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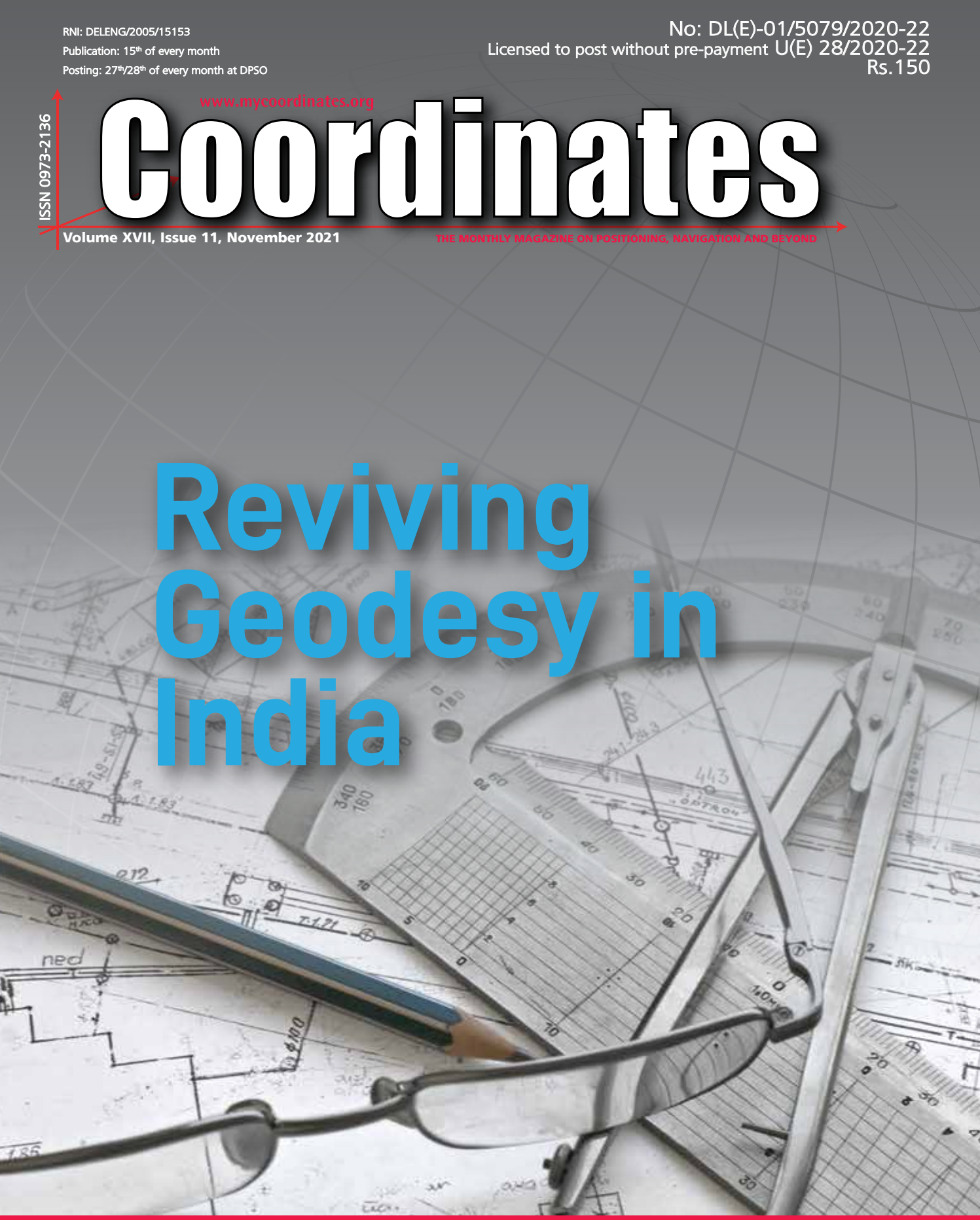
Reviving Geodesy in India



Animal mapping and ecology

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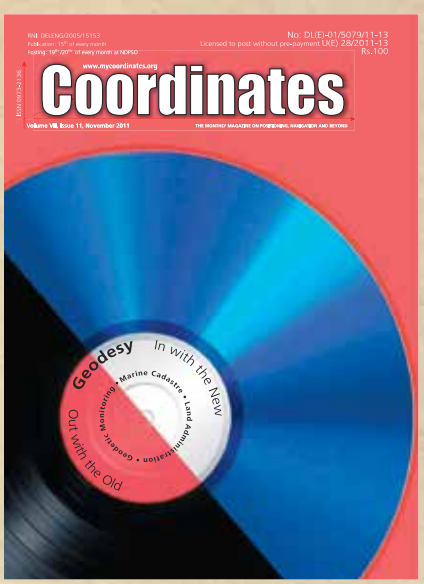

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Geodesy: Out with the Old, In with the New

Chris Rizos
Professor and Head of the School of Surveying & Spatial Information Systems, UNSW, Australia, President of the International Association of Geodesy

Geodesy is facing an increasing demand from science, engineering applications, the earth observation community, and society at large for improved accuracy, reliability and access to geodetic services, measurements and products. All countries, and all geospatial professionals can contribute. Our slogan should be "geodesy matters, now more than ever", but it must be Modern Geodesy... out with the old, in with the new.

