Current Science Reports

Earthquake Potential

Along the Himalayan arc

The north-western part of the Indian plate moves at about 37 millimetres per year. And the north-eastern part at about 44 millimetres. For the past 60 million years or so, the Indian plate has been pushing against the Eurasian plate, subducting under it, and contorting the land above into the Himalayas. On the surface, this activity has left four parallel major faults and a number of fault systems.

Interestingly, crustal shortening due to this continental convergence is only about 13 to 21 millimetres per year, from northwest to northeast. Pressure between plates is building up. And can suddenly be released as an earthquake.

Yogendra Sharma and mentor from BITS Pilani decided to measure earthquake potential along the Himalayan arc. The 2500 kilometre-long mountain belt is difficult to monitor. So, they teamed up with researchers from IIT Kanpur, Japan, and Taiwan.

Dividing the arc into northwest, central and northeast made it easier to measure the relative motions from the 41 global positioning system stations at various points along the region. The team also incorporated some published velocity data. From all this data, they worked out the geodetic strain rate accumulated due to plate motion.

Global earthquake catalogues provided the seismic moment rate released through previous earthquakes. The moment deficit rate, the difference between geodetic strain rate and seismic moment rate, determines the magnitude of future earthquakes.

In the northwest Himalayas, earthquakes of magnitudes 6 to 7.9 are likely, say the researchers. In the western part of the central Himalayas, there is a seismic gap with even greater potential. Eastern Nepal and the southern Tibetan plateau are comparatively stable. The Bhutan-Himalaya has the highest potential – capable of producing magnitudes greater than 8.2.

DOI: 10.1016/j.tecto.2020.228556

Chandra Basin Glaciers

Mapping change

Recently, an increase in melting has been observed in Himalayan glaciers. And this was taken as warning of climate warming. However, the issue is not so straight forward. Depending on geographic and climatic factors, glaciers retreat or gain length. To understand this anomalous behaviour, we need long-term studies.

From this perspective, Rakesh Sahu and R. D. Gupta from the Motilal Nehru National Institute of Technology, Allahabad recently analysed glaciers in the Chandra Basin, in the Lahaul Valley of Himachal Pradesh. Using high quality remote sensing data for 2002, they delineated geographic and other details of glaciers in the basin. Thus, they created an inventory of 395 glaciers. Most had clean ice, but about 60 were covered with debris.

There were clear remote sensing images of about 60 glaciers from 1971, 1989, 2002 and 2016. Comparing the images, the duo observed notable reduction in total glacial area. However, the breaking up of glaciers increased the number of glaciers.

The team then selected five glaciers with varying characteristics for a more detailed study. They observed the impact of non-climatic factors on the glaciers. Higher elevation, lower slope, and debris cover reduced glacier retreat. Glaciers showing high retreat rate had pro glacial lakes at the glacier terminus.

Highly resolved climate data of the region revealed the effect of climatic parameters – temperature and precipitation – on glacier retreat rate. During 1961–2015, the annual temperature trend showed a rise of 0.02 degrees Celsius rise. Changes in temperature impact glacier area more than precipitation.

The observations corroborated previous research.

'Annual temperature rise is the main cause for glacier retreat in the Chandra Basin,' says Rakesh Sahu.

DOI: 10.1080/01431161.2020.1752412

Himalayan Foothill Vegetation

Mapping with Google Earth Engine

The diversity of ecosystems along the Himalayan foothills is vulnerable to climate change. To understand the effect of climate change using ecosystem models, detailed information about vegetation is the key. However, the structure and function of vegetation vary in ecosystems, making reliable mapping and classification difficult.

In ecosystem models, vegetation distribution is represented by plant functional types – plants having similar responses to environmental conditions and effects on ecosystem processes. Mapping these types in highly diverse ecosystems is challenging.

Time-series data from remote sensing provides a feasible option for mapping. However, processing of long-term data requires high storage and computational power.

