Science Last Fortnight

Monitoring Mangroves

Using Sentinel-2 data

Detecting plant health, especially of vegetation cover over vast areas, is difficult. But remote sensing can help monitor large plant populations. Different plants reflect light differently.

The reflected frequencies are used to derive vegetation indices, to distinguish between healthy and diseased plants in real time.

However, this becomes challenging in the case of mangroves where reflectance values get mixed with the background reflectances of water, clay and soil.

Image: V Malik, via Wikimedia Commons

Post doctoral fellow, Sudip Manna, and his mentor, Barun Rai Chowdhary, from Presidency University, Kolkata decided to test the potential of Sentinel-2, a high-resolution Earth observation satellite, for monitoring mangroves in the Sunderbans.

Sentinel-2 has thirteen frequency bands. But which frequency bands of Sentinel-2 are most appropriate for studying mangroves?

To find out, Manna collected Sentinel-2 data for Lothian Island in the Sundarbans. The island has a dynamic mangrove ecosystem, influenced by tidal waves. The researchers derived spectral signatures of the area in the conventional bands – visible, red and infrared – as well as in short-wave infrared bands. They found that it is easier to distinguish mangroves from other vegetation using the short-wave band of the spectrum. The short-wave infrared bands were sensitive to leaf shape and biochemicals like cellulose, protein, lignin, starch and nitrogen.

To take a closer look, the team then accessed data from a recent airborne spectrometer that covered the reflectances of visible and infrared regions from the same study site and compared the data with the results of their analysis of Sentinel-2 data. Only the short-wave infrared band of Sentinel-2 is adequate to distinguish mangroves from other vegetation, the team observed. The highest response was shown for band 11 and band 12.

Could the available data also provide vital information about mangrove health? To validate the satellite data, the researchers conducted a field study. They selected eighty-five ground control points in the study area and recorded mangrove health, tree morphology, species diversity and distribution. The Sentinel-2 image was georeferenced using 70% of these control points in Google Earth.

The team then used a support vector machine, a discriminative classification algorithm, to differentiate between the mangrove species in the Sundarbans. The support vector tool was trained using ground control points from the field survey. The researchers obtained a map with sixteen different classes of mangrove species using this strategy. The team tested the output using the 30% ground control points from the field study. The map showed 94% accuracy.

They now propose using Sentinel-2's two short-wave infrared bands as a new vegetation index – the Discriminant Normalised vegetation Index.

'Mapping based on the index delineates the mangroves according to morphological character efficiently', says Barun, Presidency University, Kolkata.

This method can be used by environmentalists to monitor mangrove health.

'Sentinel-2 data is widely available and provides finer spatial signatures', adds Sudeep, Presidency University, Kolkata.

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Monitoring Cotton Crop Growth

Radar remote sensing

Crops such as cotton, cultivated over large tracts, are difficult to monitor from the ground. Radar signals from satellites can be used to sense vegetation water content and moisture in surface soil, making it possible to assess and monitor crops remotely. This radar vegetation index has values ranging from 0 (bare ground) to 1 (fully covered). But what aspects of the radar vegetation index should we consider to monitor the growth parameters of cotton plants?

Recently, Dipanwita Haldar from ISRO, Dehradun collaborated with researchers from ISRO, Ahmedabad to inquire into the relationships between the radar vegetation index and crop growth parameters such as vegetation water content, crop age, height and biomass. The team took images from RISAT-1.

Image: Phil Bus, via flickr

RISAT1 has a synthetic aperture that sends out radar signals. The signals, reflected from the ground, are detected by multiple antennae to create 3D images with a spatial resolution of 25 metres – the approximate area of a large cotton field.

The team collaborated with researchers at the Anand Agricultural University, Gujarat to monitor the entire growth cycle of hybrid and indigenous cotton crops. They collected field data on vegetation water content, biomass, as well as data on the age and height of plants from 100 fields in Surendranagar, Gujarat.

During the same period, scientists at ISRO monitored crop plant growth from RISAT 1 data. They calculated the radar vegetation index for initial vegetative growth, peak vegetative growth, flowering, and boll formation.