Experiences from World Bank development support for land reform

Keith Clifford Bell
World Bank, East Asia Pacific Region
Washington DC, USA

Ongoing rapid advancements in ICT, including the construction of optic fiber networks, and improved telecommunication infrastructure across East Asia is connecting rural and urban populations. The foundations are being laid for a host of e-government services and the building of NSDI that will reach beyond cities and into the rural provinces. Improving tenure security and access to land is central to alleviating poverty and advancing rural livelihoods.

Improving the administration of marine and coastal spaces

Michael Sutherland
Department of Geomatics Engineering and Land Management, University of the West Indies St. Augustine, Trinidad and Tobago

The marine cadastre ideal, based upon a multipurpose cadastre principle, will include 2- and 3-dimensional graphical representations of all rights and interests occurring within the spatial extent of focus. It will include 2- and 3-dimensional graphical representations of other spatial data described above. In other words, visualizations would include volumes and not just plan views of polygons.

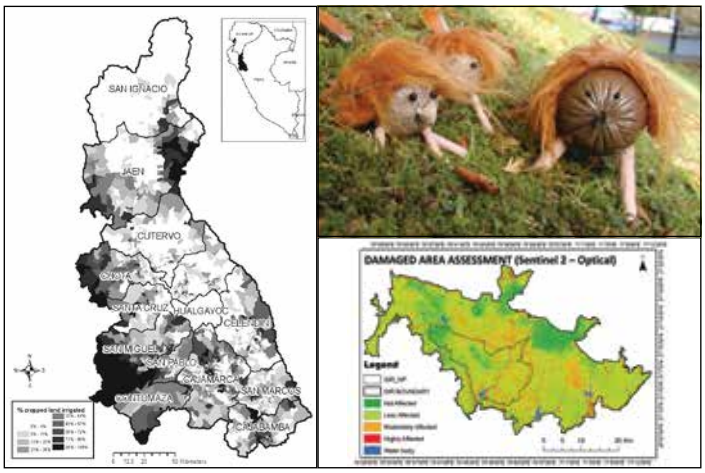
LIGHTSQUARED AND GPS

"Retrofitting the existing receivers can be a win- win situation"

Javad Ashjaee, President and Chief Executive Officer, Javad GNSS in a recent statement presents his views on LightSquared and GPS interference issue.

"A general GNSS industry view that retro-fitting new filters on all fielded receivers was impractical"

John Pottle Marketing Director, Spirent, Positioning and Navigation Group on LightSquared and GPS interference issue



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Coordinates Volume 17, Issue 11, November 2021

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Columns

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This issue of Coordinates is of 40 pages, including cover.

The tyranny and the irony

Another wave of Covid-19 sweeps Europe.

Russia and the UK face a surge,

The Netherlands heads for partial lockdown.

Austria restricts unvaccinated people.

Germany says national emergency.

Apparently in Europe ‘vaccine hesitancy’ overwhelms the ‘vaccine availability’.

The tyranny of virus continue to rage,

And the irony is that millions yet to get the first dose when some talk about booster.

We should learn to live this tyranny and the irony both.

The pandemic is far from over.

Bal Krishna, Editor
bal@mycoordinates.org

"We are trying to revive Geodesy in India"

says Maj Gen (Dr) B.Nagarajan, Professor, Department of Civil Engineering, Indian Institute of Technology (IIT) Kanpur, Kanpur

Why is geodesy an indispensable science? How it has evolved over the years?

Geodesy is the science of accurately measuring and understanding the three fundamental properties of the Earth: its geometric shape, its orientation in space, and its gravity field. All of these things have an important effect on our lives, but are always working in the background where most of us don't notice. It is a science that connects the Earth, oceans and atmospheric systems. Also, for any geospatial application, the most fundamental requirement is the set of coordinates which is provided by the subject of Geodesy. Therefore, even though you are not working in geodesy perse but almost everyone is using geodesy in their daily life.

Though the history of Geodesy started in the Greek Era (625-195 BC), with contributions from Thales of Miletus, School of Pythagoras and Aristotle, on Trigonometry, Diurnal motion of the Earth and Moon and Sphericity of Earth and possibility of Gravity, it was Eratosthenes (276-195 BC), who determined the size of the earth and also computed the inclination of axis of the earth rotation. That's why he was rightly called 'Father of Geodesy'.

After nearly 1500 years, geodesy got a boost through the various mariners like Marco Polo, Columbus, Vasco da Gama and Magellan and from great astronomers and physicists like Copernicus, Kepler, Galileo and Newton. The real revival of the subject at least in India came in the 18th century with the setting up survey organizations in India and beginning of scientific surveys in 1802-with the 'Great arc' measurements.

Geodetic & Research Branch (which was earlier called as Great Trigonometric Survey Directorate), of Survey of India, was the only organization carrying out conventional geodesy work for the last two centuries. Unlike rest of the countries in the world, for some inexplicable reasons, the science of Geodesy was treated as restricted and was taught and practiced only in Survey of India in our country, though this subject is the mother of all geosciences. Space based geodetic surveys which can provide two three orders of accuracy better than the conventional surveys have been in vogue for the past three to four decades, but Survey of India has made only a very small improvement in adopting latest techniques mainly due to manpower, budget and other resource constraints.

