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Journal of Flood Engineering and Science Research

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Numerical Modelling of Wave Propagation in Gulf of Khambat

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Abstract

Shallow-water wave transformation strongly depends upon coastal geomorphology, bottom sediment characteristics and sea bed slope. As waves propagate into shallower water they reach a point where the water depth cannot support the local wave height and eventually breaks due to wave transformation. Accurate prediction of wave parameters is vital for the coastal infrastructure developments . This phenomenon can be simulated using mathematical modeling technique. This paper aims in simulating the shallow water transformation in the Gulf of Khambhat having higher tidal range using a numerical model. Variations in wave characteristics and their physical significance is discussed . A Oil company has a proposal for development of anchorages of ships and development of a coal jetty at Hazira in the Gulf of Khambhat. The tidal range at Hazira is high. Due to presence of shoals, dissipation of wave energy takes place and at low water, significant reduction in wave height is observed at the anchorages points in the absence of effect of local wind. However, local wind prevailing in the domain contributes to increase in wave heights at the sites of port development. From the numerical simulation of wave transformation the maximum significant wave height at the anchorage was estimated to compute the yearly downtime for berthing operations.

Keywords: Tide, Wave Transformation, Spectral Wave, Gulf

1. Introduction

Prediction of design wave parameters viz wave height, wave period and their directional distribution is vital for any costal infrastructure development. Most of the time near shore wave data are not available and the available offshore wave data needs to be transformed to near shore using mathematical model technique. Transformation waves is site specific and depends upon coastal geomorphology, sea bed slope and bottom sediment characteristics it also depends upon the shape of the area. Gulf of Khambhat is located on the western coast of India in the Arabian Sea between the Saurashtra peninsula and mainland Gujarat. Oil industries such as Reliance Industries, M/s Essar M/s VOTL have developed private ports for import and export of oil products in the gulf near Hazira and Dahej. The Gulf is barely a few Kilometers wide and it opens out southward like a funnel. Because of the funnel shape and semi-enclosed nature of coast, it experiences very high tides, the tidal height increases tremendously in the upstream. The bathymetry in the Gulf of Khambhat near Hazira and Dahej is complex. The depth contours show that there is wide stretch of tidal flats and also shoals in the vicinity of site of developments. As the tidal range is more than 5m, large area is subjected to flooding and drying. This paper aims in simulating the shallow water transformation in a region having higher tidal range, using numerical model, to determine feasibility of all weather operations at the oil handling jetties and anchorages.

2. Methodology

The offshore wave data reported by India Meteorological Department (IMD) as observed from ships plying in deep waters off Hazira were transformed to nearshore location using Spectral Wave (SW) model MIKE -21 to get the near-shore wave climate at Hazira. MIKE – 21 SW models is a spectral wind wave model based on unstructured mesh developed by Danish Hydraulic Institute, Denmark. The model simulates the growth, decay and transformation of wind generated waves and swells in offshore and coastal areas.

2.1 Site conditions

Hazira is situated at 21°05'4"N latitude and 72°36'33"E longitude. The bathymetry in the Gulf of Khambhat near Hazira is complex (Fig. 1). The depth contours show that there is wide stretch of tidal flats and also shoals in the vicinity of proposed project site. As the tidal range is more than 5m, large area is subjected to flooding and drying.

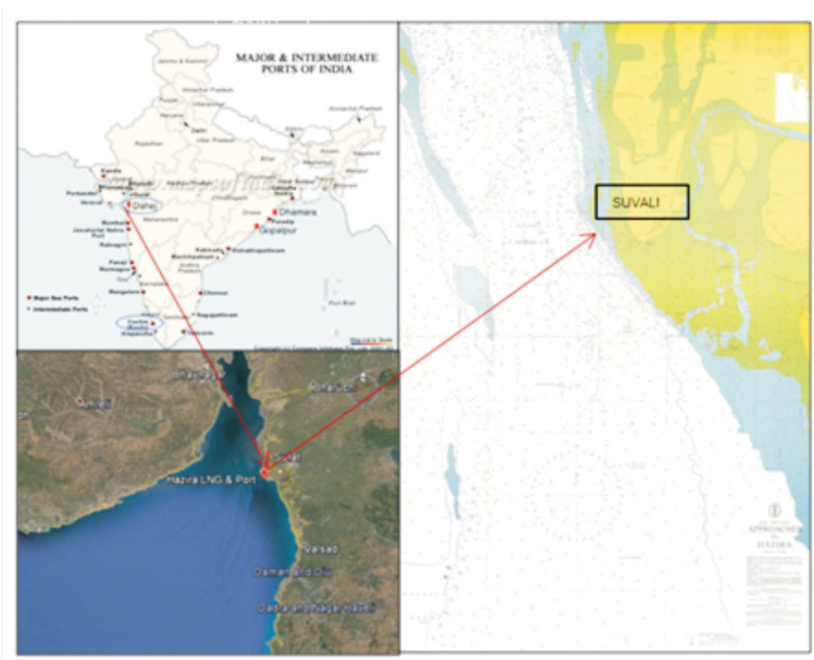


Figure 1 Location map of Hazira

2.2 Tide and wave data

The observed tide data at Hazira show the tidal range of the order of 5.7 m. The highest high water level is at + 7.4 m and lowest low water level is at +1.7 m shown in figure 2.

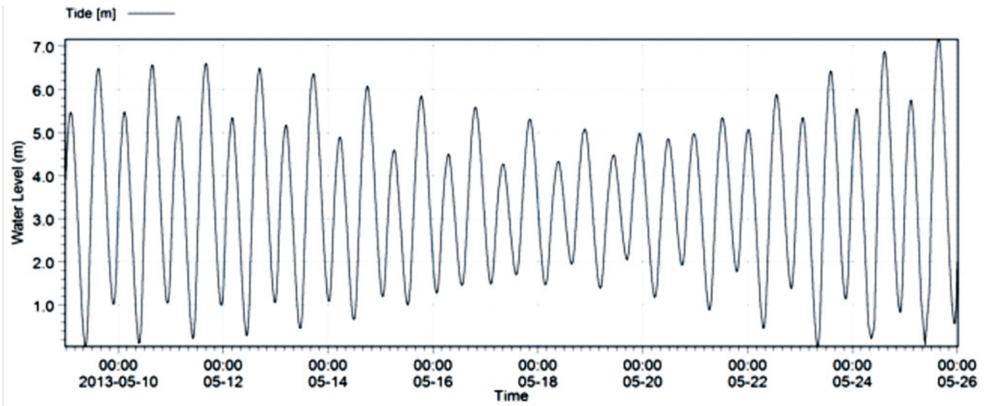


Figure 2 Observed tide at Hazira

The offshore wave data reported by India Meteorological Department (IMD) as observed from ships plying in deep waters off Hazira were analysed. The frequency distribution of wave heights from different directions for entire year of the above offshore data is given in the form of wave rose diagrams and is shown in Fig.3. It is seen from the deepwater data that the predominant wave directions in the deep sea off Hazira are from SW to NW. It may be noted that the wave height based on ship observed data corresponds to significant wave height, which represents average energy of the random wave train.

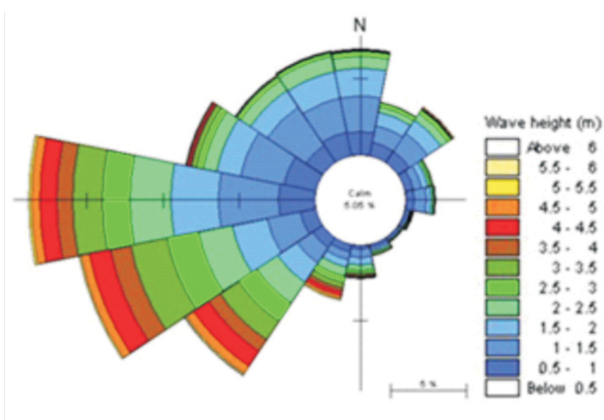


Figure.3. Offshore wave rose

3.0 Wave Transformation

Coastal area of 250 km by 200 km (Fig. 4) with an unstructured mesh was considered for studies with MIKE –21 SW models, which extends up to 50 m depth contour in deep sea and high water line near the shore. Depth adaptive mesh with coarse grid in the offshore and fine mesh near the project site was used for the simulation studies. The input wave conditions were derived from the offshore wave climate. The model was validated with measured wave data available at Pipavav at latitude 20.88^{0}N and longitude 71.49 E^{0}during monsoon season from July 1999 to December1999. Validation of the model was done by considering effect of local wind on the wave transformation. Initially, to observe effect of tidal range on wave transformation at Hazira, the model was run for the tidal cycle of two weeks shown in Fig.2. Time history of significant wave height during the tidal cycle for wave's incident from SW direction with incident wave height of 5.0m is shown in Fig.5. The model was run for wave's incident from SW, WSW and West directions for incident wave height of 5m. The model was run for the highest high water level at 7.4m and lowest low water at 1.7m, first without considering effect of local wind and then with wind speed of 15m/s.

Plots of wave height contours and wave vectors in the model area and near the proposed jetties are shown in Figs. 6 to 8 for all the incident wave directions at high water and low water respectively, considering effect of local wind on wave transformation.

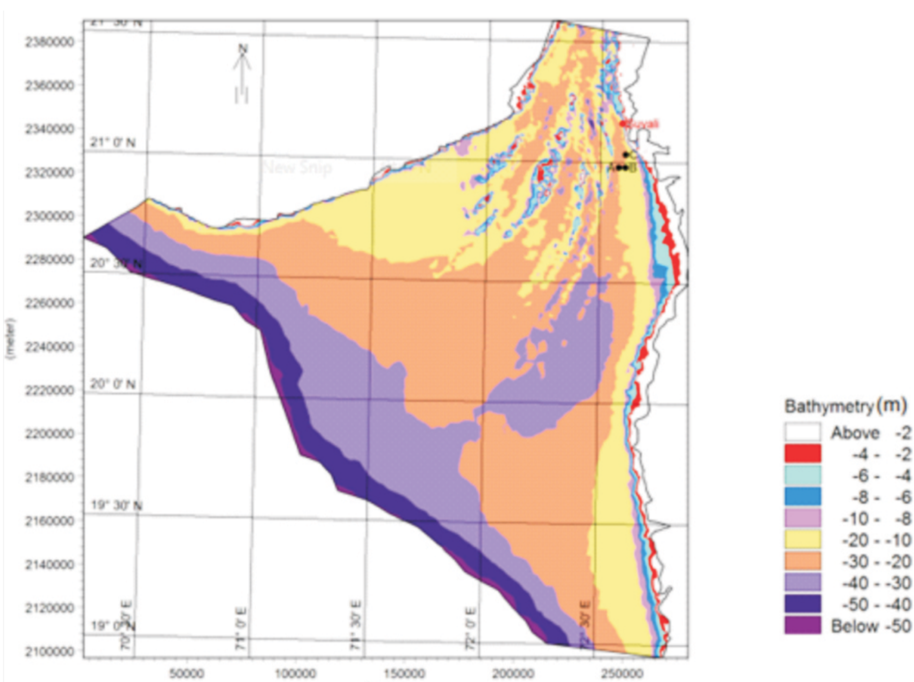


Figure.4. Model area for mike-21

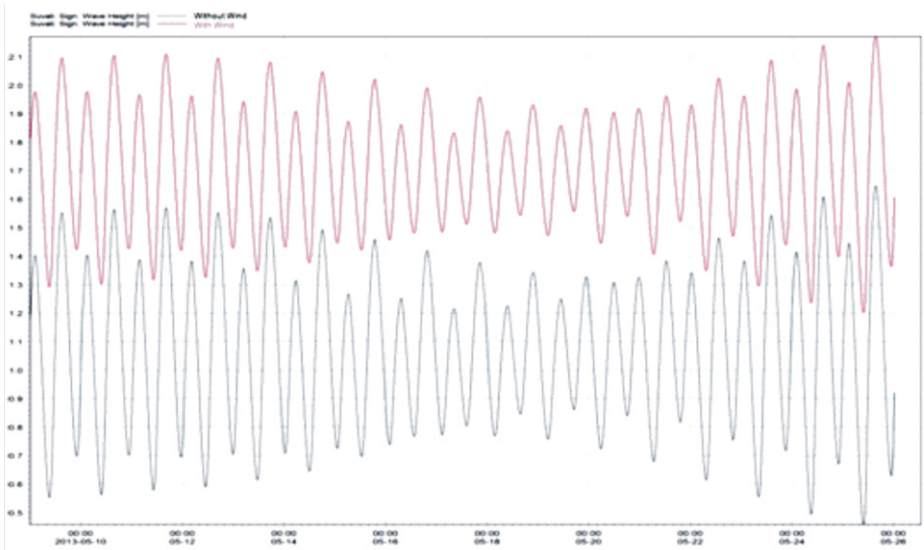
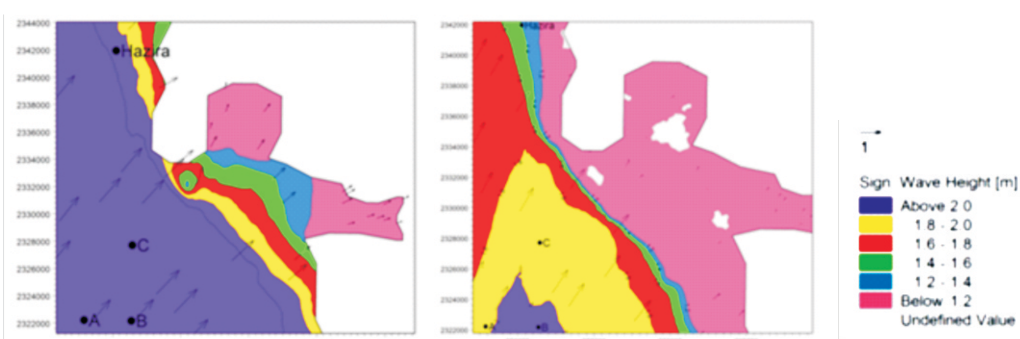


