

twice more than that of soybean and @ 80 kg/hectare/year (refs 2, 5). According to some, the quantity can be as high as 170–180 kg/hectare/year. Therefore, seabuckthorn can play a crucial role in increasing the fertility of soil in areas like Ladakh (J&K) and Spiti (HP).

Ladakh, considered the cold desert of India, is characterized by dry climate and temperature fluctuations from below –30°C in winter to above +35°C in summer. The soils of this region are poor in mineral nutrients⁶ and the vegetation is scanty and deciduous. The species was exploited for the first time by DIHAR

(former FRL), Leh under the Cold Desert Afforestation programme⁷. Therefore, seabuckthorn can convert the barren land of Ladakh into a fertile and tillable one.

1. Kumar, S. and Sagar, A., *Plant Path J.*, 2007, **6**(4), 299–305.
2. Acharya, S., Stobdan, T. and Singh, S. B., *J. Soil Water Conserv.*, 2010, **9**(3), 201–204.
3. Ahmad, S. D., Jasra, A. W. and Imtiaz, A., *Int. J. Agric. Biol.*, 2003, **5**(1), 10–13.
4. Lu, R., International Centre for Integrated Mountain Development, Paper No. 20, Kathmandu, Nepal, 1992.

5. Akkermans, A. D. L., Roelofsen, N., Blom, J., Huss, D. and Harkin, R., *Can. J. Bot.*, 1983, **61**, 2793–2800.
6. Charan, G. *et al.*, *J. Soil Sci. Plant Nut.*, 2013, **13**(2), 267–277.
7. Ali, A. and Kaul, V., *J. Plant Dev. Sci.*, 2012, **4**(2), 151–155.

SONAM TAMCHOS
VEENU KAUL*

*Department of Botany,
University of Jammu,
Jammu 180 006, India
e-mail: veenukaul@yahoo.co.in

Increasing hydrological hazards in the Himalayas: defence lies in integrated scientific preparedness

The increasing rate of water-related hazards in India is a matter of concern for the society and a challenge for the Government. In the last five years, NW Himalaya alone has witnessed three major events of rain-induced floods and each one made a new record in terms of loss of human lives and damage to infrastructure and landscape. The main reasons for these unprecedented losses have been our unpreparedness, unmindful occupation of hazardous areas, deforestation, poor knowledge of the geo-environment and insufficient forecasting capabilities. As a result, these events adversely impact the dynamic geo-environment of the terrain, social psyche and financially overburden both public and Government in rescue, relief, restoration and rehabilitation. No amount of preparedness without scientific urban planning, understanding of the Earth surface processes in terms of mass movements of debris, soil and water and other factors such as deforestation can arm a society to face these kinds of natural disasters.

The last two events have occurred suddenly in high-altitude areas of Leh and Kedarnath due to short spells of incessant rains or cloud burst due to accelerated monsoon and westerly disturbances or their confluence¹. Because of high drainage density and gradient, such terrains have a small lag time² of flood generation facilitated by the rapid transfer of water from low order *nullas* to higher order streams. This successive discharging of streamlets in the main channel not only enhances the volume of

water, but also its strength to erode and transport, that leads to floods and flows in downstream areas. The August 2010 floods of Leh triggered by 75 mm rainfall in 30 min killed more than 600 people while affecting ~60 villages³. The mud debris transported by *nullas* was deposited in the lower part of valleys burying houses and people. A similar event on 16 and 17 June 2013 in the upper reaches of the Mandakini and Alaknanda valleys in Uttarakhand Himalayas killed around 4000 people⁴, destroyed roads and houses, induced landslides, eroded the human-occupied river terraces, and transported and deposited sediments at critical sites^{1,2,5}. The magnitude and spread of the 6 and 7 September 2014 floods in parts of Jammu and Kashmir is also of extraordinary nature.

