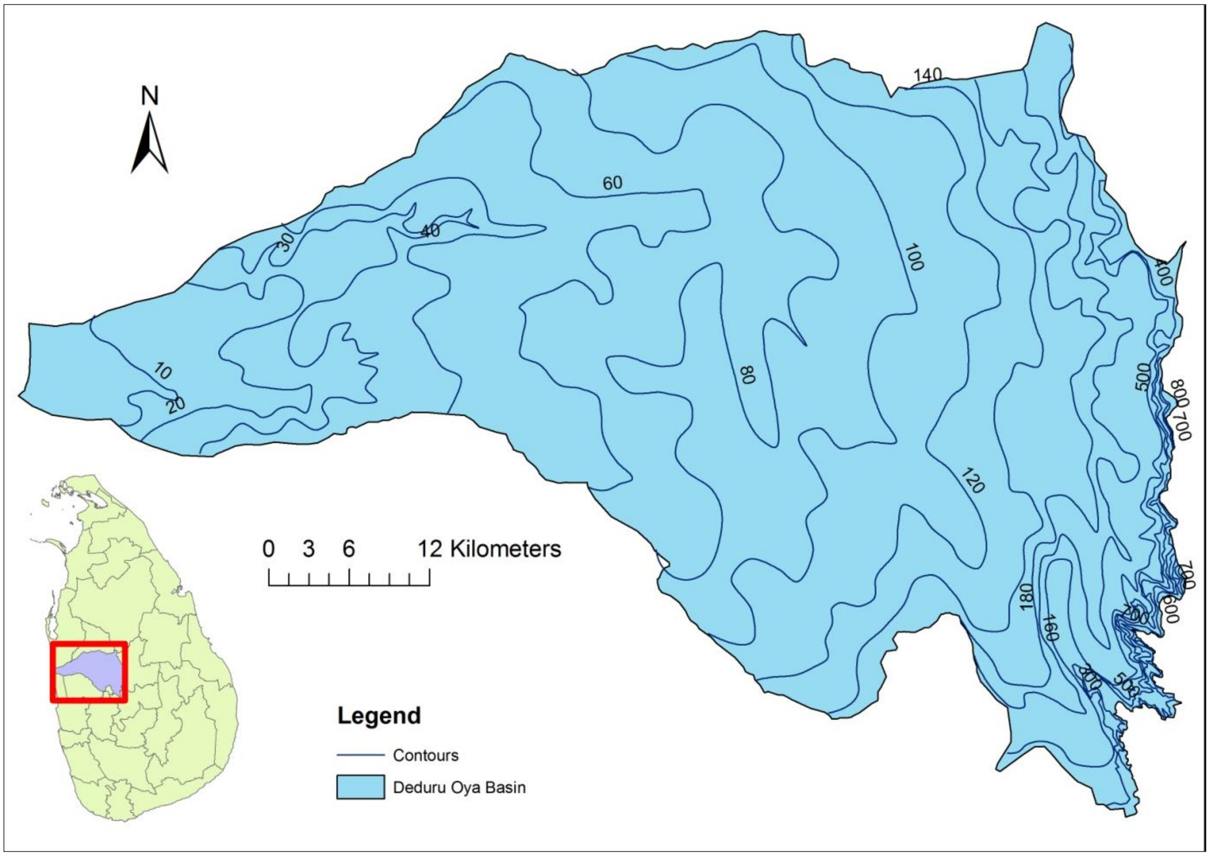

Figure 1 : Location and topography of the Deduru Oya basin, Sri Lanka.

STUDY AREA

Deduru Oya river basin is one of the major river basins of Sri Lanka. It is located between 7.32N and 7.86N latitudes, and 79.79E and 80.58E Longitudes. The Deduru Oya river has a length of 115 km and flows through, Matale, Kurunegala and Puttalama Districts. The Deduru Oya river basin has a catchment area of 2620 km2. Location of the basin in Sri Lanka and topography of the basin are shown in Figure 1.

Annual rainfall in Deduru Oya region varies from 1100 mm to 2600 mm. The rainfall pattern in the basin shows two clear peaks in the months of April/ May and October/November and the minima are in February and August. Monthly evaporation in the area is averaged 1250 mm. Farmers in Deduru Oya river and adjacent Mee Oya river basins complain non-availability of an assured water supply for the agricultural areas. Large part of the agricultural land is paddy crops. Potential water resources in the basin are: direct rainfall, stream flow, surface (tanks) water storage and groundwater storage. Quantity of water availability varies spatially and temporally across the basin significantly. There are very low flows in the stream usually during January, February, July and August months. The water available with the rainfall and collected in the existing tanks is not sufficient for two season cultivation. Seventy percent of annual rainfall in the region flows to ocean without being utilized in any way to serve needs of the local population. As a result, an optimal level of agricultural development has not been achieved.

METHODOLOGY

Development of a decision support system for managing water shortages in the project area consists four major components (Figure 2): (i) office and field visits for determining key planning issues and collecting hydroclimatic, tank/reservoir, crop and other datasets; (ii) estimation of water demands considering paddy crop irrigation water, hydropower and environmental requirements; (iii) estimation of available water supplies considering tank and reservoir storages; and (iv) water evaluation and planning for different hydroclimatic conditions, water allocation arrangements and system efficiencies.

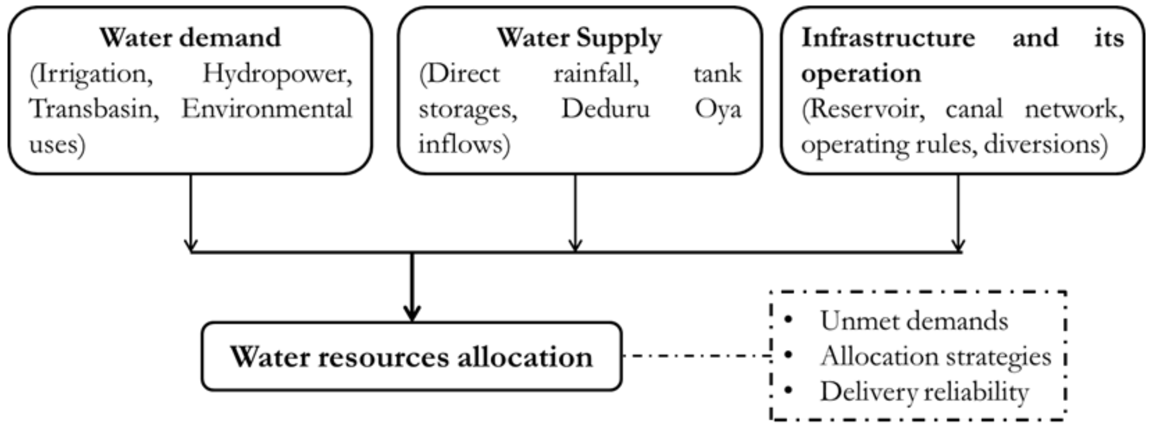

Figure 2: Schematic of water supply and demand management

Cropwat by FAO Land and Water Development Division enabled to estimate irrigation water requirement for rice crops, the main agricultural water demand. Literature review and discussions with local officials enabled to estimate environmental and hydropower requirements. A conceptual rainfall-runoff model, Simhyd, was employed to generate tank inflows [3]. Monthly normal and dry year flow corresponding to 50% and 80% probability of exceedance in ancient tanks along the left bank canal and Deduru river near reservoir site were used as potential water resources. Finally, WEAP model, an integrated water resources management tool, was employed to assess the water supply and demand management scenarios for the Deduru river reservoir project systems.

WATER REQUIREMENTS

Irrigation Water Requirement: Calculation of irrigation water requirement needs crop, climate and soil data sets of the study area. Paddy (rice) is the main crop in the region accounting for most of the agricultural water demand. The climatic data includes reference evapotranspiration and rainfall. This study used the Cropwat model by FAO Land and Water Development Division for calculation of irrigation water requirement. The irrigation water requirement is defined as the difference between the crop water requirements and the effective rainfall (FAO, 1998). The primary objective of irrigation is to apply water to maintain crop evapotranspiration when rainfall is insufficient. Crop water requirements (CWR) refers to the amount of water required to compensate for the evapotranspiration loss from the cropped field.

Estimation of the CWR is derived from crop evapotranspiration (crop water use) which is the product of the reference evapotranspiration (ETo) and the crop coefficient (Kc).The climatic data (ETo and rainfall) used for the calculations of Irrigation Water Requirement (IWR) is based on Batalagoda station [4]. Information on soil data is based on textural properties ISRIC-WISE global soil data [5]. The soils in the area are predominantly coarse textured, ranging from loamy to sandy loam in the surface horizons and from sandy loam to clay in the subsurface horizon. Red loamy soil type was assumed for the study area after reviewing textural information and ‘preliminary assessment of surface water resources’ [6]. Soil parameters are based on the standard values for Red loamy soil in the Cropwat model sample data sets. Calculation of IWR at scheme level for a given year is the sum of individual CWR calculated for each irrigated crop. Multiple cropping (several cropping periods per year) is thus automatically taken into account by separately computing CWR for each cropping period. Annual irrigation water requirement with system efficiency 0.5 (application efficiency 0.7 × conveyance efficacy 0.7) and 0.6 was found to be 24354 and 20295 cubic meter per hectare respectively.

Environmental flow requirement: There is an increasing awareness of the need to release minimum water along a river to ensure the continued functioning of ecological process that provide much needed goods and services for human use and maintenance of biodiversity. Water which is allocated and made available for maintaining ecological processes in a desirable state is referred as the instream flow requirement, environmental flows, or environmental flow requirement. The allocation of water to satisfy environmental uses initially developed out of the need to release from dams minimum flows to ensure the survival of often a single aquatic species with high economic value. However, the provision of environmental flows that attempt to preserve natural flow characteristics such as timing, frequency, duration and magnitude of flows is considered important for the sustenance of fresh water ecosystems, since the flow regime is one of the major drives of ecological processes on a river. The practice of environmental flow requirement began as a commitment to ensuring a ‘minimum flow’ in the river, often arbitrarily fixed at 10% of mean annual runoff. However, this ‘minimum flow’ approach may not be appropriate for safeguarding essential downstream environmental conditions of the river system. In this study, a minimum of 10% normal climatic year monthly river discharge has been ensured as environmental flow requirement for testing the water supply and management scenarios.

