Exploring the channel connectivity structure of the August 2008 avulsion belt of the Kosi River: Application to flood risk assessment

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1.0 Study window

The study window for this analysis was chosen from the avulsion point at Kusaha to the intersection of the avulsion channel with a canal. The lower boundary of the study window at the canal acts as a major ‘disturbance’ to the megafan drainage system. The drainage network also becomes unconfined downstream of the avulsion channel-canal intersection and resulted in a sheet of flow more than 30 km wide after the avulsed channel breached the canal. Such a wide unconfined sheet flow would not be amenable to channel network analysis.

2.0 Choice of image and Image processing

We selected post-monsoon images (Nov. 5, 2005 and Sept 29, 2009) for this study. The main reason for this is that groundwater level is higher during the post-monsoon period and therefore, the channel network appears clearly on the image. The dry season images do not show the paleochannels clearly and the identification of nodes becomes difficult. Post-monsoon images were chosen because they show the possible paths through which the water flows at least seasonally and represent the connectivity structure better than the dry season images. Although the exact dates of the images are not so crucial, the post-monsoon period is certainly important to map the connectivity structure.

We used a False Color Composite (FCC) prepared from Landsat data using the combination of spectral band 4 (0.76-0.90 μm), band 5 (1.55-1.75 μm) and band 7 (2.08-2.35 μm) for mapping the paleochannel network. We also used Normalised Water Index (NDWI) to maximize the typical reflectance of water related features to help in mapping the paleochannel network. The NDWI is defined as (Gao, 1996; McFeeters 1996):

\[
\text{NDWI} = \frac{(\text{Green} - \text{NIR})}{(\text{Green} + \text{NIR})}
\]

Although originally designed as a measure of liquid water molecules in vegetation canopies that interacted with the incoming solar radiation, NDWI has been effectively used to map open water features because vegetation is suppressed in this index.
3.0 STRM data processing

The SRTM digital elevation model contains false depressions due to the presence of voids. These false depressions in the datasets were removed by using fill sinks algorithms before using this data for modeling. The horizontal resolution of the SRTM DEM for regions outside the US is 3 arcsec (90m). The absolute vertical accuracy of the SRTM data varies with terrain and is debatable. On a continent scale, the absolute height error for Eurasia has been estimated as 6.2 m (Rodriguez et al., 2006). However, we are not using absolute height in our model. Instead, we have used relative change in elevation (slope values) for running our model. Also, the field validation with kinematic GPS shows a very good correlation between the SRTM-derived and GPS-derived slopes (Sinha R., unpublished data) providing us the confidence to use the SRTM derived slope data for this model. Further, most of the study area is agricultural land and large trees are sparse. Therefore, the impact of vegetation on the SRTM data was considered to be minimal.

4.0 Node selection and measurements

Channel network for the paleochannel belt was mapped from Landsat FCC and NDWI images generated as described above. We considered all stream junctions and sharp bends of the channel network as nodes. The coordinates of these selected nodes are fed into the computer program. Figure DR1 shows the measurements done from the maps of nodes and paleochannel network to compute the connectivity indices proposed in this paper.

5.0 Algorithm for modeling

Figure DR2 illustrates the algorithm and different steps of the model graphically. The model uses the start, end and junction nodes from the channel network manually extracted from Landsat FCC for the study window and their corresponding elevation value from SRTM data to evaluate the optimal pathway of the flow. The program starts from a given point, and the algorithm models the best possible flow path using slope and relative proximity of the nodes. This path predicted by the program is displayed, and the connectivity index is calculated using the given formula (see figure DR1).

6.0 Field validation

Field validation of the model was carried out by visiting the various points where significant changes in connectivity structure were recorded by change detection analysis and our modeling. Figure DR3 summarizes the field observations.

References

McFeeters S.K. (1996) The use of the Normalized Difference Water Index (NDWI) in the
delineation of open water features. *International Journal of Remote Sensing*. 17(7):1425-
1432.

**Connectivity Index**

\[ I_c = \frac{S_t}{L_t} \sum_{drychannels} \frac{L_d}{S_d} \]

- \( L_d \) - length of dry channels (=Ld1)
- \( S_d \) - slope of dry channel (slope of Ld1)
- \( L_t \) - total length (Lw1+Lw2+Ld1+Lw3)
- \( S_t \) - total slope between the start and end points

**Percentage Connectivity, C%** = \( \frac{100}{1+I_c} \)

C%\( \in (1, 100) \)

C% = 100% implies a fully connected river

Figure DR1. Measurements for computing connectivity indices
Figure DR2. Flow chart showing the algorithm used for generating the avulsion pathway using the distribution of nodes and SRTM based DEM.
Figure DR3. Field photos illustrating the change in connectivity structure on the fan surface.
The avulsion channel with a sizable flow in non-monsoon (March 2012, Photo A) as well as monsoon (September 2012, Photo B) months validating the interpretation that both structural as well as functional connectivity increased after the August 2008 avulsion. Local information suggests that this channel was ephemeral during the pre-avulsion period but significant stretches of this channel were excavated during the avulsion event which increased the flow both from surface runoff as well as groundwater seepage. Extensive sand sheet in the avulsion belt (Photo C) filled up large fertile land as well as several paleochannels on the fan surface. Thickness of sand fills range from 0.5 to 1.5 meters. A sharp contrast in vegetation pattern on the sand fills (white flowered grass, photo D) and areas under cultivation which were later excavated to grow cultivation is striking in the field.