93.33% females were attracted to fraction II of male volatiles (Table 2). Further, testing with fraction III in which 15 females in three groups were released, and only one female moth 6.67% responded among the lot for fraction III. The same test was repeated using fraction IV of male volatiles to study the responsiveness of 15 female moths in three groups of five moths each released into the release chamber. None of the female moths responded positively, clearly indicating that fraction IV of the male volatiles was not attractive to the females (Table 2). The \( \chi^2 \) test for goodness-of-fit also confirmed that fraction II of the male volatiles was highly attractive to females than fraction I and the rest were not attractive (Table 2).

The responsiveness of the adult moths was converted to AI and subjected to statistical analysis (Table 3). A maximum value of 1 was arrived for the females, to live males and male volatiles. An AI of 0.93, equivalent to male volatiles and live males was shown by the females to fraction II. Hence further investigations to isolate, identify and characterize the compounds in fraction II of the male volatiles will be indicative of the pheromones secreted by the males of *A. catalanaulis*.

Studies regarding reproductive biology and sexual communication in this serious pest of sesame indicated that the males produced sex pheromones.

Attractions of females to males in sesame leaf webber is well established. A similar phenomenon was also seen in another lepidoptera like the bee hive pest, *Achroia innotata* and in Greater wax moth, *Galleria mellonella*. Such pheromonal attractions were tested in wind tunnels and using the olfactometer by various workers. This study also gave similar results. Methylene chloride extraction of pheromonal glands from females of *Earias vitella* was done in the last hour of scotophase and the extract was tested for attraction to males.

In cotton caterpillar *Diaphania indica*, a Pyralid moth, Florisil column chromatography was used to fractionate sex pheromones and reports enumerated that in 5% fraction of an active substance was found. In the present study, fraction II with 15% hexane was found to be highly attractive.

Further research on this aspect to isolate, identify, characterize and synthesize pheromones will help in tackling this serious pest of sesame in an eco-friendly manner. Use of insecticides may be avoided in future to save this important oilseed crop from insecticide pollution, and instead pheromone trapping could be introduced.


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**Nature of bank erosion along the Brahmaputra river channel, Assam, India**

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A study on a selected stretch of the Brahmaputra river channel revealed that the mechanisms involved and responsible for riverbank erosion were basically related to aqueous flow of sediments (liquefaction) enhanced by the inhomogeneity in the bank materials in question, oversteepening and associated sub-aerial processes of weathering and weakening in relation to soil moisture content. The study revealed that the extent of erosion and deposition in not same for the period 1914–75 and 1975–98. Different scale and nature of shear failure are considered to be mainly responsible for bank erosion processes.

The Brahmaputra valley in Assam represents a tectonosedimentary province 720 km long and 80 to 90 km wide, with elevation ranging from 120 m at Kobo in the extreme east

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1Singhal, V., *Indian Agriculture*, Indian Council of Agricultural Research, New Delhi, 1999, pp. 1–600.


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through 50.5 m at Guwahati to 28.45 m at Dhubri in the extreme west. The channel of the river itself occupies about one-tenth of the valley, with over 40% of its area under cultivation. The Brahmaputra valley in Assam is the home of more than 15 million people. In Assam, the river flows in a highly braided channel characterized by numerous mid-channel bars and islands. The Brahmaputra is the fourth largest river in terms of average discharge at the mouth, with a flow of 19,839 m$^3$ s$^{-1}$, and second in terms of sediment transport per unit drainage area in the world. Migration of the channel with time towards the south is a characteristic feature. Moreover, the location of the system in a highly seismic area needs immediate evaluation of its geomorphologic behaviour, keeping in view its socio-economic implications.

The erosion phenomenon as evidenced on the braided Brahmaputra river channel for a stretch of 270 km from Panibiting Reserve Forest to Holoukunda Bil is studied in the help of Survey of India toposheets (1914 and 1975) and Indian Remote Sensing (IRS) satellite imagery (1998). The stretch covers the world’s largest river island, ‘Majuli’ under extreme threat of erosion$^{1,2}$ and a world heritage site, the ‘Kaziranga National Park’, habitat for the endangered Asian one-horned rhinoceros species.


Two sets of Survey of India toposheets (1914 and 1975) and a set of IRS satellite images (1998, IRS-1B, LISS II B/W geocoded data) covering the cloud-free period were used for the present study. In order to assess the rate of erosion, maps and imagery were registered and geo-referenced with respect to Survey of India toposheets. Dividing the channel configuration for a distance of 270 km from Panibiting Reserve Forest to Holoukunda Bil of the Brahmaputra river into ten segments (I to X) at an interval of 15 min east longitude in downstream direction (Figure 1) was delineated from each set of map. The bank-lines were superimposed upon each other and the areas subjected to erosion and deposition were measured with the help of a digital planimeter. The generated data were utilized for the present study.

