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REVIEW ARTICLE

ASSESSMENT AND MANAGEMENT OF FLOOD HAZARD IN NOA-MANGALDOI RIVER BASIN OF ASSAM, N.E. INDIA

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ABSTRACT

Flood has always been considered as the dominant natural hazard since long past, as most of the major river valleys of the world have the experience of high magnitude of floods. But recently, due to over population on the river valleys and various human activities including manipulation of river courses have caused this natural hazard to occur frequently and even with alarming magnitude. It has become a significant and common feature causing severe flood hazard in the monsoon regions like India. The North Eastern part of India is also being affected by monsoon floods. The Noa-Mangaldoi river basin located between $26^0 21^/$ N to $26^0 58^/$ N latitude and $91^0 56^/$ E to $92^0 05^/$ E longitude covering an area of 745 Km^2 is a part of Brahmaputra system in N.E. India experiences monsoon floods which calls for due flood protection and management strategies. The dominant impact of flood is on the agricultural sector and economy. In view of the gravity of the flood problem in the basin the present study has been carried out covering assessment and development of probable strategies for flood hazard management. The aspects like flood occurrence pattern, flood causing factors, flood frequency and probability analysis and geo-environmental impacts of floods has been analysed and discussed in this paper with the help of both primary and secondary data.

INTRODUCTION

As natural hazards, floods are historical and their occurrences in the riverine areas have always been a rule rather than an exception. However, the recent tremendously growing human population along with the concentration of their various economic activities in the world riverine areas in general and the flood plains of developing countries in particular have made the floods one of the major natural as well as manmade hazards (Bhattacharjee and Barman, 2011). The lacking of proper management strategies and measures has not only encouraged the floods to become more hazardous in recent times but also one of the major concerns of the hydrologists as well as the fluvio-geomorphologists and the social scientists as well. Thus, many research works have already been done towards evaluating and managing floods worldwide. Of course, it should mention that though in recent time due to expansive and intensified landuse and rising damage potentials in flood plain areas have made the flood research more concentrate towards socio-economic aspects, but few years back it was dominated by a technical worldwide. Floods do act both as boon and hazard. In the forms of sudden flow of huge volume of water over the banks, bank erosion, shifting of river channel and heavy sedimentation on the bed,banks and beyond the banks, they appear as hazards and stand as great barrier against regional development. But the same under tolerable levels become boon by providing the facilities of adequate water and alluvium to agricultural fields, supply of natural fishes and other materials to flood plain dwellers and recharging the ground water (Bhattacharjee and Barman, 2011). In fact, through maintaining a true adjustment with the flood especially by the flood plain dwellers and other concerned people including land-users, socio- economic planners and managers may help in achieving a true development in the flood prone areas. With 3-4 waves in a year during monsoon months, Assam is a land of flood. In Assam around o.4 million hectares of land is considered to be flood prone. The Noa-Mangaldoi river system of middle part of Darrang district covers a strip like elongated area extends from Bhutan Himalaya of north to the Brahmaputra towards south where floods and associated hazards occur annually especially in the middle and lower part. This contribution has thus been organized for evaluating flood hazard of Noa-Mangaldoi river basin by encompassing the aspects of flood causes and bases, flood damage analysis including human response and formulation of probable measures and strategies for reducing the severity of flood hazard.

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The Study Area

The Noa-nadi is a north bank tributary of the Brahmaputra river in Assam. With latitudinal and longitudinal extensions of

26^0 21′ N to 26^0 58′ N and 91^0 56′ E to 92^0 05′ E respectively, the basin lies partly in Samdrup Jongkhar district of Bhutan and partly in Darrang and Udalguri districts in Assam (Fig.1). The river originates from the Khampajuli hill ranges of Bhutan at an elevation of about 1750 m and traverses a total distance of 103 km to the outfall at the Brahmaputra. The river has a total catchment area of 745 km^2, out of which about 651 km^2 lies in the plains of Brahmaputra valley and the remaining 94 km^2 falls in the sub-Himalayan domain of Bhutan. The river maintains a steep channel gradient in its upper reach and relatively a gentle gradient along its lower plain course. The river intercepts several tributaries and rivulets on both the banks during its course. Among these Lakhmijuli or Khampajuli Nadi, Batiamari Nadi and Mangaldoi Nadi are worth mentioning. Batiamari nadi is only the right bank tributary of the Noa-Nadi.