Flooding is caused by excessive water, originated due to natural or anthropogenic reasons. Many a times it may not be stoppable unless we have prior knowledge and are fully prepared. However, for geoscientists aiming to provide vital inputs to the society at large, two relevant questions of extreme importance can be framed: (i) Can flooding happen anywhere, or can controls be defined? (ii) Is there any scope of safeguarding ourselves and our properties from floods?

Nature has a systematic way of transferring its water from source to sink. Any obstruction in the natural path alters its flow behaviour. Each river basin has a hierarchy of landforms to accommodate and regulate its normal and excessive

water volume. During lean season water flows in the active channel without causing floods, unless it has been encroached. When discharge increases due to excessive rain, water spreads on the next higher active floodplain. A further increase will raise the water to a still higher level of older floodplains, known as terraces limited by palaeo-banks. In the rarest case, a river may overspill its palaeo-bank. Flooding occurs when water inundates terraces which are preferred urbanization surfaces due to even topography and water proximity. The human occupation of natural flooding surfaces of a river and interventions in its course further augments the destructive capacity of floods.

The devastation caused due to floods in Leh, Uttarakhand as well as Jammu and Kashmir are typical cases of unscientific land use ignoring the geomorphology of drainage basins. In Ladakh, it was houses on dry *nullas* (Choglamsar, Leh, etc.), while in Uttarakhand it was the occupation of river course in Kedarnath valley, habitation on the unstable terraces and vulnerable hill slopes on river valley sides. These deposits and slopes were eroded during the overbank flow of river causing loss of life, property and infrastructure.

In some situations, at the time of excessive river discharge, flooding cannot be prevented, though its magnitude, intensity and impact can be considerably regulated and reduced through scientific planning in development. However, the main problem we face today is that large

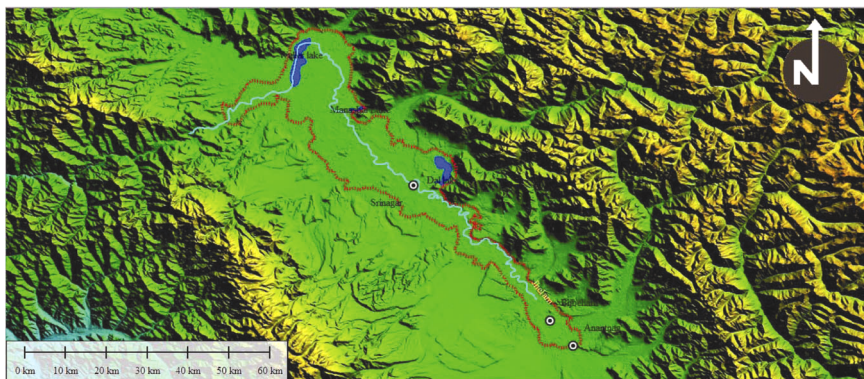


Figure 1. Northerly flowing Jhelum River in Kashmir valley on a digital elevation map. The red boundary marks the extent of flood during September 2014. The flooding is limited by hill front on the right bank and an alluvial upland on the left bank.

parts of flood-prone areas of river basins have already been developed for housing and other activities. Let us take the example of the Kashmir valley. It is a NE–SW aligned, elongated depression bordered by rocky exposures and occupied by alluvium of the northerly flowing Jhelum River (Figure 1). The river shows meandering with wide floodplains on both sides. These plains lie at nearly the same elevation of active river domain (around 1580 m) and are thickly urbanized (Srinagar and its surroundings). Many abandoned loops of the river are present on the floodplains, of which the largest and most prominent one stands out as the Dal Lake. Floodplains on the right bank extend up to the rocky hills, and on left bank they terminate against an irregular 10–15 m high alluvial upland marking the limit of the floodplain (Figure 1). Media reports and photographs show around 3 m high column of floodwater inundating the floodplain over which Srinagar is located. Even an initial assessment of the geomorphology of Srinagar and its surroundings reveals that flooding in this area is not an unusual behaviour; it occurs when the water of the Jhelum reaches the height of the bank. The problem lies in the unscientific horizontal expansion of the city in lowland floodplain, which should have been adequately avoided. Although Jhelum has been embanked and a few flood channels have been constructed to ease out the excessive water, these safeguards proved to be insufficient. Even in such habited areas, the remedial measures could have been more effective with proper preventive measures as mentioned below.

