Science Last Fortnight

Coastal Vulnerability
Historical data predicts

Coastal landforms change due to natural processes and human activities. Some changes are irreversible and make the coast vulnerable to rapid degradation. So what do we need to take into account to plan coastal infrastructure and make it safe for habitation?

B. R. Rajasree and M. C. Deo from IIT Bombay recently reported assessing the vulnerability of the central west coast of India. They focused on three stretches of coastal Karnataka – the shoreline containing the mouth of the Gangavali River, the straight and uninterrupted Udupi shoreline and a shoreline artificially interrupted by the New Mangalore port.

To model these three different stretches, they considered seven parameters related to ocean and coastal landforms: geomorphology, regional elevation, coastal slope, mean significant wave height, mean tidal range, sea-level rise, and shoreline change rate.

The researchers took Landsat images from 1979 to 2016 to measure historical shoreline changes. Wave heights were numerically simulated with climate models calibrated using data from wave rider buoys near Mangalore.

Also included were four socioeconomic factors: population, land use and land cover, tourism and heritage, and road networks.

Tsunamis and cyclones have high impact, but only for a short term and are not predictable. So the team did not consider these.

Data from 1979 to 2016 were used to construct the model. After confirming that the model was reasonably good, the researchers projected the scenario thirty-six years into the future. Their analysis of the historical data of coastal vulnerability indicates that Gangavali is the least vulnerable and that the New Mangalore Port area is most vulnerable. The projected future shows that wave activity in all three regions will intensify and larger waves will be more frequent with small shifts in wave direction.

'More multi-hazard-based evaluations of coastal vulnerability are required', says Deo, IIT Bombay.

'We need to consider the vulnerability of coastal ecosystems when planning for coastal development in the region and make sure that it does not pose socio-economic hazards', says Rajasree, his colleague.

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Groundwater Assessment
Multi-criteria decision making

Panipat is a region where groundwater use for agriculture is very high. It is a part of the Yamuna sub-basin. The alluvial aquifers here have higher potential than those in hard rock terrain. However, the present high rate of extraction for domestic, agricultural and industrial activities is creating a scenario of water scarcity in the district.

Lakhvinder Kaur and team at the Panjab University, Chandigarh were concerned. Their calculations on extraction and recharge showed that there is a shortfall of more than 200 million cubic metres of water.

So they decided to carry out a groundwater potential index assessment of Panipat region's alluvial aquifers. They took groundwater data from the Central Groundwater Board and created 3-D models of lithology and fence diagrams. Fence diagrams are useful to understand aquifer characteristics.

The researchers considered eight parameters – geology, land use/land cover, soil, rainfall, elevation, slope, cumulative sand thickness and groundwater level. They extracted details of the variables from remote sensing data. Thus they could map eight thematic layers, based on the variables, on a GIS platform.

Using a weighted overlay analysis of the layers with the analytical hierarchy process, a multi-criteria decision making technique, the team demarcated potential groundwater zones in the Panipat region. Thus, they could classify the output maps into four categories on the basis of groundwater potential zone.

As alternative to using the analytical hierarchy process, the researchers also used catastrophe theory techniques to map groundwater zones. Catastrophe theory takes into account abrupt discontinuities usually found in nature. When the results were validated with field data, the catastrophe theory technique was found to be better than the analytical hierarchy process.

'The spatial distribution trend of groundwater potential zones obtained from catastrophe theory is not only more consistent but is also supported by 3-D fence diagrams', says Lakhvinder Kaur, Panjab University.

According to the team, the district's eastern and southern parts have good groundwater potential.

'In the northwest region, it is poor because of geological factors. But, in the central-north and south-eastern parts, it is due to overexploitation', explains her mentor Madhuri Rishi.

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Manipur Wetlands
Predicting the future

Wetlands dominate the Loktak catchment area of the Manipur river basin in northeast India. However, this rich biodiversity hotspot now faces severe land degradation. The decrease in the thickness of herbaceous wetlands is alarming. How will changes in land use and land cover affect the area's wetlands 10 years from now? Will the catchment survive human activities, wondered Vicky Anand, a researcher from NIT, Manipur.

Vicky turned to his mentor, Bakimchandra Oinam, for help in projecting the future. The duo accessed Landsat 8 images in geographic information-based software to prepare temporal maps for the area and observed considerable decrease in wetlands, herbaceous wetlands and forest from 2007 to 2017.