The activity of erosion/deposition processes that operated was not similar for the periods 1914–75 and 1975–98. During the period 1914–75, the stretch under study evidenced significant erosion on both the banks of the river. However, the 30 km region on the southern bank of the river experienced maximum deposition up to a land area of 28.15 km$^2$ near Sikarighat and up to a maximum of 38.75 km$^2$ near Bhomoraguri Hills. The activity of erosion is much more pronounced near Jorhat–Majuli areas, and continues for 50 km up to Kumargaon. In this area a total loss of land measuring 49.5 km$^2$ is observed. Moreover, the area around Kaziranga National Park also witnessed major erosion activity near Sohola Bil up to Dipholumuk. In this area, a total of 83.23 km$^2$ was eroded away from the main mass till 1975. Interestingly, the banks on both sides of the Brahmaputra from Orang Reserve Forest to Haloukunda Bil are subjected to significant erosion. However, the erosion was much more pronounced on the northern bank of the river than the southern bank for the period 1914–75. The situation during the period 1975–98 is somewhat different than the earlier period (1914–75) under study. A slight reduction in erosion activity around Majuli area is observed with a shift in its position. On the southern bank, the river exhibited a depositional phase around Neemati–Jorhat and around Kaziranga National Park areas. Around Kaziranga, near the confluence of Burai River, an area of 17.65 km$^2$ was added on the southern side of the Brahmaputra. The overall activity of the erosion–deposition processes spanning the period 1914–98 is presented in Figure 2a and b.

Along the channel of the Brahmaputra bank materials are rarely homogeneous in composition, and result in uneven bank slumping. This causes the flow to take a different path and the orientation of the bank-line to the direction of flow also changes. Ground observations along the stretch under study also revealed that at some localities older alluvium protruding into the river offers significant resistance to the flow regime and causes changes in hydraulic conditions. The finely divided bank material and the constant change in flow direction produce severe bank caving along the channel. When the flow approaches the bank at an angle, severe under-cutting takes place resulting in slumping of sediments. Slumps are more common along banks composed of clayey silt and silty clay. Quite often, the highly saturated clayey silt will liquefy and tend to flow towards the channel. As the materials flow, the overlying, less-saturated bank sediments tend to slump along well-defined shear planes. Thus, there appear to be two prominent types of slumping which cause the bank-line to recede; one operating during flood stage (undercutting), and other during falling stage (flow of highly saturated sediments). However, the intensity of slumping is more acute after the flood stage. The accumulated water level during the flood stage provides additional support to the bank material as the pore spaces of the loosely bound bank materials are occupied by water and act as a continuous system. With the fall in water level, the support diminishes abruptly and the bank materials are subjected to different degrees and nature of
failure. A field survey along the proposed reach of the Brahmaputra river channel around Nematighat, Majuli and Kaziranga areas provided ample evidence on the severity of bank failure just after the flood period in comparison to the failure during flood.

In some localities, stratified fine sand, quite massive channel sands and silts underlie the silty clay of the natural levee deposits. During high stage of the river, water is forced into the strata, raising the pore pressure in the strata. As the water level in the river falls rapidly and the pressure against channel wall is lessened, water moves from the formation back into the river. This causes a lateral flow of sands and silts into the channel, resulting in subaqueous failure. This normally produces a bowl-shaped shear failure in the overlying cohesive natural levee deposits. This type of bank failure is seen near Nematighat and in some localities around Majuli and Kaziranga National Park. These types of failure with semi-circular outlines of different magnitude area abundant along the Brahmaputra river channel within the studied reach. Its chordal length along the bank varies from 10 to 54 m and amplitude from the bank varies from 8 to 15 m (Figure 3a and b).

Areas between spur nos 5 and 8, upstream of Nematighat, and some waterlogged areas were developed near the bank of the river, probably related with the construction of flood embankment. These water bodies have no direct outlets to the river. Thus, as the water level in the river recedes, water from these areas moves through permeable levee materials and oozes out along the bank of the river. This type of phenomenon also causes failure of bank materials during the post-flood period (Figure 4a and b).