Jammu area lies in a different type of flood-prone morphology. It is a piedmont

plain where Tawi River exits from the Himalayan front. A number of low-order ephemeral *nullas* debouch on this piedmont from mountain front and disappear after a short distance or join the Tawi channel. The city built-up area occupies floodplains on both sides as well as the courses of the *nullas*. High discharge in the river near mountain exit tends to widen its course. At times, the ephemeral *nullas* also carve out new courses by lateral migration. In Jammu area, the floodplains of Tawi and the courses of *nullas* are to a great extent occupied by habitation. As such, flooding is expected in the area unless adequate measures commensurate with the highest flood level are taken while developing and expanding the city.

It is not only these above-mentioned areas that are vulnerable to flooding. To safeguard such areas on long-term basis, a scientific approach is needed. Some of the preventive steps towards preparedness are: (i) Geomorphic mapping of the river valleys in the Himalaya and plains demarcating depositional and erosional alluvial landforms. It should include active and abandoned floodplains, abandoned palaeo channels, terraces with lithology and height. This will guide planners to demarcate geomorphologically suitable areas for development and to devise appropriate measures for the already developed areas. (ii) Hazard mapping: This requires assessment of direction and tendency of lateral migration of river channel, zone of bank erosion, palaeo river bunding, active and palaeo landslides, debris flow, active tectonic features, nature of rocks, minor and major structures. (iii) Palaeo-flood mapping: Based upon historical record and geological archives the timing, extent

and height of past flood events should be identified which can be used to model the return period and magnitude of floods in vulnerable areas for future use.

It is a fact that our efforts are mainly towards managing the effects of flooding rather than addressing the root cause of the problem. We need to develop and implement area-specific strategies incorporating geoscientific, town-planning, architectural and engineering inputs so as to limit the magnitude of damage and avoid unplanned public expenditure. Geomorphological and geo-environmental maps available with agencies like the Geological Survey of India can be of great use in compiling the baseline data of vulnerable areas. Investment in understanding the science of flooding and its forecasting will be much less and is bound to give high returns to the society. Besides, such an effort is essential for conservation and ecological sustainability of these vulnerable regions. It is also suggested that a new legal mechanism be framed for developmental activities in hilly terrain to comply with the site-specific geoscientific parameters so as to avoid haphazard and unregulated habitation. The task of guiding housing in hilly regions should necessarily involve geoscientists. The revenue officers should also be suitably trained and made aware of the importance of fragility of natural landscape.

1. Dhoval, D. P., Gupta, A. K., Mehta, M. and Khandelwal, D. D., *Curr. Sci.*, 2013, **105**, 171–174.
2. Durga Rao, K. H. V., Rao, V., Dobhal, V. K. and Diwakar, P. G., *Curr. Sci.*, 2014, **106**, 598–603.
3. Hobley, D. E. J., Sinclair, H. D. and Mudd, S. M., *Geology*, 2012; doi:10.1130/G.
4. Rana, N., Singh, S., Sundriyal, Y. R. and Juyal, N., *Curr. Sci.*, 2013, **105**, 1209–1212.
5. Valdiya, K. S., *Curr. Sci.*, 2014, **106**, 1658–1668.

H. S. SAINI¹
N. C. PANT^{2,*}
RAVISH LAL²
S. A. I. MUJTABA¹

¹Geological Survey of India,
NH-5P, N.I.T.,
Faridabad 121 001, India

²Department of Geology,
University of Delhi,
Delhi 110 007, India

*e-mail: pantnc@gmail.com