To predict the future scenario of these wetlands, they used the Land Change Modeler. This land planning and decision support system uses the Markov chain to model the probabilities of transitions and artificial neural networks to make sense of these transitions. For the model, the researchers used variables that contribute to changes, such as distance from road and settlements, slope and elevation.

To train the system, they took the rate of change in land use and land cover from 2007 to 2014. And they tested the model's prediction ability against the actual 2017 map. The model proved to be reasonably accurate.

Vicky then used the model to project a land use and land cover map for 2030. The model foresaw a decrease of more than 6% in wetlands and a 42% decrease in herbaceous wetlands 10 years from now.

'The wetlands are getting deteriorated and depleted at such a rapid rate primarily due to irrational land use practices', says Oinam, NIT, Manipur.

'People in the region must be alerted about the negative impacts of wetland deterioration and educated about steps to restore the wetlands', adds Vicky, his PhD scholar.

The researchers urge decision makers to implement proper environment preservation policies.

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Water Contamination
Removing copper ions

Copper is widely used in many industries. Copper ions in sewage from these industries contaminate water bodies. Large amounts of these ions are toxic to life. So researchers have developed various porous materials to remove copper ions from water. Materials prepared from natural resources have gained popularity over other existing materials owing to easy availability and low production cost.

For some time now, Senthil Kumar and co-workers from the SSN College of Engineering and the Rajalakshmi Engineering College, Chennai have been experimenting with using biochar from different plant sources. Recently they reported their results, using biochar made from *Cassia fistula* seeds to remove Cu(II) ions from water.

Image: Dinesh Valke via flickr

Though laburnum, *Cassia fistula*, flowers in spring, pods are available almost throughout the year and, since they are not commercially exploited, they are cheap raw material. So the team collected *Cassia fistula* seeds, ground them into powder and sieved the powder.

Under scanning electron microscopy, they found particles of about 10 micrometres with cracks and voids on their surfaces. Since this type of surface is not suitable for Cu(II) ion adsorption, they modified the surface, using physical and chemical processes.

They heated raw *Cassia fistula* seed powder to about 250°C to produce a carbonaceous material. Two more sets of carbonaceous material were prepared: one set by treating the powder with hydrochloric acid and another, with sulphuric acid. The surface morphology and elemental composition of all three proved useful for Cu(II) adsorption.

The team tested these materials using a copper sulphate solution and found that the sulphuric acid-treated powder showed maximum adsorption capacity – nearly 100% adsorption, at pH 5. The minimum time required to adsorb the Cu(II) ions was 30 minutes.

Large quantities of laburnum seeds are wasted every year. Water supply bodies and water purifier companies can convert this waste into raw material for removing copper from water.

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Treating Pulmonary Fibrosis
Cancer drug side effect

Bleomycin, an anti-cancer drug, can cause pulmonary fibrosis, leading to irreversible lung damage. In this chronic inflammation of the lung, collagen is deposited in between lung cells.

Such spaces contain metalloproteins that break down other proteins and metalloproteins that inhibit protein breakdown. Metalloproteinases in the cell matrix activate the transforming growth factor-β1. This growth factor is a signal for collagen deposition and induces proliferation of fibroblasts – cells of the fibrotic tissue. But once activated, the growth factor inhibits collagen accumulation and tissue degradation.

N-acetylcysteine is often used to treat pulmonary fibrosis. How and where does it act in the network of proteinases, antiproteinases and the transforming growth factor? What is the best time for initiating treatment?

Ritu Kulshrestha and team from the V. P. Chest Institute, Delhi in collaboration with researchers from the Punjabi University, Patiala investigated these questions on a rat model.

They treated three groups of male Wistar rats with bleomycin sulphate to induce pulmonary fibrosis. The rodents were given varying doses of N-acetylcysteine for one, two and four weeks. The treatment reversed bleomycin-induced inflammation and fibrosis on day 7 and reduced parenchymal collagen deposition by day 14. By day 28, there was further reduction in collagen deposition and fibrosis.

The researchers determined the protein concentration, mRNA expression and collagen content of the lung tissue. In the control group, the mRNA and protein concentration ratio of matrix metalloproteinase-9 and tissue inhibitors of metalloproteinases was approximately one. But bleomycin changed the protease–antiprotease ratio to less than one.

N-acetylcysteine therapy reduced tissue inhibitors of metalloproteinase-1 mRNA expression and protein concentration, and increased the protease–antiprotease ratio to greater than one. It also increased transforming growth

factor-β1 mRNA levels initially, followed by a decline.

'Our results suggest that N-acetylcysteine treatment needs to be initiated early', says Ritu Kulshrestha, V. P. Chest Institute, Delhi.