Recently, Subrata Nandy and team from the Indian Institute of Remote Sensing, Dehradun generated a plant functional type map of the Northwest Himalayan foothills using freely available data and tools.

Using Google Earth Engine, a cloud-computing platform, they analysed publicly available geospatial datasets.

Surface reflectance data from the Terra satellite provided a series of 8-day composite reflectance data at a 500 metre resolution. Using data from 2008 to 2018, the team calculated the time-series of the normalised difference vegetation index in Google Earth Engine. This data was analysed to calculate the greening seasons and their peaks. Thus they could prepare a seasonality map of the area.

Digital elevation model data and the topographic position index from the Shuttle Radar Topography Mission provided information about ridge tops, slopes and valleys.

To represent bioclimatic variables, the researchers took data from WorldClim V2, a global climate dataset.

With data on topographic, seasonality and climatic information in Google Earth Engine, the team used Random Forest classification to generate a plant functional type map of the Northwest Himalayan foothills – a map showing two plant functional types: moist deciduous and dry deciduous. The classification accuracy was about eighty-three per cent.

Freely-available satellite data and products available in Google Earth Engine can provide accurate and reliable plant functional type maps. The study showcases a methodology that ecologists can adopt and adapt for other regions in India.

DOI: 10.1080/01431161.2020.1766147

Assessing Groundwater Potential

In Purba Bardhaman district

The Purba Bardhaman district in West Bengal is primarily agricultural. It gets more than 1000 millimetres of rain during the monsoon. The rest of the year, nearly five million people there depend on groundwater. However, groundwater levels show a long-term fluctuating trend. So, to use groundwater sustainably, we must map potential groundwater zones in the district.

Recently, Subodh Chandra Pal and team at the Burdwan University, West Bengal assessed potential in the district using Landsat-8 satellite images and lithological maps.

Rainfall, land use, land cover and soil permeability determine percolation. Surface water and nearby rivers contribute to groundwater even after the monsoon. Rock formations below the soil constrain and direct percolation. Based on these factors, the researchers developed thematic layers in a geographic information system.

They prioritised and ranked the layers in terms of contribution to the potential. Thus, they divided the district into five zones, from lowest to highest potential.

Good groundwater recharge was observed along the Damodar, Ganga, and Ajay rivers.

The team validated the results using data from twelve dug wells and thirty-two bore wells in the region. Prediction disagreed with observation in five out of forty-four.

An accuracy of 88% is adequate to initiate planning for sustainable groundwater use.

But the mystery of the five wells that defy prediction remains. Should we tweak weights to improve accuracy? What influences on groundwater potential remain hidden?

DOI: 10.1007/s13201-020-01302-3

Groundwater Contamination

In Chidambaram

People in Chidambaram, a coastal town in Tamil Nadu, depend on shallow groundwater for drinking purposes. Groundwater quality is not only affected by geological conditions but by human activities too. This could result in a significant health crisis.

Geologists from the Anna University have been examining the water quality index for some time. Sabarathinam Chidambaram and team collaborated with their alumni, now in Malaysia, Kuwait and Vietnam, to analyse ions and microbes in 39 bore wells in Chidambaram.

The pH of all samples was within permissible limits. But the electrical conductivity of groundwater in bore wells near the Vellar and Uppanar rivers was higher than permissible. This, the researchers say, could be due to surface water seepage.

Calcium and magnesium were higher than permissible in some bore wells. This could be due to the cation exchange of groundwater with clay.

While sodium and potassium contents were well within limits, bicarbonate ions and chloride contents were too high in some bore wells. The researchers attribute the high chloride levels to the intrusion of seawater and domestic wastewater into groundwater.

The high levels of phosphate and nitrate ions may be due to fertiliser use and seepage from septic tanks. Sulphate levels were high, possibly due to pollution by wastewater or due to the oxidation of hydrogen sulphide in clays, say the researchers.