Hydropower requirements: The project is supposed to have a small hydropower scheme. The hydropower station of 1.5 MW (3 units of 0.5 MW capacity) is planned to be located just downstream of the reservoir so that water released for downstream irrigation schemes and environmental use can be utilized for power generation. This water will be diverted into the river after power generation. According to feasibility study project report, a discharge of 7 m3/s will be necessary to be released for the generation of 1.5 MW hydropower.

TANK INFLOWS ESTIMATION

SimHyd, a conceptual rainfall runoff model, was used to simulate daily inflows towards to the left bank ancient tanks. SimHyd model has been extensively used for various applications [7,8]. The SymHyd model is a component of the rainfall-runoff library (RRL) produced by Cooperative Research Centre for Catchment Hydrology, Australia. In this model, daily rainfall first fills the interception store which is emptied each day by evaporation. The excess rainfall is then subjected to an infiltration function that determines the infiltration capacity. The excess rainfall that exceeds the infiltration capacity becomes infiltration excess runoff. Moisture that infiltrates is subjected to a soil moisture function which diverts the water to the stream (interflow), groundwater store (recharge) and soil moisture store.

Calibration and validation of the rainfall-runoff model was carried out using hydroclimatic data at Tittawela tank. The Tittawela tank has drainage area of 2.95 km^2. Calibration of the model was performed over the period 1995/05/01 to 1995/12/31. The model performance is illustrated by comparing observed daily and simulated daily stream flow values over the period 1996/01/01 to 1997/03/31. The calibrated/validated rainfall-runoff model enabled generation of daily inflows to the ancient tanks using respective drainage area and climatic data. The model possesses both manual as well as automatic optimization facilities for parameter calibration. In this study, SCE-UA (shuffled complex evolution university of Arizona) option was selected for carrying automatic optimization. The Nash-Sutcliffe coefficient (E) of efficiency was used as a measure of the model performance [9]. The E value describes agreement between all modeled (Qm) and observed (Qo) runoffs, with E=1.0 indicating that all the modeled runoffs are same as the recorded runoffs. The Nash Sutcliffe coefficient for the calibration and validation was found as0.93 and 0.69 respectively.

WATER ALLOCATION MODELING

There are several tools which are designed to assess water supply and demand management in river basins. WEAP model was preferred because of its robustness and ease of use for developing and testing the water supply and demand management [1,2]. The WEAP model is GIS based integrated water resources management tool that integrates different water supplies and demands at catchment scale. WEAP was developed by the Stockholm Environment Institute. The WEAP model uses the basic principle of water balance accounting. WEAP represents a particular water system, with its main supply and demand nodes and the links between them, both numerically and graphically. Users specify allocation rules by assigning priorities and supply preferences for each node; these preferences are changeable, both in space and time. WEAP then employs a priority-based optimization algorithm and the concept of equity groups to allocate water in times of shortage. The simplicity of representation means that different scenarios can be quickly set up and compared and it can be operated easily. Water allocation to demand sites is done through linear programming solution. Therefore demand site satisfaction is maximized subject to the mass balance, supply preferences, demand priority and other constraints.

Water balance is necessary to be made for detecting the condition of water demand and available discharge at the intake. Analysis of water balance is usually based on normal (mean) and 80% reliable flow [10]. Normal and dry year corresponds to the amount of flow with 50% and 80% probability of exceedance respectively. Monthly normal and dry flow in Deduru Oya near reservoir site for the period of 1970-1995 has been estimated for developing and testing the water supply and demand management scenarios. Comparison of water surplus and deficit is based on normal and 80% reliable flow.

RESULTS

Scenario analysis enabled to answer 'what if' questions such as: what unmet demands can be expected if current trends are projected into the future?; What alternative allocations could be?; How should reservoirs be operated? The following scenarios were created for developing and testing sustainable water supply-demand management:

• Tanks supply only for two cultivation seasons: Graphs of irrigation area coverage and unmet water demands pointed out that most tanks are not able to meet two cultivation season irrigation water requirements. Water shortages occurred in the months of March, May, June and September.

• Tanks supply only with single (Maha) season cultivation: Most of tanks are able to meet single season irrigation water requirements. Water shortage occurred for some of the tanks in September.

• Reservoir supply only: Reservoir alone in normal climatic year is well enough to meet all the irrigation, hydropower and environmental flow requirements.

• Tanks and reservoir supply with dry climatic year: In dry climatic year, tanks and reservoir supplies are not enough to meet 100% water demands if operated normally. Water shortage occurred in the month of September. Alternative water allocations as well as minimization in water losses need to be considered.

• Tanks and reservoir with dry year climatic year and reduced water losses: This scenario was modelled to assess the impact of improved irrigation efficiency. Tanks and reservoir supplies will be only enough to meet all the water demands if ancient tanks are given higher filling priorities for the use in September, the water shortage month.

CONCLUSIONS

WEAP results reveal that traditional tanks are highly important to meet the water shortages in the dry climatic year. Existing tanks with larger storage than demands can be used to supplement other tanks. Additionally, water loss reductions and optimal reservoir operation with alternative water demand priorities and allocations can play important role to meet water shortages in dry climatic year. Accurate data is important to perform such analysis. Cropwat model successfully enabled to estimate rice crop irrigation water requirement. The estimated irrigation water requirement was found to be similar to that of Sri Lankan counterpart. Alternative agricultural practice (e.g., plantation time) can help in addressing unmet demands. A conceptual rainfall-runoff model, Simhyd, enabled generation of tank inflows. Calibration and validation results indicated that the modelled results were good. However, the model can perform better with availability of long observation hydroclimatic data.

The Deduru Oya Reservoir project with optimal water allocation will highly resolve water scarcity problems. With the completion of the Deduru Oya reservoir project, paddy cultivation will be increased by many folds. The productivity of not only paddy but also other highland crops, including vegetables and fruits, will increase many fold contributing further to the socio-economic betterment of the agricultural families. Additionally, all neighboring areas will be benefitted through the replenishment of groundwater aquifers.

REFERENCES

[1] Hussein, I., Weshah, R.A., 2009. Optimizing the water allocation system at Jordan Valley through adopting water evaluation and planning system

model, Thirteenth International Water Technology Conference, Hurghada, Egypt, pp. 753-777.

[2] Holf, H., Noel, S. and Droogers, P., 2007. Water use and demand in the Tana Basin – analysis using the Water Evaluation and Planning (WEAP) tool. Green Water Credits Report 4, ISRIC – World Soil Information, Wageningen.

[3] Chiew, F. H. S. and Siriwardena, L., "Estimation of SIMHYD parameter values for application in ungauged catchments", MODSIM Congress, Melbourne, Australia, 12–15 December, 2005, pp. 2883–2889.

[4] Dharmarathna W.R.S.S., Weerakoon S.B., Herath S., Rathnayake U.R. and Weerakoon W.M.W., 2011. Application of Decision Support System for Agrotechnology Transfer (DSSAT) model to optimize irrigated paddy cultivation under changing hydro-climate, Technical papers, Annual Transactions of IESL, Volume I, Part B, pp 207-211.

[5] Batjes, N.H., 2008. ISRIC-WISE Harmonic Global Soil profile dataset (version 3.1), Report 2008/02, ISRIC-World Soil Information.

[6] Wickramaarachchi, T.N., 2004. Preliminary assessment of surface water resources- a study from DeduruOya Basin of Sri Lanka, APHW Proceedings (http://rwes.dpri.kyoto-u.ac.jp/~tanaka/APHW/APHW2004/proceedings/OHS/56-OHS-A341/56-OHS-A341.pdf).

[7] Podger, G., 2004. Rainfall runoff library, CRC for Catchment Hydrology (http://www.toolkit.net.au/cgi-bin/WebObjects/toolkit) Australia.

[8] Chiew FHS, Siriwardena L. 2005. Estimation of SimHyd parameter values for application in ungauged catchments (http://www.mssanz.org.au/modsim05/papers/chiew_2.pdf).

[9] Nash, J.E. and Sutcliffe, J.V., 1970. River forecasting using conceptual models, part 1, A discussion of principles, Journal of Hydrology, 10: 282-290.

[10] Juwono, P.T., Priyantoro1, D., Rumaropen, N., 2012. Evaluation of Flow Capacity and the Pattern of Water Requirement in Irrigation Area of Lereh, Jayapura Regency of Indonesia, J. Basic. Appl. Sci. Res., 2(8)8218-8229.

AUTHOR'S PROFILE

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Education background: PhD (Urban and Environmental Engineering, Kyoto University, Japan), MSc (Water Resource Engineering, Tribhuvan University, Nepal), B.Sc. (Civil Engineering, The Institution of Engineers, India)

Selected publications:

1. Mishra, B.K., Awal, R., Herath, S. and Fukushi, K. (2014, accepted): Trends and variability of climate and river flow in context of run-of-river hydropower schemes: a case study of Sunkoshi river basin, Nepal, International Journal of Hydrologic Science and Technology (http://www.inderscience.com/info/ingeneral/forthcoming.php?jcode=ijhst)

2. Mishra, B.K. and Herath, S. (2014): Assessment of future floods in Bagmati River Basin of Nepal using bias corrected daily GCM precipitation data, Journal of Hydrologic Engineering, ASCE, DOI: 10.1061/(ASCE)HE.1943-5584.0001090.

3. Mishra, B.K. and Takara, K. (2014): Integrating synthetic flood data for selection of regional frequency distribution, International Journal of Hydrologic Science and Technology, Vol. 4, Issue 1. pp. 1-17.