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Sugarcane Waste
Pressmud to biofertiliser

India produces around 40% of worldwide sugarcane industrial waste. Vermicomposting is used to convert this waste, pressmud, into fertilisers. Pressmud is primarily cellulose. Cellulose can be broken down by bacteria in cow dung. For better bacterial activity during composting, some nitrogen is also needed. Leaves of leguminous plants contain enough nitrogen. But what is the best ratio of such green manure and cow dung to convert pressmud into fertiliser?

Recently, a team led by Balachandar from the Aarupadai Veedu Institute of Technology, Tamil Nadu, in collaboration with researchers from South Korea, designed experiments to find optimum ratios.

The team collected leaves of *Gliricidia sepium* and *Leucaena leucocephala*. The leaves were cut, dried and mixed with different proportions of cow dung and pressmud. Water was sprinkled on the mixture for three weeks to keep it moist for bacterial growth.

Earthworms were then introduced into the mixture. After 50 days, the team observed that the total nitrogen, phosphorus and potassium in the vermicompost had increased substantially. Enzyme activities and microbial populations increased initially, indicating that microbes were actively degrading organic materials. Microbial populations decreased towards the end of the period, indicating the vermicompost's maturity.

'Pressmud, cow dung and green manure in a 2 : 1 : 1 ratio seems optimum for earthworm activity and for the vermicompost's nutrient quality', says Natchimuthu Karmegam, Vinayaka Mission Research Foundation, Salem.

For every ten tonnes of sugar produced, three tonnes of pressmud is generated as waste. Sugar factories can use this technique to convert pressmud into fertilisers for sugarcane cultivation.

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Next-Gen Biofertilisers
Bradyrhizobium-based

Biofertilisers are available as talc-based formulations. But these formulations have a short half-life. So when they are applied in the field, the effect is not as high as expected.

Shilpi Sharma and Sakshi Tewari from IIT Delhi have been struggling with this problem. Bacteria that work as biofertilisers exude secondary metabolites into the surrounding soil. Could these exudates be useful for plant growth, they wondered.

To check, the researchers procured and cultured a known nodulating strain of *Bradyrhizobium* species. They centrifuged the culture broth to remove live cells and prepared a cell-free culture supernatant.

Using high pressure liquid chromatography and other techniques, they detected plant growth-promoting metabolites released by the bacteria in the supernatant – siderophores, indole acetic acid, phosphate solubilising enzymes and exopolysaccharides...

The duo precipitated the exopolysaccharide fraction from the cell-free culture supernatant containing the secreted metabolites. Then, they tested the ability of the strain individually, in combination with cell-free culture supernatant and exopolysaccharide and also without live cells.

They collaborated with Vijay Pooniya from the Indian Agricultural Research Institute, New Delhi to test differences in growth and yield when different combinations of supernatant and live cells are used. For field experiments, they used pigeon pea, *Cajanus cajan*, an important leguminous crop.

They found that treated plants germinated more easily and had more biomass. There was significant increase in the rate of nodule formation and the weight of nodules. The protein content of the harvest was also higher.

The combined application of cell-free culture supernatant and exopolysaccharide also had a pronounced effect though it was slightly lower than that obtained with the live cell in combination with the supernatant.

'The cell-free culture supernatant and exopolysaccharide promote the growth of indigenous rhizospheric populations and help nodulation and overall plant growth', explains Shilpi, IIT Delhi.

'This is an alternative approach for synthesising next-generation biofertilisers that are stable under storage conditions', says Sakshi, her colleague.

Agro-based companies can take up this initiative for synthesising cell-free biofertilisers to benefit farmers.

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Pesticide Contamination in Water
A natural photocatalyst

Pesticides often contaminate confined water bodies. To degrade contaminants in water, photocatalysis has proved effective and inexpensive. However, chemical-based photocatalysts tend to leave chemicals behind in the water. So what are the alternatives?

Last fortnight, Vijay Luxmi and her supervisor, Ashavani Kumar, from NIT Kurukshetra reported making a natural catalyst from turmeric rhizomes. The team collected healthy turmeric plant rhizomes from their campus. They cleaned, boiled and dried them. The dried rhizomes were then ground to powder that the duo calcined in a furnace at high temperature.

Then, the researchers examined the powder's surface chemistry, morphology and composition. They found that the particles in the calcined powder had large surface area, nano porous structure and a band gap in the visible range – all the requirements for a substance to be a photocatalyst.