Now with the importance in geodata increasing, and geospatial technologies becoming the order of the day, even Government of India has felt the necessity of popularizing the subject in the country. The setting up of National Centre for Geodesy is one such attempt in this direction.

What has been the contribution of space geodesy to the growth and evolution of this science?

Space Geodesy has revolutionised the way Geodesists used to observe the earth. Traditional ground surveying techniques,

though accurate, require intensive labour and time and also provides limited positional accuracy. On the other hand, the space based geodetic techniques provide measurement accuracy two to three orders better than the conventional methods and has opened up plethora of applications that could not have been thought of few decades ago. Advanced communication and computing facilities have further increased the relevance of employing space geodesy in all scientific applications. With the launch of satellite missions on space Geodesy, studies related to understanding various Earth, atmosphere and ocean system phenomena have got a significant boost. Several global geodetic applications like crustal deformation, post-glacial rebound, and determination of earth's centre of mass, ice melting, seismic deformation, sea ice melting, volcanic activity, precise satellite orbit determination, earth rotation, land and territory management, and many more are now being studied with the help of space Geodetic observations.

What is the role and mandate of National Centre of Geodesy at IIT Kanpur? Do you have any international collaboration? What is the significance of IGS installation?

The NCG was initially conceived on account of limited education in Geodesy at the national level. Although courses on Surveying and Mapping, Geoinformatics, Remote Sensing/ GIS, etc. are being taught at a few universities, none delve into the fundamentals and advanced concepts in Geodesy.

The primary objective of the NCG is to nucleate and strengthen activities in the area of Geodesy education, capacity building and academic research and development by:

1. Organizing outreach activities: capacity building in Geodesy through regular short and long term training programs; preparing well-trained PG students, development of courses and reference material, and disseminating relevant information in Geodesy.
2. Conducting state-of-the-art research and development activities (academic research, sponsored/consulting) in Geodesy.
3. Acting as the National Resource Centre for extensive support (laboratory, equipment, training, library, SW, etc.) to students and researchers from various universities and institutions and advise state/central government departments on all issues related to Geodesy.

We do have international collaboration. One of our PhD students, Mr. Ropesh Goyal is pursuing joint PhD with Curtin University, Australia and another student, Ms. Sujata Dhar with GFZ Potsdam, Germany. Further, there are various international experts from Germany, Switzerland, USA, Australia, Argentina, Spain, Italy, Austria, and Canada who have been supporting us for establishment of geodetic VLBI in India. We also have the MoUs signed with Curtin University, Australia and NCTU, Taiwan for doctoral joint degree program.

We all are familiar with International Terrestrial Reference Frame (ITRF), but it is surprising that there is no contribution from India of its realisation. The primary objective of IGS installation at IITK is to contribute to the ITRF realisation and Earth orientation parameter computation. The station is also intended to tie a national datum to the ITRF. It is already included in the Asia-Pacific Reference (APREF) network and will be recommended to be included in IGS list probably by this month end.

We don't have many geodesists in India – what are the reasons? How do you see the academic scenario of Geodesy in India?

In India, Geodesy has been portrayed as a subject which involves rigorous mathematical understanding and analysis. Due to this, many undergraduate, postgraduate and doctoral students do not prefer to study Geodesy. On the contrary, many such students are fascinated towards the study of Geospatial Science, Geomatics, Geographical Information System, and Remote Sensing. However, Geodesy is the foundation for all geospatial technologies, the mother of all disciplines relevant to Geospatial Science.

It is noticed that many IITs, NITs, reputed government institutions and private universities are known to offer and award Masters and PhD degrees in GIS and Remote Sensing in India. However, Geodesy is not covered in depth at most of these institutions, due to the lack of trained personnel and availability of latest geodetic equipment. This issue has been widely discussed at various forums where experts in the area of Geodesy have emphasized the need to develop adequately trained human resources and standardized course syllabus to expose the subject of Geodesy to the professionals, teachers, and students. To overcome this gap in the area of Geodesy education and research, there is a need for training of the trainers, who would be involved in further training of professionals, researchers, teachers working in the field of Remote Sensing, GIS, and Earth Sciences across the country.

You represent a prestigious technology institute. How do you find the students' interest in the subject like geodesy given the inclination towards supposedly glamorous streams of technology like computer sciences?

Though geodesy is the fundamental science of the geospatial technology, it is rarely taught in any institution with a degree course on geoinformatics, geomatics or remote sensing. So, this is obviously a new subject for the students joining us at MTech or PhD level. In 2016, we had only one PhD student working in core geodesy. However, slowly the numbers increased and presently,

Space Geodesy has revolutionised the way Geodesists used to observe the earth. Traditional ground surveying techniques, though accurate, require intensive labour and time and also provides limited positional accuracy. On the other hand, the space based geodetic techniques provide measurement accuracy two to three orders better than the conventional methods and has opened up plethora of applications that could not have been thought of few decades ago

with the establishment of NCG at IIT Kanpur, we have more than 14 PhD students working in physical, geometrical and satellite geodesy.