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RAINFALL-BASED LANDSLIDE AND DEBRIS FLOW FORECASTING APPROACH

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Abstract: Sediment disasters such as landslides and debris flows frequently occur in the mountainous areas due to heavy rainfall. The establishment of early warning systems and evacuations strategies is very important essential to reduce loss of life and property damage. In this paper, rainfall-based forecasting approach for landslide and debris flow has been presented. The relationship between rainfall and soil water index has been analyzed for forecasting system by using hydrological distributed model. The approach has been analyzed by using both ground-observed and satellite based rainfall data. The Sabagawa river basin located in Yamaguchi prefecture of Japan was selected for case study. The snake lines could be useful for forecasting and warning system of sediment disasters.

Keywords: Landslide, debris flow, forecasting, snake curve, soil water index.

INTRODUCTION

Recently landslides and debris flows frequently occur in the mountainous areas due to heavy rainfall, which cause severe damage to property and loss of life [1]. It is thus essential to implement reliable and accurate forecasting system to provide communities timely information enabling them to prepare for hazard events and reduce loss of life and property damage. Effective forecasting systems for rainfall-induced landslide and debris flow must have strong hydrological, meteorological and geotechnical components [2]. Forecasting is a very important component in preparedness systems in non-structural measures of landslides and debris flows, which may help save more lives and reduce property.

Rainfall and soil water are important indicators of rainfall-induced landslide and debris flow. In this paper, rainfall-based forecasting approach for landslide and debris flow has been presented. The relationship between rainfall and soil water index (SWI) has been analyzed for forecasting system by using hydrological distributed model. The soil water is an important parameter in the hydrological balance and is essential for understanding land-surface interactions [3]. The approach has been analyzed by using both ground-observed and satellite based rainfall data. The satellite based rainfall data could be also useful to get supplementary information for forecasting system. The Sabagawa river basin located in Yamaguchi prefecture of Japan was selected for case study. There was a heavy rainfall in the Sabagawa river basin in July 2009 and large number of sediment disasters occurred in the areas. The relationship between rainfall and soil water index was thus analyzed for rainfall event in July 2009.

STUDY AREA

The Sabagawa river basin is located in Yamaguchi prefecture of Japan (Figure 1). The catchment area of the basin and length of main stream are 460km^2 and 56km, respectively. Geology of its mountain areas is mainly composed of fresh and weathered granite. This area is thus vulnerable to sediment disasters such as landslides and debris flows [4]. There was a heavy rainfall on 21 July 2009 and caused a large number of landslides and debris flows. Figure 2 shows the rainfall and accumulated rainfall at Manao station with some occurrence time of sediment disasters. The figure shows that sediment disasters occurred when accumulated rainfall was exceeded about 200 mm. The accumulated rainfall was about 268 mm and maximum hourly rainfall was about 60 mm/hour at Manao station.

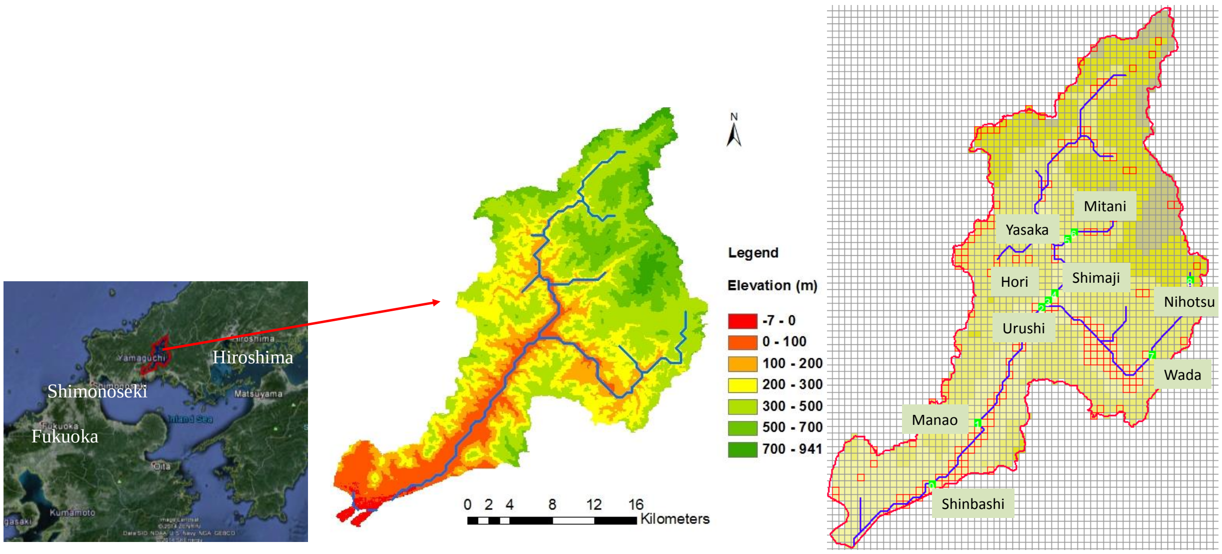

Figure 1 Location of Sabagawa river basin and hydro-meteorological stations

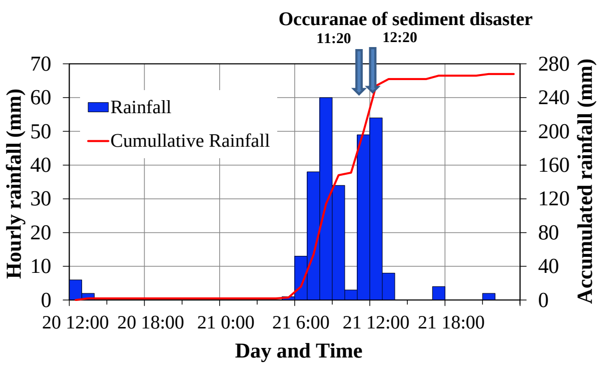

Figure 2 Ground observed rainfall and accumulated rainfall at Manao station.

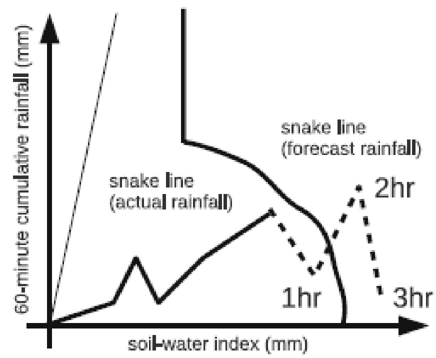

Figure 3 Basic idea used for sediment disaster warning models in Japan (Source: Osanai et al. [5])

METHODOLOGY

In Japan, the timing of the issuing of early-warning information is determined by the expected values of the 60-min cumulative rainfall and soil water index calculated using the forecast rainfall for 1–3 h into the future. A sediment disaster alert will be issued when the Critical Line is predicted to be exceeded by the expected rainfall in the following 1–3 hours as shown in Fig. 3 [5] [6].

In this study, Integrated Flood Analysis System (IFAS) model was used to simulate rainfall-runoff and temporal variation soil moisture in the soil mass [7]. The IFAS is a concise rainfall-runoff analysis system based on a hydrological distributed tank model (Fig. 4). In the model Global map elevation and land cover data were used. The three layer tanks (surface, subsurface and aquifer layers) were considered. The model was