The team found that the index of the cotton crop during the growth period ranged from 0.2 to 0.9, increasing with crop growth from July to September. The index showed a higher value in the hybrid cotton fields than was seen in the indigenous fields.

Statistical analysis confirmed that the index correlates well with crop age and biomass, as well as with vegetation water content.

'It is an efficient index to monitor crops during the rainy season when field visits are difficult', says Dipanwita Haldar, ISRO, Dehradun.

The findings can help agriculturalists assess cotton crop conditions on a regional scale.

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Butterflies in Sikkim

Biodiversity indicators

Sikkim, Himalayas. A hotspot of biodiversity. Forests cover nearly half the state. There are three indigenous farming practices here: mandarin orange-based, farm-based and large cardamom-based agroforestry. The types of butterflies in each agrosystem also differ.

Researchers from the University of Sikkim, the Mountain Institute India, and the Tripura University and from Italy investigated butterfly diversity in these farming systems and compared it with that of forests, in a search for indicator species.

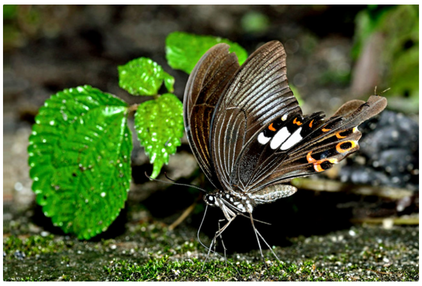

Image Sandip via Wikimedia Commons

In each ecosystem, the researchers made one kilometre transect walks, stopping at predetermined points, exploring and identifying butterflies within a five-metre radius and documenting the environment. They undertook two such walks separated by at least one kilometre in each ecosystem. And the walks were repeated six to eight times.

Since South and East Sikkim are geographically distinct, data was collected from both parts. The exercise lasted from 2012 to 2017.

The team identified more than 8000 individual butterflies representing 268 species from six families – nearly forty per cent of butterfly species reported from Sikkim Himalaya.

More than two-thirds were forest specialists, one-third were picky eaters, eating only one type of food, and about one-fifth turned out to be protected species.

More than 90 species were common to all four ecosystems. The team identified 21 that were found exclusively in forests and 60 that confined themselves to agroforestry systems.

Forests had the least local diversity. Local species diversity was most in mandarin orange-based agroforestry, followed by the one based on large cardamom.

The researchers attribute the higher diversity in the mandarin orange system to higher tree species richness, diversity and density in the traditionally managed agroecosystems.

There was variation between seasons. From winter to post monsoon, butterfly richness and abundance increased in the forests. But this pattern was not prominent in the agroforestry systems. The presence of shade trees and intercropped pulses, vegetables, and fruits provides food for larvae and adults even during winter, say the scientists.

The researchers identified 15 indicator butterfly species. Eleven were forest specialists, including two protected species. Six were exclusive to mandarin orange-based agroforestry.

So the monitoring of at least one third of the indicator species can be done by local farmers – if only they have the necessary information.

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Rainbow Trout Farming

Scope in Himalayan region

Rainbow trout, *Oncorhynchus mykiss*, can tolerate a wide range of water temperatures from zero to 20 degrees centigrade. It flourishes in different types of freshwater sources and is, therefore, cultivable in different terrains. So rainbow trout farming has become an economic activity in many countries. However, the rivers, streams, lakes and tributaries in the Himalayan region, highly suitable for trout farming, are under-utilized for aquaculture.

What factors need to be considered to develop trout farming as a livelihood and for employment generation in the region?

Image: Liquid Art via Wikimedia Commons

Atul K. Singh from the National Bureau of Fish Genetic Resources, Lucknow collected and analysed data on critical areas of trout farming in the Himalayan states, and came up with a detailed and comprehensive trout-farming ecosystem. There are nearly nine hundred kilometres of river streams, twenty-eight hundred hectares of reservoirs and nine hundred hectares of lakes that have potential for trout culture in the Himalayan states. However, less than 20 hectares of water area is used for trout farming here.

