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Dynamics of a River System– the Case of the Kosi River in North Bihar

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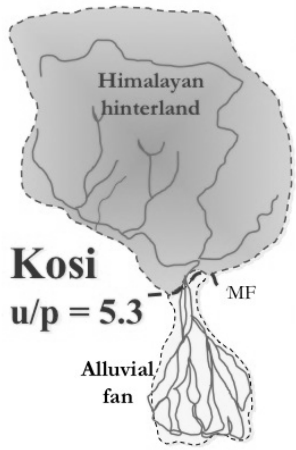
Abstract

The paper presents an account of the Kusaha breach of the Kosi river which has been widely perceived as a flood event in the media and scientific circles. It is true that a large area was inundated after this event but it is important to appreciate that this inundation was different from a regular flooding event. It is argued that this event marked a mega-avulsion of the Kosi river. While the basic mechanism of this avulsion needs a detailed study, this paper aims to document the avulsion event and speculates the causative factors of the dynamics of the Kosi in general based on limited field evidence and available maps.

Introduction

The Year 2008 witnessed one of the greatest fluvial disasters in recent history when the Kosi river draining the parts of north Bihar shifted by ~120 kilometers eastward triggered by the breach of the eastern afflux bund at Kusaha in Nepal. The Kosi river in north Bihar plains, eastern India is a major tributary to the Ganga river system (see Fig. 1 for major morphological and hydrological characteristics; Sinha and Friend, 1994) and has long been considered as a dynamic river due to frequent changes in its course and extensive flooding (Sinha and Jain, 1998; Sinha, 1998). A preferentially westward movement (150 kms in the last 200 years) has been recorded by the previous workers (Gole and Chitale, 1966; Wells and Dorr, 1987). However, the August 18, 2008 event was different in two ways. Firstly, the river moved eastward of the modern course – unlike the westward migration trend over the last 200 years, and secondly, the total movement was of the order of ~120 km – an order of magnitude higher than any single movement recorded in historical times (Fig.2). Such sudden movements of river channels involving large spatial shifts are termed as 'avulsion' (Smith *et al.,* 1989) which commonly originates from a nodal point and is characteristically different from slower lateral movements through meander migration or lateral tilting. It is also obvious that such large scale movement of the river channels would cause extensive inundation which is again different from 'regular' flooding by the river through overbank spilling. This article is aimed at highlighting the causative factors responsible for the avulsive shift of the Kosi river with particular emphasis on the Kusaha breach and also to make a case that such events need an altogether different strategy for management.



	Kosi	Ganga	Amazon
Catchment area (10^3 km^2)	101	1073	7180
Total length (km)	1216	2700	6518
Average Annual discharge (m^3/s)	2036	15,000	480,000
Annual sediment load (mt/yr)	43	1670	1000
Discharge/Area	20	14	25
Sediment yield (mt/y/km^2)	0.43	1.56	0.14

Fig.1: The Kosi River: Morphology and hydrology (u/p indicates upland to plains area ratio; after Sinha and Friend, 1994).