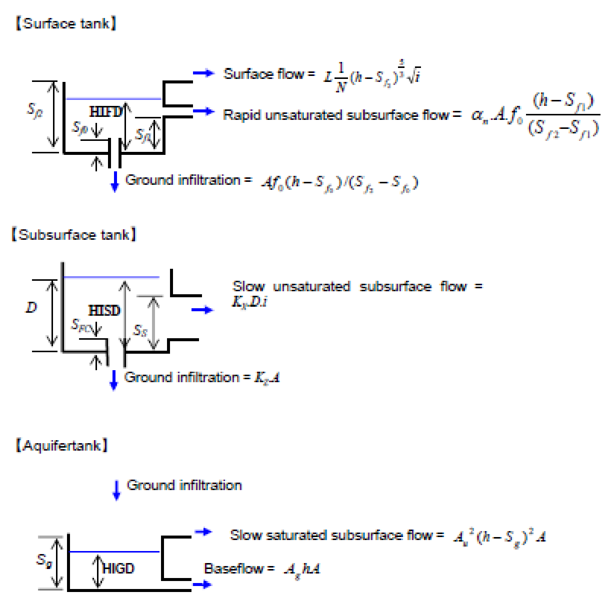

Figure 4 Basic structure of a model

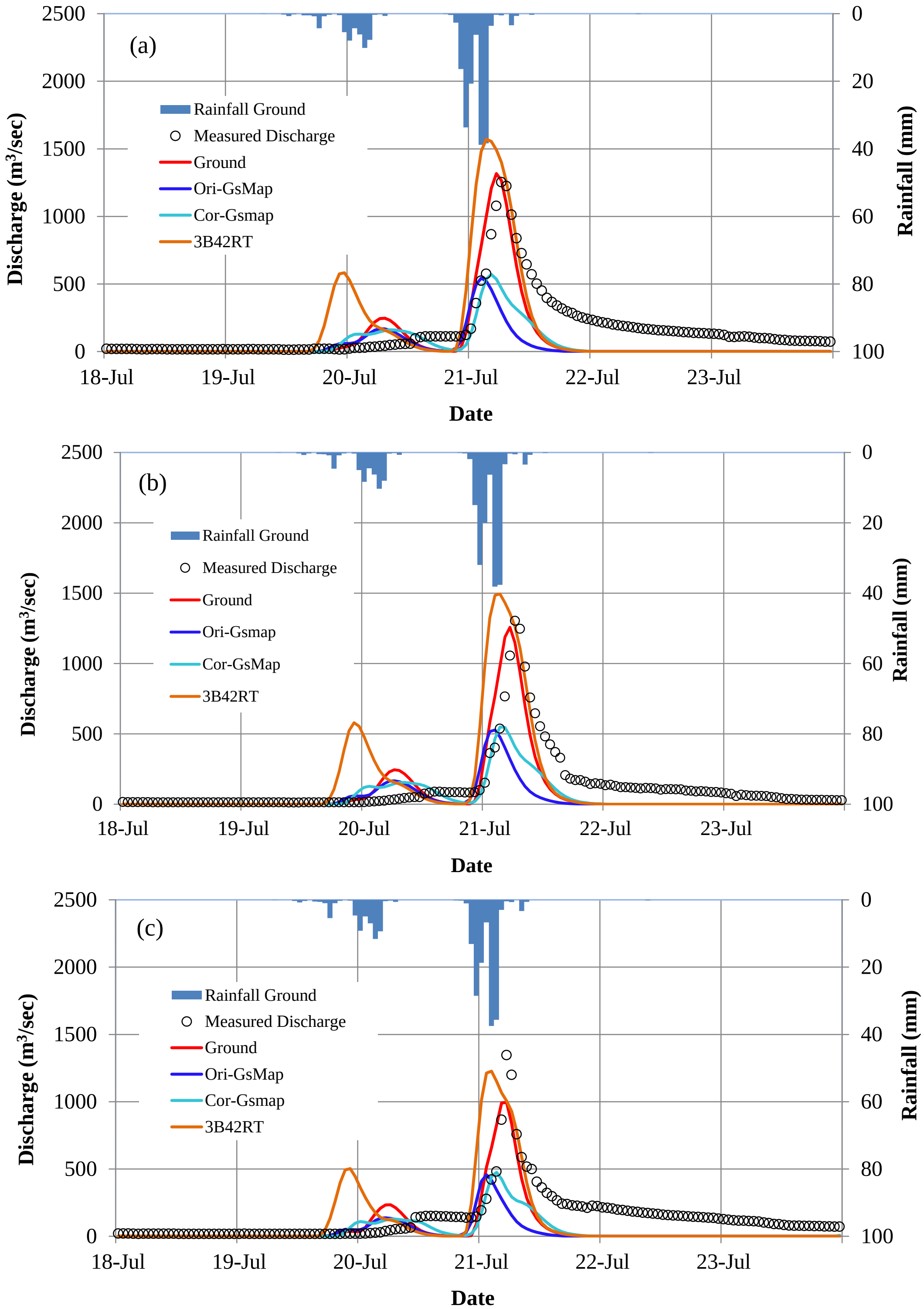

Figure 5 Calculated and observed discharges at (a) Shinbashi, (b) Manao and (c) Urushi Stations.

calibrated and validated by comparing simulated discharge with observed discharge. The rainfall event in July 2009 was used for calibration of model and the calibrated parameters were validated using rainfall event in September 2005. The absolute value of the soil water index was defined as the sum of water depths in

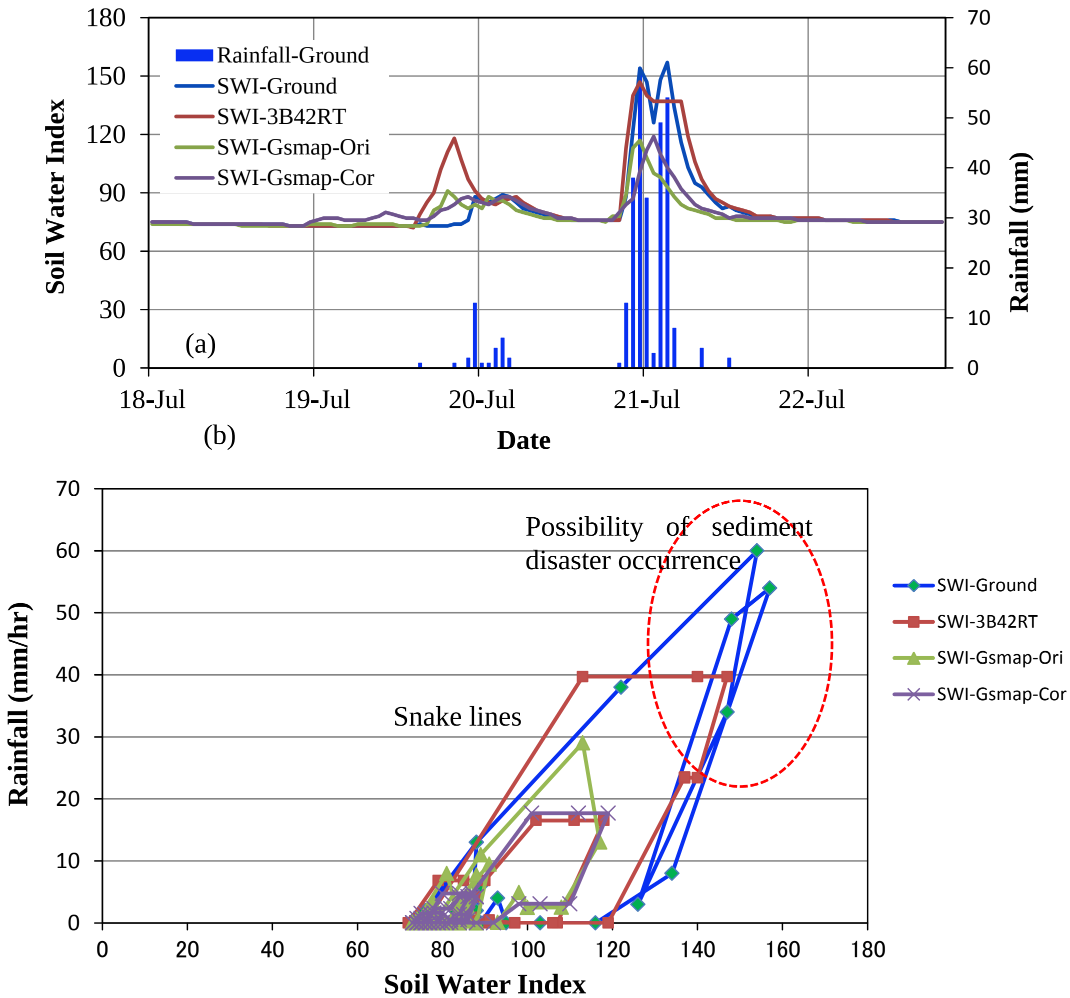

Figure 6 (a) Relationship between rainfall and soil water index, and (b) Calculated snake lines using ground observed and satellite based rainfall data (at Manao Station).

each of the tank layers. The relationship between SWI and rainfall was analyzed by using ground based rainfall and satellite based rainfall data (3B42RT and GSMaP).

RESULTS AND DISCUSSIONS

Figure 5 shows comparison of calculated river discharges with observed discharges at Shinbashi, Manao and Ursuhi stations. The calculated discharges using ground rainfall and 3B42RT satellite based rainfall data are more agreeable with observed discharges.

Figures 6 and 7 show relationship of rainfall and soil water index calculated by using ground rainfall and satellite based rainfall data at Manao and Shinbashi stations, respectively. The figures also show the calculated snake line which could be used for early warning and forecasting systems. The soil water index increases when rainfall intensity is increased, which can cause sediment disasters in the area. The satellite based rainfall data also could be useful to get supplementary information for forecasting and warning system of sediment disasters. The results show that results of SWI obtained using 2B42RT satellite based rainfall data are closer to those obtained using ground rainfall data than GSMaP rainfall.

The snake lines could be useful for forecasting and warning system of sediment disasters. To use snake line for warning system in sediment disasters, critical lines for warning criteria, alarm criteria and evacuation criteria should be determined based on past data of sediment disasters. The determination of critical line is very important for judging warning criteria based on