Another type of failure that occurs in the upper bank and natural levee materials is clearly related to the subaqueous flow. Because of the braided nature of the river channel and constant migration of the river, many abandoned channels intersect the modern bank-line. This gives rise to a zone of well-sorted silt and fine sand localized in the abandoned channel fill. During rising and flood stage,
Figure 2. Erosion and deposition in the studied reach of the Brahmaputra River channel during (a) 1914–75 and (b) 1975–98.

Figure 3. Bowl-shaped failure due to liquefaction (a) downstream and (b) upstream of Neematighat.

the sand and silt become highly saturated. The rapid drop in water level in the channel results in rapid withdrawal of water from these sediments. The highly saturated sediments will liquefy and flow towards the channel. As the materials flow, the overlying less-saturated bank sediments tend to shear along well-defined planes. This type of failure is conspicuous in the western tip of Majuli Island and also upstream of Nematighat.

Shear failure is one of the most effective causes of bankline recession of the Brahmaputra. Majority of the failures occurred as a result of the current undermining of the natural levee deposits, due to which large blocks of natu-
ralement levee sediments are shearing-off and tilting into the river. The other major cause of shear failure is over-steepening of the bank materials as that of the channel hug banks. In localities where bank materials are slightly cohesive, shear failure of the bank results in a rotated step-like structure leading from the top of the bank to the water edge (Figure 5a and b). Most of the shear planes diminish in the slope as they penetrate into sub-surface and as a result the blocks are tilted land-ward by rotation.

In some areas around Salmora in Majuli Island and in some localities in Kaziranga National Park, the bank is composed of cohesive materials. In such areas banks with a slope approaching 90° and more with over-hangs are observed. This type of over-steepening always enhances the failure of the bank. Fluvial erosion, in turn, is linked to mass-failure processes through the concept of basal endpoint control. Fluvial erosion of the basal area of the bank can lead to undercutting and subsequent cantilever failure. Equally, a mass failure event supplying sediments to the basal zone will tend to increase bank stability (decreasing bank angle), unless fluvial conditions result in the critical shear stress for removal of the material being exceeded. As stream power is observed to be at a peak in the middle reaches of a basin, fluvial erosion will dominate there. With increasing channel depth downstream, Lawler suggested that there will be a point at which the maximum (or critical) bank height for stability with respect to mass failure is exceeded and mass failure thus dominates erosion down-
stream of this point\textsuperscript{3,10,11}. Different types of shear failure occur during the receding stage of the river. As the water level recedes in the channel, saturated levee materials lose support from the channel side. This results in shearing of small blocks from the saturated bank due to its own weight. However, this type of failure is always observed in a small scale.

A peculiar type of bank failure is observed in some localities around Kaziranga National Park. Here fine-grained overbank deposits with mudcracks are present along the banks. The formation of mudcracks can directly be attributed to subaerial processes, which include wetting and drying of soil (and associated desiccation). These are commonly thought as ‘preparatory’ rather than ‘erosive’ processes\textsuperscript{12-16}. They weaken the surface of the bank prior to fluvial erosion, thus increasing the efficacy of the latter. The blocks are separated by cracks, detached from the bank. These types of blocky detachment from the bank give it an appearance which resembles the tooth of a saw. The cumulative effect of blocky separation of fine-grained sediments enhances the activities of shearing, which may ultimately lead to large-scale bank failure. Although subaerial ‘wakening and weathering’ of the soil can occur in a number of ways, all are associated with moisture conditions within the material\textsuperscript{17-19} and with the physical state of this moisture\textsuperscript{20}. Both Wolman\textsuperscript{13} and Simon \textit{et al.}\textsuperscript{20} found that the highest rate of retreat occurs as a result of high flow during prolonged wet periods, rather than simply the largest storm of floods. An increase in soil moisture content acts to decrease the magnitude of inter-particle forces within the material\textsuperscript{21}, thus reducing the ‘resistance’ of the bank to the shear forces associated with the flow. Alternatively, low moisture content can also weaken the soil. As the cohesive soil mass dries, volumetric shrinkage results in the formation of a ‘pad fabric’, with blocks of soil separated by desiccation cracks\textsuperscript{22}. These desiccation cracks provide lines of weakness in the bank face, as cohesion is greater within the pads than between them\textsuperscript{23}. Green \textit{et al.}\textsuperscript{21} found desiccation to be one of the dominant forms of bank erosion on the tributaries of the Namoi River in Australia, although they do not differentiate sub-aerial erosion rates from other processes. Slaking (detachment of aggregates from the soil surface caused by positive pore water through the soil), leaching of clay minerals may also contribute to a greater extent in the weakening of the bank face\textsuperscript{17,18}. Braided river represents a high-energy fluvial environment often characterized by non-cohesive banks lacking vegetation and consequently, high rates of bank erosion and bed-load transport\textsuperscript{21}.