Figure.5. Time history of significant wave height at Hazira

4.0 Discussions

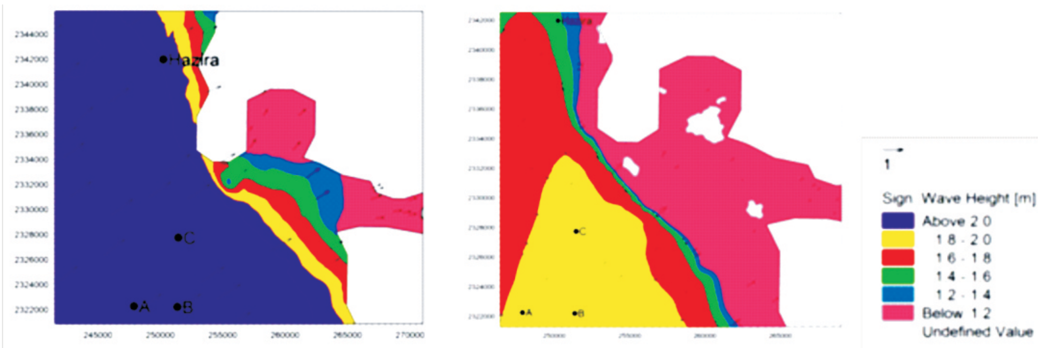
An anchorage is a location at sea where ships can lower anchors. These locations usually have adequate depth for ships with larger draft and provide protection from weather conditions, and other hazards. Oil industries such as Reliance Industries, M/s Essar and M/s VOTL are engaged in import and export of oil products near Hazira and Dahej. For carrying these products Panamax vessels are used and three anchorage locations (A, B and C) were proposed near Hazira.

Wave height and directions were extracted at the three anchorages as shown in Fig. 4. These wave heights are shown in figure 6 to 8 at high water and low water respectively for the three predominant incident wave directions.



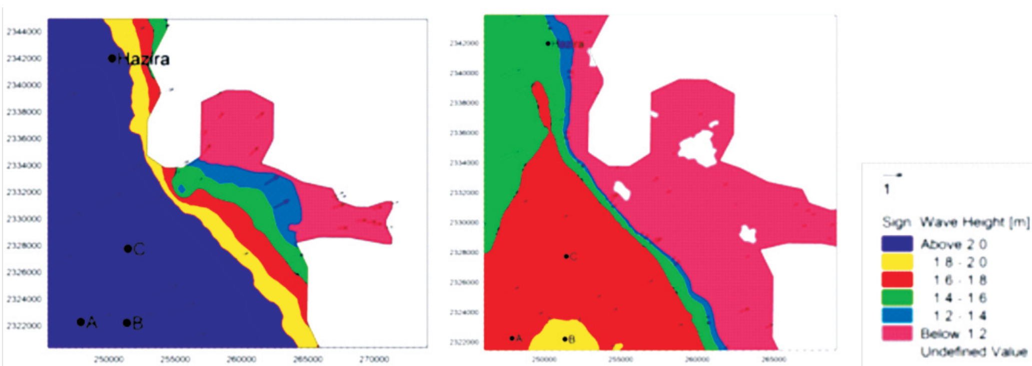
High Water Low Water

Figure.6. Wave height distribution at the proposed development at Hazira for waves from South West direction



High Water Low Water

Figure.7. Wave height distribution at the proposed development at Hazira for waves from WSW direction



High Water Low Water

Figure.8. Wave height distribution at the proposed development at Hazira for waves from West direction

5.0 Conclusion

Numerical model MIKE 21 SW was used for simulation of wave transformation from deep water to near shore for deciding locations of anchorages for oil tankers in Gulf of Khambat As the tidal range is more than 5m, large area is subjected to flooding and drying. Due to presence of shoals dissipation of wave energy takes place at low water and significant reduction in wave height is observed at anchorage location in the absence of effect of local wind. However, local wind prevailing in the domain contributes to increase in wave heights at the proposed site of port development. It was observed that the anchorages location proposed by Reliance Industries at offshore Hazira, Gujarat provide protection from weather conditions, and other hazards for Panamax and similar vessels. At these anchorages

locate
on the maximum significant wave height at high water and low water is of the order of 2.7m and 2.0 m respectively. Thus numerical modeling technique was found to be a useful tool for estimation of wave climate in the coastal region having complex bathymetry with high tidal range.

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Authors are grateful to Mr. S. Govindan, Director, Central Water and Power Research Station for his continuous encouragement and motivation during the course of studies and for granting permission to publish this paper.

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Non-Point Pollution Modelling in River System With Input Reduction in Time Series Data Mining Domain

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ABSTRACT

In any hydrological processes the flow and the pollutants, specially coming from non-point sources (NPS), are always important for accurate planning and smooth operation of the water resource system. The NPS pollutant such as nitrogen etc. poses a threat to human and environment. A reliable prediction of pollutants and its correlation with past values of river flow and observed non-point pollutants in river system is vital. Present work demonstrates reliable prediction of streamflow and non-point pollutants in river system. Non-point pollution scenario in this work is simulated using fuzzy rule based and ANFIS (Adaptive Neuro fuzzy inference system) models. The FIS, ANFIS are examined using the long-term observations of monthly river flow discharges, total nitrogen loads, total phosphorous loads and sediment loads. The four quantitative standard statistical performance evaluation measures, the coefficient of correlation (R), Nash-Sutcliffe efficiency coefficient (E), root mean squared error (RMSE), mean absolute error (MAE), are employed to evaluate the performances of various models developed. The performance of Fuzzy Ruled Based models and ANFIS models show potential applicability of developed models for flow and nitrogen load predictions. The results of ANFIS models are comparatively better than fuzzy rule based models. Performances of these AI techniques are also compared with statistical methods. Further, data mining techniques are employed to pre-process and to reduce the time series inputs. Results obtained with reduced inputs when compared to the earlier results gives improved efficiency.

Keywords: prediction, streamflow, fuzzy inference system, ANFIS, non-point pollution.

1. Introduction

These days problems associated with fluctuations in flow values and elevated nutrient concentrations in water bodies vary from eutrophication to hypoxia (low concentrations or absence of dissolved oxygen) (Cheng & Chi 2003). Nutrient enrichment results in the excessive growth of plants including phytoplankton in surface waters. The gradual accumulation of water quality data records over the past few decades has increased the value of these data for examining long-term trends. Transport of nutrient into river or streams is complex function of hydrology of the region and land use patterns in a given river or stream basin which are difficult to quantify accurately. Recently, the dominance of deterministic models in hydrology has gradually weakened, because a number of factors affect the constitution of hydrological events. The random nature of hydrological variables needs to be studied (Nash & Sutcliffe 1970). Development of models based on temporal observations may improve understanding the underlying hydrological processes in such complex phenomena. These days ANFIS modelling is extensively used by hydrologists. In this study, models are developed for monthly nitrogen load prediction based on FIS and ANFIS techniques. The aim is to improve the accuracy of flow and NPS load prediction in river system.

Nitrogen and phosphorus are nutrients that are natural parts of aquatic ecosystems. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water. But when too much nitrogen and phosphorus enter the environment - usually from a wide range of human activities - water can become polluted. Nutrient pollution has impacted many streams, rivers, lakes, bays and coastal waters for the past several decades, resulting in serious environmental and human health issues, and impacting the economy.

High concentration of nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish. Some algal blooms are harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water (Brady & Weil 2008)

Nutrient pollution in ground water - which millions of people in the world use as their drinking water source - can be harmful, even at low levels. Infants are vulnerable to a nitrogen-based compound called nitrates in drinking water. Excess nitrogen in the atmosphere can produce pollutants such as ammonia and ozone, which can impair our ability to breathe, limit visibility and alter plant growth. Eutrophication can stimulate rapid algal growth, resulting in massive algal glooms. High biomass during algal blooms may cause significant ecological problems and harmful effects in the biota of the region (Jorgensen & Richardson 1996). Concentrations of nutrients have been a persistent problem in streams and rivers throughout the world. Estimates of these nutrient fluxes are necessity as well as challenges for water quality management. The transport of nutrient loads (nitrogen and/or phosphorous) from watershed into river or stream system is not straight forward but complex function of hydrology, geology, and land use of the region. There are statistical approaches to predict the nutrients loads in rivers (Saad et al 2002). . Nitrogen enters the environmental cycle through various types of anthropogenic activities. Nitrogen and phosphorus have complex cycles that are mediated by physical, chemical, and biotic processes in the water and in the soil.

In this paper Nitrogen load prediction is pursued with the help of the fuzzy interference system and ANFIS (adaptive neurofuzzy) modelling therefore, nitrogen and phosphorus cycles are expected to be affected by the timing of floodplain inundation. Excessive addition of nutrients, usually nitrogen and phosphorus (N and P), to natural water is usually refers as eutrophication (Saad et al 2002).

1.1 General introduction

According to USEPA Nutrient pollution is one of world's most widespread, costly and challenging environmental problems, and is caused by excess nitrogen and phosphorus in water. Water quality is one of the main characteristics of river systems irrespective of the purpose their water is used for. Water, in the sources such as canals and rivers, is not only utilized as human water supply, but it also used for various activities (Dogan 2008).Other than that every stream supports its own ecosystem which is highly susceptible to incoming dosage of nutrients. These nutrients disturb the balance of the food chain in the aquatic system. In recent years, nitrogen load in streams emerged as one of the biggest environmental threat for aquatic ecosystem. Eutrophication has been recognized as an important issue for environmental concern. It becomes one of the most serious water pollution problems (Lee & Arega 1999) & (Su & Dong 1999).

Recently, the dominance of deterministic models in hydrology has gradually weakened, because a number of factors affect the constitution of hydrological events. The random nature of hydrological variables needs to be studied (Nash & Sutcliffe 1970). Development of models based on temporal observations may improve understanding the underlying hydrological processes in such complex phenomena. These days ANFIS modelling is extensively used by hydrologists. In this study, models are developed for monthly nitrogen load prediction based on FIS and ANFIS techniques. The aim is to improve the accuracy of flow and NPS load prediction in river system.

1.2 Objective of the work

Perceiving the need to assess and simulate the flow and nitrogen load in the river system this work has been done. The prime objective of this work is to simulate the flow & total nitrogen pollution scenario in river systems. In this work Fuzzy rule based modelling & ANFIS (Adaptive Neuro fuzzy) is done for river flow and nitrogen pollution prediction in river system. Thereafter Nitrogen modelling with reduced input is developed using data mining techniques. Lastly Comparative studies and performance evaluation of the developed models is done.