Obviously, computer science can be seen as a glamourous field, but it should be noted that it is a technology that can be used with geodesy also. Though you cannot escape coding in the geodesy field, it actually depends on the interest of a student that up to what level they would like to use the computer science technology in their geodesy research. For example, our REO, Dr. Ashutosh Tiwari uses deep learning and computer vision in his geodetic applications. He is also a member of IAG working group on Machine learning in geodesy.

To be honest, geodesy is an amalgamation of physics, mathematics and computer science. Since we are trying to revive geodesy in India, it is our duty to promote geodesy and make it interesting for the incoming students.

Key research projects by your Centre.

NCG is presently involved in undertaking and coordinating projects of national importance and of high social relevance. Some of these projects are described in brief:

(i) **Project Saptarshi-** This project involves realizing the international terrestrial reference frame (ITRF) by setting up a network of Very Long Baseline Interferometry (VLBI) stations in India, co-located with other geodetic techniques like Satellite Laser Ranging (SLR), Doppler Orbitography and Radio-positioning by Satellite (DORIS), Global Navigation Satellite System (GNSS), Gravimeter, Corner reflectors for Interferometric Synthetic Aperture Radar (InSAR) and weather, hydrological and seismic sensors. The aforementioned techniques collect different types of observations, and synergistically provide better accuracy and error identification, leading to establishment of an accurate reference frame. These sensors, however, need to be closely co-located to achieve a robust connection, thereby reaching sub-mm level accuracy in the realization of the ITRF. This project has been taken up as a multi -organisational effort as we need to employ the competencies of several organisations in India. The collaborating organisations are Space Applications Centre, ISRO, Ahmedabad, National Centre for Radio Astrophysicists, Pune and National Physical Laboratory, New Delhi. This project visualises India joining International campaigns involving cutting edge research and also work on our Prime Minister's vision of Atma-Nirbhar Bharat, in fabricating our own Geodetic VLBI antenna and designing Backend electronics and Correlator required for observation and analysing the VLBI data from extra- galactic sources.

(ii) **Indian National Geodetic Reference Frame:** NCG is coordinating a project with an aim to establish precise and consistent Indian horizonal, vertical, gravity, and tidal datums. The establishment of the four datums for the country is the need of the hour, which we have collectively termed as Indian National Geodetic Reference Frame (INGReF). After tripartite meeting amongst Survey of India, Department of Science & Technology, and National Centre for Geodesy, a detailed recommendations in this regard have already been submitted to the Government.

(iii) **Observatory for upcoming NISAR mission:** NCG is involved in a project which aims to establish an observatory for calibration/validation and deformation monitoring using images from the upcoming NASA ISRO NISAR mission.

(iv) An IGS station has been set up with the policy of 'open data centre' to initiate all kinds of application research in the field of Geodesy using GNSS data.

What is the status of Indian National Geodetic Infrastructure? What is the way forward?

Geodetic infrastructure of a country implies establishment of the precise national horizontal, vertical, gravity and tidal datums. In India, organisations have claimed that we do have well established datums but in our brainstorming meeting on "Indian Geodetic Infrastructure: current status and a way forward" it has been unanimously agreed that those datums were established with the best available data during those times and all of which do not meet the present accuracy requirements, and they are not consistent among themselves. Moreover, no information about these datums is available in the public domain for the use by various stakeholders. In such a scenario, the major aim of geospatial policy, i.e., collection of consistent geospatial data without duplication is hard to achieve.

Since establishing the precise and consistent geodetic infrastructure is of national importance, it is inevitable to bring in different stakeholders (Government, academia, research organisation, industry) to realise the same. Recently, we conducted a tripartite meeting among NCG, DST and Survey of India and have provided some recommendations that include formation of three working groups one each for Horizontal datum, gravity and vertical datum, and tidal datum. There will be one apex body to monitor and coordinate the activities of these three working groups.

NCG would be very happy to coordinate this project of national importance. In fact, one of our students, Mr. Ropesh Goyal, has already developed a gravimetric geoid model for the whole of the mainland India and is proactive in conceiving the ideas for the definition and realisation of IRNSS based Indian geodetic reference frame. There are a few new PhD students also who are working in this domain. Now is the crucial time for a collaborative effort among various organisations to develop our national reference frame. We hope DST may be working on the realisation of the recommendations emerged from the brainstorming session and the tripartite meeting as a way forward to the Indian Geodetic Infrastructure.

You had a long association with the Survey of India. Do you think the organization has evolved vis-à-vis the fast-evolving technology and demanding users' needs?

Being India's National mapping agency, Survey of India prepares maps for the whole country. The organization is making efforts to keep pace with the international mapping agencies. However, the growth requires significant jumps in terms of technology awareness, adoption and application to keep pace with the fast-evolving technology. In my opinion, Survey of India is far from absorbing the new technologies. Though there can be several reasons, main reason is that they need sufficient trained manpower and financial resources. This requires training of the SoI personnel on the use of advanced geodetic instruments, and the relevant science and application. Today, there are umpteen number of applications which require the use of geospatial data and maps. User needs can better be fulfilled with the adoption of advanced geodetic techniques and technologies in mapping.