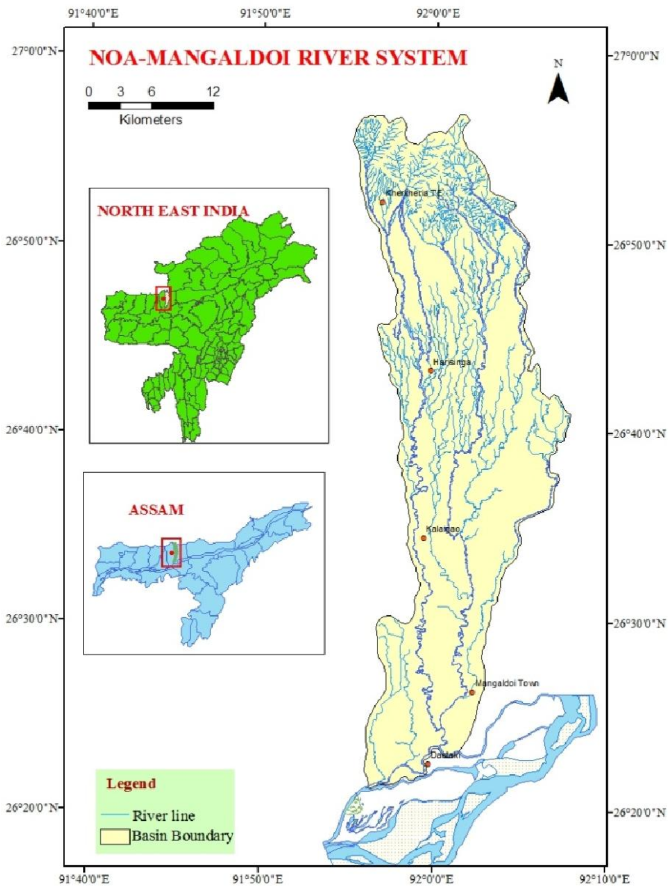

Figure 1. The study Area

Objectives

The main objectives of this research paper are

(i) To examine the causes and bases of floods including their magnitudes, intensity, frequency and duration.
(ii) To analysis the various damages caused by floods including human responses to flood.
(iii) To formulate measures and strategies for reducing the intensity of flood hazards and sustainable management of flood plain resources.

MATERIALS AND METHODS

The study incorporates both the primary and secondary data sources. The base map of the study area has been prepared by using topographical sheets of Survey of India on the scale of 1: 50,000 (toposheets no. 78N/13, 78N/14, 78N/15, 83B/1, 83B/2, and 83B/3). Long profile has drawn with the help of Google Earth. Necessary data in respect of water level, flow discharge, sediment load, ground water availability and distribution, rainfall distribution etc have been collected from Irrigation department, govt. of Assam (Hydrological section), Central Ground Water Board, meteorological department, (Guwahati) govt. of India etc. Data regarding flood damages and losses were collected from circle office to DC's Office, Darrang district, govt. of Assam. To observe the ground reality regarding flood as hazard household survey on 25 villages was also conducted using standard statistical techniques.

Analysis

As a part of the Brahmaputra valley of Assam (India), floods in the Noa-Mangaldoi river basin have always been considered as a normal feature specially in the middle and lower parts since very long past. Though any written past records regarding floods of the basin are not available because as per the decision of Central Flood Control Board, the State Flood Control Departments were to collect and compile annual flood data with effect from 1960, yet, some written accounts of flood of Assam clearly reveal the devastating dimension including extent and volume of flood damages of the basin in the past. The basin had the experience of frequently occurring floods characteristically of high magnitudes with major geomorphic impact on flood plain morphology and channel configuration together with heavy damages on agriculture and infrastructure. The recent flood records available from Flood Control Department of Assam clearly show that the high flood in the basin during 1982, 1987, 1988, 1990, 1993, 1997, 1999, 2000, 2003, 2004, and 2006 caused tremendous damage to standing crops, cattles and infrastructure.

Bases and causes of floods

Floods with their varying depth, extension, volume, intensities and duration always play a major role in the landform developmental process and they have their differential genetical expressions in accordance with diverse topographic, geologic, climatic, hydrologic and vegetational foundations (Bhattacharjee and Barman, 2011). Originating from Bhutan Himalaya and covering an area of 745 km^2, the Noa-Mangaldoi river system is an important north bank tributary of the Brahmaputra. The river system takes a fern like elongated shape with characteristic hill slope and high erodible tertiary rocks along with high seismicity in the Bhutan Himalayas, alluvial fan and cones in the foothill zone, alluvial plains with interfluves in the middle and the chronically flood affected zone in the lower part extending upto the confluence with the Brahmaputra. The rich network of tributaries along with high flow variability, frequent channel changes, bank erosion and floods have made the fluvial regime of the system more dynamic and complex. The basin has thus a unique and diverse geophysical as well as hydrological set up which encourages the natural processes and factors alone to create frequent devastating floods especially in the lower part of the basin.

Natural factors

As a part of Brahmaputra valley, the Noa-Mangaldoi basin has been under ‘tropical Monsoon Climate’ that enjoying an average annual rainfall in excess of 2500 mm, which generally occurs during monsoon months (June to September). The northern hilly part of the basin has the maximum annual rainfall of 2873 mm, whereas the southern plain reach has an annual rainfall of 1908 mm (Table 1). During monsoon the monsoon axis oscillates from its normal position to the north and south. When the axis moves towards foothills of Himalayan ranges the rainfall over the entire north east India and Bhutan occurs heavily and this becomes the main cause of floods in the Brahmaputra valley including Noa-Mangaldoi basin. Besides, the frequently occurring landbased insitu depressions in Assam and adjoining areas also influence heavy rainfall over the entire Noa-Mangaldoi basin which immediately caused the floods.

This very high relief and high channel gradient together with weak geological base constituted by easily erodible Tertiary Himalayan rocks accelerate the stream power manifold to carry more water and the erosional loads downstream immediately after heavy rain and leads to heavy siltation on the river bed, bank erosion, channel shift and subsequent floods. High channel shifting along the middle and lower courses is an annual feature of the basin. Erosion at many concave bends of the river has been observed which encourage the process of channel shifting. Recently, there has been some erosion near Harisinga from the tributaries Bikhaiti and Bhola. Erosion also occurred near Kalaigaon, Mangaldoi and Monitary near outfall. More than 30 numbers of bends have so far been identified as sensitive to bank erosion. The bank erosion together with channel shifting has now become an important factor of floods in the basin. Although more than medium to small size wetlands are scattered locally known as ‘beel’ in the middle and lower courses of the basin also have accelerated the flood havoc during heavy rainfall by passing the flood waters through them.

