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Remote Sensing and Morphotectonic Analysis in Hazara Kashmir Syntaxis Using River Longitudinal Profiles

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ABSTRACT

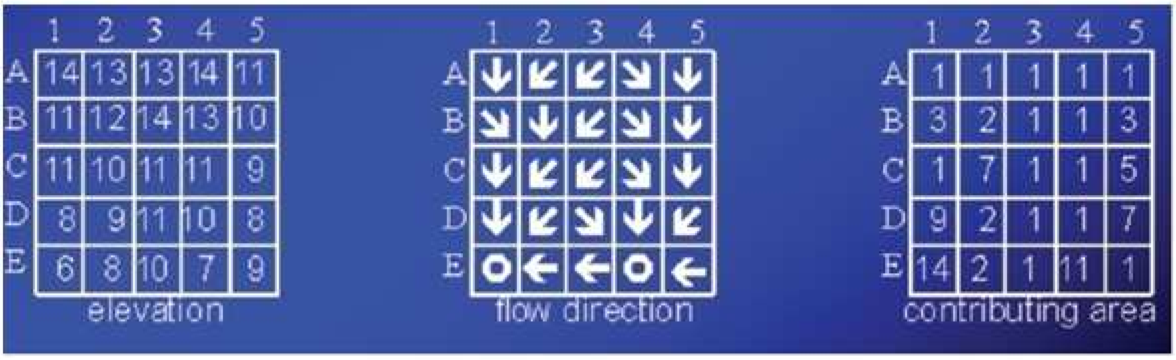
The disastrous tremor of Hazara Kashmir Syntaxis (HKS) in Pakistani Himalayas on October 8, 2005 was a result of neotectonic movement through the advanced propagation of the NW- end of Indo-Pak subducting plate below Eurasia. The purpose is to observe neo-tectonics and allied active deformation through SRTM DEM 90 m based automated drainage network and geomorphometry. The geomorphic indices such as Hack-SL gradient, steepness, concavity and relative uplift rate maps are quite significant for the analysis of active tectonics. A comprehensive river longitudinal profile analysis discovered that the outcomes achieved for the topographic relative uplift rates (TRUR), steepness, Hack SL and concavity indices are reliable with the active tectonics of HKS. The TRUR are higher in the central, north-northeast, north-northwest and south-southwest (i.e., 2. 5 mm/yr.) in comparison with the lower (0.1 mm/yr.) in the eastern part of HKS. This scenario proposes neotectonic control over the local drainage network and the topography in the study area. The TRUR map confirms that the central, NNE, NNW and SSW parts of the study area tectonically more deformed and uplifted than region in the east towards Sri Nagar basin. The spatial distribution of variable relative uplift rates is a clear indication of unique and complex active deformation along and in the HKS.

Keywords: SRTM DEM, Stream Profile Analysis, Active Tectonics, HKS and India-Eurasia Collision.

1. INTRODUCTION

Geomorphologic features are controlled by many factors in the mountainous area that includes the relative uplift rates, upright and translational motions that define the major relationship of stream incision with the strength of rock to erositvity (Anderson 1998). Stream profile gives the information assimilation of geological developments with many tectonic factors. Stream profile is proportional to the rock strength. As the strength of rocks changes, the erosion rates are change and also the stream network is affected (Baig 1987, Bossart 1990, Bull 1991). This study is concerned with the identification of tectonic signals and the relationship of faults with streams in HKS in Himalaya Pakistan in Northern flank which demonstrates that differential relative uplift rates in HKS using remote sensing technology. Mapping of these tectonic phenomena is important to check the tectonic hazards and the nature of deformation across the region.

The methodology used in this research is about DEM- based extraction of automated drainage network using D8 flow grid technique (Figs. 1 and 2). Digital elevation model incorporates a chance to enlist the dimensions in the form of variations in its elevation. Neo-tectonic slips demonstrate the variations in many geomorphic expressions such as elevation, mass movements, slope breaks, stream offsets, fluvial terraces, moraines and consisting of linearized drainage networks. On the NW margin of Low Himalaya, the terrain of HKS is located. The main tectonic features sculpturing this terrain in the shape of folds and faults are: Main Mantle Thrust (MMT), Main Boundary Thrust (MBT), Hazara-Kashmir Syntaxis (HKS), Panjal Thrust (PT), Indus Valley Faults (IVF), and Hazara Thrust (HT) (Burbank 1992).



elevation

	1	2	3	4	5
A	14	13	13	14	11
B	11	12	14	13	10
C	11	10	11	11	9
D	8	9	11	10	8
E	6	8	10	7	9

flow direction

	1	2	3	4	5
A	↓	↙	↙	↘	↓
B	↘	↓	↙	↘	↓
C	↓	↙	↙	↘	↓
D	↓	↙	↘	↓	↙
E	○	←	←	○	←

contributing area

	1	2	3	4	5
A	1	1	1	1	1
B	3	2	1	1	3
C	1	7	1	1	5
D	9	2	1	1	7
E	14	2	1	11	1

Fig 1. Diagram Showing D8 Algorithm method, e.g, foe pixle A1, there are three surrounding cells (A2, B1 and B2) and the least of among them is B1, so the flowpath southward and downward. for pixcel. C3, the least of all 8 nearby pixcel is D2, so the is southwest towards lower- left. Cells E1 and E4 don't have lower neighbors there are thus "sink"