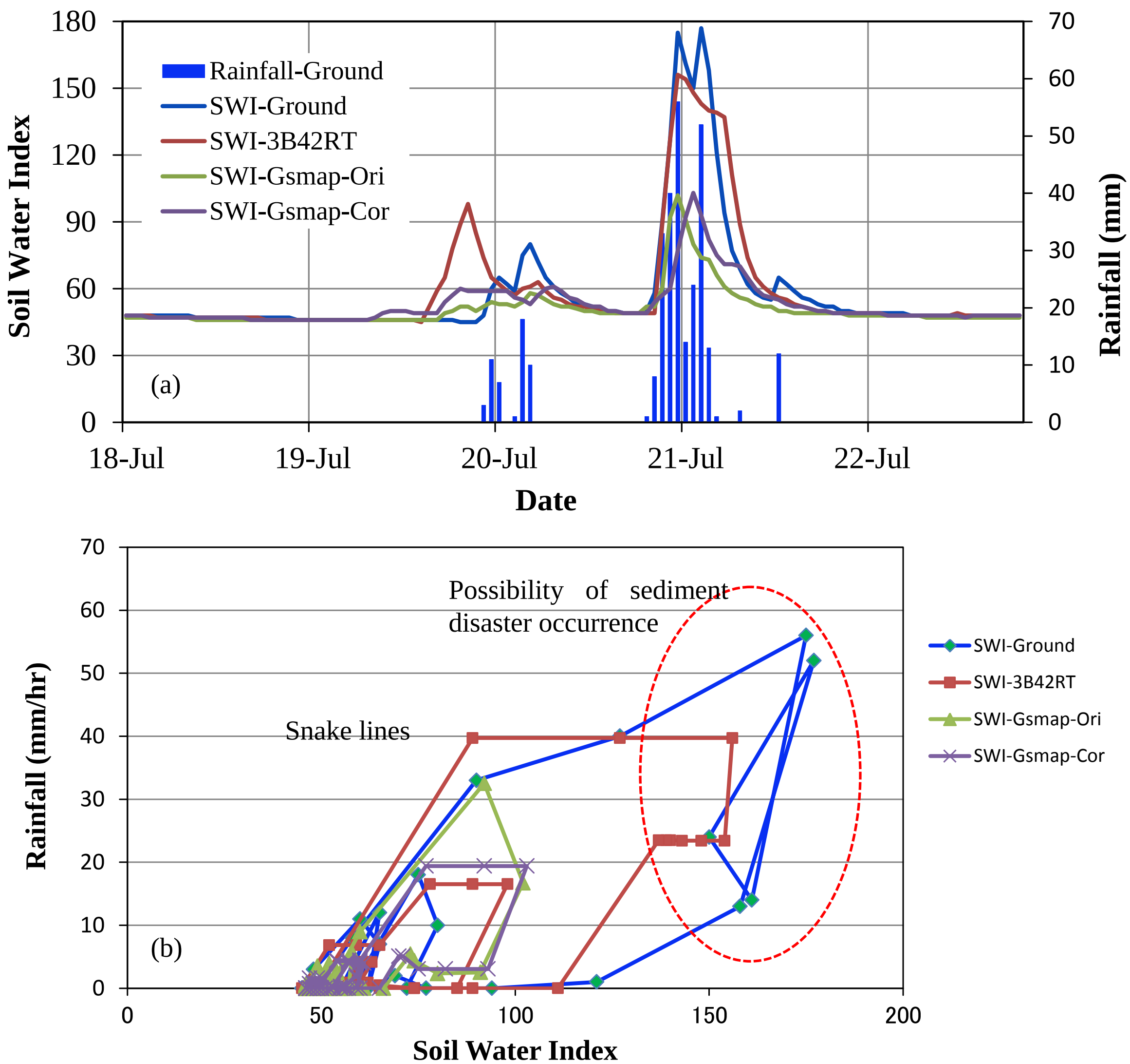

Figure 7 (a) Relationship between rainfall and soil water index, and (b) Calculated snake lines using ground observed and satellite based rainfall data (at Shinbashi Station).

snake line. The warning/alerting can be issued when snake line crosses the critical line. The lines inside red circle in Fig. 6 (b) and Fig. 7 (b) could be critical line for possibility of sediment disaster occurance.

COMCLUSIONS

The relationships between rainfall and soil water index were analyzed by using ground observed and satellite based rainfall data in Sabagawa river basin. The snake line calculated based on rainfall and soil water index could be useful for effective warning and forecasting systems of sediment disasters by determining critical lines.

When we planned any monitoring and alerting systems for sediment disasters such as landslides and debris flows, we must consider at least following issues:

- Any alerting systems must capable to issue warnings early enough ahead of potential disasters to enable adequate preparation and evacuation.
- A good warning/alert system not only needs to promptly issue alerts before a disaster occurs, but must also avoid false alerts since local governments and inhabitants will ignore the warnings if there are too many false alerts.

REFERENCES

[1] Shrestha, B. B., Nakagawa, H., Kawaike, K., Baba, Y. and Zhang, H.: Driftwood deposition from debris flows at slit-check dams and fans, Natural Hazards, Springer, Vol.61, No. 2, pp.577-602, 2012.

[2] Baum, R. L. and Godt, J. W.: Early warning of rainfall-induced shallow landslides and debris flows in the USA, Landslides, Vol. 7, pp. 259–272, 2010.

[3] Hunt, E. D., Hubbard, K. G., Wilhite, D. A., Arkebauer, T. J. and Dutcher, A. L.: The development and evaluation of a soil moisture index, International Journal of Climatology, Vol. 29, pp. 747-759, 2008.

[4] Nagano, H., Hashimoto, H., Kuroda, Y. and Takaoka, H.: Debris flows produced by heavy rains on July 21, 2009 in Hofu City, Japan, Italian Journal of Engineering Geology and Environment – Book, pp.725-733, 2011.

[5] Osanai, N., Shimizu, T., Kuramoto, K., Kojima, S. and Noro, T.: Japanese early-warning for debris flows and slope failures using rainfall indices with radial basis function network, Landslides, Vol. 7, pp. 325-338, 2010.

[6] Chen, C. Y. and Fujita, M.: An analysis of rainfall-based warning systems for sediment disasters in Japan and Taiwan, International Journal of Erosion Control Engineering, Vol. 6, pp. 47-57, 2013.

[7] Sugiura, T., Fukami, K., Fujiwara, N., Hamaguchi, K., Nakamura, S., Hironaka, S., Nakamura, K., Wada, T., Ishikawa, M., Shimizu, T., Inomata, H. and Ito, K.: Development of integrated flood analysis system (IFAS) and its applications, Proceedings of 7th ISE & 8th HIC, Chile, 2009.

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- Shrestha, B. B. and Nakagawa, H.: Assessment of potential outburst floods from the Tsho Rolpa glacial lake in Nepal, Natural Hazards, Vol. 71, No. 1, pp.913-936, 2014.
- Shrestha, B. B., Nakagawa, H., Kawaike, K., Baba, Y. and Zhang, H.: Glacial hazards in the Rolwaling valley of Nepal and numerical approach to predict potential outburst flood from glacial lake, Landslides, Springer, Vol. 10, No. 3, pp. 299-313, 2013.
- Shrestha, B. B., Nakagawa, H., Kawaike, K., Baba, Y. and Zhang, H.: Driftwood deposition from debris flows at slit-check dams and fans, Natural Hazards, Springer, Vol.61, No. 2, pp.577-602, 2012.

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AN OVERVIEW OF RIVER WATER ENVIRONMENT IN KATHMANDU VALLEY

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Abstract: Water is a key element in sustaining human and environmental health. Healthy ecosystems are sustained by good water quality, which leads to improved human well-being. In recent years, surface water in several developing countries including Kathmandu Valley is considered to be highly deteriorated. Water demand for drinking, domestic, industrial, and recreational uses has increased over the time with increase in population, quality of life, economic activities and development activities in Kathmandu. Several government and non-government institutions, civil societies and others are working for the improvement of river environment inside the Kathmandu Valley. UNU-IAS (United Nations University-Institute for the Advanced Study of Sustainability), Japan has launched a research program 'Water and Urban Initiative (WUI)' for enhancing urban water quality in rapidly developing Asian cities. This study under WUI provides preliminary overview of river water environment inside the Kathmandu Valley. The study will contribute in figuring out an effective management plan for the sustainable urban water environment. A WUI study team visited Kathmandu Valley for field observation and conducting interaction and discussion with concerned stakeholders of various government and non-governmental line agencies to perceive the existing water environment situation of the valley. The field observation showed that wastewater produced from households, industries, vehicle machinery repairing and washing centers, agro-lands have been discharging directly to the river system without any even primary treatment except upstream of Guheshwori.

Keywords: Urban Water Environment, Environmental Health, Water Quality, Sustainability, Field Observation.

INTRODUCTION

Water is a key element in sustaining human and environmental health. Healthy ecosystems are sustained by good water quality, which leads to improved human well-being. Due to over population and its consequent stress on the environment, the water quality and quantity both are getting worse. The problem is more severe in urban areas of fast growing cities. Deterioration of water bodies by improperly treated or untreated industrial/domestic wastewater, chemicals or heavy metals is a common environmental problem in most of the developing countries.

UNU-IAS Japan is carrying out a research program titled WUI with the objective of 'enhancing urban water quality in rapidly developing Asian cities'. In this research, existing water quality management frameworks and spatial relationships between land uses and urban water quality measured with biological, water chemistry and habitat indicators will be reviewed in selected urban watersheds.

Kathmandu Valley experienced rapid urbanization due to accelerated immigration after the onset of democracy in 2007 B.S. [1]. The major river system of the valley is Bagmati River system (Figure 1). The main sources of water in the river are rainfall and natural springs. About 82% of water volume is extracted daily from the surface water sources for drinking water supply in the valley [2]. The amount of water required for drinking, domestic, industrial, and recreational uses has increased over time with increase in population, quality of life, economic activities and development activities in Kathmandu. The rising demand for water and limited available resources of water in the Kathmandu Valley has put pressure on the quality of water. The status of health and environmental indicators directly and indirectly related to the quality of water. Table 1 presents the health and environmental indicators of Kathmandu

Valley [3].

Water pollution is the most serious public health issue in Kathmandu Valley. The solid wastes like kitchen wastes, dead animals, hospital wastes, industrial wastes are dumped by the riverside. Additionally, the sewer lines of domestic and industrial wastewater are connected in the river. The river receives direct discharge of untreated wastewater and becomes extremely polluted when it reaches core city areas. These activities excessively polluted the river system and are responsible for causing water borne diseases such as diarrhea, dysentery, cholera, and skin diseases. Table 2 presents the estimated volume of wastewater generated by municipalities of Kathmandu Valley in 2001 [5-6].

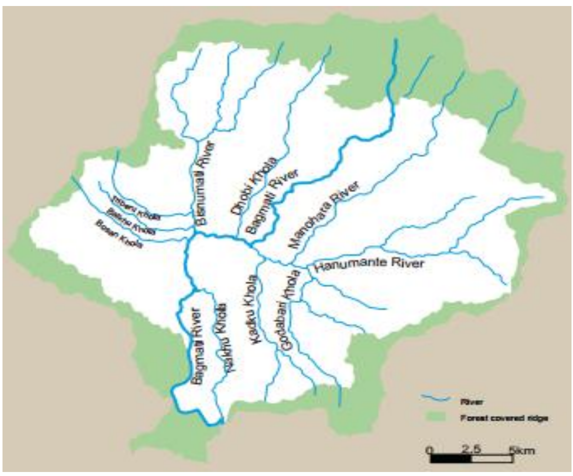

Figure 1 Map showing river systems in Kathmandu Valley (Source: THE BAGMATI: Issues, Challenges and Prospects [4])

Table 1 Health and environmental indicators of Kathmandu Valley

Municipality	Infant Mortality/1000 live births	Population with access to sanitation (%)	Population without access to safe (%)
Kathmandu	30.65	92.30	11.05
Lalitpur	40.12	81.42	15.85
Bhaktapur	24.01	83.16	19.71
Total urban	51.71	77.06	11.46
Nepal	68.51	39.22	20.48

(Source: UNDP, 2004 [3])

Table 2 Estimation of wastewater generation in Kathmandu Valley urban region, 2001

Municipality	Population, 2001	Million litres/day
Kathmandu	671,846	34.3
Lalitpur	162,991	8.3
Bhaktapur	72,543	3.7
Kirtipur	40,835	2.1
Madhyapur Thimi	47,751	2.4
Total	995,966	50.8

(Source: CBS, 2001 [5]; NWSC, 2001 [6])

Scientific studies have reported that the River health is at good condition at upstream but gradually decreases as it enters the core city areas [7-12]. The original communities of aquatic fauna have completely disappeared and two groups of pollution tolerant aquatic fauna like Tubificids and Chironomids. Also, most of the river stretches, at the core urban areas have no any living organisms in it [12].