Table 1. Seasonal Rainfall (cm) in Noa-Mangaldoi River Basin during the period 1978-2006

Sl.No.	Name of Station	Status of data used	Dec to Feb (Winter)	March to May (Pre-Monsoon)	June to September (Monsoon)	Oct to Nov (Post-Monsoon)	Annual total
1	Kherkheria T.E	1978-2005	85.4	637.7	1973.6	171.1	2873.8
2	Majuli T.E	1978-2006	144.4	682.5	1859.9	168.9	2855.7
3	Hatigarh T.E	1978-2006	75.7	621.8	1740.1	125.9	2563.4
4	Mangaldoi	1978-2006	51.6	343.2	1441.7	71.5	1908.1
	Average		89.3	571.3	1755.3	134.3	2550.3
	Percentage to total		3.50%	22.40%	68.83%	5.27%	100%

Source: Brahmaputra Board, Guwahati, Assam

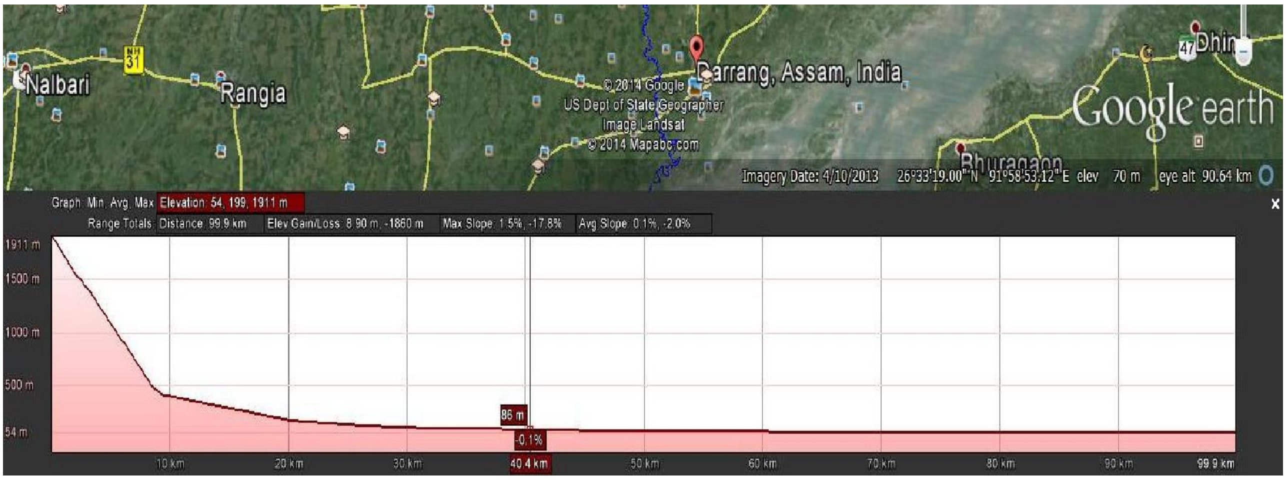

Figure 2. Longitudinal profile of the channel

Physiographically the river basin is characterized by high terrain topography with steep hill slopes in the north and flat plain of very low gradient towards southern extremity. In between these two extreme elevations, the middle part has the elevation which varies from 150 mts to 250 mts from the sea-level. The high relief of the basin has thus from north to south with the differences of maximum height 1750 mts north and 52 mts minimum height of the south. Being a river originating from the Khampajuli Hill ranges of Bhutan Himalaya at an elevation of 1750 mts has very high channel gradient ranging from 27.24m /km to 0.22m /km downstream.

Human Factors

Like natural causes, the manmade causes are also to some extent responsible for creating and encouraging the flood situation more devastating. The increasing population pressures especially the lower flood plain area which is more than 390 person/km^2 together with the development of some new human habitation points (new settlements) have now stood as barrier in the free path of the water flow during floods which make the situation more severe. The deforestation and unwise cutting of tree especially the foothill and hilly reach of

Table 2. Yield of river Noa-Nadi (in m cum) at N.T. Road Crossing Gauge Discharge Site during the period 1982-2011