1.3 Study area and data used

The present work utilized the monthly data for the Iowa River to estimate the nitrogen loads using Fuzzy modelling and neurofuzzy modelling. Monthly input of nitrogen load and river flow is utilized to develop time series observations of flow (discharge) and nitrogen loads. The modelling (Fuzzy and ANFIS) is performed for data obtained from United States Geological Survey (USGS) site. The site is of the River Iowa (Wapello site, USGS Station ID 05465500). This data is utilized by models to predict the monthly nitrogen load in a stream. The monthly variation of input parameters, namely flow (cumecs), total nitrogen load (ton) in respective water year is shown in Fig.1, Fig.2 respectively.

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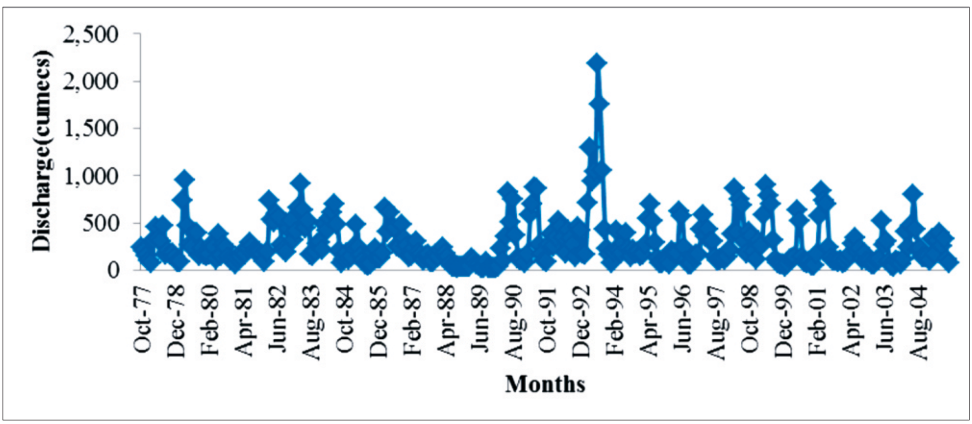

Figure 1 Monthly flow (discharge) values

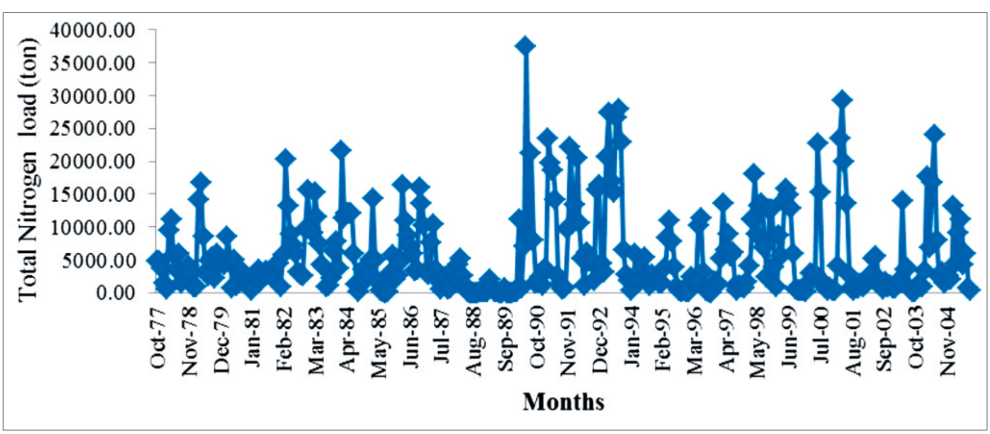

Figure 2 Monthly nitrogen loads

1.4 Data evaluation criteria

The performances of the developed models are evaluated based on some performance indices in both training and testing set. Varieties of performance evaluation criteria are available which could be used for evaluation and inter comparison of different models (Nash & Sutcliff 1970). Following four performance indices represented as correlation coefficient (R), root mean square error (RMSE), model efficiency (Nash–Sutcliffe Coefficient, ME_{Nash}), and mean absolute error (MAE) are selected in this study based on relevance to the evaluation process.

1) ***Root Mean Square Error (RMSE) :*** measures the differences between values predicted by a hypothetical model and the observed values. In other words, it measures the quality of the fit between the actual data and the predicted model. RMSE (eq.1) is one of the most frequently used measures of the goodness of fit of generalized regression models. These differences are prediction errors or residuals.

$$RMSE = \sqrt{\frac{1}{n}(\sum_{i=1}^{n}(Xai - Xpi)^2)} \qquad (1)$$

2) Mean Absolute Error (MAE): The MAE (equation 2) measures the average magnitude of the errors in a set of forecasts, without considering their direction. The MAE is the average over the verification sample of the absolute values of the differences between forecast and the corresponding observation. The MAE is a linear score which means that all the individual differences are weighted equally in the average.

$$MAE = \frac{1}{n}(\sum_{i=1}^{n}(Xai - Xpi) \qquad (2)$$

3)Correlation coefficient (R): A correlation coefficient (equation 3) is a statistical measure of the degree to which changes to the value of one variable predict change to the value of another. In positively correlated variables, the value increases or decreases in tandem. In negatively correlated variables, the value of one increases as the value of the other decreases.

$$R = \frac{\sum_{i=1}^{n}(Xai - \overline{X}ai)(Xpi - \overline{X}pi)}{\sqrt{\sum_{i=1}^{n}(Xai - \overline{X}ai)^2 \sum_{i=1}^{n}(Xpi - \overline{X}pi)^2}}$$

(3)

4) Model Efficiency (Nash-Sutcliffe Coefficient $ME_{Nash}(E)$

The Nash–Sutcliffe model efficiency coefficient (equation 4) is used to assess the predictive power of hydrological models.

$$ME_{Nash}(E) = 1.0 - \frac{\sum_{i=1}^{n}(Xa_i - X_{pi})^2}{\sum_{i=1}^{n}(X_{ai} - \overline{X}ai)^2}$$

(4)

Where Xai and Xpi are measured and computed values of nitrogen concentration values in streams; $\overline{X}ai$ and $\overline{X}ai$ are average values of Xai and Xpi values respectively; i represent index number and n is the total number of measurement.

2. Methodology

The methodologies used for this work and the techniques that are used to improve the results are discussed here. This includes methodology and specific steps for modeling of nitrogen in river or streams. Methodology for development of FIS and ANFIS models are illustrated with flow chart.

In this work the various inputs from sites previously discussed are used in model building. The models their types and their salient features are discussed in this section. Data availability is the major factor in deciding the types of model that can be developed for reliably accurate results. In this work flow and nutrient prediction is the main objective. Depending on the types of input three types of models are developed in this work:

Models developed-

I. 2 lag flow model
II. 3 lag flow model
III. 3 lag Nitrogen model

2.1 Data partition for model assessment

The datasets available are divided into two datasets i.e. training dataset and testing dataset. Training Error Percentage: 70% of the data available of the flow is used for the developing of the model. The error in the predicted value of the output and the actual value of the output is calculated. Testing Error Percentage: 30% of the data available of the flow is not used during the model development. As these dataset are used to cross check the model and check its authenticity. The error in the predicted value of the output and the actual value of the output is calculated.

2.2 Various methodologies used

For the flow and nutrient prediction various methodologies used in this work are the Fuzzy inference system (FIS), Adaptive neurofuzzy inference system (ANFIS), data processing techniques and the regression analysis have been used in this work for flow and total nitrogen prediction.Methodology used for model developing Fuzzy Inference System has four components Knowledge base, fuzzification interface, decision making unit and the defuzzification interface. In the fuzzification interface the input parameters are fuzzified by assigning suitable membership functions to each input parameter. The shapes of the input parameter membership function used in this work are triangular and trapezium represented as trimf and trapmf in the MATLAB FIS editor. Further these data is used in the processing and finally the output is defuzzified to give the output.

Adaptive Neuro-fuzzy inference system or Neuro-fuzzy modeling is an approach where the using of neural networks and fuzzy logic combines together. These two techniques complement each other. The neuro-fuzzy approaches employ heuristic learning strategies derived from the domain of neural networks theory to support the development of a fuzzy system. ANFIS is a powerful modeling technique and it works on a set of linguistic if-then rules. It can handle imprecision and uncertainty present in the model and the data structure and thus can be used for real-time applications. ANFIS uses neural network algorithms and fuzzy reasoning to map an input space to an output space (Ullah & Choudhury 2013).

3 Data mining

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Data mining (the analysis step of the "Knowledge Discovery in Databases" process, or KDD) is the analysis of discovering patterns in large data sets involving methods at the intersection of artificial intelligence, machine learning, statistics, and database systems (Singh et al 2014). Principal component analysis is utilized for data mining (input reduction) in this work. Real-world datasets usually exhibit relationships among their variables. These relationships can generally be analysed by common analysis techniques as they are often linear, or can be assumed so approximately. One such technique is Principal Component Analysis (PCA), which rotates the original data to new coordinates, making the data as flat as possible (Manly 1986).

PCA can be defined as a statistical procedure that uses orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called **principal components**.

4. Results & Conclusions

4.1. Flow model

The 2- lag flow models are developed using triangular and trapezoidal membership functions with 2, 3 & 5 partitions for each membership functions and the results obtained show that model 5 5 TRIA results is better in training data set with 40 percent model efficiency. However, the result in testing dataset is not better compared to others. By analyzing the ANFIS results we see that ANFIS results are much better than FIS results in terms of efficiency RMSE, MAE and correlation. Efficiency as high as 86.79% is obtained by using 3 3 gaussmf architecture of ANFIS in training dataset but testing efficiency is high of 2 2 gaussmf which is 45 %. So this model can be effectively used to predict somehow accurate results as compared to FIS and can be used with real time data in 3 lag flow model FIS results were not that good and efficiency was quite low but ANFIS models have shown better results and efficiency as high as 85.6 % is obtained in training and 54.23 in testing dataset which is so far the best. MAE & RMSE have also reduced considerably from 115 to 82 in 2 2 gaussmf when compared with 2 lag and 3 lag model results.

4.2.3 Lag Nitrogen model

Results of this model are the main highlights of this research work as input reduction technique has been applied to this which has yielded quite promising results as shown in Table 1.

Table 1 Results of nitrogen model

Nitrogen model	Modelling technique used	Dataset	R	RMSE	E	MAE
Nitrogen 3 lag results	FIS(555 trian)	Training	0.8639	4021.86	64.72	3983.78
		Testing	0.6015	4937.02	59.06	3177.67
	ANFIS(333gaussmf)	Training	0.8948	2948.33	84.54	1810.95
		Testing	0.8873	3025.43	72.51	3909.86
	ANFIS with reduced input	Training	0.9326	3025.43	92.936	3447.5
		Testing	0.9357	4530.61	81.13	3855.81
	regression	Training	0.6883	4429.98	57.97	3421.46
		Testing	0.5671	4869.12	50.32	4098.12

From Table 1 we see that in this nitrogen model (3 lag) efficiency calculated by using ANFIS is around 84 % in training and 72% in testing but when input reduction technique is applied the result improves up to 92 % for training and up to 81% for testing. So this model is so far the best one in this work and can be readily applied to any real time data having similar characteristics.

Conclusions

Performance evaluation statistics of the models shows potential capability of developed models for nutrient prediction in river system. Performance of models is further improved by knowledge extraction from data mining techniques for input reduction. The performance of these models demonstrates that these models can be successfully applied for the prediction of flow and concentration of non-point pollution in river systems

This work presents the general framework for simulating flow and nutrients load in river systems.Development of these models improve understanding the underlying complex hydrological processes that convert a set of inputs into the observed outputs. FIS and ANFIS models are developed with different architecture (in terms of shape and number of membership functions).

By lag analysis the maximum numbers of lags for better results have been calculated by autocorrelation analysis. As the

numbers of lags are increased it has been observed that the prediction by the models improves but only up to a certain limit. For flow prediction and nitrogen prediction two lag models & three lag models have been developed.
In FIS flow models as the number of partition is increased the efficiency increases and the triangular structure gives better efficiency. Using 5 partitions the efficiency is 40.36 % and using 3 partitions the efficiency is 18 %. In all the set of the models ANFIS results show better efficiency than FIS. Efficiency as high as 88 % is obtained using ANFIS in nutrient models. In some ANFIS models RMSE values are higher for testing than in training which may be due to small datasets available in testing data set.
The best results have been obtained by the nutrient model in which the modelling technique ANFIS with reduced input is used. Efficiency as high as 92 % is obtained in this model. So this model can be practically used for efficient prediction in the current scenario. In some models like nutrient modelling (nitrogen and phosphorous) the value of efficiency decrease from training to testing dataset but the RMSE value and the MAE value decreases.