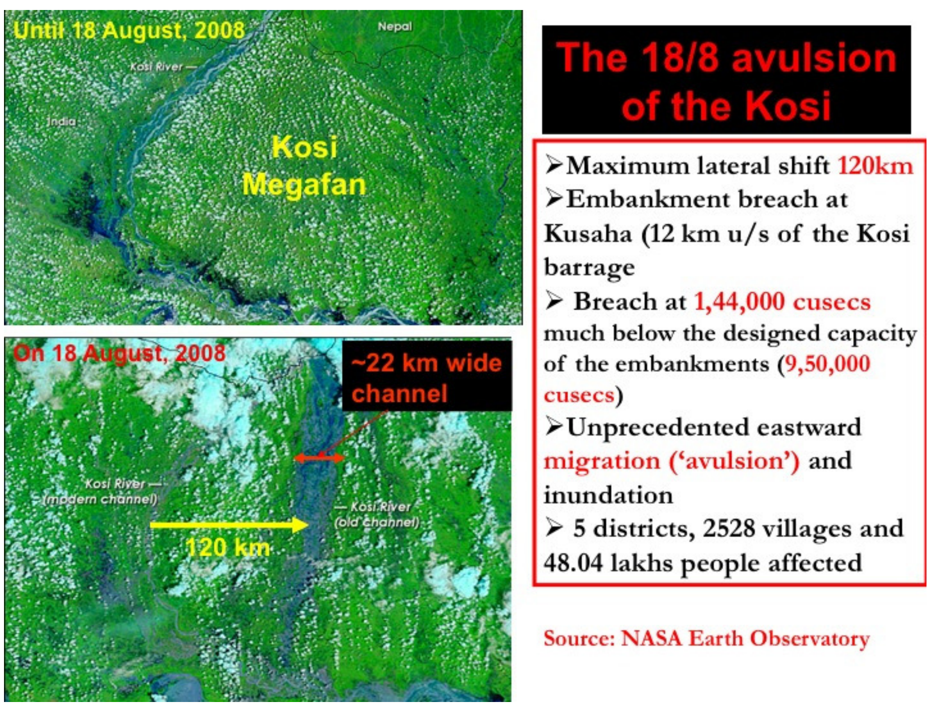


Fig. 2: The August 18 (2008) avulsion of the Kosi river.

Dynamics of the Kosi river

The channel movements of the Kosi river have been described as 'avulsive' shifts. Before focusing on the dynamics of the Kosi river in particular, it is imperative to discuss the basic mechanism and anatomy of avulsion. As mentioned before, avulsion involves a sudden movement around a nodal point (divergence point) and occurs when an event of sufficient magnitude (usually a flood) occurs along a river that is at or near avulsion threshold (Fig. 3). *Avulsion threshold* (Jones and Schumm, 1999) is defined by the changing channel instability through time represented by line 1 on Figure 3, the slope, curvature and shape of which vary from river to river. The vertical lines on this figure represent floods of different magnitude. It is obvious from this figure that avulsion may not always be triggered by the largest flood in a given river, and that even a small flood can trigger an avulsion if the river is close to avulsion threshold. One of the most common mechanisms of avulsion is 'channel reoccupation' (rapid) when the new channel occupies a pre-existing channel in the vicinity. On the other hand, 'crevasse splaying' involves a gradual process of breaching through the banks and development of a new channel through time.

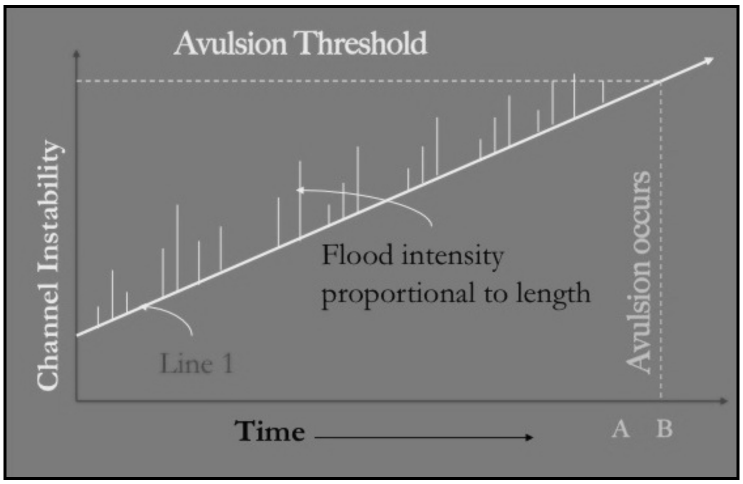


Fig. 3: The concept of avulsion threshold (after Jones and Schumm, 1999)

Dynamics of the Kosi river was initially reported by Shillingfield (1893) and followed by several workers who focused on the westward movement of the Kosi river in north Bihar plains. Shillingfield (1893) suggested that the progressive westward movement of the Kosi river would be followed by the eastward movement in one great sweep. Leopold and Maddock (1954) attributed the lateral shift of Kosi river to the tendency of a braided stream, which depends on the rate of sedimentation. However, the continuous movement of Kosi river in one direction remained unexplained. Mookerjea (1961) first mapped the position of Kosi river channel at different times in the past and this map was brought to prominence by publication in the Holmes' popular book (Holmes, 1978 p. 351). Gole and Chitale (1966) reported that the Kosi has shifted by about 150 km in the last 200 years and related the shifting process with the cone (megafan) building activity. The control of topography on the shifting of the Kosi river over the cone was assessed with the help of contour plan of the area. They further explained that other Himalayan rivers are not so dynamic because they have built longitudinal valleys whereas Kosi is building up a conical delta. The unidirectional channel shifting was explained that terms of conical delta building, sediment deposition, rise of bed levels and shifting of river course occur progressively form one edge of the cone to the other edge. After reaching the other edge, the process of deposition and the rise of riverbed would continue but in the opposite direction. It was predicted, that after the completion of this cone, the river would start migrating in the East direction.