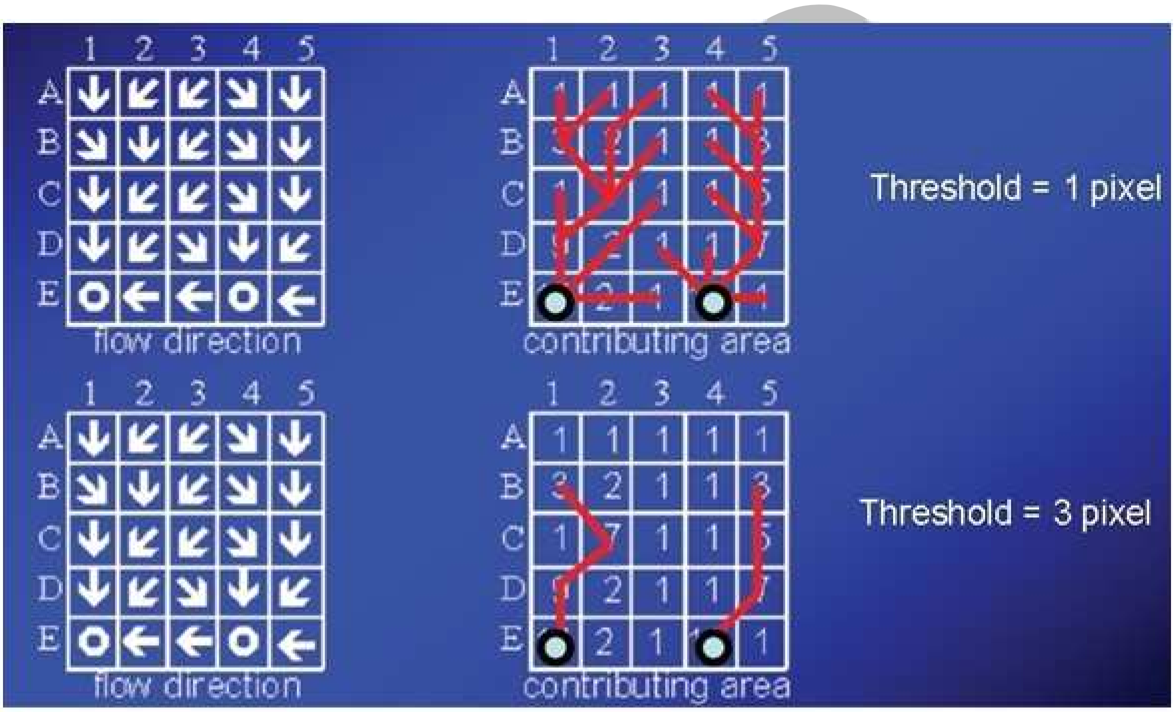


Fig 2. for the river network extraction, the threshold can be roughly considered as the minimum amount of water required to produce a stream. Based on this, the streams are defined according to the flow grid.

2. THE STUDY AREA

Hazara Kashmir Syntaxis (HKS) is the most vital structural characteristics of the NW Himalayan region and shows a clear demarcation (Burbank 2001). The southern boundary of Himalaya extends in the north direction that continues into Hazara and Kashmir districts in Pakistan where the syntaxis is bounded by main boundary faults that seems to Muree and Punjal faults (Chen 2003). Sub Himalayas contains the foreland fold and thrust belt that extends into the outer zone of HKS in Kaghan Valley. The formation of Muzafarabad anticline is affected by North South inclination fault called Kashmir Boundary Thrust (KBT) which is the west edge thrust. Many neotectonic features exist along this thrust. The footwall of Main boundary thrust contains many rock pattern formations describes the thrust fold belt of Indian Foreland. Murree formation is due to emerging processes in the core of HKS that contains the igneous rocks of Precambrian age and metamorphosed rocks at Balakot that cause of Hazara Basin has completely missed the sedimentary zone on joining two trusts the PT and MBT (Strahler 1952), but ear Muzafarabad the Main Boundary Thrust is exposed between Hazara and Muree Formations. Anticline of Muzafarabad displays the rocks of Paleocene age that overlies the Abbotabad formation of Cambrian age (Figs. 3 and 4).

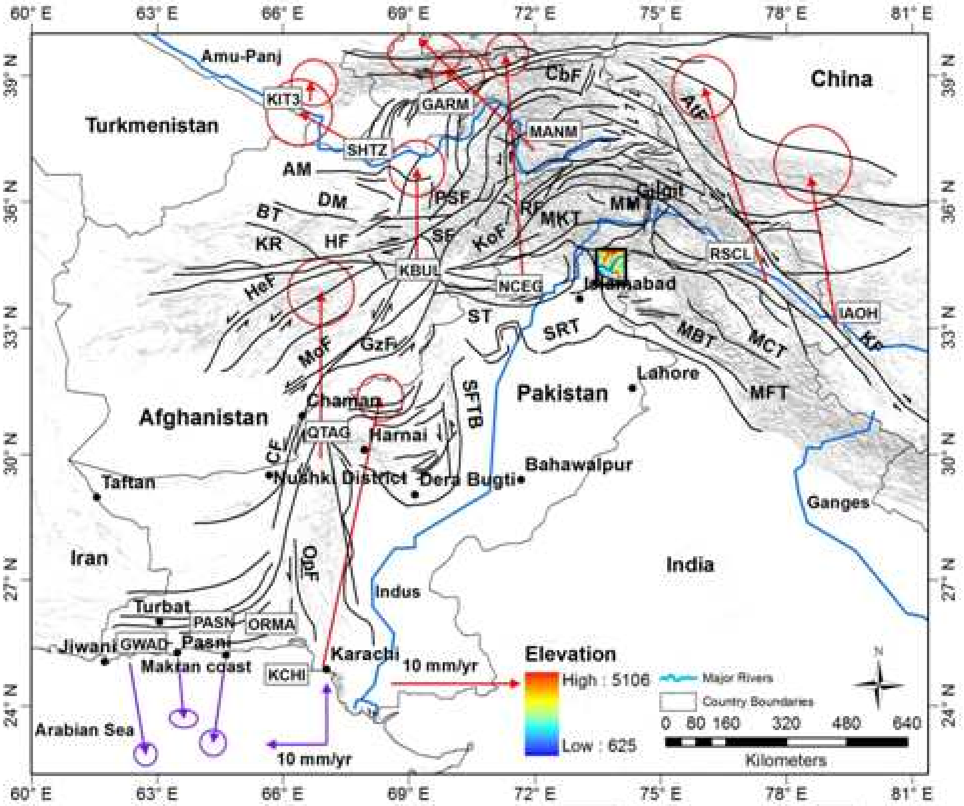


Fig 3. Map showing regional structures of the Hindu Kush- Himalaya- Pamirs- Karakoram, with black square representing the study location shown in (Figure 2). "Red vectors show GPS velocities W.r.t Eurasia fixed". "The purple vectors show velocities with respect to India fixed". Note the direction and decreasing GPS velocities towards north showing convergence and anticlockwise rotation of India.