With one of the objectives of NCG to organise outreach activities, we have signed an MoU with Survey of India to conduct different short- and long-term courses for the training of Survey of India's personnel. We have already conducted a course on Geodesy for senior level officials of Survey of India and have planned another course for surveying officers to be conducted in December 2021.

Thoughts on the Geospatial policy

The new geospatial policy is very thoughtful. It will be very productive and supportive for the geospatial industry and other stakeholders in India, and are likely to be the game-changer in the long run. We also feel that the availability of comprehensive, highly accurate, granular and constantly updated Geospatial Data will significantly benefit diverse sectors of economy.

In India, organisations have claimed that we do have well established datums but in our brainstorming meeting on "Indian Geodetic Infrastructure: current status and a way forward" it has been unanimously agreed that those datums were established with the best available data during those times and all of which do not meet the present accuracy requirements, and they are not consistent among themselves

However, one should note that the geospatial data collection and preparation of maps follow the survey principle of 'whole to part'. Few decades back, the horizontal coordinates of a point on the surface of the earth were usually referred to Great Trigonometric Survey (GTS) station coordinates and the heights to the Indian Mean Sea level (IMSL) datum. With the introduction of space-based technologies and modern survey techniques, the required accuracy of point positions and contour heights have increased several folds. For maintaining the consistency and avoiding the duplication, it is a welcome step that SoI topographic database will be accessible to the public. As per policy itself, the individuals can collect data of any high-resolution and accuracy, but it is also mentioned that the spatial accuracy of the sharable topographic database shall be one meter for horizontal or planimetry and three meters for vertical or elevation.

Moreover, it is welcoming step that any individual can process any geospatial data, but there exists no standard operating procedure. In such a scenario, these guidelines may not provide the consistency of the national database and hence, cannot avoid the need of duplication. As per the plottable error defined by SoI and the present accuracy availability (3m horizontal and 1 m vertical) we cannot even contribute towards the consistent mapping of the country at 1:10000 scale (plottable error=2.5 m) with heterogenous data collected by several individuals/ industries and collated by one organisation. No doubt, it can be useful in mapping the entire country at relatively smaller scale, but which is not the need of the hour.

Therefore, to meet the vision of the new geospatial policy, we should start working on a consistent National geodetic infrastructure with a long-term goal of IRNSS based Indian National Geodetic Reference Frame.

Humorous science: Animal mapping and ecology

This paper highlights amusing research related to the animal kingdom, improving our understanding of animal behaviour, ecology and conservation, often by employing spatial tools and innovative approaches to data collection and analysis.

Volker Janssen
Publications Officer, Association of Public Authority Surveyors (APAS), New South Wales, Australia

This is the fourth in a series of papers celebrating some of the weird and wonderful research findings hidden amongst the scientific literature. It aims to ensure that we remember the funnier side of science and provides answers to questions we may have been too afraid to ask. This study was conducted entirely in the author's spare time and is in no way related to his employer. Here, we examine selected research focussing on animal mapping, behaviour, ecology and conservation. Ecology is the study of the relationships living organisms have with respect to each other and their natural environment.

Haggis

McNoleg (1996) reported on several breakthroughs in the field of geomatics and demonstrated their application in a particularly difficult habitat mapping exercise for the endangered haggis. This 4-legged mammal is mainly native to the Scottish Highlands and unique because it has one pair of legs (either on the left or right side) that is shorter than the other pair. This evolutionary adaption allows it to easily walk around the very steep mountainous terrain in either clockwise or anti-clockwise direction, depending on its legs. Understandably, haggis have a natural aversion to any other plane of movement, preferring areas where the angle of slope is within a certain tolerance of the difference in height between opposite pairs of legs. After finding its niche, each haggis walks the same path around a hill for its entire life, creating an effect akin to a contour line (which can be visible in aerial and satellite images) due to soil compaction and the reduction in vegetation cover.

By substituting the traditional fuzzy logic image processing technique with misty logic (found more suitable for the environmental conditions encountered in Scotland), introducing a neural-network approach to evidence combination and adopting an innovative data structure hierarchy (Polymorphic Euclidean Adaptive Region tree, PEARtree), the path for each haggis was modelled based on a combination of environmental, spectral, spatial, economic, temporal, taxonomic and astrologic data. A mathematical derivation (even the most outrageous ideas can look credible if expressed using complex symbology) showed that haggis habitats can also be located from geophysical data sources. Due to the forces at play when a well-fed, sodden haggis rolls downhill after losing its footing, the path taken can be detected as an extremely bright localised streak in gravitational anomaly maps and therefore be identified via image differencing. However, it was noted that no haggis tracks were detected despite the sophisticated analyses applied, leading McNoleg (1996) to conclude that the haggis is even more endangered than anticipated. On a more serious note, this paper also drew attention to the peer-review process and that some authors include large amounts of buzzwords in titles and (unnecessarily) complex maths to increase the paper's chance of acceptance.

Addressing efforts to ensure the survival of the haggis (particularly as it is

also considered a Scottish delicacy), King et al. (2007) pioneered the use of ultrasonography in its reproductive management and introduced new genetic material to improve the animal's welfare and productivity under farmed conditions. Selective breeding successfully increased body length, reduced hair coat, modified (drinking) behaviour, reduced seasonality and increased fank (litter) size. However, the uneven leg length remained a problem as it requires the provision of suitably inclined grazing.