When the hydrogeologists turned their attention to the microbial contamination of groundwater – a factor usually not taken into account under the water quality index – they were not prepared for the shock: 36 bore wells out of 39 had higher counts of total coliform and vibrio species than limits allowed! Fourteen had more than safe limits of streptococci. The highest microbial activity was in residential areas, cultivated regions and around landfill sites.

The researchers examined the relationship between ionic content and microbial contamination. High levels of nitrate, bicarbonate, calcium, magnesium and potassium ions in groundwater were correlated with the presence of *Vibrio cholera* and high streptococcal count.

Most of the groundwater from shallow bore wells in the area is contaminated with high levels of ions and bacteria. The quality is suitable only for irrigation, not for drinking, say the researchers. The situation may not be very different in other coastal towns of Tamil Nadu and perhaps most of India's east coast.

'Unless locals take urgent measures to reduce groundwater pollution and treat water before consumption, we face a public health crisis,' says S. Chidambaram, Anna University.

DOI: 10.1007/s10653-020-00712-1

Arsenic Bioremediation

Metal sequestration by algae

Some algae not only photosynthesise, but also assimilate nutrients from water. Algae have been used to sequester heavy metals from polluted water bodies. *Chlorococcum* species, especially, have been used to flocculate lipids from water. These algae can survive in water with heavy metal contamination. So why not explore the potential for accumulating arsenic?

Researchers from the Babasaheb Bhimrao Ambedkar University, the University of Lucknow and the Munger University collaborated to check. They collected samples from a wastewater pumping house in Lucknow and, through serial dilution and plating, isolated *Chlorococcum* cultures.

The isolates were then grown on media containing different concentrations of arsenic. From spectrometric

recordings of optical density, the researchers estimated the growth of the microalgae. There was exponential growth after five days and the rate decreased after ten days.

The rate of growth decreased with increased concentrations of arsenic. But the algae survived even when exposed to 40 micromolar arsenic.

The team analysed the algae and found that chlorophyll concentration decreased with increase in arsenic. Peroxidation of membrane lipids suggested that, at high concentrations, arsenic is toxic.

Microalgae treated with a lower arsenic concentration showed an increased concentration of proline – an amino acid involved in metal chelation. Proline also protects plants from stress. At lower concentrations of arsenic, the team also observed higher concentrations of carotenoid – an antioxidant that helps in the functioning of the microalgae's photosynthetic machinery. These responses of the alga could explain the adaptive tolerance of *Chlorococcum* against arsenic.

After 10 days, *Chlorococcum* accumulated high concentrations of arsenic from the media. One gram of dry weight of the microalga grown at a 20 micromolar concentration accumulated more than 250 micrograms of arsenic!

For large-scale commercial applications, further studies are needed.

DOI: 10.1007/s00128-020-02964-0

Soil Suitability Analysis

With GIS and remote sensing

Uttarakhand has extremely hilly and rolling topography, difficult to access. People there cultivate crops in what little fields they can carve out in the mountainous terrain, without considering the soil's suitability for the crops and thus end up with low yields. Soil testing can help select better suited crops. But it is time consuming and laborious.

If, however, conventional methods of soil analysis are complemented with satellite data, perhaps it will provide a standardised data product to characterise soil suitability even in such difficult terrains.

So, scientists from the ICAR-National Bureau of Soil Survey and Land Use Planning set about applying remote sensing and GIS to map soil suitability in the region. They used remote sensing satellite camera images from Resourcesat, ISRO merged with a spatially enhanced image of the Khulgad watershed on a 1 : 12,500 scale resolution.

To classify physiographic units, the team adopted visual interpretation methods based on associations of tone, texture, size, and shape patterns. They combined the visual and digital interpretation of remote sensing data and identified six major physiographic units – hilltop, hills with very steep slopes, hills with steep slopes, moderately steep hill slopes, hill terraces and valley land.