Year	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	Annual total	Monsoon (May-Sept)	Non-Monsoon (Oct-April)
1982-83	7.41	13.98	33.71	33.38	35.45	33.14	23.98	20.85	15.37	13.52	11.43	2.76	244.98	123.93	121.05
1983-84	17.06	17.23	34	41.88	62.41	25.61	27.26	19.94	11.49	6.51	3.34	13.31	280.04	172.58	107.46
1984-85	25.39	13.85	45.16	31.94	37.26	17.91	14.82	12.85	9.77	7.36	6.99	16.37	239.67	153.6	86.07
1985-86	16.54	40.37	37.73	26.88	35.15	24.77	18.93	16.18	14.08	12.02	7.85	17.18	267.68	156.67	111.01
1986-87	9.38	5.75	4.81	12.43	21.64	23.19	13.21	8.79	4.78	2.51	2.05	1.52	110.06	54.01	56.05
1987-88	1.46	4.23	65.06	40.82	36.45	34.13	33.17	23.08	13.78	10.89	8.08	3.58	274.73	148.02	126.71
1988-89	25.65	20.05	32.54	61.15	64.39	49.41	27.69	21.86	11.28	7.28	6.52	13.36	341.18	203.78	137.4
1989-90	28.61	51.3	48.54	29.63	38.05	21.93	15.55	11.23	8.84	7.89	9.56	20.83	291.96	196.13	95.83
1990-91	26.09	54.2	50.43	51.37	39.34	56.75	21.72	15.47	13.8	6.7	3.06	13.21	352.14	221.43	130.71
1991-92	33.23	50.31	53.37	38.29	44.06	42.28	26.54	21.64	14.15	10.29	6.21	3.43	343.8	219.26	124.54
1992-93	21.64	31.64	40.21	29.59	34.78	20.83	16.54	10.95	9.81	11.1	8.35	12.55	247.99	157.86	90.13
1993-94	15.44	63.85	47.85	52.52	69.64	50.12	16.76	12.95	8.56	9.74	7.64	1.54	356.61	249.3	107.31
1994-95	34.58	72.09	27.13	41.38	20.07	23.01	19.42	13.75	10.46	7.68	6.53	2.38	278.48	195.25	83.23
1995-96	23.45	34.03	67.47	56.24	47.03	18.55	15.82	13.52	5.33	3.06	2.6	2.61	289.71	228.22	61.49
1996-97	22.06	28.97	51.05	40.81	26.21	26.12	21.72	12.6	11.71	18.66	11.16	6.23	277.3	169.1	108.2
1997-98	15.46	50.05	52.36	32.75	55.93	14.13	11.28	5.32	6.1	4.22	3.77	15.58	266.95	206.55	60.4
1998-99	14.58	70.4	64.16	65.21	40.78	35.46	20.04	11.58	6.21	2.62	1.55	1.25	333.84	255.13	78.71
1999-2000	58.67	31.57	84.07	85.92	71.9	62.12	34.8	20.96	18.16	11.34	7.65	4.45	491.61	332.13	159.48
2000-01	21.5	53.16	39.67	76.41	87.7	48.17	41.12	23.37	10.97	4.79	3.49	20.62	430.97	278.44	152.53
2001-02	36.49	32.61	46.16	35.99	40.74	38.5	26.06	19.59	16.83	9.2	14.34	23.04	339.55	191.99	147.56
2002-03	33.86	54.93	81.05	25.84	22.1	23.16	15.14	7.71	4.59	2.84	15.12	22.55	308.89	217.78	91.11
2003-04	36.83	71.86	80.97	81.89	81.55	74.14	55.55	38.27	31.78	30.25	25.17	61.95	670.21	353.1	317.11
2004-05	78.78	101.5	105.41	74.88	87.98	86.56	60.18	43.57	29.55	11.87	6.86	43.99	731.13	448.55	282.58
2005-06	49.26	66.56	70.82	106.54	72.33	78.85	63.75	43.53	24.97	20.79	16.41	25.06	638.87	365.51	273.36
2006-07	31.19	91.9	45.28	46.81	72.15	65.85	44.23	38.02	31.21	32.68	27.06	56.07	582.45	287.33	295.12
2007-08	34.78	85.38	76.88	89.68	98.34	70.25	34.93	27.12	22.37	19.19	17.63	35.34	611.89	385.06	226.83
2008-09	31.6	20.6	30.07	30.95	52.53	12.08	6.9	6.89	7.23	5.96	4.13	5.72	214.66	165.75	48.91
2009-10	7.53	15.28	37.59	35.25	15.86	9.99	6.99	4.02	2.98	3.88	6.47	24.92	170.76	111.51	59.25
2010-11	37.23	45.2	48.9	47.07	51.37	38.24	28.51	22.3	18.32	14.21	14.46	10.99	376.8	229.77	147.03
Total	795.75	1292.85	1502.45	1423.5	1463.19	1125.25	762.61	547.91	394.48	309.05	265.48	482.39	10364.91	6477.74	3887.17
Average	27.43966	44.581	51.8086	49.08621	50.45483	38.8017	26.297	18.8934	13.6028	10.6569	9.154483	16.634	357.4107	223.37034	134.04034

Source: Water Resource Department, Central Assam investigation Division, Mangaldoi, Darrang, Assam

Bhutan Himalaya during last few years have accelerated the sedimentation and flood potentiality of the basin downstream. The recent population increase over the entire basin with increasing demand for fire wood, fuel, timber and other forest products has substantially decreased the forest cover. The structural measures of flood management (control), especially the construction of embankments were carried out during 1955-56 on both the banks of Noa-Nadi covering a total length of 18.25 km of which 6.275 km are in left bank and 12.55 in the right bank. Apart from these 18.825 km of embankment, no other embankments have been constructed along the 94 km plain reach of the basin.

Thus, the existing embankments system could provide minimum protection to very small area of 60 km^2 from small to medium flood only. But during high floods these embankments could be of little relief due to their little height and less strength. Thus, due to such poorly designed embankments system the lower flood plain area often experiences sudden floods through overtopping and breaching.