The braided Brahmaputra river channel within the studied stretch exhibited differential rate of erosion and deposition. The overall activity of processes that operated was not similar for the period 1914–75 and 1975–98. During the period 1914–75, both the banks of the river evidenced significant erosion, while during 1975–98 the river witnessed a dominant phase of deposition. The inhomogeneity in bank materials and the constant change in flow direction have caused severe undercutting, which enhances the intensity of slumping along the banks. There are two types of bank slumping, undercutting during the flood stage and the flow of highly saturated sediments during the falling stage, through well-defined shear planes. The preparatory processes leading to the formation of mud-cracks increase the efficacy of the processes through generation of ‘pad fabric’ in relation to associated moisture content.


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Some common and contrasting features of earthquake dynamics in major tectonic zones of Himalayas using nonlinear forecasting approach

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Although the Northeast, Western and Central Himalayas distinctly differ in their tectonic activities, this distinction is not examined from a dynamical perspective. The identification of dynamical pattern is, however, central for characterizing the appropriate models of seismic hazard analysis in such critical tectonic regions. We examine here the temporal evolution of seismicity (M ≥ 4) of the Central Himalaya (CH), Western Himalaya (WH) and Northeast Himalayas (NEH) for the period 1960–2003 using the modern nonlinear forecasting scheme to decipher the comparative determinism of underlying dynamical patterns, which may yield insight into earthquake processes. The nonlinear analyses of monthly resolution earthquake frequency time series suggest that earthquake processes in all three regions evolved on a high-dimensional chaotic plane, though with a contrasting predictive pattern. The predictive correlation analysis suggests that the available earthquake data of the NEH and WH can be predicted by more than 40–50%, whereas CH data only by 0–30%, implying that the earthquake dynamics in the NEH and WH are better ‘organized’ than in the CH. The significant distinction in the earthquake dynamical patterns seems to be associated with the underlying seismo-tectonics of these three regions. These results may place significant constraints for developing criteria to test the models of Himalayan earthquakes on a more rigorous and quantitative basis.

HIMALAYAN collision boundary is one of the most seismically vulnerable corridors and has already faced four great earthquakes (M ≥ 8) in the past ~100 years. The Northeast in particular has seen the seat of two great earthquakes (M > 8): the 1897 great Shillong earthquake (M = 8.7) and the 1990 great Assam earthquake.1,2 The increase in population density and relative weakness of structures make it important for a continuing study and monitoring this region.

During the past several years, one of the main themes of the researchers has been the characterization of the nature of earthquake dynamics and its interpretations. Temporal variations in fractal dimension have been used to quantify the nature of earthquake-generating processes3 and have been linked to the self-similarity behaviour of the active fault system.4 To gain quantitative insight into the complex behaviour of earthquake dynamics in the Northeast and Himalayas, the fractal dimension and b-value of earthquake time series were calculated and related with heterogeneity of the fractured crust.5–7 Srivastava et al.8 have shown evidence of a low-dimensional chaotic ‘strange attractor’ of the order 6–7 in Northeast Himalayas (NEH; Shillong Plateau and its adjoining areas) earthquake data using the method of Grassberger and Procaccia (G–P).9 The presence of low-dimensional deterministic chaos in the data suggests that only a few independent variables would be required to model the underlying system dynamics. From a practical point of view, a system dominated by such a low-dimensional deterministic chaotic process (of order 6–7) bears an interesting feature, which implies that the immediate future evolution of this phenomenon is predictable.10 However, detecting a chaotic behaviour using the G–P method requires large number of data points, which are often not available, and even if enough data are available, a finite attractor dimension might not actually be indicative of deterministic chaos due to low signal-to-noise (N/R) ratio.11 In such a situation, the resulting anomalous scaling behaviour could be simply a hallmark of random fractal. Such fractal characteristics have their origin in the re-scaled random process, generally known as fractional Brownian motion. Fractals from the cellular automata seismicity models (dynamically high dimensional and stochastic in nature) fall into this class. Although evidence for ‘low-dimensional chaos’ in earthquake has been reported in many of these cases, there is no general consensus on their modes of origin (high dimension/low dimension) due to the reasons cited above. Distinguishing these classes of evolutionary seismicity is, therefore, essential for understanding and constraining the models of crustal dynamics.

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