In this study, we provide an overview of existing urban water environment of major rivers in Kathmandu Valley which will be helpful to figure out an effective management plan for the sustainable urban water environment of the valley in future.

CONCERENED INSTITUTIONS IN RELATION TO RIVER WATER POLLUTION

Several government and non-government institutions, civil societies and other stakeholders are working for environmental improvement of rivers in Kathmandu Valley and they are in increasing trend, but the status of the rivers is deteriorating day to day. Several studies in the pasts have indicated that the coordination among the stakeholders is one of the key issues behind the current situation of these rivers. All stakeholders need to be involved in an integrated and coordinated way in both planning and implementation of the activities. Some of the major concerned institutional and management set-up in relation to urban water pollution are discussed below:

High Powered Committee for Integrated Development of the Bagmati Civilization (HPCIDBC): The government formed this High Powered Committee to examine ways of improving the quality of water in Bagmati River through priority in construction and improvement of sewer lines and treatment plants.

Kathmandu Upatyaka Khanepani Limited (KUKL): KUKL should follow the norms and regulations for using water from rivers and groundwater so that impact of use of such natural resources has minimum impact in the river ecosystem.

KUKL should also manage sewerage network and make sure the waste water discharge into the river should meet the national quality standard. KUKL should develop, operate and maintain major waste water treatment systems in the valley.

Other Government Line Agencies: Many activities that help in protecting river ecosystem have already been initiating in different ways by different government line agencies. Some of the key agencies are: Department of Urban Development and Building Construction; Department of Roads; Kathmandu Valley Town Development Committee; Solid waste Management and Technical Support Center; Department of Land Survey-Cadastral Survey and Registration; Ministry of Science, Technology and Environment; Water and Energy Commission Secretariat (WECS); Ministry of Forests and Soil Conservation; Department of Hydrology and Meteorology; Department of Water Induced Disaster Prevention; District Development Committees (DDCs); Municipalities; and Village Development Committees (VDCs).

Users committee and community-based institutions: There are several users committee and clubs working for improving environmental status of the rivers in community level. There are many good initiations taken by such communities which can be replicated in different parts of the rivers, such as creating awareness about importance of river environment to the people along the river banks, conserving culture and heritage, promoting eco-friendly practices such as river side plantation, rain water harvesting, river side cleaning campaign, etc.

NGOs and Private Sectors: NGOs and private sectors have also played significant roles in activities such as awareness campaign, community based waste management, cleaning campaign, plantation and protection of river side cultural and heritage, management of parks, and other public utilities along the river banks.

POLLUTION ABATEMENT ACTIVITIES

The conservation of Bagmati River system is a key issue to sustain Kathmandu Valley. Although efforts have been made to conserve the river, the impacts are not significant. Nepal Government approved Bagmati Action Plan (2009-2014) to manage Bagmati basin. Since the Bagmati basin has a number of crosscutting issues, the progress in implementing the plan is not satisfactory.

From May 19, 2013, a strong civil society movement and public's general interest named as “Bagmati Cleanup Campaign” is generating tremendous concerns for cross-sectoral coordination to divert the sewerage discharge from the river course. High level government officials are hosting the programme on a voluntary basis. People from all backgrounds come around a predefined place and collect solid wastes scattered around the river stretch. The collected waste is managed by Kathmandu Metropolitan City (KMC). The campaign has collected thousands of metric tons of solid wastes from the river.

The Bagmati River system receives sewerage from wide range of sources. The river system receives liquid wastes from drainage networks made by KMC and also from illegal drainage networks. Additionally, the squatter settlements near the river side discharge their wastes directly into the river. The Bagmati Cleanup Campaign has created awareness among the local people; and participatory community efforts for the river restoration are increasing. The Pudasaini Sewa Samaj, Jorpati Youth Club, Gokarna youth club, Ama Samuha are the examples of such groups. The local clubs has also controlled most illegal sewage discharge points into the river.

FIELD OBSERVATION

Bagmati and Bishnumati Rivers are the main artery of Kathmandu, the capital of Nepal and king pin of its socio-economic, touristic, industrial, educational, scientific, religious and cultural centers. It has been observed that the Bagmati and its tributaries (Hanumante, Manohara, Dhobi Khola, Kodku, Tukucha, Bisnumati, Balkhu, Godawari and Nakhkhu) are heavily polluted primarily due to disposal of untreated raw domestic and industrial sewage, solid waste and other sources such as slaughtering at the bank of the river, sand mining and dead animals/carcasses disposal.

Recently a WUI study team has visited Kathmandu Valley for field observation and conducting interaction and discussion with concerned stakeholders of various government and non-governmental line agencies to perceive the existing urban water environment situation of the valley. While travelling along the river site the study team observed gradual decline in water quality towards the downstream reach of the rivers.

Main contributing factors for the degradation of river water quality were observed as haphazard urbanization, unmanaged poultry and pig farms stock activities, direct disposal of sewage to rivers. The urbanization of Kathmandu Valley is strongly associated with the river systems. The process of urbanization is now more rapid and massive, mainly because it is now rampant in the Kathmandu Valley. The present trends in the valley clearly reflect that there will be a growing pressure on limited water resources. The direct impacts of present urbanization are especially visible in the Bagmati River with its tributaries.

At present, Bishnumati and Bagmati Rivers and their tributaries are found as dumping sites for all types of wastes. The rich cultural heritage along the river and the tributaries such as traditional monuments, ghats and temples, are seen slowly eroding. Some section of urban population living in riverside are found to be using polluted river water for washing and other purposes. Shortage of water in the city have forced certain section of the society to use the polluted water from the valley rivers for various purposes which has severely affected human health due to water born diseases.

As a part of the river restoration activities, the construction of sewage diversion structures, concretizing river bank for bank stabilization, altering river flow, flow modification, sewerage line construction works are in progress.

Figures 2-5 illustrates more about the present condition of Bishnumati and Bagmati Rivers.

Figure 2 The young generation has been practicing to have picnic at Sandarijal, they swim, wash the clothes and leave the used solid wastes even practice open defecation at source

Figure 3 The squatter settlement near Bagmati River side, Thapathali

Figure 4 Direct disposal of sewage from Balaju industrial area to Bishnumati River

Figure 5 Solid waste disposal in Bishnumati River

The field observation showed that wastewater produced from households, industries, vehicle machinery repairing and washing centers, agro-lands have been discharging directly to Bagmati and Bishnumati Rivers and their tributaries without any even primary treatment except upstream of Guheshwori.

Guheshwori Waste Water Treatment Plant (WWTP) is partially in operation and existing rest WWTPs and Waste Stabilization Pond (WSP)/Aerated Lagoon with fine bubbled diffusers at Sallaghari, Bhaktapur and WSP at Sundarighat, Lalitpur are entirely out of function. WWTPs and WSPs at Bode, Madhyapur Thimi and Kodku, Patan, Lalitpur are partially processing the wastewater by natural forces such as settling, evaporation, surface aeration and aquatic water plants. Under the initiation of KUKL and HPCIDBC, a few WWTPs (about five) are under construction, which are financed by Government of Nepal (GoN) and Asian Development Bank (ADB).

CONCLUSIONS

The quality of both surface and groundwater in Kathmandu Valley has deteriorated and safe drinking water is not easily available in Kathmandu. Main causes for the degradation of urban water quality are domestic waste, industrial waste, change in land use pattern and increase in the use of agrochemicals. Municipal and industrial effluents are often directly discharged to natural water bodies without any treatment. Recently, the Bagmati Cleanup Campaign is generating tremendous concerns to divert the sewerage discharge from the river course. The campaign has created awareness among the local people; and participatory community efforts for the river restoration are increasing.
The field observation showed that wastewater produced from households, industries, vehicle machinery repairing and washing centers, agro-lands have been discharging directly to river system without any even primary treatment except upstream of Guheshwori. Though there are some wastewater treatment systems, most of them are not functioning well. A scientific study has become essential for the improvement of urban water environment of Kathmandu Valley.

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REFERENCES

[1] Dixit, A. and Upadhyaya, M., Augmenting groundwater in Kathmandu Valley: challenges and possibilities, Nepal Water Conservation Foundation, Kathmandu, Nepal, 2005.
[2] Dahal, A., Khanal, M. and Ale, M., Bagmati River festival: conservation of degrading river, Proceedings of the 2011 Georgia Water Resources Conference, the University of Georgia, 2011.
[3] UNDP, Human Development Report, United Nations Development Programme, Kathmandu, 2004.
[4] NWCF and NTNC, The Bagmati: Issues Challenges and Prospects, National Water Conservation Foundation and National Trust for Nature Conservation , Kathmandu, 2009.
[5] CBS, Statistical Year Book of Nepal 2001, Central Bureau of Statistics, Kathmandu, 2001.
[6] NWSC, Annual Report 2001, Nepal Water Supply Corporation, Kathmandu, 2001.
[7] Shrestha, T. K. (1980): The Biological indicators of pollution in the river Bagmati, Kathmandu Valley, Journal of T.U., Vol. 11 (1), pp. 114-135, 1980.
[8] Upadhaya, N. P and Roy, N. N., Studies on river pollution in Kathmandu Valley, Indian Journal of Environmental HCTH, Vol 24 (2), pp. , 1982.
[9] RONAST, Water quality of the Bagmati River in the Pashupati area, In Proc. of the Seminar on Environmental Issues of Pashupati Area: Identification and Control Measures, Royal Nepal Academy of Science and Technology, pp. 99-124, 1987.
[10] DISVI/ENPHO, Water Quality Assessment of the Bagmati River, Health Education and Service Project, Kathmandu, 1988.
[11] Moog, O. and Sharma, S., Biological rapid field assessment of water quality in the Bagmati River and its tributaries, Kathmandu Valley, Nepal, Proceedings of the Ecohydrology Conference on High Mountain Areas, March 23-26, Kathmandu, Nepal, pp. 609-621, 1996.
[12] Shah, R. D. T. and Shah, D. N., Evaluation of benthic macroinvertebrate assemblage for disturbance zonation in urban rivers using multivariate analysis: Implications for river management, Journal of Earth System Science, pp. 1125-1139, 2013.