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Hydropolitics Between India & China: Status vs. Perspectives

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Abstract

The Indian subcontinent is continually facing rising incidents of conflicting water events; some even reach the level of violence. The primary reason attributed to the friction due to water is ratio of freshwater percentage to population percentage which is at a dismal low of 0.38 for Indian subcontinent where as the rest of world average is 1.16. Majority of the water resources available in India are transboundary in nature making the region one of the most hotly contested. Transboundary Rivers 'not bounded by nature but divided by people' have a distinct characteristic to define itself which includes socio-politico-techno-economical exercises to receive water and frame its laws between countries. . Cooperation along Transboundary Rivers among hydro politically sensitive countries is all the more complicated due to the absence of distinct international laws on shared waters. The unresolved boundary issues further exacerbates the problem. India as middle downstream riparian in the Brahmaputra river system (spanning across China, India, Bhutan and Bangladesh) is highly susceptible to water resource projects (especially storage types) planned by China on the upstream. The lack of trust and absence of sound political partnership makes dialogue in the area of water resources between India and China a rare phenomenon which defies joint water cooperation. This paper covers the different aspects of Sino-Indian hydropolitics keeping in view the long term consequences on the issues related to and beyond the Brahmaputra River. In addition, a distinct water conflict management approach has been considered to examine the hydropolitical stability between India and China.

Keywords: Brahmaputra River; Hydropolitics; Transboundary; Territorial Sovereignty

1. Introduction

A majority of the developing countries is facing serious freshwater shortages in the 21st century even as the incidents of floods keep increasing when the excess discharge is ultimately disposed to the sea . The distribution of precipitation is erratic and the spatio-temporal variations produce unequal amount of surface water resource for different riparian states. The problem lies in the fact that the excess availability of water rarely coincides with surplus demand. Whether the demand is for natural processes or human needs, the only way water supply can match demand is through storage .

The Brahmaputra also named as Yarlung Tsangpo, is a major transboundary river (surface water resource) flows through China, India and Bangladesh and the basin spans across Bhutan as well. The basin covers 580,000 km^2 across four countries (Fig.1): China (50%), India (34%), Bangladesh (8%) and Bhutan (8%). The river has an approximate length of 2840 km; a major part of which flows through China before entering India through a U-bend and traversing the plains and merging with the Ganges in Bangladesh in the downstream. The Brahmaputra River is a rich source of natural resources that contributes directly to the social, economic and environmental well-being of its riparian countries. The Brahmaputra Basin introduces a significant chance for territorial cooperation and socio-economical exploitation of water resource between India and China . All the riparian states of the Brahmaputra Basin are facing continuous water resources development and management challenges introduced by flood, erosion of bed and banks, meandering of river, excessive sediment load and further enhanced by climate change impacts taking its toll .

The southwest monsoon produces high intra-seasonal variability of flow in the basin (which contributes about 60-70% of total annual average flow) which poses complex water management challenges. Unequal spatio-temporal water distribution in the Brahmaputra basin results in water stress and growing competition amongst riparian states. The complexities in the Brahmaputra basin ranges from hydrological (intra-seasonal variability), to geographical (approx. elevation range 0-8600 m) to hydropolitical (transboundary in nature-four countries are involved).The efficient management of the Brahmaputra basin water resource essentially needs better hydropolitical environment and policies from India as well as china, the major stakeholders of the basin resources.

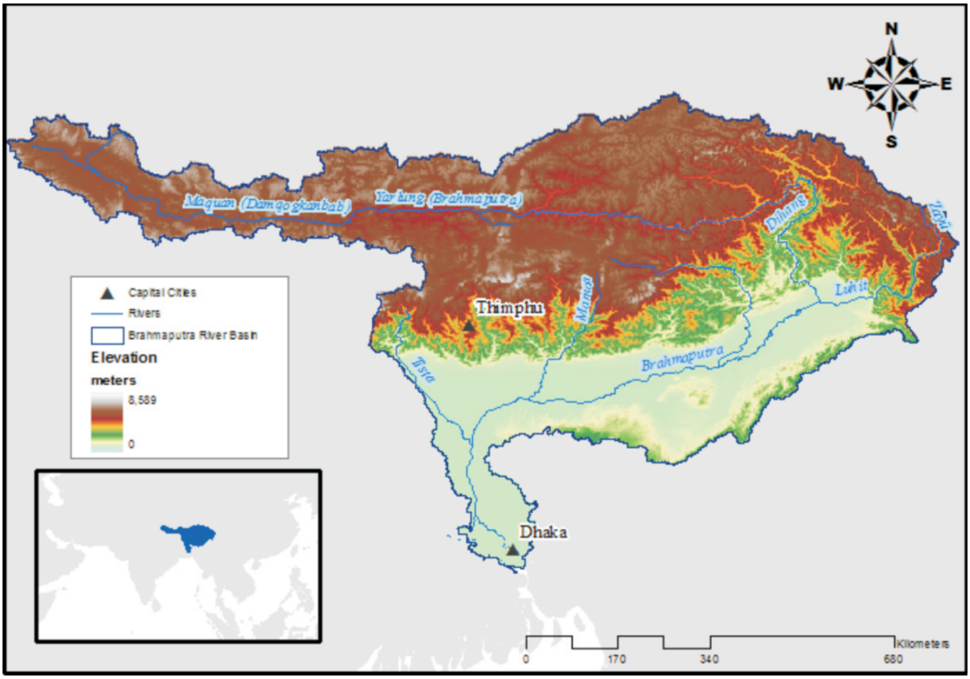

Figure 1 Brahmaputra River basin Elevation Map

Since water resources are essential to agriculture, hydropower, municipal and sanitation, industrial development and ecosystem, the amount of water available can have a drastic impact on the social, political, economic and environmental conditions of a country. Although wars over water have not yet occurred, there is ample evidence showing that water scarcity has led to intense political instability . This is very much true for the Brahmaputra River. China referred by some as an 'upstream superpower' and shows various expert views on their own capacity . (Liu 2015).

2. Experts Views

According to Brahma Chellaney a strategic policy researcher "Water is becoming a key security issue in Sino-Indian relations and a potential source of enduring discord. China and India are already water-stressed economies. The spread of irrigated farming and water intensive industries, together with the rising demands of a growing middle class, have led to a severe struggle for more water. The issues that divide India and China, however, extend beyond territorial disputes." (Chellaney 2007).

Wong (2009) explains the development disputes between India and China as “China claims a part of historical Tibet that is now under Indian control as part of the state of Arunachal Pradesh. To influence this territorial dispute, China tries to block a $2.9 billion Asian Development Bank loan to India because it would help finance Indian water projects in the disputed area.”

Zeitoun and Mirumachi evidently explicate the dilemma of transboundary water issues in the following lines. They say that “Most work on the subject situates transboundary water conflict and transboundary water cooperation at opposing ends of a continuum. The examination of either conflict or cooperation, we argue, refutes the reality of the vast majority of contexts where cooperation and conflict actually co-exist, and perpetuates the paradigm that any conflict is 'bad', and that all forms of cooperation are 'good'. The efforts of the international water academic and practitioner communities may be better served through a combined reading of conflict and cooperation as transboundary water interaction.”

The issue of effective development and management of transboundary water resources has not been an easy subject to deal with at the major international forum. While there are lots of grounds for this uneasiness, credibly the two most significant grounds for this in the past have been due to the issue of national sovereignty and the absence of mutual agreement on the management of vast majority of transboundary freshwater bodies. India and China adopt different approaches with respect to theories of territorial sovereignty as well as polices which promotes the mutual agreement.

3. Theories of territorial sovereignty

Since state sovereignty is at the heart of international relations, the use and allocation of transboundary waters revolves around this fundamental notion. There are four main theories of territorial sovereignty within water law which the nations pursue in order to deal with other riparian's of the basin: absolute territorial sovereignty, absolute territorial integrity, limited territorial sovereignty and the community of interests

3.1 Absolute Territorial Sovereignty (ATS)

Under this theory riparian state is free to utilize the water resources within their border. The 'Harmon Doctrine' of absolute territorial sovereignty is generally favored by upstream riparian state. This theory justifies a state's right to use its resources without any limitations until it crosses its borders. This theory, in effect, is disadvantageous for the downstream states, whose rights to the use of natural resource are hampered due to actions of upper riparian state .

3.2 Absolute Territorial Integrity (ATI)

On the contrary, the theory of absolute territorial integrity is best-loved by downstream riparian's, holds that each state is entitled to an uninterrupted flow of the water into its territory. It supports the uses of resource in such a way that it will not produce any danger to the downstream riparian's. These two contradicting theories in international water law reflect the upstream–downstream dilemma, especially in the case of the Brahmaputra (Yarlung Tsangpo) River .

3.3 Limited Territorial Sovereignty (LTS)

It lies in the foundation of UN Watercourse Conventions. It allows utilizing the shared water resources with equal rights to all the watercourse states and each riparian respect the counterpart's sovereignty and rights which calls for balancing of interests.

3.4 The Community of Interests (COI)-

According to this principle, water can be used 'as and where' basis.

4. Foreign Policies

Both India and China opt to pursue riparian states at the bilateral level. Indian major policies on water issues have been bilateral in nature. Several treaties and memorandum of understandings have been signed by Indian government as upper riparian with Pakistan (on the Indus River) and Bangladesh (on the Ganges River). In the case of Brahmaputra, India is the middle riparian state preceded by China as the main stem of Brahmaputra flows through China, India and Bangladesh. Addressing India, as a middle riparian state, its approach to territorial sovereignty in terms of transboundary waters would seem to have two strands, consistent with upstream and downstream positions. India has signed over twenty bilateral water agreements with Bhutan, Bangladesh, China, Nepal and Pakistan, the majority of which are concerned with the construction of water projects . (Liu 2015; Roger 1997).

In the case Brahmaputra as an upper riparian the policy of China really matters the most to promote sustainable water management. China's foreign policies, directly influenced by historical events, have firmly embedded sovereignty as the governing principle. China has formulated a foreign policy based on good neighbourliness and non-intervention .Theory of limited territorial sovereignty has great influence on China's treaty practice on transboundary water cooperation with lower riparian states.

At the bilateral level, India-China water cooperation mainly revolves around data and information sharing more specifically for flood control. The two states have, since 2002, concluded five Memorandums of Understanding (MoUs) on the provision of hydrological information of shared rivers, three of which concern the Brahmaputra River: the 2002 MoUon the Provision of Hydrological Information of Brahmaputra River in Flood Season by China to India (expired in 2007) and its implementation plan, the 2008 MoU and its implementation plan on the same topic for the period of 2008–12. During the Prime Minister's visit to China in October 2013, both side also signed a separate “Memorandum of Understanding on Strengthening Cooperation on Trans-Border Rivers” on 23rd October 2013, in which inter alia the scope of provision of hydrological information of three hydrological stations has been extended to start from May 15th instead of June 1st to October 15th of the relevant year, from 2014 onwards .

The Hon'ble President of the People's Republic of China paid a state visit to India from November 20-23, 2006. During the visit, it was agreed to set up an Expert-Level Mechanism to discuss interaction and cooperation on provision of flood season hydrological data, emergency management and other issues regarding trans-border rivers as agreed between them. Accordingly, the two sides have set up the Joint Expert Level Mechanism. The Expert Group from Indian side is led by Joint Secretary level officers. Eight meetings of ELM have been held so far . (GoI 2014).