Hydrological Characteristics

By receiving and carrying 250 cm and 289.66 $m^3 s^{-1}$ of average annual rainfall and discharge respectively, the Noa-Mangaldoi basin of Brahmaputra valley experiences high to very high floods of more damaging nature like the other tributary basins of the Brahmaputra. The data available from concerned secondary sources compared with field study clearly indicate the regular occurrence of floods for 3 to 4 times every year in the lower part of the basin. Out of total yield of 10364.91 m cum for the period 1982-83 to 2010-2011, the monsoon yield is 6477.74 m cum (Table 2) which is about 62.49% of average annual yield reflecting the strong influence of monsoon rain on floods. The stage- discharge hydrographs prepared for the year 1981, 1986, 1991, 2006 and 2011 clearly indicate the fluctuating nature of peak floods where it has also been observed that the high flow occurs during monsoon period (May-September) with corresponding high level of water. The water level goes down normally with corresponding fall of discharge during non-monsoon months. Of course, in few cases inconsistencies are also noticed, which may be attributed to the changes in the channel morphology of the river due to ongoing scouring, silting and widening activities in the channel (Bora, 2003). During the period from 1982 to 2011 the highest recorded water level 56.45 mts above mean sea level on August 28, 1988, while the lowest recorded water level was 51.13 mts on June 15, 2007. The average annual discharge was recorded to be 289.66 m^3 s^{-1} of which average annual monsoon discharge was 182.22 m^3 s^{-1}. Though during this period the highest recorded maximum flood lift was 5.32 mts but personal experience from field study shows that even during a normal flood water level goes up 2 to 2.5 mts above the general level of agricultural field and thus inundates not only the low lying areas but of high grounds also.

Variations regarding maximum and minimum flows have also been found from the graphs prepared for this period with mean maximum and minimum flows of 45.817 $m^{3\ s-1}$ and 1.003 m^3 s^{-1} respectively. The maximum and minimum flows are highly fluctuated from their respective means. The highest positive variation of flow which is 51.80% from the mean annual maximum flow of 45.817 m^3 s^{-1} was recorded in the year 1999. Again in 2009 the annual maximum flow shows the highest negative variation of flow representing -52.78% variations from the mean maximum annual flow (Fig.4). In case of annual minimum flow (Fig.5) seems the highest positive variation of 270.18% from mean annual minimum flow of 1.003 m^3 s^{-1} was observed in 2007, whereas the higher negative variation of flow with -88.03% from mean annual minimum was observed in the year 1987. The calculated co-efficient of variations of maximum and minimum flow are found to be 29.40% and 92.72% respectively. As the co-efficient of variation value in respect of minimum flow series (92.72%) is more than that of the maximum flow (29.40%) , the minimum flow series of the river is inconsistent. In other words, the maximum flow series of the river represent relatively consistent pattern of flow than the minimum flow series. As the minimum flow pattern in the Noa-Nadi is found to be inconsistent the river is not ideally potential for irrigation purpose. Various flood frequency analysis methods that have been carried out for determination of flood magnitude and recurrence interval reveal that the mean annual peak flow of 45.817 m^3 s^{-1} can be considered as the commonly occurring flood having about 2 years of recurrence interval.