Near the institute, farmers use carbofuran and malathion as pesticides. So the researchers investigated the effectiveness of the photocatalyst for these two types of pesticides by dispersing the calcined turmeric root powder in pesticide solutions. They found that 77% carbofuran was degraded in less than two and a half hours. And malathion was reduced by 95% in the same period.

'Turmeric root powder can be a very effective alternative to chemical photocatalysts since it is natural and eco-friendly', says Ashavani Kumar, NIT Kurukshetra.

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Increasing Forest Fires

Drying up water resources

Forest fires are a major reason for the worsening of air quality at regional scale. But how do these fires affect water resources?

Image: Naveen N, via Wikimedia Commons

K. Venkatesh, K. Preethi and H. Ramesh from NIT Karnataka decided to investigate. They analysed forest fires over the Kudremukh national forest in Karnataka from 2000 to 2017 to understand the impact on water balance.

Reanalysis data from NASA suggest an increase in temperature during the last decade. The increase dries out forests rapidly in summer. Since dry biomass is more susceptible to catching fire, there is increased forest fire intensity. The researchers confirmed this by examining satellite images of the burnt area.

'There's been an increase of about 22% in forest fires during the last decade', says Preethi, NIT Karnataka.

In addition to satellite and reanalysis data, the team used the soil and water assessment tool to model the infiltration of water over the burnt area. They used data from 2002 to 2008 to train the tool, and 2009 to 2012 to validate the model and the remaining period to assess the effect of forest fires on water balance.

The simulation for fire and non-fire period suggests about 32% change in water runoff. The simulated runoff correlated well with observations during the validation period.

Forest fires reduce vegetation cover. And the hydrophobic nature of burnt soil increases water runoff from the surface, reducing the infiltration of water in the soil.

'Increased runoff results in frequent flooding in the Kudremukh area', says Ramesh, NIT Karnataka.

'Increasing temperature is likely to lead to intense forest fires, resulting in more runoff water and less groundwater. A serious threat to water resources', says Venkatesh, his colleague.

The method can be adapted to understand biomass burning and its impact on water resources in other parts of India.

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Design for Drones

Students reconfigure multirotor

Drones are increasingly used for agriculture, security, transportation and entertainment. They are often fitted with multiple motors that respond to remote commands for changing speed or direction. However, quick and instantaneous response to such commands can often destabilise the drones. So what are the best configurations of rotors in a drone? How do drones with four, six or eight rotors differ in performance in terms of stability and energy use?

Yasasvi Harish Kumar and Utkarsh Tripathi, students from the Manipal Institute of Technology, Karnataka along with their faculty supervisor, Balbir Singh, have now proposed a mathematical model to simulate and design energy efficient and stable drones.

They also made a prototype of a multirotor aerial vehicle which can switch configurations between quadrotor, hexrotor and octorotor. The design consists of six arms at an angle of 60 from each other. The motors are mounted on these arms. Motors 1–6 are upward facing. The two downward facing motors are coaxial to 5 and 6.

Motors 1–4 are active and respond to all user inputs: throttle, roll, pitch, and yaw. Motors 5–8 respond only to throttle.

The team mathematically analysed the dynamics of such a system of rotors – equations of motion, forces and torques acting on the system, the effect of propellers on torques and yaw counter torque that may be experienced by the system even when yaw input is not given.

The team then designed a controller for such a system based on the proportional integral derivative. Controller inputs normally only go into active rotors. In this case, the user can switch configurations to suit needs. The user can choose from a quadrotor where all passive motors are disabled, a hexrotor where motors 5 and 6 are enabled and motors 7 and 8 are disabled, and an octorotor where all motors are enabled.

In the prototype, a joystick gives inputs to the proportional integral derivative controller which feeds the flight controller and the output of this is fed back to the proportional integral derivative controller. Simulation revealed that the settling time for the quadrotor configuration for a step response is more than it is in the octorotor configuration. The octorotor configuration provides more thrust to the system and is, therefore, more responsive but tends to overshoot.

The team tested this unconventional design and found it quite stable.

'Our mathematical model did not consider phenomena such as wind, imperfections in the construction of the system and device inaccuracies. We need to test the system more extensively', says Harish Kumar, one of the students in the team.

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Reports by: **Kamal Kumar Tanti, Prashant Singh, Swarnendu Roy, Monisha Chetia, Ratamali Machahary, Dalchand Jhariya, Tongbram Malemnganbi Chanu, Porag Bora, Priti Rekha Gogoi** and **Puja Sah**

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scienceandmediaworkshops@gmail.com