5. International Water Law

The theory of limited territorial sovereignty, as codified under Article 5(1) of the UN Watercourses Convention, aims to reconcile conflicting interests across international borders, so as to “provide the maximum benefit to each State from the uses of the waters with the minimum detriment to each”. Article 7 of the UN Watercourses Convention codifies and clarifies the scope of the duty “not to cause significant harm”. This obligation, otherwise known as the “no significant harm” rule requires that States, “in utilizing an international watercourse in their territories, take all appropriate measures to prevent the causing of significant harm to other watercourse States.” The obligation “not to cause significant harm” derives from the theory of limited territorial sovereignty . (Chen et al. 2013)

6. Planning Approaches on India and China

Two types of planning approach were generally followed by system managers; first is centralized and second one is decentralized. The formulations of centralization and decentralization of water resource system depend on the spatial variation (distance) concept and it may be described as follows:

The distance between water resource

system positions and its area,

The distance between organizational levels or operations,

The distance (physical or organizational) between where decisions are made and where they are enacted.

Centralized approach is termed as vertical planning approach and Decentralized approach is termed as horizontal planning approach. There are certain advantages and disadvantages of both approaches and it is discussed briefly in the next paragraph

6.1 Advantage of Centralized approach

Closeness to Planning Team
Easy knowledge sharing to Planners
Better response to In-progress report
Technology Rotation is Easy
Easy workload transfer

6.2 Disadvantage of Centralized approach

Distance from work areas
Less accessibility to managers
Sparse feedbacks

6.3 Advantage of Decentralized approach

Closeness to work areas
Accessibility to managers
Easy to get feedbacks form the ground level

6.4 Disadvantage of Decentralized approach
Distance from planning areas
Isolated from other planners
Difficult to share planned workload

with respect to water issues, India has decentralized approach. More than 12 different ministries are directly or indirectly involved to the water issues. Sometimes it makes the water resource planning system very slow and lethargic. List of some Indian inependent ministries is given below which are directly involved with water issues.

Ministry of Water Resources, River Development and Ganga Rejuvenation

Ministry of Drinking water and sanitation

Ministry of Environment and forest for climate change

Ministry of shipping

Ministry of finance

Ministry of external affairs

Ministry of Power

On the contrary, China follow centralized approach. China has one main water resource ministry which can take all the decisions on the water issues. Under the same ministry, 11 different departments having different responsibilities on water sector (Table 1).
From the management point of view, centralized approach is directly linked with top-down approach and decentralized approach is associated with bottom-up approach. To get a better idea

about top-down and bottom-up approaches the development of management approaches have been detailed below.

Table 1 Department and Responsibilities of Water Ministry

Department		Area of Responsibilities
1	General Office	Coordinating activities among different departments
2	Department of Planning and Programming	Developing national water resources development plans
3	Department of Policy, Law and Regulations	Formulating water policies and relevant rules and regulations
4	Department of Water Resources Management	Managing the water-drawing permit system and water resources fee system;
5	Department of Finance and Economics	Formulating economic regulatory measures for the water industry
6	Department of Personnel, Labor and Education	Managing personnel, establishment of institutions and their staffing, labor and wage management
7	Department of International Cooperation, Science and Technology	Managing water issues foreign affairs between the Chinese Government and foreign governments, and for the development of science and technology for the water industry
8	Department of Construction and Management	Formulating rules and regulations and technical standards for the management and protection of water areas,
9	Department of Water and Soil Conservation	Water and soil conservation and coordinate the overall control of water and soil loss
10	Department of Irrigation, Drainage and Rural Water Supply	Formulating policies and pro grams with respect to rural water resources and develop relevant specifications and standards
11	The Office of State Flood Control and Drought Relief headquarters	Organizing nationwide activities of flood control and drought relief, undertake the day-to-day work

6.5 Top-down approach

Scientists and academics have long been adopting top-down approach when natural resources and environmental management is considered. It solely values or prioritizes professional 'expert' scientific knowledge as a basis for formulating environmental policies and guiding decisions concerning the environment . It is this that led to the downfall of this strategy. The consequences of prioritizing 'expert' knowledge was that the knowledge and experiences gained by the local population at the 'grass roots' level were not considered for decision making .

6.6 Supply-driven approach

It was realized of late that water resource management is greatly interconnected with the growth of the world's population . Till the 19th century, water resource management focused primarily on water supply to uses for agricultural, domestic and industrial uses and was successful due to the low population growth.

6.7 Bottom- up approach

During the last quarter of 20th century, the conventional supply-driven management approach could not cope up with the growing water requirements and proved incapable and inefficient especially in developing countries. This lead to the realization and acceptance of local knowledge and experiences at the 'grass root' level, which resulted in the introduction of participatory approach to natural resource management denoted as the bottom-up approach . This approach encourages local people to work together on issues related to environment and natural resources in the vicinity. It promotes capacity building and generates empowering opportunities for communities that are able to define their specific needs, wants and aims in relation to local water access and management .

6.8 Ecosystem-based approach

Conventional water resource management approaches were typically of command control type aimed to control the hydrological cycle through hydraulic structures to derive benefits from water and its controlled use . Proper functioning of ecosystems such as headwaters, wetlands and floodplains is vital for sustenance of life as the society relies heavily on benefits derived from ecosystems and biodiversity .

All approaches have certain merits and demerits. The Integrated Water Resources Management makes use of the top-down approach whereas for climate change assessment down-up approach is more useful. Bottom-up approaches first identifies system vulnerabilities to a very wide range of future climates and then determining the plausibility of particular climate impacts using the best available and most credible climate information. In the context of water resource management, the top-down approach means formulation of policies, plans and programs were based solely on technicality and science, which lacks the dynamics of the social realm . As far as water resources management in changing climate is considered an amalgamation of both top-down and bottom-up approaches should be followed as both are complimentary and can be used to support each other.

7. Conclusions

In totality, it can be summed up that for the hydropolitical amalgamation of geopolitical interests of China and India, a balance has to be formulated for sustainable water resources development and management especially in the Brahmaputra Basin. The Brahmaputra basin provides ample opportunities and natural resources to develop the poverty stricken region to a socio-economically developed one. From the analysis, it is clear that the conflict management approaches as well as the approaches for internal management of natural resources and its related issues followed by China and India are completely different from each other. The two countries have to converge on important issues like hydrological storage schemes, power generation, agriculture development, climate change adaptation and mitigation in order to develop the basin socially, economically and hydrologically.

This can be achieved by coercing the efforts of China and India. Both should divert from the approaches of absolute territorial sovereignty or absolute territorial integrity and adopt limited territorial integrity as the conflict management approach as adopted by UN.

For China which follows a centralized approach, a change is policy at the top level decision making body will serve the purpose while India which follows a decentralized approach will find it more difficult to gain consensus among the various decision making bodies. Still for the cause of the basin inhabitants, efforts need to be taken to bring about a change. This is where the merger of top-down and bottom-up approaches and maintaining a proper balance between them is very important.

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Change Detection and Hydrologic Responses Simulation for LULC Changes using Remote Sensing and GIS

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Abstract

Land cover maps represent earth cover reality due to natural or political changes.Satellite images are utilized to analyze land cover and land use (LULC) maps to understand changes in hydrologic response of an area. LULC may be extracted through the processof classification which is categorization of all pixels in a digital image into one of various land cover classes. Changes of specific features within a certain time intervalare ascertained to find change detection.The impact of land-use changes on hydrological response can be evaluatedby integration of remote sensing, GIS and hydrological model. Landsat-7 ETM+ and Landsat-8 OLI/TIRS imageries acquired in 2003 and 2014 respectively are used for the study area. Both imageries are geometrically corrected using corresponding toposheet. The georeferenced imageries are then classified by Maximum Likelihood Classification (MLC) in ERDAS IMAGINE 2011. Image differencing change detection is performed to depict the changes. Significant changes in forest areas and increase in urban areas is observed. Hydrologic response in terms of surface runoff is simulated using ArcSWAT 2005 hydrological model. Watershed delineation is done using ASTER GDEM of 30m resolution. The watershed is divided into sub-basins which are further divided into Hydrologic Response Units (HRUs). Soil and LULC maps of the study area are inputs to the ArcSWAT 2005 model to define HRUs. Change in hydrological response of the study area is correlated with change in LULC.

Keywords: LANDSAT, LULC, MLC, change detection, hydrologic responses, HRUs, SCS-CN, ArcSWAT model.

1. Introduction

Land cover is the surface of the earth covered naturally while land use describes how the land is utilized. Land use may result due to the process of development, conservation practices, or mixed uses. Water, snow, grassland, deciduous forest, wetlands, impervious surfaces and bare soil come under the category of land cover. On the other hand, land use includes wildlife management area, agricultural land, urban, and recreation area. Some LULC maps include a mix of land cover and land use. Change detection is a technology that ascertains the changes of specific features within a certain time interval. It provides the spatial distribution of features and qualitative and quantitative information of features changes. The quantitative analysis and identifying the characteristics and processes of surface changes is carried through from the different periods of remote sensing data. It is useful in many applications like land use changes, habitat fragmentation, rate of deforestation, coastal changes, urban sprawl etc.

Earlier Treitz et al.(1992) developed a two stage digital analysis algorithm incorporating a spectral class frequency based contextual classification of eight land cover and land use classes of the rural-urban fringe Toronto, Canada using SPOT HRV multispectral and panchromatic data. Xu et al.(2000) employed Landsat TM images to characterize land-cover types and land-cover changes in Fuqing City and its adjacent areas in Fujian Province, southeast China. The suggestion on the regional sustainable development for the county is also presented. Ahmadi and Hames (2008) utilized remote sensing technologies to extract land cover and land use (LCLU) from satellite images for remote arid areas in Saudi Arabia. Four different classification techniques unsupervised (ISODATA), and supervised (Maximum likelihood, Mahalanobis Distance, and Minimum Distance) were applied in three sub-catchments in Saudi Arabia for the classification of the raw TM5 images. The developed maps are then visually compared with each other and accuracy assessments utilizing ground-truths are undertaken.

The understanding and prediction of hydrologic processes can be done by the use of hydrologic models.Xianzhao and Jiazhu (2008) applied SCS-CN method in the estimation of runoff in Wangdonggou watershed, located in Changwu County of Shaanxi Province of China. In this work, based on the remote sensing geo-information data of land use and soil classification all obtained from Landsat images in 1996 and 1997 and conventional data of hydrology and meteorology, the SCS model was investigated for simulating the surface runoff for single rainstorm in watershed. They concluded that the SCS model is legitimate and can be successfully used to simulate the runoff generation and the runoff process of typical small watershed based on the remote sensing geo-information in the Loess Plateau.In the present work ArcSWAT hydrologic model is used to determine hydrologic responses in terms of surface runoff and potential evapotranspiration.

2. Land use classification and Change detection

The satellite image classification is applied to extract the land use land cover (LULC) of an area. It is the process in which the pixels of asatellite image are sorted into a finite number of individual classes based on their Digital Number (DN) values. When a pixel satisfies a certain set of criteria, then a particular class is assigned to that pixel. The most common technique of satellite image classification is supervised classification. In this process, the training samples are selected based upon the pre-knowledge of data. These training samples are used to train computer system to identify patterns in the image so that pixelswith similar values can be classified to a meaningful class. In the present work Maximum Likelihood Classifier is utilized to do the extraction of LULC of study area.

Change detection involves the multi-temporal datasets to quantitatively analyze the temporal effects. It can be defined as the process of identifying the differences in the state of an object or phenomena by observing it at different times. In the present work image differencing change detection technique is employed to depict the changes occurred from 2003 to 2014 in the study area. This simple method is widely used and consists of subtracting registered images acquired at different times, pixel by pixel and band by band.

$$Dx_{ij}^{k} = x_{ij}^{k}(t_2) - x_{ij}^{k}(t_1)$$

where, Dx_{ij}^{k} is the difference between pixel value x located at row i and column j, for band k, between acquisition date 1 (t_1) and date 2 (t_2).