Tectonic influence on fluvial dynamics of Kosi river was also considered by some workers. The instability of Kosi river was related to a N-S fault with a throw to the west (Arogyawami, 1971; Agrawal and Bhoj, 1992). It was argued that the Kosi river is shifting as the rate of subsidence is much in excess of sedimentation, giving rise to strong gradients and a regional tilt from east to west. It was also argued that with the progress of sedimentation, unequal loading of the downthrow (western side) of this fault will produce a tilt of the east, and the river will switch back to an easterly course. However, Wells and Dorr (1987) didn't find any correlation between any major changes in Kosi and major earthquakes in the region. Even the local westward and southward tilting near the Kosi fan head, identified by Williams (1982) and the major flood events in the Kosi river couldn't be correlated with the shift of Kosi river. Wells and Dorr (1987) concluded that tectonic events and severe floods surely influence the Kosi system but their effects are neither direct nor immediate. The lateral shift of Kosi river is largely autocyclic and stochastic.

The Kusaha breach and the aftermath

The Kusaha breach on August 18, 2008 occurred at a location 12 km upstream of the Kosi barrage. Widening the breach, the river started flowing in a new course east of the original course and more than 80-85% of the flow of the river was diverted through the new channel. At the time of the breach, the discharge of water was 1,44,000 cusecs in the new course as against only 25,744 cusec in the usual course. In this new course, the width of the river was 15 to 20 km and length was 150 km from north to south. The breach of the afflux bund was 1500 m wide and the flow volume around the breach point was ~25000 m3 with a flow velocity of 1m/s (Fig. 4).