By introducing genetic material from haggis native to the southern hemisphere via artificial insemination, they intended to produce even-legged haggis that could graze on flat land. The resulting fank contained nine hagglets with four being the desired even-legged variety of medium leg length, two exhibiting longer left legs, two exhibiting longer right legs, and one occurrence of the unexpected and worrying diagonally long-legged state (Figure 1). This state sometimes occurs in the wild where affected animals cope by grazing the sides of narrow ditches and streams with their two long legs in the water and their two shorter legs on either bank. It was emphasised that further research is required to prevent reoccurrence of this state under farming conditions and that the diagonally long-legged hagglet has been adopted by a lady in a Scottish village where it is living happily on a diet of hand-picked heather and Old Pulteney.

Figure 1: (a) Wild haggis with two hagglets on a steep slope, (b) farmed haggis and her fank of nine hagglets at two days old, and (c) two hagglets demonstrating the desired even-legged state (right) and the unexpected diagonally long-legged state (left) (King et al., 2007).

Drop bears

The tagging and tracking of animals has been a vital tool in the quest to better understand animal behaviour and ecology. The use of Global Navigation Satellite System (GNSS) technology has been responsible for significant advances by providing accurate and frequent estimates of the changing distributions of many rare animal species. However, it is extremely difficult to apply conventional methods to the drop bear, a predatory Australian marsupial closely resembling the koala, which hunts by dropping out of a tree and skilfully latching onto the victim's neck to kill its prey. The dense tree canopy regularly causes extended periods of complete GNSS signal loss, and sensors are often damaged during attacks on prey.

Addressing this problem, Janssen (2012, 2013) proposed an indirect GNSS-based approach by tracking the prey rather than the predator. Using bushwalkers equipped with GNSS and heavy-duty helmets to pinpoint the location and timing of drop bear attacks, he successfully estimated the number and spatial distribution of drop bears the study area (Figure 2). This research also provided valuable insights into the animal's hunting behaviour, confirming that foreigners are much more likely to be dropped on than Australians and indicating that drop bears do not necessarily target the last person walking in a line. Fortunately, bushwalkers can protect themselves from drop bear attacks, e.g. by wearing forks in their hair, spreading Vegemite behind their ears or under their armpits, urinating on themselves, and avoiding talking in a foreign language or non-Australian accent. Drop bears may be identified by lying down beneath a tree and spitting upwards (a sleeping drop bear will most likely wake up and spit back). However, this method includes some risk, with potentially devastating consequences if drop bears are on the hunt for prey or in the middle of the mating season.

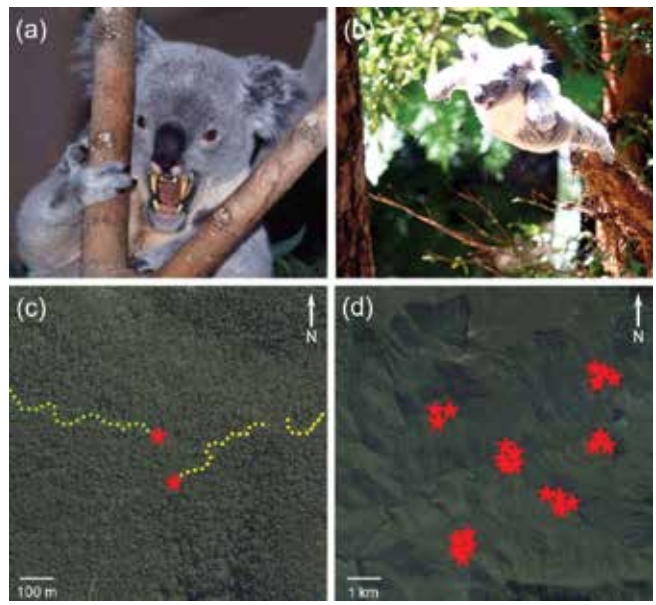

Figure 2: (a) Drop bear in its habitat, (b) drop bear attacking prey, (c) two GNSS tracks ending with a drop bear attack (denoted by a star), and (d) summary of all drop bear attacks observed (Janssen, 2012, 2013).

The original journal paper (Janssen, 2012) was intended to demonstrate how a research paper should be written, that science can be fun and to increase awareness of GNSS technology (and drop bears, of course). These goals have been achieved, with the paper attracting much attention from Australia and overseas, including in the media. It

quickly and unexpectedly became the most downloaded paper in the journal's online history. For obvious reasons, we can use this study to briefly explore how such a humorous paper was received.