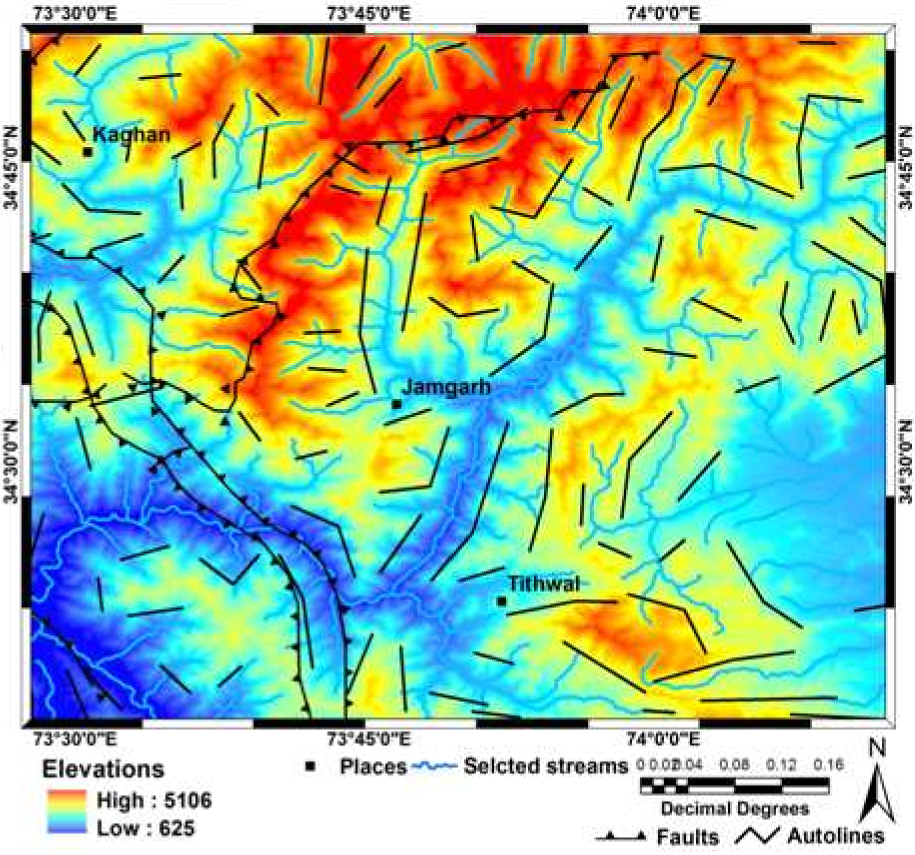


Fig 4. Study area location of part of Neelam River in the Hazara Kashmir Syntaxis region with lack teeth lines as thrust fault, black simple lines as automated SRTM DEM-based lineaments.

3. MATERIAL AND METHODS

Normally, D8 algorithm is used for calculating the Stream Network form a Digital Elevation Model and the same algorithm is used to extract the streams form Hazara Kashmir Syntaxes. The selected DEM-based automated streams are formulated into text format for processing. The river longitudinal stream profile analysis (RPA) was performed on every individual small or big stream to calculate vital details regarding the bed rock detachment limited incision model. The formula for this model is as follows:

(1) $Rate\ of\ change\ of\ elevation = Uplift - Erosion$

Equation (1) can be rewritten as:

(2) $$\frac{dz}{dt} = Uplift - KA^{m}S^{n}$$

In the above equation A gives the area of drainage and S gives the slope of the stream through which water is transported. m and n are the erosion rates with respect to the basin geometry. When the equilibrium is sustained, $\frac{dz}{dt} = 0$. Therefore equation (2) is as follows:

(3) $$slope = \left(\frac{uplift}{erosion}\right)^{1/n} A^{m/n}$$

The factor (uplift/K) $1/n$ gives the channel steepness of the streams and m/n ratio gives the concavity index of stream profile. The stream power may be calculated as:

(4) $$S = k_s A^{-\theta}$$

where θ and k_s may be directly calculated by regression techniques that are known as channel and concavity indices. The last two equations are merged to compute differential relative incision/uplift rates for Hazara Kashmir Syntaxes.

(5) $$Uplift = k_{sn}{}^{n} K$$

where k_{sn} is the steepness index that gives rate of incision in a steady state situation at local topographic growth by taking suitable values for n, k and m. River Profile Analysis (RPA) is carried out on choosing convex up movement for every stream individually to compute geomorphic indices (steepness and concavity indices).