The maps generated were validated by ground truthing – checking and carrying out soil surveys using conventional methods. After establishing a physiography–soil relationship, the scientists prepared a detailed soil map with the types and distribution of soils.

For the soil suitability analysis, they selected crops commonly cultivated in the region: wheat, rice maize, finger millet, mustard and potato. From the maps, they inferred that mustard, wheat and finger millet are suitable to moderately suitable for the area in the Kumaon Himalayas.

Because of severe soil and topographic limitations, the area moderately suited for potatoes is marginal.

Now farmers in the region can use the map to identify crops to cultivate.

This technique can be used to map soil suitability in other agricultural districts too.

DOI: 10.1007/s12524-020-01143-2

Nano Lipid-based Gel

Treating skin cancer

In recent years, polyphenols and flavonoids of plant origin have found use in cancer treatment. These natural compounds have fewer side effects than synthetic or semisynthetic compounds. However, they have low solubility in water. So, to treat skin cancer, there is no point taking these drugs orally.

We can, however, pack the drugs in liposomes for applying on skin. But then, liposomes are challenging to store as the contents leak.

Nanostructured lipid carriers have recently been shown to overcome the problem. But can two naturally occurring polyphenolic compounds be packed together for synergistic action in a nano lipid gel?

Researchers from Jamia Hamdard and Jamia Millia Islamia, New Delhi tackled the problem. The team first mixed resveratrol and quercetin in almost equal ratios. Spectral analysis revealed no chemical interaction between the two.

The next task was to select the type of lipids for encapsulating the drugs. Should it be solid, liquid, or a combination? The team finalised the combination of solid and liquid lipids based on the solubility of the two drugs. Both lipids were derivatives of natural oils.

'For delivery into skin, particle size has to be about 200 nanometres. By tweaking the concentrations of lipid and surfactant, and using ultrasonic waves, we managed to get the right size,' says Mohammad Imran, Jamia Hamdard, New Delhi.

The group confirmed the size with transmission electron microscopy.

'We tested for drug leakage by vortexing the emulsion at high speed and found it retained the drugs effectively by up to 90%,' says Javed Ali, Jamia Hamdard, New Delhi.

Zeta potential measurements confirmed stability.

The team then prepared two gels using a gelling agent – one with quercetin–resveratrol-loaded nano lipid carrier, and the other with quercetin–resveratrol alone.

The nano lipid gel permeated deeper layers of skin than the conventional gel. Spectroscopic measurement suggested a distortion in the skin cell membrane's lipid layer. 'The nano lipids seem to merge with skin cells, delivering the drugs to target cells,' says Moshahid Alam Rizvi, Jamia Millia Islamia, New Delhi.

A skin irritation test on normal mice failed to detect toxicity. The team tested the gels on the human epidermal cancer cell line and found it destroyed cancer cells more effectively than standard formulations.

Applying the gel on wounds showed that the migration of cells for wound closure was inhibited, suggesting

it may also stop cancer cell metastasis.

'The gel needs to go through more testing – *in vitro*, animal studies, and then clinical trials – before hitting the market,' says Sanjula Baboota, Jamia Hamdard, New Delhi.

DOI: 10.1016/j.ijpharm.2020.119705

Curing Malaria

Catching it early

Malaria, often fatal, is caused by the Plasmodium parasite. Drugs such as primaquine target the parasite in the liver stage of infection, killing it at an early stage. However, the drug shows liver toxicity in those deficient in glucose-6-phosphate dehydrogenase, an enzyme.

Decoquinate, an experimental drug, inhibits both liver-stage and blood-stage infection. However, selectively delivering the drug to liver cells for effective early stage treatment remains a challenge.

Researchers from the Bombay College of Pharmacy in collaboration with the Central Drug Research Institute, Lucknow have now found a strategy. As target, they took asialoglycoprotein receptors on the surface of liver cells. These receptors are overexpressed in malaria infection. To target the receptors, the researchers modified the surface of liposomes by conjugating them with two different liver-specific ligands, stearylated arabinogalactan and glycyrrhetinic acid.