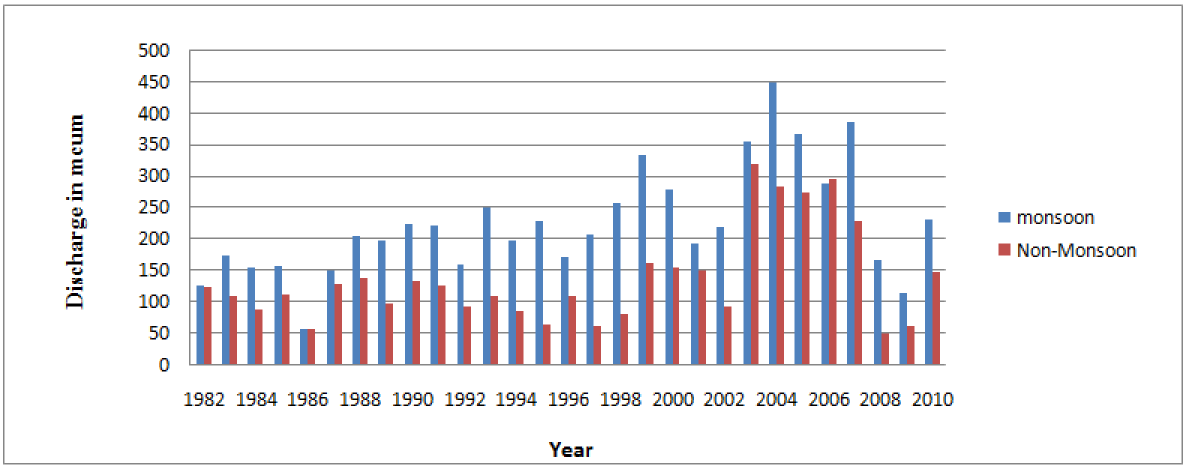

Fig. 3. Monsoon and Non-monsoon yield of river Noa-nadi during 1982-2011

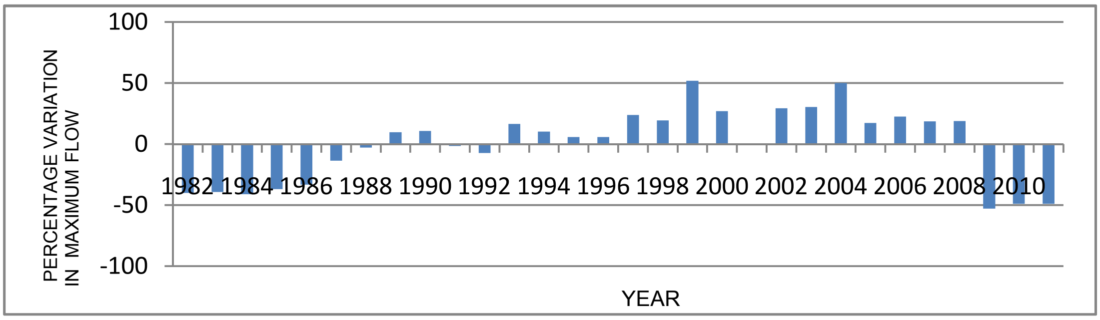

Fig. 4. Percentage Variations in maximum flow series of the Noa-Nadi at N.T Road crossing Gauge-Discharge site, Assam (1982-2011)

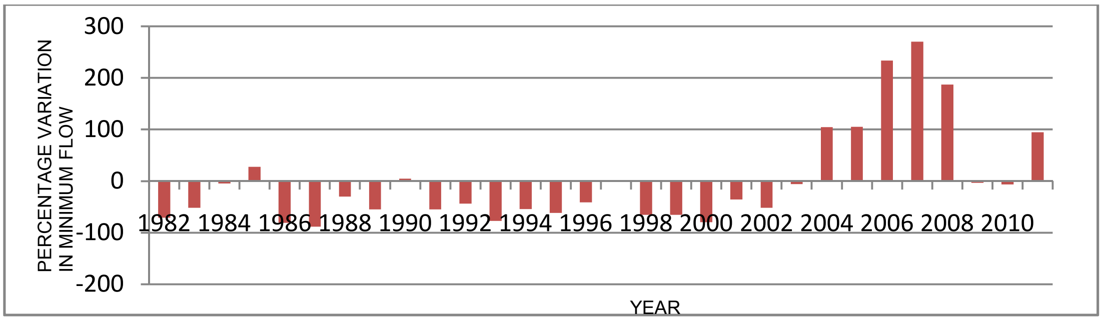

Fig.5. Percentage variations in minimum flow series of the Noa-Nadi River at N.T Road crossing Gauge-Discharge site, Assam (1982-2011)

Table 3. Estimation of flood magnitudes in different return periods by Gumbel's Extreme Value Distribution for the Noa-Nadi, Assam

Return Period	Mean peak flow (Ẋ)	Standard Deviation (Ϭ)	Frequenccy Factor (K)	KϬ	XT= Ẋ+KϬ
5			0.866	11.8642	57.68
10			1.541	21.1117	66.92
20			2.188	29.9756	75.79
25	45.817	13.7	2.393	32.7841	78.6
50			3.026	41.4562	87.27
75			3.393	46.4841	92.3
100			3.653	50.0461	95.86

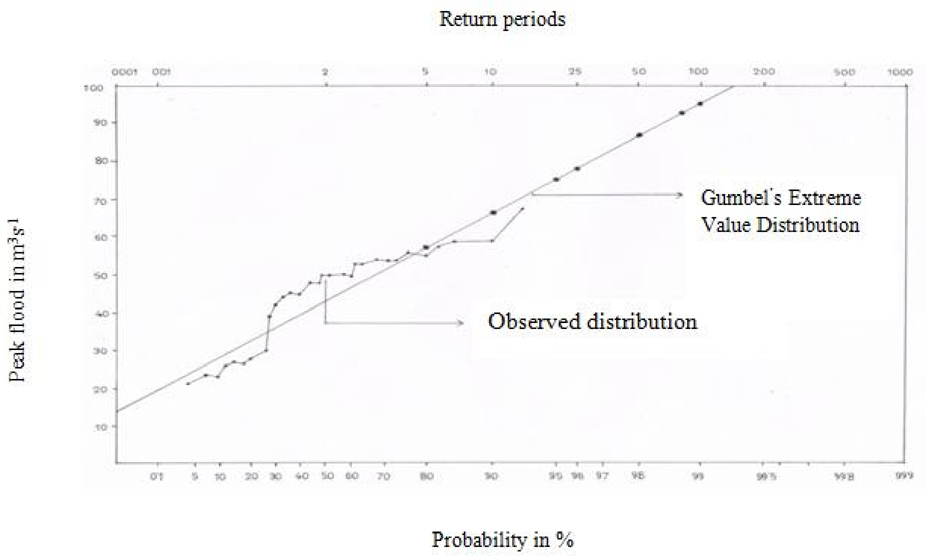

Fig.6. Estimation of flood frequency of Noa-Nadi, Assam by Gumbel's Extreme Value Distribution Method during 1982-2011