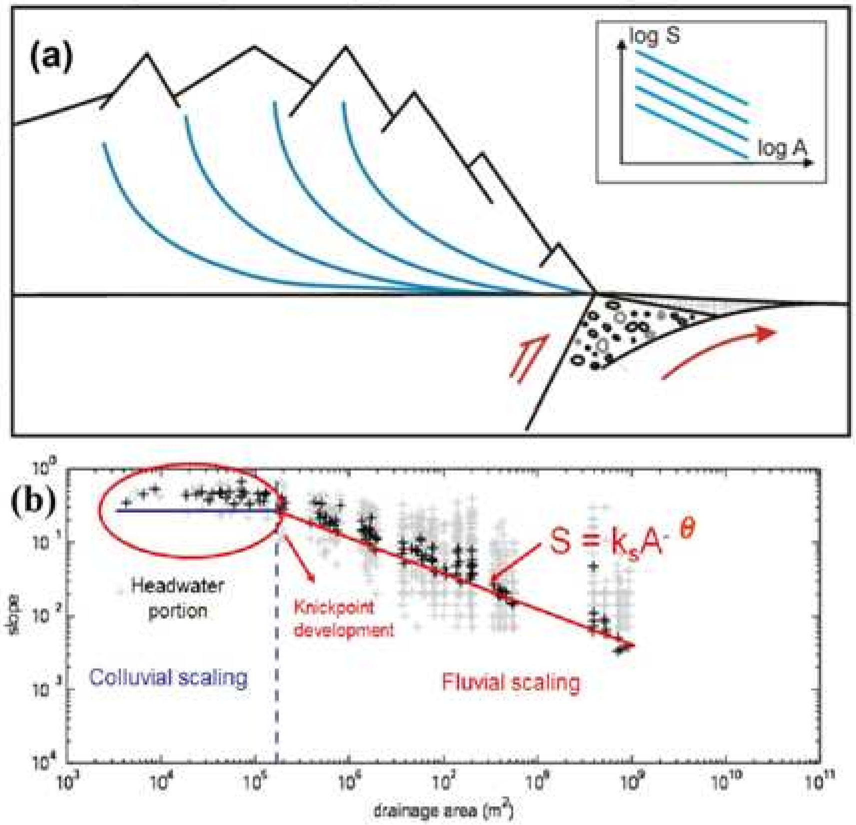


Fig 5. (a) Development of river longitudinal, log area and log slop profile, (b) A regression analyses of log slope Vs. log area for individual stream segments were calculated using the expression $S = k_s A^{-\theta}$, which provides the values for concavity (θ) and the steepness index (k_s)

θ is the angle of channel with respect to horizon which is computed by taking all the values of θ from all the channels individually. Finally, identical steepness index k_{sn} is calculated by taking mean θ. In equation (4), the relative incision rate U is closely related to k_{sn}, n and K. We calculate U from the steepness index in the HKS region as suggested by (Burbank 1996). We identified many knick points on each profiles and their diverse distributions on the map view is important to see the tectonic/lithological contrast (Whipple 1999).

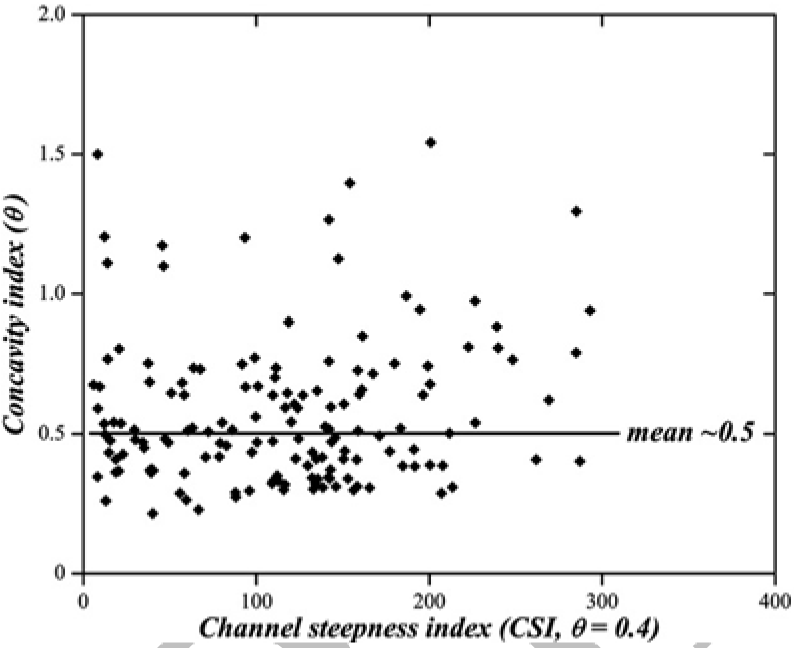


Fig 6. Plot Showing mean concavity mechanism

4. DISCUSSION

In this research, river profile analysis (RPA) is applied in the HKS region of Azad Jammu Kashmir of Pakistan. Conferring to generated results of stream longitudinal profiles (Figs. 7 to 10) observed in the study area, significant differential erosional stages and level of neo-tectonic activity is evident through different breaks in scaling, knickpoints and disequilibrium profiles. Moreover, a marked variation in the values of concavity and steepness indices shows complex form of surface deformation, especially after the October 08 Kashmir earthquake. The analysis of geomorphic indices, the HKS and adjacent areas deliver an understanding into the development of the current topography, uplifting of the local surface and crustal block sloping affecting the whole region. The RPA was executed on about 144 small and large channels of the SRTM DEM-based extracted streams to calculate the concavity (θ) and steepness (k_s) indices using detachment limited stream power law of scaling relations. To excavate neo-tectonic indications from RPA, we found that, the steepness and concavity data allowed analogous facts: a downstream change between different steepness values (or two convex up segments) is generally bridged by a high or low concavity (Figs. 7 to 10). Such a changeover zone is because of spatially varying rock uplift rates, or spatially variable lithology. The non-equilibrium river profiles show numerous prominent knickpoints a few of which are traveled up-stream by the response of the channel due to the increased channel incision, channel narrowing, increased sediment removal and the erosion of tectonic units. These profiles exhibit a disequilibrated behaviour due to the neo-tectonic activity along the fault.