They loaded decoquinate in the modified liposomes and tested the antimalarial efficacy of the formulations using a mouse model and human liver hepatocellular carcinoma cells. Both *in vivo* mice studies and *in vitro* cell studies showed that the liposomal-drug formulations had better antimalarial efficacy than currently used drugs. Moreover, as little as 0.5 milligrams per kilogram body weight of the formulation offers more antimalarial protection than the currently used 35 milligrams per kilogram dose of primaquine.

Liposomal-drug formulations are stable for 10 days at 4 degrees centigrade and can be stored long-term by cryopreserving or lyophilizing.

Annually, about two million deaths are caused by malaria. Though the formulation is promising, we have to wait till clinical trials establish safety and efficacy in humans.

DOI: 10.1016/j.ijpharm.2020.119710

Food Grade Bioplastics

From red seaweed

Plastics from biological materials such as potato and corn starch have been devised, to replace non-biodegradable petrochemical-based plastics in food packaging. But why encroach on food materials? Why not try abundantly available seaweed?

Recently, researchers from the National Institute of Ocean Technology, Chennai used red seaweed, *Kappaphycus alvarezii*, to produce bioplastic films for food packaging. *Kappaphycus alvarezii* grows fast and contains carrageenan, a sulphated polysaccharide that forms gels when hydrated. Plastic sheets can be made when the gel is mixed with a plasticiser, spread thin and heated. The choice of plasticiser reflects the elasticity of the sheet.

While earlier researchers used lower molecular weight plasticisers, the team tried polyethylene glycol with a molecular weight of 3000.

They collected red seaweed from the Rameshwaram coast. After washing and shade-drying the seaweed, they used a mixer grinder to make 3, 4 and 5 per cent solutions of the dried biomass. Then, they mixed the solutions with PEG 3000 and spread the mixtures.

After peeling off the films thus formed and drying them overnight, the researchers conducted a battery of tests on them. Atomic force microscopy showed that the surface was smooth. The researchers attribute this to the good adhesion between seaweed biomass and plasticiser.

The bioplastic with 3 per cent seaweed biomass had maximum thickness. However, the bioplastic with 4 per cent seaweed biomass had the best tensile strength, the force required to break a specimen. It also had better elongation and stiffness than existing bioplastics.

'The tensile strength meets the standards for commercial bioplastic and synthetic plastics,' says Muthiyal Prabakaran Sudhakar, NIOT, Chennai.

But, to use the film for food packaging, it must have high shelf life. And this depends on good barrier properties against the transmission of water vapour and oxygen. Water uptake and solubility increased with the concentration of seaweed in the plastic.

The researchers found that the film's water vapour transfer rate was least for bioplastic film with 3 per cent biomass. And so was the oxygen transmission rate.

'PEG 3000 creates better bioplastics than other plasticisers,' says Muthiyal Prabakaran Sudhakar, NIOT, Chennai.

'Experiments with different plasticisers may further improve bioplastic properties,' adds Dharani Gopal, his colleague.

India has a coastline of thousands of kilometres. 'Cultivating *Kappaphycus alvarezii* for bioplastic production and for highly valued kappa carrageenan may provide livelihoods for the coastal poor,' says Dhassiah Magesh Peter.

DOI: 10.1007/s11356-020-10010-z

Reports by: **G. Sharath Chandra, Shwetakshi Mishra, K. Sri Manjari, Sileesh Mullasseri, R. Baskar, Ravi Mishra, Priti Rekha Gogoi, D. C. Jhariya, Monisha Chetia** and **Sushmitha Baskar**

ACKNOWLEDGEMENT: IISER Pune for providing access to scientific databases.

scienceandmediaworkshops@gmail.com