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2. Regmi, R. K., Jung, K., Nakagawa, H., Kang, J. and Lee, G., Sediment Erosion and Transport Experiments in Laboratory using Artificial Rainfall Simulator, Journal of the Korea Geo-Environmental Society, 15 (4): 13-27, 2014. DOI: http://dx.doi.org/10.14481/jkges.2014.15.4.13

3. Regmi, R. K., Jung, K., Lee, G., Analysis on Failure of Slope and Landslide Dam, KSCE Journal of Civil Engineering, 17 (5): 1166-1178, 2013. DOI:10.1007/s12205-013-0049-y

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RAINFALL RUNOFF MODELLING FOR FLOOD FORECASTING (A CASE STUDY ON WEST RAPTI WATERSHED)

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Abstract: Floods are the most widespread climate-related hazards in the world, and they impact more people globally than any other type of natural disaster. In Nepal each year, on an average 330 lives are lost due to floods and landslides and infrastructure and property amounting to more than US$ 100 million is damaged causing negative impacts on the social and economic development of the country.

Structural solutions are mainly preventative and focusing on curtailing the magnitude of floods using different methods such as dams, embankment, compound channels, widening of river beds, etc. However these solutions have adverse environmental, hydrologic, ecologic or economic consequences. The non-structural mitigating measure places people away from flood. This method is designed to reduce the impact of flooding to society and economy. Rainfall runoff modeling for the flood forecasting and warning schemes is a non-structural hydrologic method for mitigating flood damages.

In this context due to unavailability of detail information of the study area, lumped model NAM is used for simulating rainfall into runoff. Due to lack of hourly interval data of rainfall, development of synthetic unit hydrograph from Snyder method is done to determine runoff hydrograph of the basin. The Snyder coefficients, coefficient of slope (Ct) and coefficient of peak (Cp) are calibrated for each sub basins and the values are found to be in the range from 0.41-0.58 and 0.32-0.43 for Ct and Cp respectively. Mike UHM rainfall runoff model is used to incorporate developed unit hydrograph

Keywords: Rainfall runoff, Unit hydrograph, Flood forecasting, Snyder method

INTRODUCTION

Floods are the most common natural disasters that affect societies around the world. More than one third of the world's land is prone to flood affecting about 82 percentage of the world's population (Dilley et al., 2005). The study area is located in Terai region downstream of sikta dam to the Nepal- India border of Banke district, Nepal in which flood is one of the natural hazards. A large portion of the Nepalese territory is inundated every year by the flood of Rapti River in the Banke District of Nepal (DWIDP, 2006). In Nepal, like many other developing countries, the hydro-meteorological station networks are sparse and rainfall data are available only after a significant delay. Precipitation is highly variable in both space and time and is an important input in rainfall-runoff modeling. Flood forecasting in basins with sparse rain gauges poses an additional challenge. Using hydrologic modeling techniques, it is possible to better prepare for and respond to flood events. Use of appropriate hydrologic models can mitigate flood damage and provide support to contingency planning and provide warning to people threatened by floods. The accuracy of operational hydrological models primarily rely on goof rainfall data input in terms of temporal and spatial resolution and accuracy (Pathirana et al., 2005).

STUDY AREA

The West Rapti River inside Nepalese territory is selected as the study area. The West Rapti River (WR) basin is located in the mid-western region of Nepal (Figure 1). Geographically the study area extends from 27^0 56' 50" to 28^0 02'30" North latitudes and $81^0$45' 00" to $81^0$40'00" East longitudes. The length of main stream channel is 257 km. The river originates from the middle mountains of Nepal, then enters the lowlands and finally drains to the Ghagra (Karnali) River, a tributary of the Ganges River. It has several tributaries. Major tributaries are Jhimruk River, Mari River, Arun River, Lungri River, Sit River, Dunduwa River, Sotiya and Gandheli rivulets. Downstream of the confluence of the Jhimruk and Mari Rivers, the river is named the West

Rapti River. The average slope of the basin is 16.8%. The source of runoff is due to the monsoon rainfall and groundwater. The drainage network of the river basin and telemetry stations are shown in Figure 1. There are four hydrological stations. The catchment area of the basins of Nayagaon, Cherneta, Bagasoti and Kusum gauging stations are 1980 km^2, 644 km^2, 3380 km^2 and 5200 km^2 respectively.

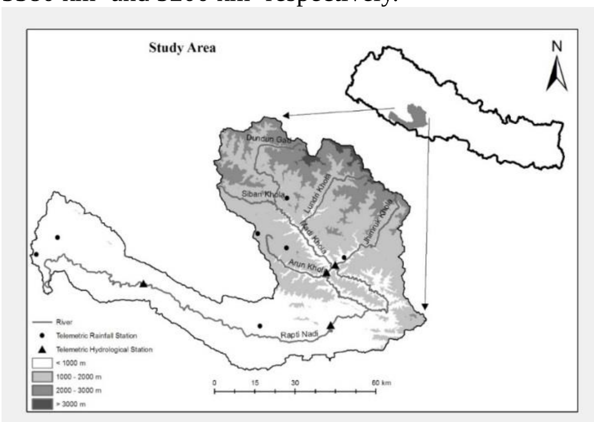

Figure 1. Location of WR Basin

While the upper WR basin has a temperate climate, the lower basin including the Banke district has a tropical to subtropical climate. The period from March to May is hot and dry, June to August is hot and humid, September to October is pleasant, and November to February is cool and foggy with occasional rainfall due to westerly winds. The temperature reaches 46 ^{o}C in summer in the lower part of the basin and falls below 2 ^{o}C during winter in the upper part of the basin. The study area receives summer monsoon rainfall extending from June to September, accounting about 80% of the total annual. The average rainfall for WR Basin is about 1500 mm. The relative humidity goes as low as about 60% in May to above 90% in January. (Talchabhadel R, 2012)

LITERATURE REVIEW

Rainfall-runoff relationship is mostly used mathematical model for water resource management planning, flood forecasting and warning schemes. For this purpose, different types of models with various degrees of complexity have been developed. They are based on empirical, physically-based or combined conceptual-physically-based model. Sherman,(1932) was the first to explain the procedure for development of the unit hydrograph and recommended that the unit hydrograph method should be used for watersheds of 5000 km^2 or less. Snyder analyzed a larger number of basins in the Appalachian mountain region of the United States. He proposed equations for estimating synthetic unit hydrograph and gave the value for Coefficient of slope(Ct) and Coefficient of peak (Cp). The values for Ct and Cp range from 0.3 to 6 and 0.31 to 0.9 respectively.

Flood forecast and modeling refer to the processes of transformation of rainfall into a flood hydrograph and to the translation of that hydrograph throughout a watershed or any other hydrologic system. In a country like Nepal, where the unavailability of the required information is quite prominent, the mathematical model should be so chosen that, the input parameters shall be as least as possible and that the model can establish a well-defined and consistent rainfall-runoff relationship. In this regard, the attempt has been made to use lumped model Mike NAM. This study proposed to use Snyder method since unit hydrograph can be developed from the basin characteristics. Mike UHM rainfall runoff model has been used to incorporate so developed unit hydrograph.

Snyder (1938), based on a study of a large number of catchments in the Appalanchian Highlands of eastern United States developed a set of empirical equations for synthetic unit hydrographs in those areas. These equations are used in USA and with some modifications in many countries including Nepal. The synthetic unit hydrograph of Snyder is based on relationships between the characteristics of a standard unit hydrograph and basin morphology. Snyder formulate equation for the effective rainfall duration (Tr), the peak direct runoff rate (qp), and the basin lag time (Tl). From these relationships, five characteristics of a required unit hydrograph for a given effective rainfall duration is calculated (Chow et al., 1988) the peak discharge qp, the basin lag Tl, the base time Tb, and the widths W (in time units) of the unit hydrograph at 50 and 75 percent of the peak discharge.

$$Tl = Ct(L * Lc)^{0.3} \qquad Qp = \frac{(2.78 * Cp * A)}{Tl} \qquad qp = \frac{Qp}{A}$$

$$Tb = 5(Tl + \frac{D}{2}) \qquad Tr = \frac{Tl}{5.5} \qquad Tl1 = Tl + (\frac{D - Tr}{4}))$$

$$W50 = \frac{5.9}{(qpl)^{1.08}} \qquad W75 = \frac{3.4}{(qpl)^{1.08}}$$

Where L is the length of the main stream in kilometers from the outlet to the upstream divide, Lc is the distance in kilometers from the outlet to a point on the stream nearest the centroid of the watershed area, Ct,Cp are coefficients which need to be calibrated, A is the area of the basin in km^2 , D is rainfall duration in hour.