Interpolation of the concavity map (Fig. 11) displays that the HKS indicates comparatively supplementary erosive behaviour on both sides and north of the HKS. The main reason for this behaviour is that the channels in these areas display relatively more disequilibrium profiles compared to those areas which show lower concavity values due to a relatively more uplifted and disturbed stream profile. This can be a sign of neo-tectonic activity. The steepness index map (Fig. 12) shows steeper gradients in Kaghan valley, Jamgarh sector and Tithwal sector within the HKS. These steeper slopes are steadfast with the existence of neo-tectonics along the HKS and are also more noticeable everywhere in the study area except east of the HKS. This is why we observe more landslides and slope instabilities due to neo-tectonic activity (Fig. 13)

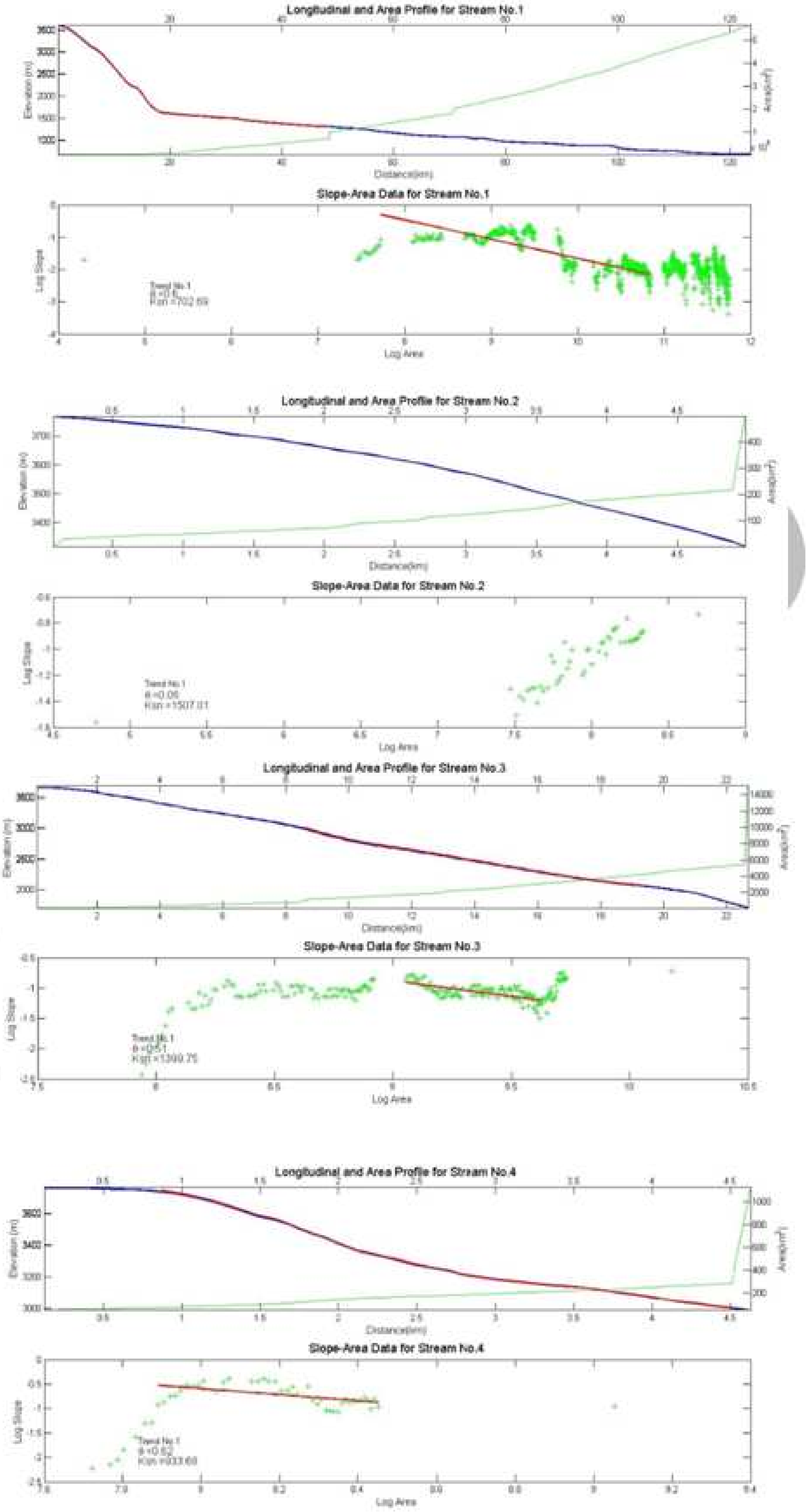


Fig 7. Stream longitudinal profile and log area- log slope profile for the streams 1- 4, along with their best fit regression analysis to calculate the steepness Ks and Concavity theta used to generate the interpolated maps for the relative uplift rates in mm/year for the HKS.