Excerpts of the received feedback include:

- "We incorporate drop bear numbers in our Integrated Forest Condition Assessment Methodology (IFCAM). Drop bear encounters represent an important opportunity to include citizen science in our programs, through voluntary reporting (or non-reporting, as the case may be)."
- "We will adopt your GNSS technology as part of our now revised field risk assessments. I have forwarded your paper to our WHS [Work Health and Safety] officers regarding the threat posed to staff. This will result in a number of working parties to be established to assess insurance and WHS implications of this threat from undergraduate students through to senior staff venturing into the field."
- "We at the National Vietnam Veterans Museum salute you. Most Australian veterans are aware of drop bears and have conscientiously offered warnings on at least one occasion to their more junior or newer members."
- "I am especially grateful for the tips regarding Vegemite application. I don't believe GNSS has ever drawn more interest from a wider audience than when combined with one of Australia's most fascinating creatures."
- "We have a real problem with drop bears here in Logan [Queensland], so this research is much appreciated."
- "It is general knowledge around these parts that drop bears almost seem to have a craving for tourists visiting the Gippsland Lakes [Victoria]. Boat tours are now offering discount prices on neck braces and thick woolen scarves to try and thwart any attempts of a 'lock on' by any fury offender."
- "We at the University of Exeter [England] are really enjoying your drop bear paper – despite our Head of School being Australian, few people had heard of drop bears and most fell for it until they hit the Vegemite section. I am a biologging ecologist and this paper is going to become a classic for my future teaching."
- "I shared the article with friends and colleagues and all but one loved it. This one colleague almost fell for it. She checked out the Australian Museum webpage and it took a while before she cottoned on (well, she's from South Africa and has only been here a couple of years, so we'll let her off). I especially enjoyed the references."
- "It is brilliantly executed – had me weeping with laughter. The references alone are very, very clever. Thank you for injecting fabulous humour and wit into the dry halls of academia."
- "Your article has inspired me as an outstanding example of scholarly and nationally significant research, innovative study design, and the timely dissemination of findings. I am sharing the article widely – my colleagues in the Academy of Science and CSIRO are impressed by its citability."
- "The paper should be required reading for all PhD students on how to construct a journal paper, and to teach them a bit of Australia that I thought had been lost for the last 30 years. I have just added it to the reading list for the [students' field trip] and the suggestion that their lunch should be Vegemite sandwiches."
- "Your ground-breaking research on drop bears is an invaluable tool for environmental lawyers. Many thanks for this worthy contribution to the study of Australia's biodiversity. The walls were shaking with laughter."

These examples clearly show the positive impact humorous science can have. However, it must be noted that (very little) negative feedback was also received, even including an accusation of academic misconduct. Apparently, the humorous nature of the paper was not clear enough to everyone. Hopefully this study and the wide-ranging, inter-disciplinary discussions it was able to initiate amongst professionals and the general public will not only contribute to a happier coexistence of drop bears and humans but also encourage others to embrace the funny side of science.

Other amazing animals

Several other studies have successfully unlocked mysteries in the animal kingdom. Dacke et al. (2013) showed that dung beetles use the Milky Way for orientation. They experimentally determined that dung beetles transport their dung balls along straight paths under a starlit sky but lose this ability under overcast conditions. On a starlit night, beetles were released with their dung balls from the centre of a circular arena of levelled sand. This was repeated after obscuring the beetles' dorsal visual fields with small cardboard caps to prevent them from seeing celestial cues. Filming the beetles from above, their rolling paths were reconstructed and measured, clearly showing much shorter radial paths under clear conditions (Figure 3). In a planetarium, the beetles orientated equally well under a full starlit sky or the Milky Way only but took much longer when presented with only the 18 brightest stars or total darkness. Dung beetles therefore do not rely on a single bright (guiding) star but use the band of light representing the Milky Way for orientation, most likely not being able to discriminate individual stars.

In a paper whose initial findings were presented at a conference as 'How do wombats make cubed poo?' but which received a more mundane title upon publication, Yang et al. (2021) explained this mystery about a much-loved Australian marsupial renowned for its unique production of cubic faeces. Combining experimental and numerical elements of the study, it was shown that these cubes are formed within the last 17% of the intestine, exhibiting regions with a two-fold increase in thickness and a four-fold increase in stiffness, which facilitates the formation of corners by contractions of the intestine. Wombats use these faeces as markings

within their territory, deposited in aggregations found on or next to distinctive landscape features, such as prominent rocks, logs, small rises and burrow entrances. Their cubic form prevents the faeces from rolling off these raised surfaces.

Meyer-Rochow and Gal (2003) investigated the pressures produced when penguins poo. Measuring the distance the faecal material travels before it hits the ground, its density and viscosity, and the shape, aperture and height above ground of the rectal vent (Figure 4), they calculated that adult penguins generate pressures of around 10 kPa to expel watery material (corresponding to the pressure occurring at the bottom of a 1 m water column) and 60 kPa to expel material of higher viscosity similar to olive oil. The forces involved are well above those known for humans but do not lead to an energetically wasteful turbulent flow. Whether a penguin chooses the direction into which it decides to expel its faeces, and what role the wind plays in this regard, currently remains unknown.

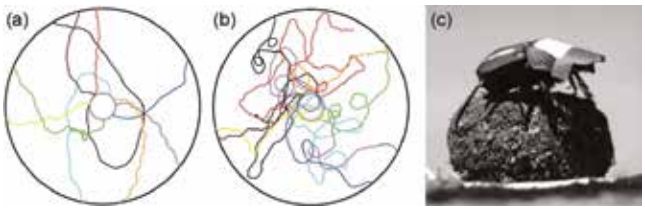

Figure 3: Paths of dung beetles rolling outward from the centre of a circular arena with (a) clear and (b) obstructed views of a moonless night sky, and (c) small caps attached to the beetle enabled blocking its view of the sky (Dacke et al., 2013).