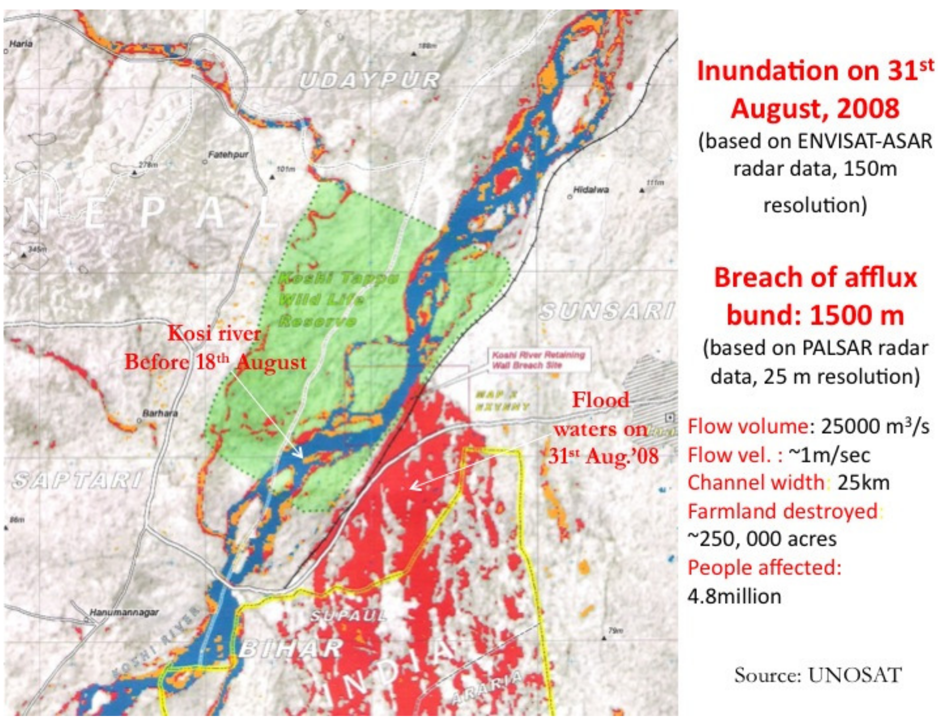


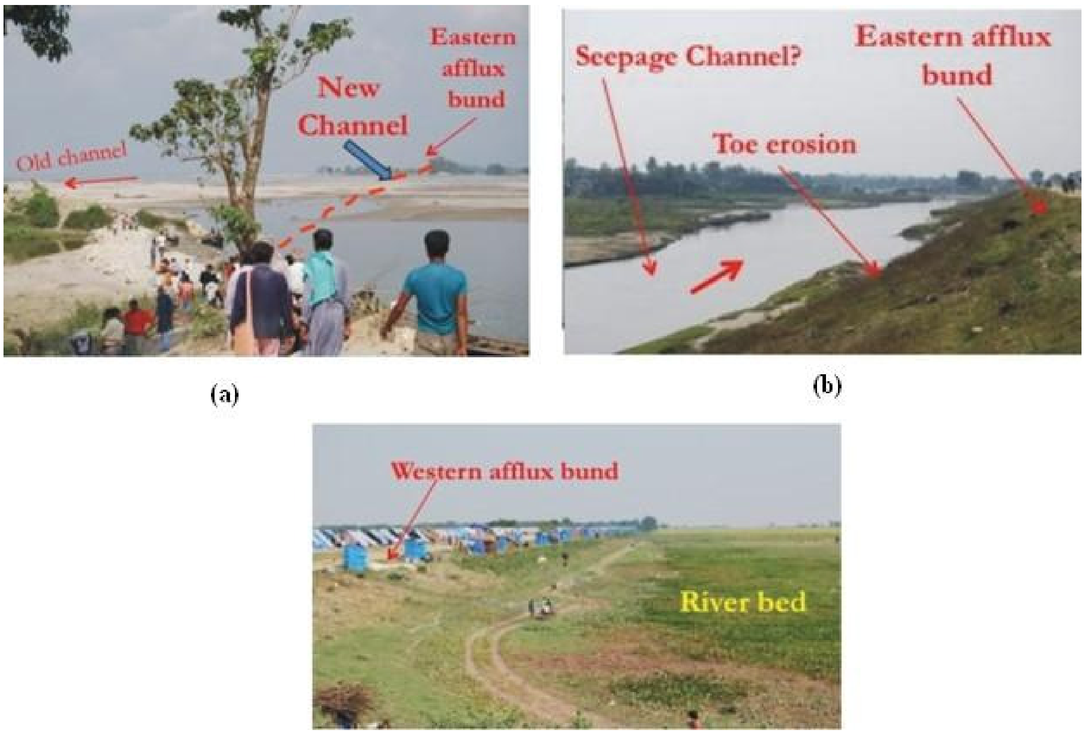
Fig.4: Breach point around Kusaha, which diverted more than 85% of the flow volume to the new channel

Before the Kusaha breach upstream of the Kosi barrage, all previous seven breaches in the embankments occurred downstream from the Kosi barrage (Mishra, 2008). The first breach occurred in 1963 at Dalwa (Nepal), where the loss of property was relatively small, and there were no casualties. The second breach took place in 1968 near Jamalpur in Darbhanga district and the third incident occurred in 1971 when the Bhatania approach bund collapsed downstream of Bhimnagar. The fourth breach in 1980 occurred near Bahuarawa in Saharsa district, which eroded the easterm embankment but water receded quickly after the breach. The year 1984 recorded a severe fifth breach of the eastern embankment near Hempur village in Saharsa district, which affected 50 lakhs of people in Saharsa and Supaul districts. A similar incident struck the western embankment in 1987 when the sixth breach occurred in Samani and Ghoghepur villages of the Mahisi block of Saharsa district. In the seventh breach, in 1991 at Joginia, the river eroded the embankment for a stretch of about two km, but receded without causing any damage. The Kusaha breach in 2008 is the eighth in line and has been most devastating in terms of suddenness of the event, loss of life and property and prolonged inundation of water in the affected areas. The new course affected approximately 3,000 sq km of area; a number of houses, schools, roads, and hospitals were damaged due to the flow of the river. A total of of 33,45,545 people and 7,12,140 animals from 993 villages of 412 panchayats of 35 blocks of 5 districts were affected out of which 239 humans and 1,232 animals lives were lost. Till today, large areas are waterlogged in Madhepura district and boats are plying in paddy fields. In areas from where water has receded, more than a meter of sand has accumulated which will take years to be reclaimed for cultivation.

Repetitive satellite images show that the river has been moving towards the eastern embankment around Kusaha region at least since 1979 and a breach in the embankment at Kusaha was detected as early as 5th August 2008. A ground visit to the breach site at Kusaha supports these reports and it was also observed that a well-defined seepage channel parallel to the eastern afflux bund formed some years ago. This channel has also been causing significant toe erosion of the afflux bund. In contrast, the river bed around the western afflux bund was observed to be at least 4-5 m higher than the surrounding floodplain level (Fig. 5).