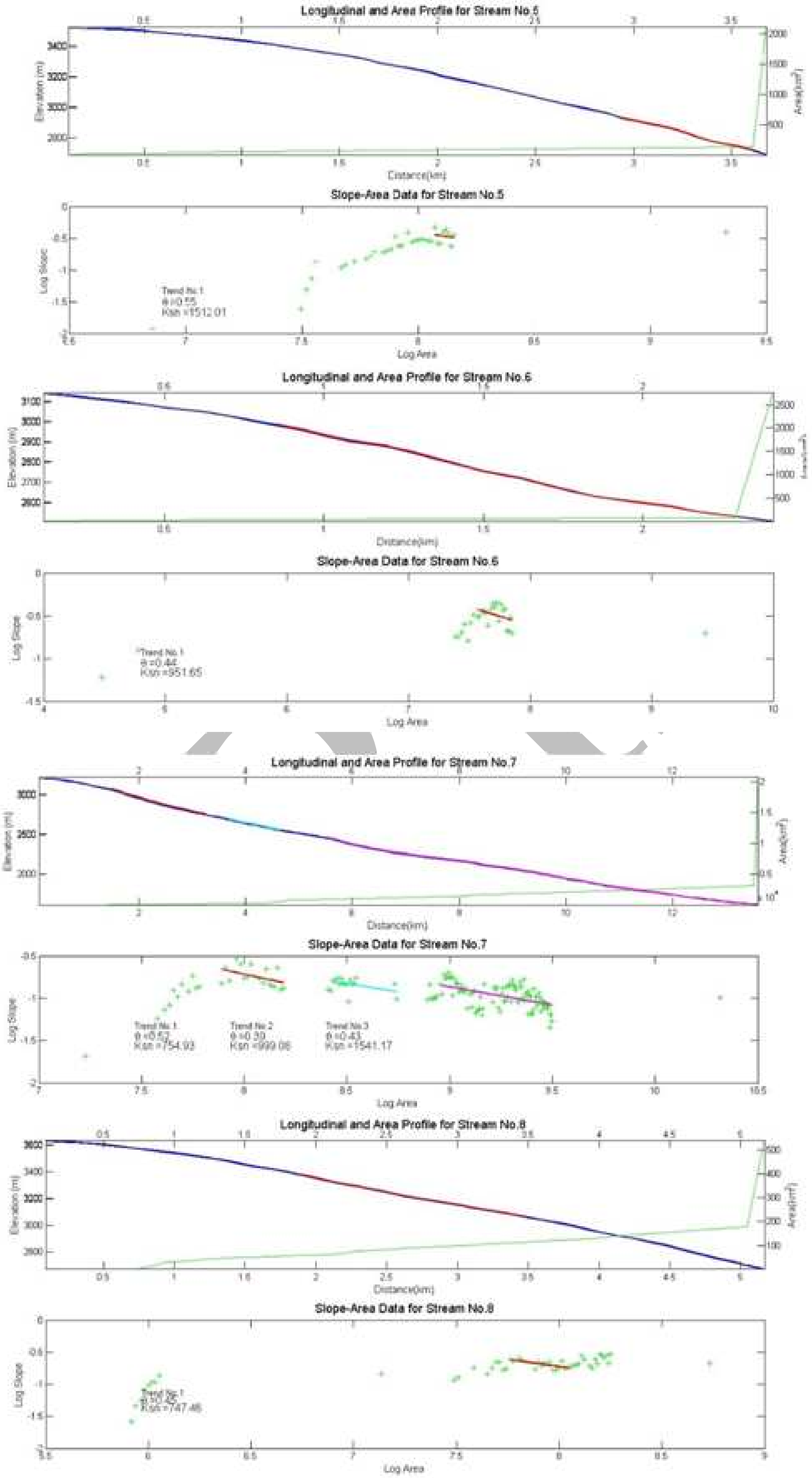


Fig 8. Stream longitudinal profile and log area- log slope profile for the streams 5- 8, along with their best fit regression analysis to calculate the steepness Ks and Concavity theta used to generate the interpolated maps for the relative uplift rates in mm/year for the HKS.