3. Runoff estimation

3.1. SCS-CN method

The SCS-CN runoff equation is as follows:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \quad \ldots(1)$$

where, P = Rainfall (in), I_a Initial abstraction (in), Q = Runoff (in), S = potential maximum retention after runoffbegins (in)

Initial abstraction (I_a) is all losses before runoff begins. Through studies of many small agricultural watersheds, (I_a) was found to be approximated by the following empirical equation for Indian conditions:

$$I_a = 0.3S \quad (2)$$

By removing I_a as an independent parameter, this approximation allows use of a combination S and P to produce a unique runoff amount. Substituting equation (2) into equation (1) gives:

$$Q = \frac{(P - 0.3S)^2}{(P + 0.7S)} \quad \ldots(3)$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

$$S = \frac{25400}{CN} - 254 \quad \ldots(4)$$

Weighted CN is given by:

$$CN = \frac{\sum A_i * CN_i}{\sum A_i} \quad \ldots(5)$$

3.2. ArcSWAT

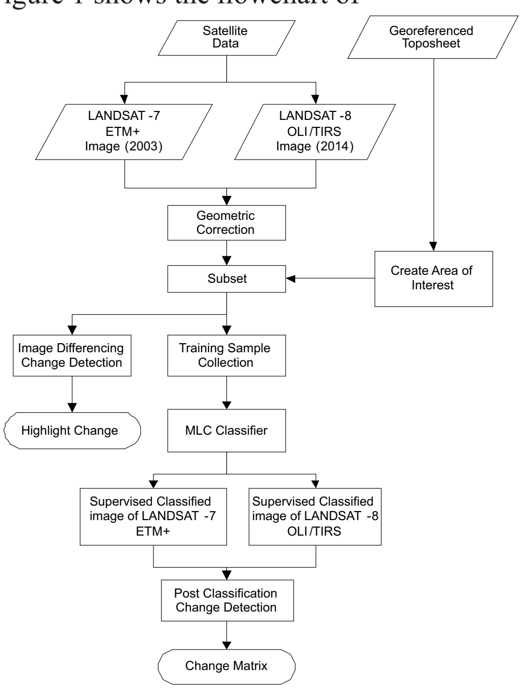
ArcSWAT is an ArcGIS-ArcView extension and graphical user input interface for SWAT. SWAT was developed by USDA-ARS (Agriculture Research Service). Prediction of impacts of land management practices on water, sediment and agricultural chemical yields was the aim for the development of this physically based model(Neitsch et al. 2011). The basin is divided into sub-basins, each one of them corresponding to a stream and then the sub-basins are discretized into sub-areas called HRUs, which are unique in terms of soils and land use. Presently SWAT model works at daily and monthly time step.Guo et al. (2008) employed SWAT to know how the climate, land-use and land-cover changes in the region affect the annual and seasonal variations of basin hydrology and streamflow in

Poyang Lake basin as well as the lower reaches of the Yangtze River. A major finding of this study was that the climate effect is dominant in annual streamflow. While land-cover change may have a moderate impact on annual streamflow it strongly influences seasonal streamflow and alters the annual hydrograph of the basin. Panhalkar (2014)applied SWAT model to predict runoff, erosion, sediment and nutrient transport from agricultural watersheds under different management practices in Satluj basin up to the Bhakra dam. ArcSWAT model with SCS-CN option is employed in this work.

4. Methodology

4.1 Methodology for image classification and change detection

Figure 1 shows the flowchart of



In order to depict the changes ocurred from 2003 to 2014, image differencing change detection is performed in ERDAS IMAGINE 2011. The subsetted images of the two imageriesare the inputs for image differencing change detection method to calculate the highlighted changes. Moreover a change matrix is created in ArcGIS 9.3 to perform post classification change detection.For this the classified images of LANDSAT-7 and LANDSAT-8 are the inputs to this method.

4.2Methodology for runoff estimation using ArcSWAT

Figure 2 shows the flowchart of methodology for estimation of runoff using ArcSWAT 2005. Initially three data are required namely ASTER GDEM, classified map of LANDSAT-7 ETM+ and soil sheet of the study area. ASTER GDEM of 30m resolution is downloaded from http://earthexplorer.usgs.gov/ whereas the soil sheet of 1:500,000 scale is obtained from National Bureau of Soil Survey and Land Use Planning (NBSS & LUP). ASTER GDEM is mosaicked and then subsetted to desired area. It is then projected to UTM projected coordinate system. The classified image of LANDSAT-7 is obtained in first part of methodology. Moreover, the soil sheet is georeferenced, subsetted and digitized to prepare soil map of the study area. The determination of runoff using ArcSWAT involves various steps: setting up the project; automatic watershed delineation; defining land use, soil and slope; defining Hydrologic Response Units (HRU); editing static geodatabase; writing input tables for weather stations; and run SWAT model .

5. Application of methodology in study area

The study area considered in the present work is Allahabad and adjoining districts from 2524° to 26.00° N and 80.99° to 82.00° E. The study area includes major parts of Allahabad district along with some portion of Pratapgarh, Raebareli, Fatehpur and Banda districts. It includes confluence of river Ganga and river Yamuna in Allahabad. The maps of supervised classification of LANDSAT-7 ETM+ and LANDSAT-8 OLI/TIRS are shown in Figure 3 and Figure 4 respectively.

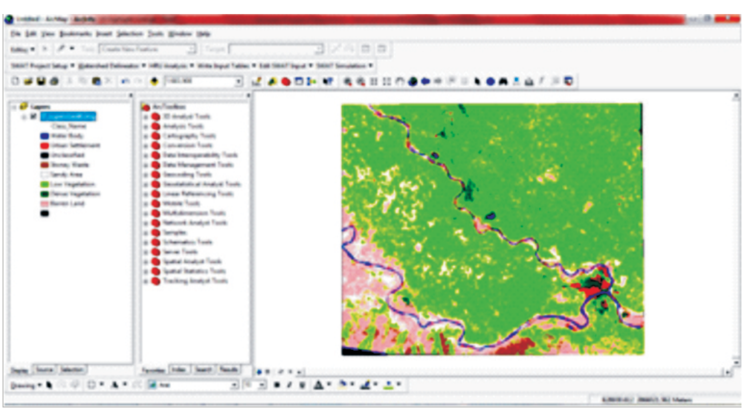


Figure 3 Supervised Classified map of LANDSAT-7 ETM+ acquired in 2003

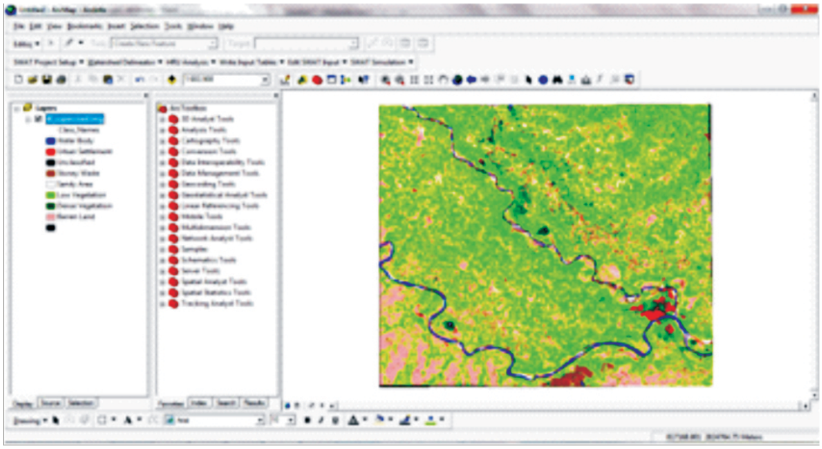


Figure 4 Supervised Classified map of LANDSAT-8 OLI/TIRS acquired in2014

The result of image differencing change detection method is shown in Figure 5. In Figure 6 there are five sub-divisions of pixel difference values. These are -120 to -47, -47 to -17, -17 to -6, -6 to 68 and 68 to 160. Figure 7 highlights the change in the study area from 2003 to 2014. Red colored, black colored and green colored pixels represent decreased area,no change area and increased area.

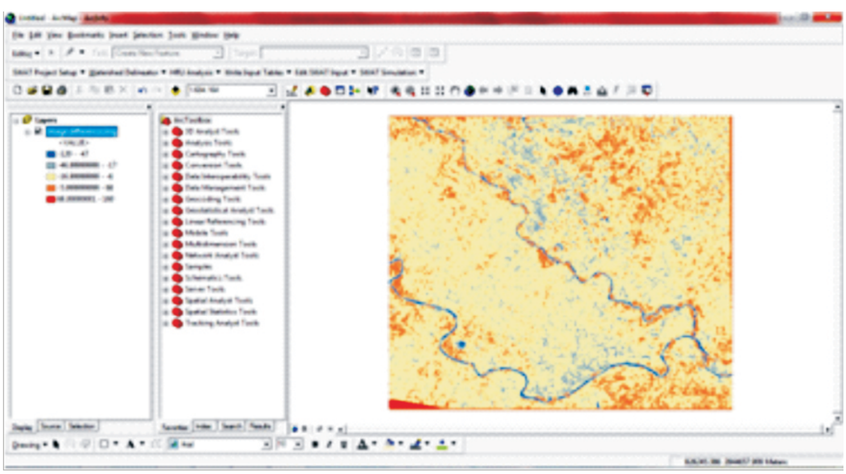


Figure 5 Image difference from 2003 to 2014

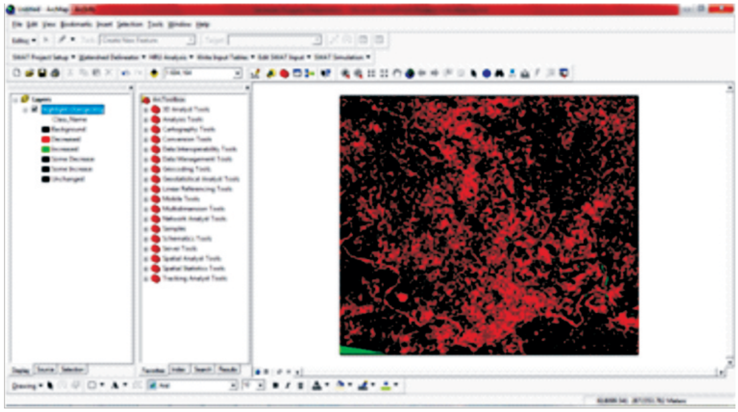


Figure 6 Highlighted change from 2003 to 2014

In order to estimate runoff using ArcSWAT 2005 first we have to delineate watershed in the study area which can be done by using digital elevation model. In the present work ASTER GDEM of 30m resolution is used to identify the river network in the watershed. The watershed delineated in the study area is shown in Figure 7. It contains the blue-colored streams along with black colored outlets. Moreover, longest stream in each sub-basin is represented by green colored streams.

Figure 8 gives the details of LULC classes clipped to the boundary of watershed. These LULC classes are reclassified in accordance with land use classes available in ArcSWAT 2005 geodatabase. Water body is reclassified as WATR, sandy area by AGRC, urban settlement by URBN, low vegetation by RNGE, stoney waste by SWRN, barren land by FRSD and dense vegetation by FRSE.

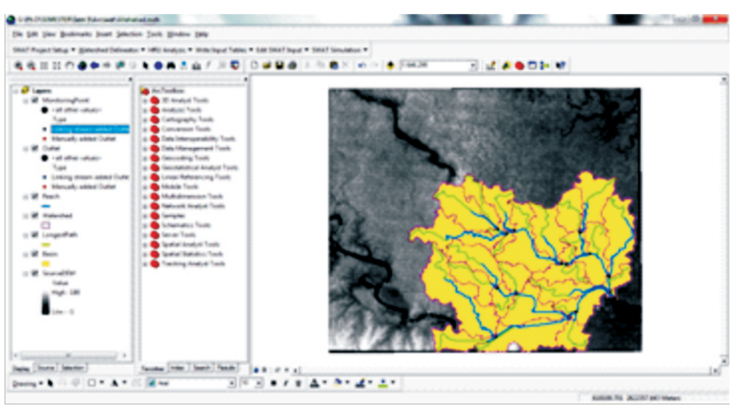


Figure 7 Watershed delineated in the study area

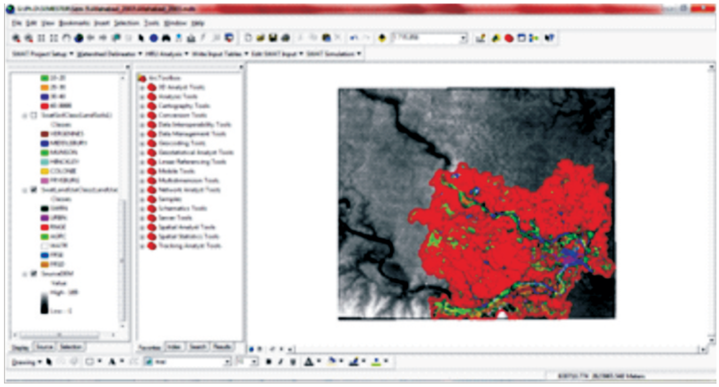


Figure 8 Reclassified SWAT landuse classes

Reclassified soil classes in delineated watershed is shown in Figure 9. Fine soil is reclassified as vergennes, fine loamy as middlebury, fine silty as munson, sandy skeletal as hinckley, sandy over coarse loamy as colonie and coarse loamy as fryeburg. Figure 10gives the distribution of slope in the watershed. Slope is reclassified into multiple slopes from 0-10, 10-20, 20-30, 30-40 and 40-9999.