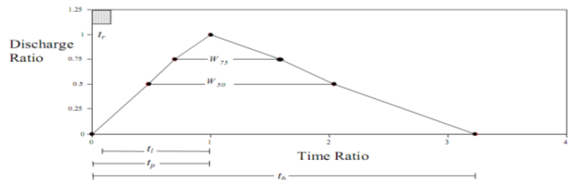

Figure 2. Snyder synthetic unit hydrograph

METHODOLOGY

Digital Elevation Model (DEM) of study area was downloaded and hydraulic data were extracted using spatial analyst of ArcGIS. Precipitation, hydrological and evaporation data were acquired from Department of Hydrology and Meteorology (DHM) and were processed. For modeling in sub catchment, mean catchment rainfalls were calculated using thiessen polygon analysis.

Table 1- Calculated rainfall depth from thiessen method

SN	Station No.	Station Name	Date	Q Instantaneous m^3/s	Rainfall Depth mm
1	339.3	Jhimruk at chemeta	29/07/1989	577	26.34
2	330	Mari at nayagaon	7/9/1984	1240	57.13
3	350	West rapti at bagasoti	10/8/2000	4170	45.45
4	375	West rapti at kusum	31/07/2003	5440	53.88

MIKE NAM was used for rainfall runoff modeling for daily interval data set. The NAM model can be characterized as a deterministic, lumped, conceptual model of overland flow+ interflow + base flow with moderate input data requirements. Parameters were calibrated and validated. Since there is not hourly interval data set of rainfall and evaporation, the simulated discharge from daily rainfall runoff model will not take account of extreme discharge so for this purpose unit hydrograph for instantaneous discharge was made in event basis. Synthetic unit hydrograph method is adopted to determine runoff hydrographs. Unit Hydrographs were developed using Snyder method and were calibrated for Snyder coefficients Ct and Cp. S–curve method was applied to generate 1hour, 2 hour and 3 hour unit hydrograph to determine duration of rainfall in each sub basins.
Mike UHM module simulates the runoff from single storm events by the use of the well-known unit hydrograph techniques and constitutes an alternative to the NAM model for flood simulation in areas where continuous stream flow records are not available or where unit hydrograph techniques have already been well established. Duration of rainfall and position of rainfall for each sub basins were calibrated and validated with observed instantaneous maximum discharge Finally the flood hydrograph was prepared for different scenarios.

RESULTS AND DISCUSSIONS

The study results are from Mike NAM method, Snyder method, Mike UHM model and flood hydrograph for various situations. The hydrological model is calibrated based on secondary data of 1980 – 2003 and validated for consecutive five years from 2004 to 2008. The average coefficient of determination for calibration and validation in all four stations are tabulated in Table 2.

Table 2: Average coefficient of determination for calibration and validation period

	Mari	Jhimruk	Bagasoti	Kusum
Calibration	84.3	81.9	83.4	83.85
Validation	82.7	81.1	80.8	82.3

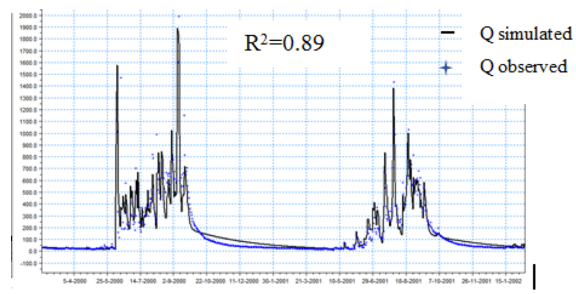

Figure 3.Calibration plots against discharge at Kusum for the year 2001 and 2002

The difference between daily Qmax and Q instantaneous is shown in Figure 4. It is clearly seen that the instantaneous peaks are missing by the calibrated model from average daily discharge.

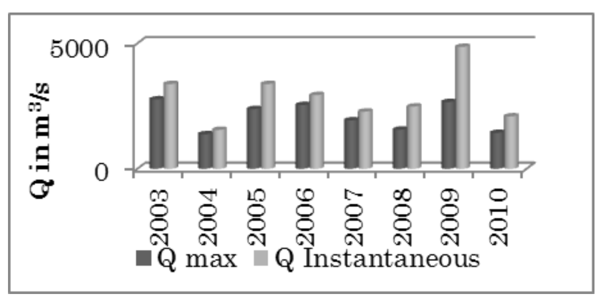

Figure 4: Daily maximum discharge and instantaneous discharge at Kusum

Table 3: Simulated discharge for different days of the year 2011

Date	6/13/2011	6/19/2011	7/27/2011	8/3/2011
Discharge	Q sim in m^3/s	Q sim in m^3/s	Q sim in m^3/s	Q sim in m^3/s
mari	108.7	286.7	38.3	485.3
jhimruk	168.9	280.2	47.3	388.5
bagasoti	808.6	1000.8	838.4	1175.6
kusum	928.6	1125	1119.7	1351.7
Max. Water Level at Kusum	4.2	4.3	4.5	4.6
Q Kusum from rating curve	843	916	1072	1156
% diff	10.15	22.82	4.45	16.93

Unit hydrographs for the sub basin in event basis from the max instantaneous discharge are prepared using Snyder Method and used in MIKE UHM model for rainfall runoff relationship. The calibrated value for Snyder method of Ct ranges from 0.41-0.58 and Cp ranges from 0.32-0.43 for West Rapti basin. The MIKE UHM model is calibrated and validated at each sub basin outlets using observed instantaneous maximum discharge from the year 1964-2008. When the position of starting of rainfall at same time for all the sub basins, the multiple peaks are seen as in Figure 5 .The maximum simulated discharge at Kusum station is found when the position of rainfall intensity in sub basins at Mari, Jhimruk, Bagasoti and Kusum is provided at 3hr, 6hr, 5hr, and 1hr respectively. The relative error for peak discharge is within 10%. Upon running different scenario to look the flood hydrographs it is found that the discharge at outlet of Kusum is higher when peak rainfall is considered in downstream two sub basins at Bagasoti and Kusum rather than upstream two sub basins at Mari and Jhimruk.

There are 4 telemetric hydrological stations and 7 telemetric rainfall stations from 2011 onwards in the basin with continuous time series data of every 15 min. interval (Easily downloadable from www.hydrology.gov.np).

Random 4 monsoon days are picked up as June 13, June 19, July27 and Aug 3 2011 to see the applicability of model with available real time rainfall and discharge data shown in Table 3. Stage Discharge Rating curve table for Kusum station is used to convert water level into discharge.

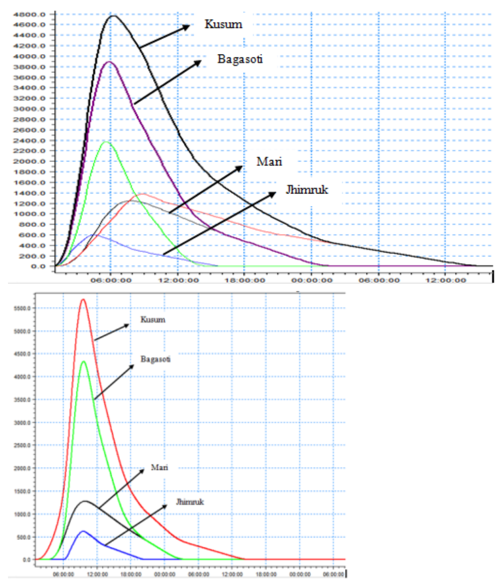

Figure 5. Runoff hydrograph considering rainfall at the same time (Top) and various starting time (Bottom)

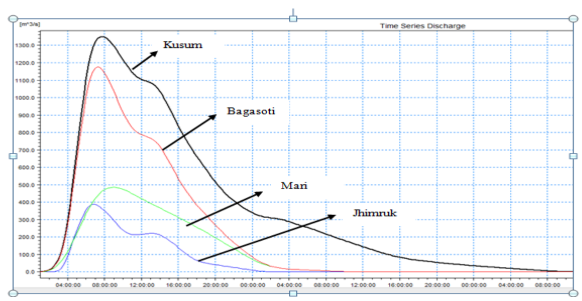

Figure 6. Simulated Runoff Hydrograph on Aug 03, 2011

CONCLUSIONS

The relationship between rainfall and runoff is an important parameter for flood forecasting. For an ungauged basin or basin with the lack of availability of hourly data, unit hydrograph needs to be developed to get runoff hydrograph at the outlet. The study only focuses on the Snyder method for the development of Synthetic unit hydrograph. For better result different synthetic unit hydrograph method should be applied to compare the output.

REFERENCES

[1] Bhunya P.K., Panda S.N. and Goel M.K. , 2011, "Synthetic Unit Hydrograph Methods: A Critical Review"

[2] Chow, V.T., Maidment, D., and Mays, L. W., 1988. Applied Hydrology. McGraw Hill.

[3] Dilley M., Chen R.S., Deichmann U., Lerner-Lam A.L., Arnold M., with Agwe J., Buys P., Kjekstad O., Lyon B. and Yetman. G. 2005, "Natural disaster hotspots: a global risk analysis", International Bank for Reconstruction And Development/ The world Bank and Columbia University, Washington, DC

[4] DHM, 2006, "Stream Flow Record of Nepal - 2006", Department of Hydrology and Meteorology, Kathmandu, Nepal.

[5] DHM, 2008, "Climatological Records of Nepal (1964-2008)", Department of Hydrology and Meteorology, Kathmandu, Nepal.

[6] DWIDP, 2006, Disaster Reviews from 1983-2006. Department of Water Induced Disaster Prevention, Lalitpur, Nepal

[7] Pathirana A., Herath S. , Swain D., 2005, "Hydrometeorological input for improving flood forecasting in the Mekong" in Proc. International Symposium on role of Water science in transboundary river basin management, Ubon Ratchathani, Thailand,

[8] Ramírez, J. A., 2000: Prediction and Modeling of Flood Hydrology and Hydraulics Chapter 11 of Inland Flood Hazards: Human, Riparian and Aquatic Communities Eds. Ellen Wohl; Cambridge University Press.

[9] Talchabhadel R. (2012) Master Thesis on Rainfall Runoff Modeling for Flood Forecasting: A case study on West Rapti Watershed. MSc Library IOE Pulchowk Campus.

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