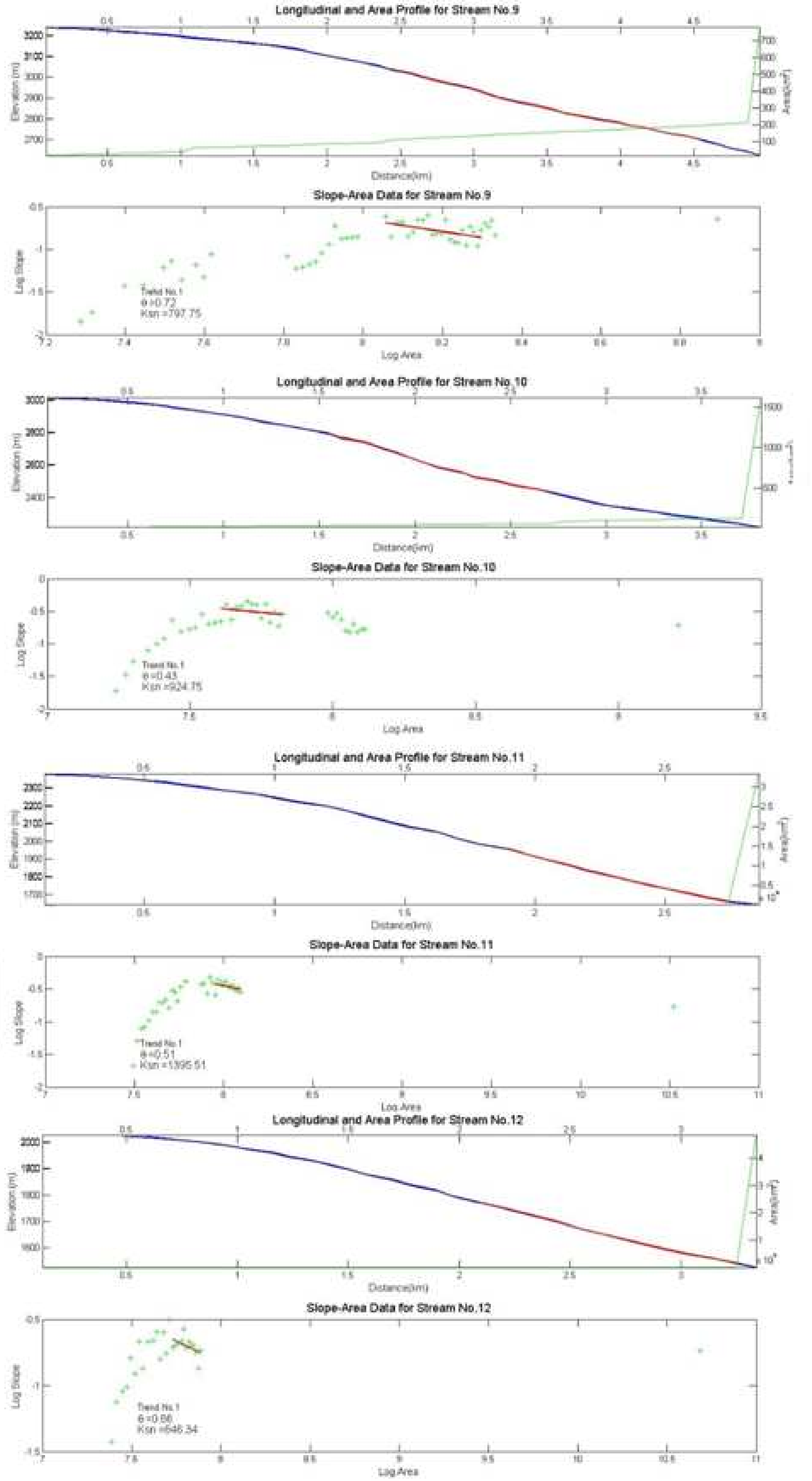


Fig 9. Stream longitudinal profile and log area- log slope profile for the stream 9- 12, along with their best fit regression analysis to calculate the steepness Ks and Concavity theta used to generate the interpolated maps for the relative uplift rates in mm/year for the HKS.

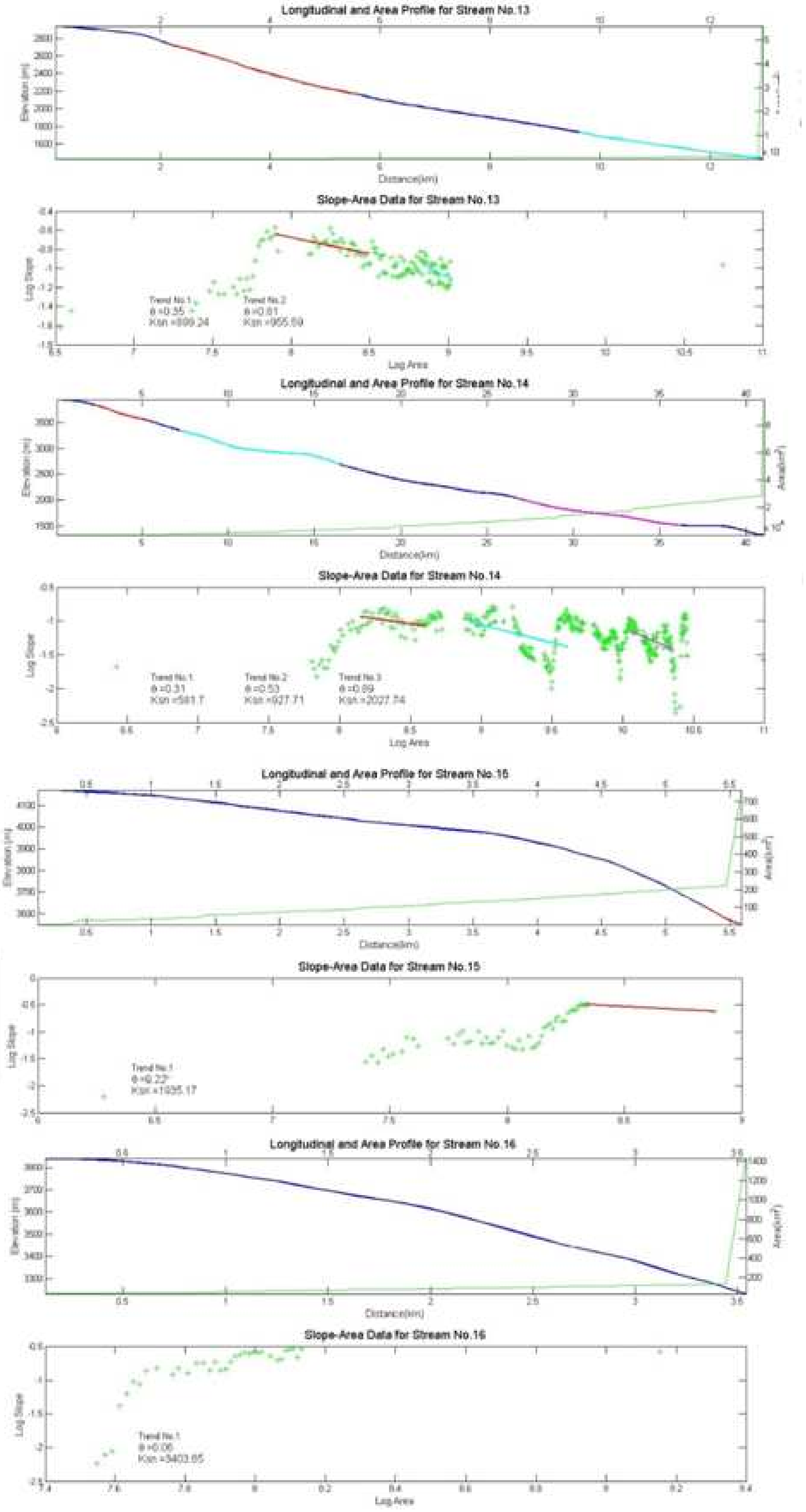


Fig 10. Stream longitudinal profile and log area- log slope profile for the stream 13-16, along with their best fit regression analysis to calculate the steepness Ks and Concavity theta used to generate the interpolated maps for the relative uplift rates in mm/year for the HKS.