Discussion

The Kosi river has an exceptionally high sediment yield of 0.43 million tines/year/km2 which is accommodated in a very narrow alluvial plains (Fig.1) – almost one-fifth of the upland area. This has resulted in predominantly aggrading channels of the Kosi and building up of a very large positive topography called 'megafan'. Most analysts agree that the confinement of the Kosi within the embankment further worsened the situation and has caused significant aggradation within the channel belt (Sinha *et al.,* 2008). Further, the embankments along the Kosi have not only outlived but are also poorly maintained. This must have facilitated the breach at Kusaha, and the consequent avulsion and inundation. Therefore, unlike the previous movements and flooding history, this disaster seems to have a strong human component in terms of our intervention and ill-planned, outdated river management strategies. This breach and all previous breaches after the construction of embankments question the embankment strategy for taming the Kosi river. Even a casual look at the data and interactions with local people would reveal that there has been no appreciable flood moderation in the Kosi and other rivers of north Bihar even after the construction of embankments and dam and there will be very little effect on the river stage. It is time to develop a process-based understanding of rivers and encompass all physical attributes of the earth's surface involved in water cycle for river management. There is an urgent need to adopt an integrated river basin management which requires a rigorous understanding of the physical processes by which river channels are formed and maintained.



(C)

Fig.5: Ground check at Kusaha: (a) the new channel broke through the eastern afflux bund; (b) A well-defined seepage channel parallel to the eastern afflux bund; (c) Aggraded river bed around the western afflux bund.

Following are the specific strategies suggested for such 'integrated' management of the Kosi river in particular:

1. Compilation of historical and site-specific conditions is critical for successful river management, which must include the geomorphological parameters of the river basin. Some recent works (Jain and Sinha, 2003a, b) in smaller rivers of north Bihar have shown very encouraging results by incorporating drainage network parameters and river morphology in flood analysis.
2. Integration of modern technology such as high resolution aerial and satellite data (see Jain and Sinha, 2003c; Chandran, 2006) in understanding fluvial geomorphology and river engineering is the need of the hour. Such data would facilitate a complete understanding of river dynamics and would also help in planning the flood control strategy in the Kosi basin.
3. Detailed geomorphological investigations must be coupled with long-term hydrological data to develop a better understanding of the causative factors of floods in the area.

4. Extensive erosion in the hilly catchment area contributes excessive sediment load to the Kosi, which in turn influences the flow parameters. A better understanding of the sediment supply in the upper catchments of the Kosi is necessary particularly in relation to developing long-term river management strategies.
5. The eventual goal of such studies should be to develop basin-scale risk maps and to improve the decision support systems. Traditional methods of risk mapping based on ground surveys and aerial observations are not adequate and a multi-parametric approach in a GIS environment should be adopted. There is an urgent need for a preparation of reliable risk maps which should involve (a) river dynamics and flooding system, (b) historical database on the performance of the system, (c) distribution of river dynamics and flood risk, (d) options for intervention in flooding system, and finally (e) an efficient decision support system.
6. It is also important to spread awareness about the risks of river dynamics and floods amongst the local population and to understand the risk perceptions of the people. In most circumstances, local population fails to understand the risk involved due to a poor understanding of river processes. The river-specific and site-specific knowledge base has to be compiled in the form of guidance documents for planners as well as local population.

Concluding remarks

While a great deal of research needs to be done to find a long-term solution to Kosi avulsion and flooding, field and map-based observations so far suggest that:

- A ‘system’ approach to river management keeping in view the dynamic equilibrium of rivers must be adopted in line with the new paradigm in river management. A process-based understanding of river systems and the coupling between river form and processes are needed to find long-term solutions to river dynamics and floods.
- The August floods in the Kosi region primarily occurred due to breach at Kusaha triggering the change in course of the Kosi river towards east. This resulted in flooding of the large areas in Nepal and north Bihar which have not been flooded for the past ~100 years.
- The breach at Kusaha occurred primarily due to human negligence and poor maintenance of the afflux bund for the last several years. This means that this event was essentially a ‘human disaster’ rather than regular flooding in north Bihar plains.
- The embankment strategy for flood control as well as several other human interventions such as highways and railway embankments has produced severe drainage congestion in the region.
- Non-structural measures instead of high dams and embankments should be favoured for river management in north Bihar in general and the Kosi in particular.

At this stage, two important questions are: (a) whether or not the breach at Kusaha be plugged, and (b) whether it is desirable to continue the new course of the Kosi even partially. While the former is already underway, the sustenance of the plugging is questionable and the possibility of another breach in near future at other locations can not be ruled out. A good possibility is to use the new channel as a diversion channel for the excess water during floods and follow the age-old practice of controlled flooding. Perhaps a few other paleochannels of the Kosi can be surveyed and a system of channel network can be developed as a long-term effort. The course of the Kosi through the barrage and within the embankment would need significant channel improvement perhaps through dredging in selected reaches.

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