Table 4. Flood damage during major floods in Noa-Mangaldoi river basin

Year of Major flood	Duration of floods (days)	No. of flood waves	Area affected ('000 hectare)	Villages affected (No.)	Population affected ('000 No.)	Crop damaged ('000 hectare)	Damage (Rs. In lakh)
1980	20	9	8.56	NA	23.75	6.2	31.72
1982	37	13	27.8	41	13.4	0.57	21.26
1983	54	13	0.1	56	2	0.1	N.A
1984	40	12	15.4	103	74.1	8.9	448.45
1985	52	18	0.01	N.A	0.21	0.01	N.A
1987	40	7	19.26	N.A	142.3	10	N.A
1988	91	11	47.5	115	67.8	34.5	1271.0
1990	23	9	0.19	6	0.51	0.11	0.18
1991	20	10	6.4	28	28.6	1.28	407.90
1993	49	18	11	81	43.3	0.97	33.11
1996	23	8	0.25	8	0.64	0.31	30.41
1998	82	14	13.9	76	64.21	29	885.32
1999	93	19	48.4	91	72.8	16	921.54
2000	85	12	35.8	N.A	N.A	9.8	N.A
2004	178	11	51.2	117	94.4	41.2	1582.1
2006	24	10	0.2	7	0.62	0.15	N.A

Source: Compiled by the researcher on the basis of data collected from various departments of Government of Assam (India)

The Noa-Mangaldoi basin had the experience of highest peak flow of about 66.99 $m^3 s^{-1}$ in 1999. As per plotting position method this highest peak flow has a return period of about 31 years with 3.22% probability. The lowest peak flow, on the other hand, which occurred in 2011, has a recurrence interval of 1.03 year with 99.77% probability, while the mean flood of 45.817 $m^3 s^{-1}$ shows 58.06% probability with 1.72 years return period. The Log Pearson Type-III method shows that the highest peak flood of 69.85 $m^3 s^{-1}$ and the mean peak flood of 45.817 $m^3 s^{-1}$ have the return periods of 21.55 and 2 years respectively. However, after a comparative analysis of D-Index, the Gumbel's Extreme Value distribution method has been proved to be the best method for frequency analysis of floods of Noa-Mangaldoi basin, which shows 12.96 and 2.57 years of return period for highest and mean flood respectively (Fig.6). It has been observed that the duration of common average annual peak flow varies from a maximum of 178 days with 11 flood waves in 2004 to minimum 5 days with 4 waves in 1994 in accordance with the duration and intensity of rainfall especially the location of landbased insitu depression. From the field visit it has also been found that the average annual flood duration above the danger level is about 10-12 days and sufficient to bring heavy damage to the rural economy of the lower part of the basin.

Flood hazards and Human responses

Floods are always considered as the most common natural hazards especially in the alluvial plains of riverine environment (Leopold *et al.,* 1964). The lower part of the Noa-Mangaldoi basin has the experience of recurring floods characteristically of high magnitudes, large extension, long duration and wide devastating dimensions. The basin has about 63.75% flood plain area (470 km^2) of which 58.57% (278 km^2) area has been identified as flood affected area where 3-4 waves of flood having various magnitudes and duration commonly seen during every monsoon period.

It should mention that, as the hill catchment is very small compared to plain catchment, total damages of the plain catchment are taken as damages in the basin. Maximum damages in the basin occurred in the year 1988 and 2004 amounts to Rs 1271.0 lakh and 1582.1lakh respectively at 2006 price level (Table 4). The agriculture sector of the basin was extensively suffered than the other sectors. Agriculture alone showed about 84.62% damages to the total damages. It has been observed that the gradually increasing damages to agriculture sector may be attributed to the increasing intensity and duration of floods, growing tendency of flood plain dwellers to encroach riverine areas and more dependency on summer crops.

Besides, the recent bank erosion along with channel shifting in many concave bends in the flood plain area have also encouraged the floods to become more severe and devastating for large scale damage on agricultural crops. Assam with rich networking of big and small rivers is a land of recurring floods of various magnitudes and duration (Bora and Goswami, 1988). Hence, from very past, the flood plain dwellers of Brahmaputra valley including Noa-Mangaldoi basin had acquired the required art of living with floods to some extent. But the recent high magnitudes floods of unpredictable nature have made the traditional methods of living with floods meaningless to a great extent, especially for the poor farmers who generally practice rice cultivation during peak monsoon period even by accepting total risk of probable loss and damage. Hence, the traditional mode of human adjustment in the flood affected area necessarily needs a shift towards the reduction of flood damages by introducing new techniques of cultivation (Bora, 2003). In this regard, from direct field survey it has been observed that some farmers have already practiced flood resistance rice variety having the qualities of short time maturity, capacity to survive even after inundation for several days, capacity to stand against flood waves and storms etc.