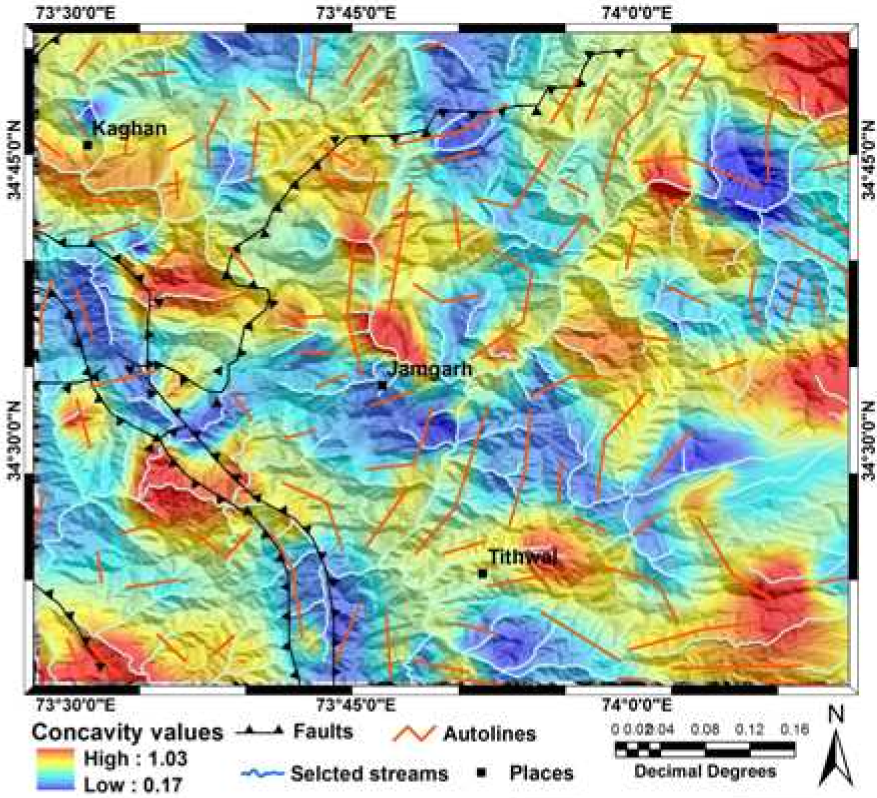


Fig 11. Interpolated concavity map (θ) for HKS. Thick black lines with teeth symbols show published geological faults and thin red lineaments are automatically extracted from SRTM DEM using LINE algorithm. Heterogeneous spatial distribution of hot red spots and cold blue spots represent the variable amount of erosion in the study area.

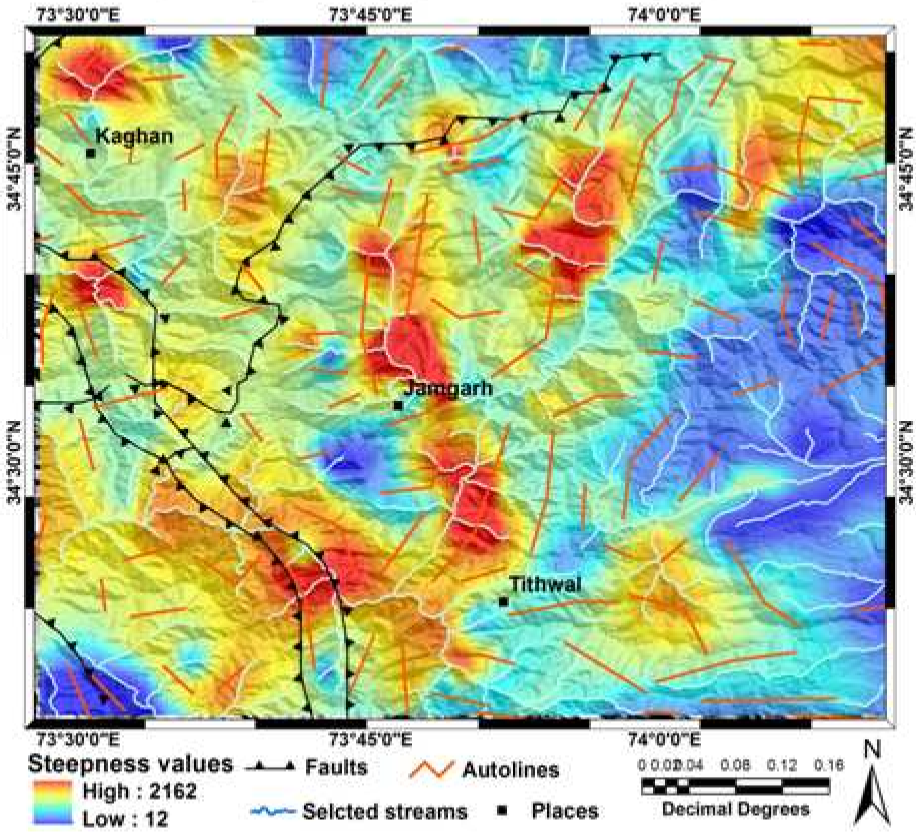


Fig 12. Spatial distribution of steepness index showing variable values of steepened regions.

Fig 13. Field photographs, (a) Active processes due to steep gradients, (b) The high gradient streams responsible for more down cutting and differential erosion causing knick points.

5. CONCLUSIONS

Neotectonic surface deformation in a rugged terrain of HKS and its peripheries caused breaks in scaling of regional topographic slope, thus modifies the channel slopes and stream lengths gradients. The RPA develops as a much easier and faster approach to delineate the sites which are influenced by recent tectonic activity. RPA gives the spatial allocation of stream steepness to give the relative variable and differential uplift rates. The big value of Ks indicates that faults are reactivated along PT and MBT within depth of 500-100 km beneath the surface due to recent earthquake of October 08, 2005. The drainage pattern of this area indicates that there are high relative uplift rates in the north east of HKS as dictated by the Hack gradients and channel steepness (Figs. 11 and 12). It is the main reason that inside and on north-northeast side of HKS is uplifting with high rates as compared to South West side of HKS. Elevated topography contains higher gradients and the margins of the elevated topography indicate that HKS is a seismically active zone. DEM gives an advantage of conservation of information that permits the justification of preferred commands of lateral stream movement as a result of recent tectonism such as differential uplift.

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