There is limited infrastructure available for rainbow trout farming in the Himalayan states. The researcher suggests that using fabricated recirculating systems with fibre reinforced plastic tanks may increase trout production by fifteen to twenty per cent in the Kumaon region.

Atul recommends using such technology for scaling up commercialization in trout farming in the area.

'For intensive trout production, minimize land and water use', says Singh.

He finds that water quality can be maintained in flow-through raceways and ponds constructed adjacent to the water bodies in the region.

To overcome another challenge of trout intensification in water bodies, the researcher suggests inducing reproductive sterility. The most practical and effective way is manipulating chromosome sets – induced triploidy.

'There are many advantages to using triploid fish for commercial purposes. The fish has three sets of chromosomes and so it's genetically sterile', says Atul Singh.

And that spells ecological safety for the pristine and untapped aquatic bodies in the higher Himalayan reaches where aquaculture is still rudimentary.

The production technology for triploid rainbow trout is being standardized at the ICAR-Directorate of Cold Water Fisheries Research, Bhimtal using thermal and pressure shock to produce triploidy.

'Once the technology reaches a commercial scale of adoption, it will be a safe approach to stock the untapped natural water bodies in higher reaches beyond 2500 metres above sea level in the Himalayas', adds the scientist.

Trout production can be boosted with financial support from the government sector for larger infrastructure facilities, as well as improved quality of feed and better management practices. Along with other inputs, good governance and environmental regulations are necessary for successful trout farming at higher altitudes with scope for employment generation in the Himalayan region.

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Just Enough Salt

For the perfect fish!

The common carp, *Cyprinus carpio,* has a good domestic market, and is an important candidate of the Indian fishery sector. But this freshwater species tolerates only moderate fluctuations in temperature and salinity.

V. K. Tiwari and Jahan Iffat from the Central Institute of Fisheries Education, Mumbai set about to find the optimum salinity required to maximize carp breeding and development. Salinity is measured in parts per thousand.

Image: A F Lydon via Wikimedia Commons

The researchers used inland water with a salinity of 15 parts per thousand and diluted this water with freshwater to a salinity of 10 parts per thousand and 5 parts per thousand.

They reared common carp in these different grades of saline water and a batch of carp in freshwater. Common carp, like other fish, have external fertilization. That is, eggs and sperm are released into water by adults, and the zygote is formed in the water.

For breeding carp, the researchers transferred adults to chambers of similar salinity. They monitored gonad development, egg weight and sperm motility in adults and found that sperm motility, gonad weight and egg count decreased with increasing salinity.

Larvae were also kept under different conditions of salinity to measure incubation time, fecundity and embryo development. Incubation period, larval mortality and deformations were lower in freshwater and in salinity of 5 parts per thousand.

'Common carp can be cultivated where surface water contains salts to the order of five parts per thousand', says V. K. Tiwari, ICAR-CIFE, Mumbai.

With this baseline drawn, the scientists now hope to develop a breed of *C. carpio* adapted to brackish water to increase economic benefits to the fisheries sector.

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Discarded Disc Drives

Recovering rare metals

Hard disc drives of computers and laptops have trace amounts of precious metals. But once the drive gets corrupted, it is discarded, adding to electronic waste.

Recently, researchers at IIT Roorkee found an effective way for recovering useful materials from waste hard disc drives. They dismantled the hard disc and separated the two major components – magnetic units and printable circuit board.

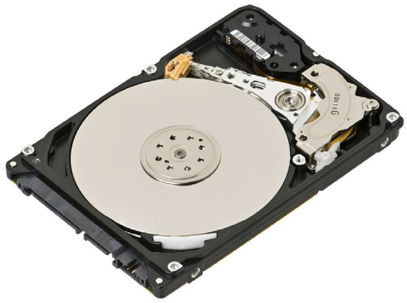

Image: Evan Amos via Wikimedia Commons

The printable circuit board was cut into small pieces, ground and sieved. Then the researchers used a customized water classifier instrument, where the fluid force separates metals according to their mass.

They heated the magnetic unit of the hard disc under a muffle furnace. The units were then crushed and pulverized. The powder was kept in the microwave oven and leached using hydrochloric acid, to dissolve rare earth materials like neodymium and dysprosium.