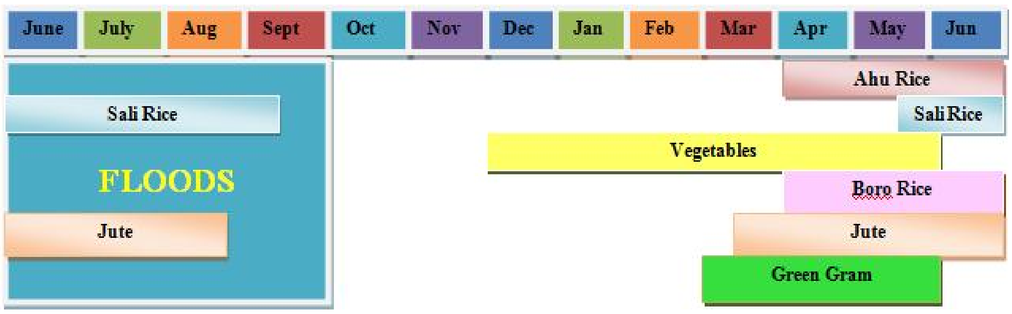

Figure 7. Present cropping pattern of the Noa-Mangaldoi basin

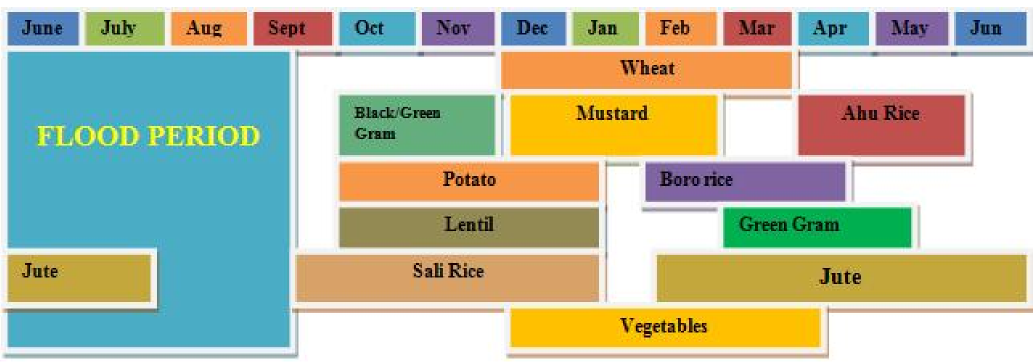

Figure 6. Restructuring of cropping pattern in the Noa-Mangaldoi basin

Of course some farmers have accepted the cultivation of corn at large scale as an alternative to rice during non-monsoon months. Thus, the idea of restructuring of cropping pattern has entered in the mind of farmers. During high floods people generally uses small wooden hand boats and even motor boats as a means of transport by rejecting the traditional raft. The new generation is also very much interested to raise the plinths of their houses to cope with high magnitudes floods. The government has made some raised platforms where victims take temporary shelter during floods is another new way of adjustment against floods.

Measures and strategies for flood control

The recent high magnitudes recurring floods with increasing trend of damages especially in the lower part of the basin have made the existing measures of flood management which include the embankments measuring a total length of 18.825 km of which 6.27 km are along the left bank and 12.55 km are in the right bank, anti-erosion schemes and 4 raised platforms almost incapable of bringing the severity of floods under control. Thus, in view of the increasing severity of flood hazards formulation of effective flood management measures for overall development of the basin have become very urgent. In this regard, the following measures may be suggested for reducing and managing the flood and its hazards.

(i) A part of the river which has usually been occupied by it during the high stage of the river is known as flood plain. History reveals that earlier human settlement and the locations of towns and villages were though very close to the banks rarely affected by floods because of their higher locations. But the recent increasing population pressure has resulted indiscriminate encroachment of flood plains. The middle and lower parts of the Noa-Mangaldoi basin have been affected by large scale human encroachment that has led increasing flood magnitudes and severity. Thus, to restrict the damages caused by recurring floods, flood plain zoning for the basin is highly essential which involves regulating the land-use of the flood plain. In this regard the concern authority may undertake effective survey for demarcating areas likely to be affected by floods of different magnitudes, frequencies, depth etc for reducing the damages to minimum.

(ii) Out of total 470 km^2 flood plain area of the basin 278 km^2 area has so far been identified as the flood affected area of which only 60 km^2 has got minimum protection against low to medium magnitudes floods from the existing very poorly designed embankments of only 18.825 km long. Thus, remaining 218 km^2 flood affected area of 94 km long plain reach along with more than 20 sensitive erosional bends still does not have any embankments to provide protection from floods. It is therefore, suggested that properly designed embankments having appropriate height and strength to cope with high floods especially along the left bank and right bank where maximum number of erosional concave bends are located needed to minimize the severity of flood hazards. Stabilization of erosional bends by proper plantation on the banks may be one of the effective anti-erosion measures against floods.

(iii) To get immediate relief from high floods people of chronically flood affected areas generally look for higher lands for temporary stay. For this, the affected people along with their livestock usually take shelter on the P.W.D. roads, National highways and embankments. In this process the roads and embankments gets damaged and it also disturbs in distributing the flood reliefs among the victims. Only four poorly design raised platforms without having the facilities of drinking water, sanitization, and temporary lighting arrangement have so far been constructed by the state government to serve five downstream villages Sarang chapari, Rangamati, Monitary, Gerimary and Moamari. That it may be suggested to construct more than 15 other raised platforms having all basic amenities for providing temporary shelter to people of all the villages located chronically flood affected areas of the basin.

(iv) To meet the food requirement in the basin the extension of irrigation facilities have now become urgent.

(v) In the chronically flood affected areas of the basin, various crops may be raised during flood free period. Thus, restructuring of existing cropping pattern may be one of the important measures for reducing flood hazards in the basin.

Conclusion

The Noa-Mangaldoi basin of Brahmaputra valley with unique and diverse geo-physical as well as hydrological setup always encourages the natural factors and processes alone to create floods of devastating dimensions especially in the lower parts. In recent years, of course, high population pressure and resultant indiscriminate encroachment of flood plains have made the man induced factors more responsible to become the natural floods further devastating and severe. The existing structural and non-structural schemes for managing flood hazards are very poorly designed and these are fully incapable of bringing flood hazards under control. For overall development of flood plain resources by managing the flood and its hazards, effective and timely measures and strategies are highly essential.

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