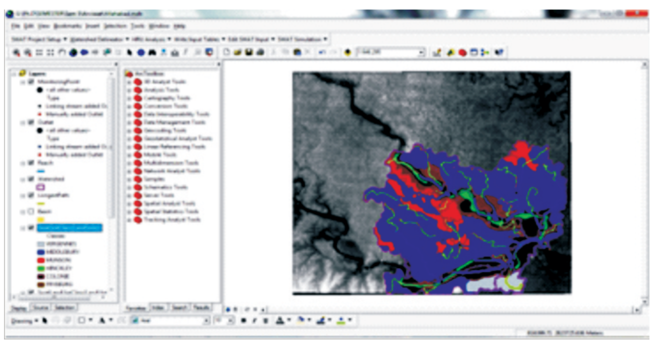


Figure 9 Reclassified soil classes in delineated Watershed

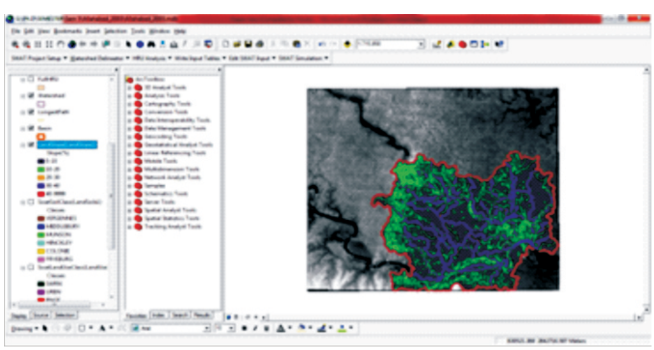


Figure 10 Reclassified slope classes in delineated watershed

Figure 11 shows the Hydrologic Response Untis (HRUs) of each sub-basin. There are 31 sub-basins and 233 HRUs defined in the delineated watershed. Moreover, figure 12 gives the location of weather station located at latitude of 25.5 and° longitude of 81.5.°Precipitation gage is represented by green hexagonal while temperaure gage by mazenta circular shape.

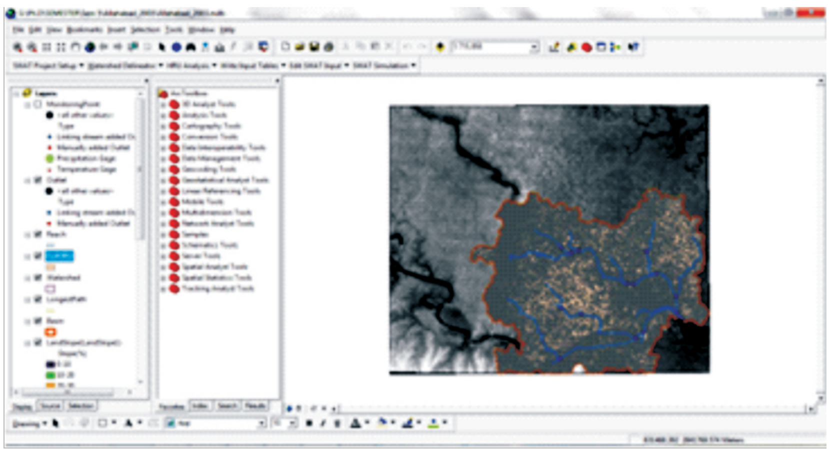


Figure 11 HRUs in delineated watershed

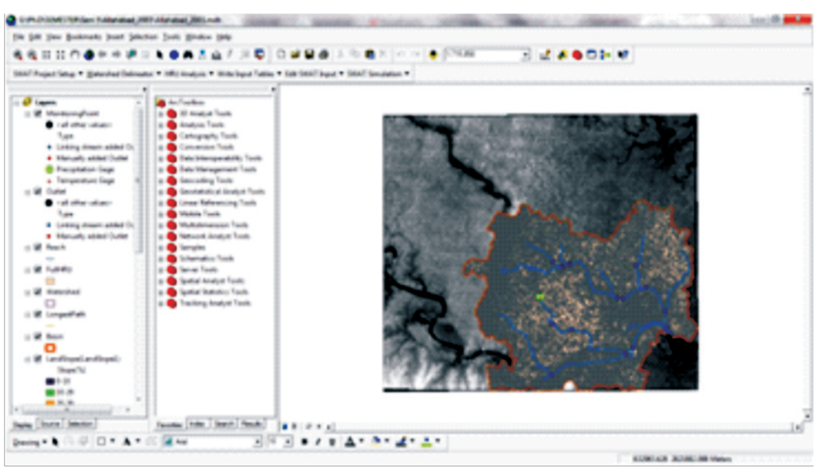


Figure 12 Precipitation and Temperature gage in delineated watershed

6. Results and Discussions

Details of LULC classes in LANDSAT-7 ETM+ (2003) and LANDSAT-8 OLI/TIRS (2014) are shown in Table 1.

Table 1 Details of LULC classes in LANDSAT-7 ETM+ (2003) and LANDSAT-8 OLI/TIRS (2014)

S. No.	LULC Class	Area Covered in 2003 (km^2)	Percentage of Area in 2003	Area Covered in 2014(km^2)	Percentage of Area in 2014
1.	Water Body	106.949	1.27	115.954	1.38
2.	Urban Settlement	114.024	1.35	173.774	2.06
3.	Stoney Waste	104.619	1.24	296.444	3.52
4.	Sandy Area	571.582	6.78	304.03	3.61
5.	Low Vegetation	6011.49	71.31	4610.82	54.69
6.	Dense Vegetation	170.06	2.02	418.722	4.97
7.	Barren Land	1276.82	15.15	2450.91	29.07

In both years (2003 and 2014), the maximum area is covered by low vegetation. There is a reduction of 23.3% in low vegetation from 2003 to 2014 whereas urban settlement is increased from 1.35% to 2.06% in these 11 years. This indicates that most of the low vegetation is converted into urbanized area. Water body is increased from 106.949 km^2 to 115.954 km^2 while sandy area is decreased from 571.582 km^2 to 304.03 km^2.

In the present work surface runoff Q (mm) is estimated by SCS-CN method.Rainfall and corresponding estimated runoff are shown in Figure 13. Temporal variation patterns in rainfall and runoff almost matches.

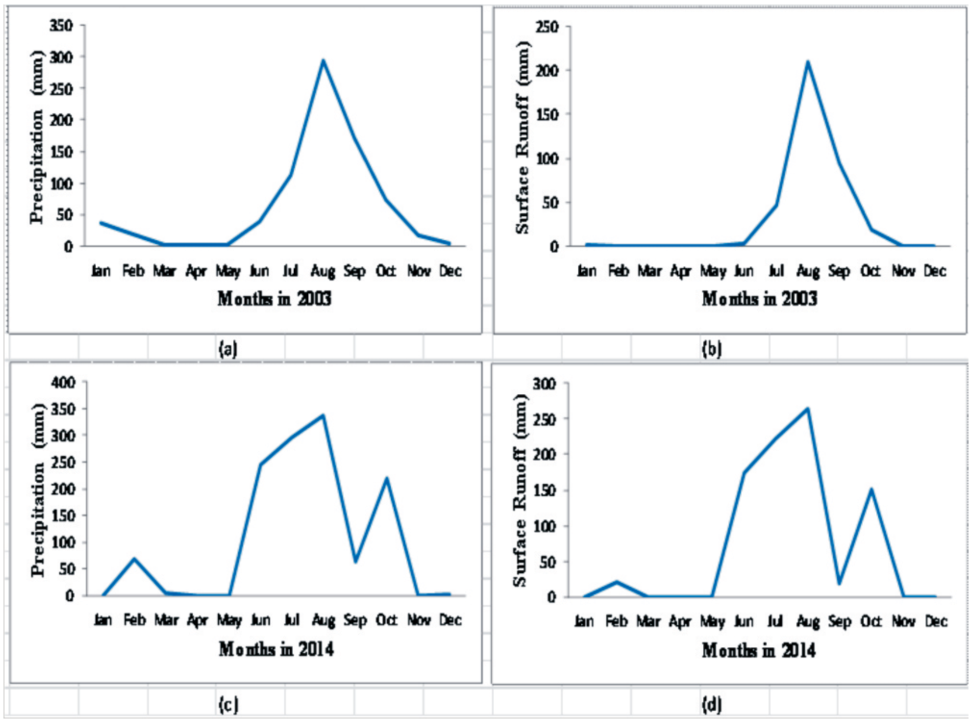


Figure 13 Comparison of rainfall and runoff: (a).Precipitation (mm) in 2003, (b). Surface Runoff (mm) in 2003, (c). Precipitation (mm) in 2014, (d). Surface Runoff (mm) in 2014

The mass balance for observed precipitation in the study area is shown in Table 2.

Table 2 Mass balance corresponding to observed rainfall in 2003

P (mm)	SUR Q (mm)	LAT Q (mm)	GW Q (mm)	PERCO LATE (mm)	TILE Q (mm)	SW (mm)	ET (mm)	Mass Balance (mm)
766.871	23.42	33.65	86.35	100.43	0.00	111.17	405.63	760.65

In Table 2, P is precipitation in mm, SUR Q is amount of surface runoff in mm, LAT Q is lateral flow contribution to streamflow in mm, GW Q is groundwater contribution to stream in mm, PERCO LATE is water percolation past bottom of soil profile in mm, TILE Q drainage tile flow contribution to stream in mm, SW is amount of water stored in soil profile and ET is actual evapotranspiration in watreshed in mm.

8. Conclusions

The methodology presented in this work demonstrates potential application for land cover classification and change detection in a study area. Maximum Likelihood Classifier in identified sevenclasses for the study area namely water body, urban settlement,lowvegetation,dense vegetation, barren land, sandy area and stoney waste.Maximum decrement of 23.3% has occurred in low vegetation from 2003 and 2014 whereas the urbanized area is increased by 52.4%. These statisticsinfer that reduction in low vegetation has emerged into urbanization to a great extent in these 11 years. The runoff values estimated directly using SCS-CN method and by ArcSWAT simulation. The temporal variation in surface runoff estimated by SCS-CN method follows the trend in observed precipitation in 2003 and 2014. The mass balance of the total observed precipitation in the study area almost balances with the total estimated outputs from ArcSWAT simulation.

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Processing Cloudy Images of NRSC to Acquire Reservoir Details

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Abstract

A significant obstacle of extracting information using satellite imagery is the presence of clouds. Reservoir boundaries cannot be extracted as the images are covered with clouds. The problem can be mostly resolved by mosaicking the cloud areas with the cloud free areas in other temporal images. In this project, a complete approach, including image enhancement, cloud detection and cloud areas mosaicking, is proposed to generate cloud free images from multi-temporal satellite images.

***Keywords**:* Mosaicking, multi-temporal, main image, reference image.

1. Introduction

Instrumentation division of CWPRS is involved in assessing sediment volume based on integrated hydrographic survey techniques. In case of large reservoirs the contour extracted from this satellite imagery at different levels are very much essential to limit the survey boat movement within the required data login (collection) area. However, most of the times the contours could not be extracted as the images are covered with clouds. The variously dated scenes or cloud-free scene parts that might compose an image mosaic will differ in atmospheric conditions, sun-target-sensor geometry, sensor calibration, soil moisture, and vegetation phenology. These differences cause the relationships between land-cover classes and pixel brightness values to vary across space over a mosaic period, which refers to the time period spanning the cloud-free scenes or scene parts that compose an image mosaic.