From a single hard disc, the team isolated 6 grams of high pure metal concentrates (out of this 75% was copper) and 1.4 grams rare earths. And they confirmed the quality and purity of the components using scanning electron microscopy.

Thus a combination of water fluidization and leaching under microwave exposure seems reliable for effectively extracting metals and rare elements. The method can be scaled up to better manage e-waste.

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Biodegradable Pesticide

To protect crops from pests, pesticides are often used. But pesticide traces in crops and vegetables can affect health. So many new biodegradable pesticides have sprung up in the markets. While they may degrade in the soil, it's not clear if they do or do not leave traces behind in the crops.

Scientists from the Bihar Agricultural University and The Bidhan

Chandra Krishi Viswavidyalaya decided to test the biodegradability of such a pesticide, pyridalyl, in the field.

Pyridalyl is recommended for tomato, cabbage, cotton and a few other important crops. The team selected tomato and cabbage since these are consumed raw.

They grew tomato and cabbage in different plots. In one plot, pyridalyl was sprayed at the recommended dose. In another, it was applied at double the dose. And a third plot was left untreated. The researchers repeated this for two seasons, and recorded rainfall values for both seasons.

Image: B Navez via Wikimedia Commons

In each season, the researchers collected the vegetables and soil samples two hours after spraying and then after 1, 3, 7, 10 and 14 days. Using gas chromatography, they estimated pyridalyl residue in the soil. And on both types of vegetables when harvested.

In soil, there was some amount of toxicity to algae.

'Rains seem to lower the risk of residual accumulation of the chemical in the soil', says Pritam Ganguly, Bihar Agricultural University.

The researchers found that pyridalyl has low persistence in tomato and cabbage. From the results, they assessed the dietary and soil risks associated with the use of pyridalyl pesticide.

They suggest a waiting period of about 18 days after the last pyridalyl application before harvesting vegetables to ensure safety for human consumption.

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Next Gen Networking

We live in a 4G networked world, where a typical mobile tower handles up to about 400 connections at a time, using a long-term evolution (LTE) range of 600 megahertz to 6 gigahertz. Waiting on the wings is 5G technology that uses the spectrum at higher frequencies, extending the bandwidth available for consumers.

But first, the technology has to solve some of the inherent problems. For instance, for effective linkages between the 'cells', the number of base stations has to increase. And even then, small millimetre radio frequency waves will not work when it is raining. And free space optical communication signals will be affected by fog and clouds – anything that reduces visibility, even atmospheric turbulence.

Suman Malik and Prasant Kumar Sahu from IIT Bhubaneswar analysed the problem in detail and have now come up with a potential solution.

They propose a communication system based on a combination of line-of-sight optical signals and millimetre-wave radio-frequency to connect between the base stations horizontally and, with unmanned aerial vehicles, vertically. The vertical connections need not be with all base stations, since the base stations distribute the signals among themselves.

Atmospheric attenuations of the signals are different in vertical and horizontal direction. And the inbuilt redundancy of the two bands of signals can help overcome individual weaknesses in response to atmospheric conditions.

Suman and Prasant analysed the effects of various types of losses in signals under various weather conditions as well as in the orientations of the transmitters and receivers in such a system. In line-of-sight optical signals, there can be loss of signals due to divergence of the beam from its path. Misalignments between transmitter and receiver, caused by earthquakes, tremors and strong winds, can also create problems, besides attenuation caused by fog, snow, cloud, rain, dust and aerosols. The team derived equations to calculate such losses and to determine critical factors and their impacts on the performance of the system.

The problem of fade out of signals was reduced but not eliminated completely. So the researchers came up with intensity modulation, direct detection and a diversity technique as a means to respond to changing weather conditions.

When the bandwidth of signals stretches to the visible range, the technology to deal with the signals also needs to be stretched, so that consumers have an uninterrupted and dependable communication system to take advantage of the promise of a data rate of up to 500 megabits per second in clear weather conditions.

The testing of the 5G spectrum has just begun. And the intensity of the race among service providers will determine the difference between promise and delivery.

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