A significant obstacle for extracting information from remote sensing imagery is the missing information caused by clouds and their shadows in the images. There are some radar satellites that do not have cloud contamination problems because they operate in the microwave range of the electromagnetic spectrum. It is possible to obtain microwave imagery information from some of the satellites that goes back in time to 1991. But these kinds of images cannot replace information provided by optical remote sensing data. The emitted radiation in microwave range is very low while in the visible range the maximum energy is emitted. Consequently, in order to obtain imagery in the microwave region and measure these signals, which are weak, large areas are imaged. This results in relatively poor spatial resolution. On the other hand, by contrast, images in the visible range have a high resolution.

Feng Chun (2004) put forward a method based on statistical characters of image information, an improved homomorphism filtering. Instead of the filtering in frequency field, it isolates the low frequency component of the image representing cloud information with calculating neighborhood average in spatial field. But this method applies only to the images having thin cloud cover. Surfaces under thick clouds has to be retrieved by using patches from multi-temporal images, which it doesn't considers at all.

Bin Wang (1999) uses the image fusion technique to automatically recognize and remove contamination of clouds and their shadows, and integrate complementary information into the composite image from multi-temporal images. The cloud regions are detected on the basis of the reflectance differences with the other regions. Based on the fact that shadows smooth the brightness changes of the ground, the shadow regions are detected successfully by means of wavelet transform. Further, an area-based detection rule is developed in this paper and the multispectral characteristics of Landsat TM images are used to alleviate the computational load.

Chao-Hung Lin (2011) proposed a patch-based approach that mathematically formulates the reconstruction problem as a Poisson equation and then solve this equation using a global optimization process. In the optimization, the selected cloud-free patches are globally and consistently cloned in the corresponding cloud-contaminated region. This process potentially results in good cloud removal results in terms of radiometric accuracy and consistency. But their approach is semi-automatic. Users have to manually refine the cloud detection results through an interface of selection and erase operations.

Tapasmini Sahoo (2008) used an image fusion technique to remove clouds from satellite images. The proposed method involves an auto associative neural network based PCAT (principal component transform) and SWT (stationary wavelet transform) to remove clouds recursively which integrates complementary information to form a composite image from multi-temporal images. Some evaluation measures are suggested and applied to compare their method with those of covariance based PCAT fusion method and WT-based one. The PSNR and the correlation coefficient value indicate that the performance of their method is better than others. It also enhances the visual effect.

2. Implementation of the proposed system

2.1 RGB to Gray Conversion

Processing the coloured images directly is computationally time consuming and processor heavy task. Also the threshold value can be easily selected from a grey image rather than a coloured image. Hence the images are converted to grayscale.RGB values of images are converted to grayscale values by forming a weighted sum of the R, G, and B components:
Grey value=0.2989 * R + 0.5870 * G + 0.1140 * B

2.2 Correction of brightness

The main image and the reference image defined in this paper are two images which were observed at different times but cover the same region over the ground. Due to the different solar irradiance and atmospheric effects, it is necessary to correct the brightness of the two images before the image fusion. The correctness of brightness can be performed using

$$f'_{ref}(i,j) = k \times f_{ref}(i,j) \qquad (1)$$

Where $f_{ref}(i,j)$ is the old brightness value of a pixel of the reference image and $f'_{ref}(i,j)$ is its new value, k is any real number greater than zero.

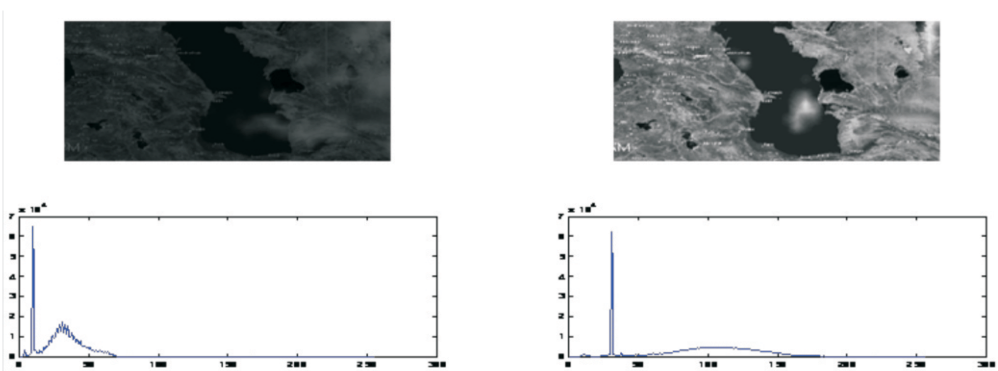

Figure 1. Main and reference images with their histograms

2.3 Detection of clouds

In general, clouds reflect the solar radiation in the visible and infrared spectra to a much higher degree than the ground. By setting a threshold *C*, we can distinguish the cloud regions from the ground regions, if

$$f_{main}(i,j) > C_1$$

or

$$f'_{ref}(i,j) > C_1 \qquad (2)$$

Where $f_{main}(i,j)$ is the brightness value of a pixel of the main image, it can be assumed that there is a cloud in the main image or the reference image at the location *(i,j)*. The threshold value can easily be determined by investigating the histogram of the image or by trial and error with different values to get the best result. The cloudy area is then replaced with a new pixel having value let say '1' and saved as another image

$$(f_{Thres-main}(i,j), f_{Thres-ref}(i,j))$$

so as to mark/tag the detected areas of both the main and reference images. The following equations explains this:

If $f_{main}(i,j) > C_1$ then $f_{Thres-main}(i,j)$=1

Else $f_{Thres-main}(i,j) = f_{main}(i,j)$

and

If $f'_{ref}(i,j) > C_1$ then $f_{Thres-ref}(i,j)$=1

Else $f_{Thres-ref}(i,j) = f_{main}(i,j)$ (3)

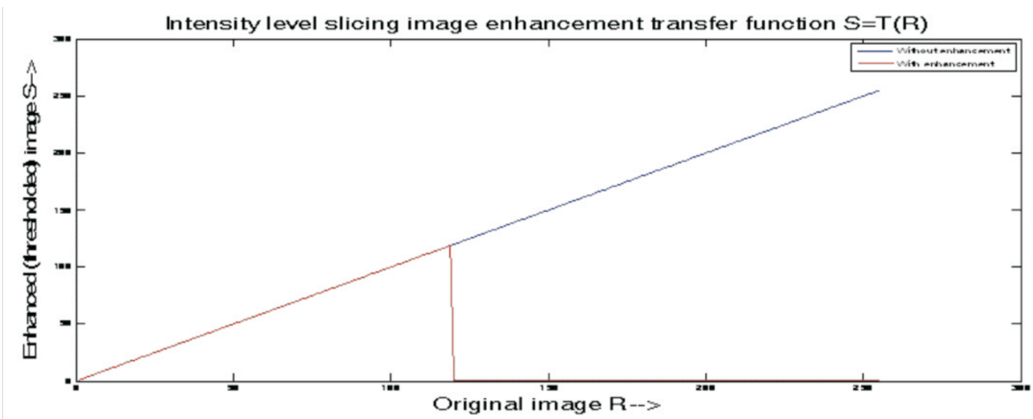

Figure 2. Graph of intensity level slicing with C_1=120

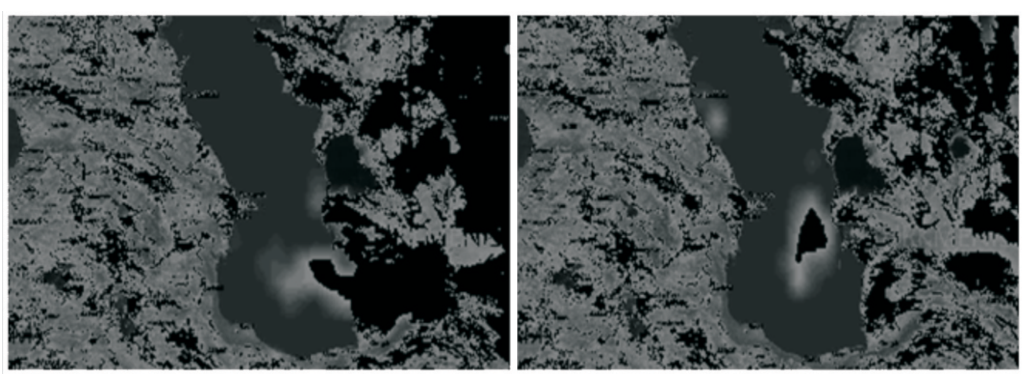

Figure 3. Main and reference thresholded images

2.4 Restoration of land features

Some objects on ground like snow covered mountains, have fairly approximate reflectance with the clouds and hence might get tagged as clouds, but they cannot move as the clouds do. This property is used to restore the land features. The algorithm used is as follows:

If $f_{Thres-main}(i,j)$ is equl to 1 then then it is either a common cloud covered area or a land feature. Hence it is restored,
And

$$f_{Thres-main}(i,j) = f_{main}(i,j)$$

$$f_{Thres-ref}(i,j) = f''_{ref}(i,j)$$

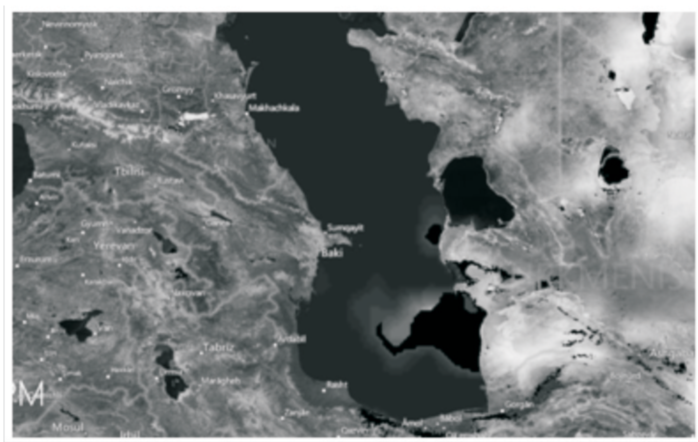

Figure 4. Main thresholded and restored image

2.5 Mosaicking the cloudy areas

Mosaicking is different from restoration in the sense that in mosaicking an image patch from a different image (reference image) is used whereas in restoration the image patch is from the same image (that has not been thresholded). The algorithm is:

If $f_{Thres-main}(i,j)$ is equal to 1

then $f_{Thres-main}(i,j) = f'ref(i,j)$ (5)

The final cloud-free image is obtained in colour by using the intermediate grey images as a binary map/marker for cloudy areas. All the processing like brightness correction, thresholding restoring the land features, are first performed on the grey images. Only brightness correction and mosaicking is performed on the colour image based on the grey images.

Figure 5. Final cloud-free colour image

3. Results

Table 1. 'Cloud' pixel count

Sr. No.	Image	Number of pixels
1.	Main image 'Cloud' count	152010
2.	Reference image 'Cloud' count	120943
3	Restored cloud/land count	115810
4.	Actual cloud count in main image	36200
5.	Final(cloud-free) image mosaicked area pixel count	35917
6.	Remaining cloud covered area pixel count in final image	283

4. Conclusions

In this paper we presented a scheme to automatically detect and remove clouds. The entire algorithm is mainly composed of four stages: brightness correction, detection of clouds, restoration of land features, image mosaicking. This scheme has a lower computational complexity as the entire processing of image is done in spatial domain and not in frequency domain. In addition, this algorithm can also be used to detect and remove fog, mist and haze contamination. Further, we believe that this automated removal of clouds can be considered as a kind of preprocessing before quantitative study, and should be very useful for many practical applications such as environment monitoring.

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1. Professional paper (contribution offering experience useful for improvement of professional practice but not necessarily based on scientific methods);
2. Informative contribution (editorial, commentary, etc.);
3. Review (of a book, software, case study, scientific event, etc.)

Language

The article should be in English. The grammar and style of the article should be of good quality. The systematized text should be without abbreviations (except standard ones). All measurements must be in SI units. The sequence of formulae is denoted in Arabic numerals in parentheses on the right-hand side.

Abstract and Summary

An abstract is a concise informative presentation of the article content for fast and accurate Evaluation of its relevance. It is both in the Editorial Office's and the author's best interest for an abstract to contain terms often used for indexing and article search. The abstract describes the purpose of the study and the methods, outlines the findings and state the conclusions. A 100- to
250- Word abstract should be placed between the title and the keywords with the body text to follow. Besides an abstract are advised to have a summary in English, at the end of the article, after the Reference list. The summary should be structured and long up to 1/10 of the article length (it is more extensive than the abstract).

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Acknowledgements

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