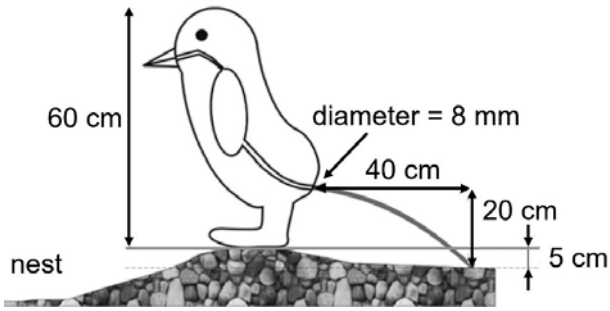

Figure 4: Penguin during defaecation and physical parameters used to calculate rectal pressure necessary to expel faecal material over a distance of 40 cm (Meyer-Rochow and Gal, 2003).

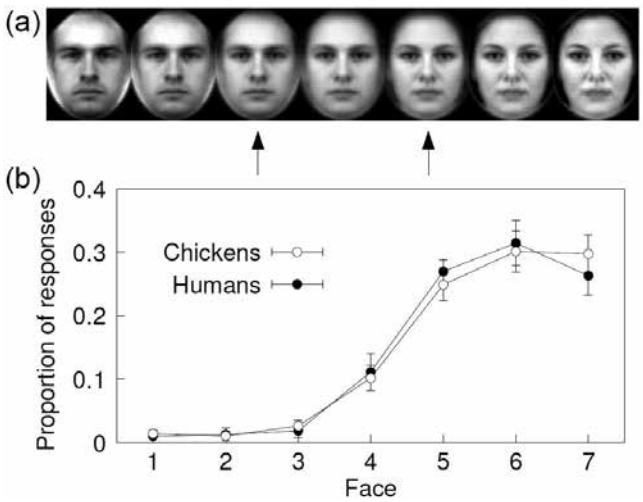

Figure 5: (a) Generated test faces with the average male and female face indicated by an arrow, and (b) average proportion of pecks by chickens in response to these faces along with human ratings of the same faces (Ghirlanda et al., 2002).

Moving on to farm animals, Harvey et al. (2002) analysed the forces required to drag sheep over various surfaces to help improve work health and safety associated with sheep shearing. An experiment using eight experienced shearers, five sheep and 400 trials in total revealed significant changes in the mean dragging force depending on surface texture and slope. The best option was found to be a floor sloped at 1:10 (5.6°) constructed of timber battens that are oriented parallel to the path of the drag, resulting in a 15% reduction of the mean dragging force compared to the worst combination tested. While amusing to others, this research will be much appreciated by shearers who drag and shear up to 200 sheep per day.

In a more obscure example, Ghirlanda et al. (2002) determined that chickens prefer beautiful humans. By averaging 35 individual images each of males and females, average male and female faces were generated. A third face was obtained by averaging these two averages. Graphical image manipulation (linear extrapolation based on pixel patterns) was then used to create four additional faces, showing either exaggerated male or female traits, resulting in a set of seven faces increasing in femininity from left to right (Figure 5a). Biology students (7 males, 7 females) were asked to rate all faces, in random order and on a scale from 0 to 10, according to how desirable it would be to go on a date with the portrayed person. The total scores collected by each face were transformed into relative scores, allowing comparison with animal data. Chickens (2 roosters, 4 hens) were first trained by being rewarded with food after pecking at the average male (hens) or female (roosters) face and then shown all seven faces at random. The results showed that human and chicken behaviour was almost identical (Figure 5b), thus proving that chickens prefer beautiful humans.

Hart et al. (2013) demonstrated that dogs are sensitive to small variations of the Earth's magnetic field by measuring the direction of the body axis in 70 dogs of different breeds during defaecation and urination over almost two years (7,475 observations in total). The dataset was sorted according to the geomagnetic conditions prevailing during the respective sampling periods, and relative declination and intensity changes of the magnetic field during the dog walks were calculated. Circular statistics revealed that dogs preferred to excrete with their body aligned along the north-south axis under calm magnetic field conditions but abolished this directional behaviour under unstable conditions.

The best predictor of the behavioural switch was the rate of change in declination, i.e. the polar orientation of the magnetic field, rather than geomagnetic intensity changes. However, it was noted that calm magnetic conditions occurred in only 30% of all cases.

Perhaps unsurprisingly, Wilkinson et al. (2011) found no evidence of contagious yawning in the red-footed tortoise, although it was not for lack of trying. Over 6 months, a demonstrator tortoise was trained to yawn when presented with a red stimulus. Six observer tortoises were then exposed to three conditions: observation of trained yawn, observation of non-yawning demonstrator (non-demonstration control) and observation of red square-shaped stimulus without demonstrator present (stimulus-only control). Measuring the number of yawns for each observer animal in each condition revealed no significant difference between conditions, even after increasing the number of trained yawns presented. Considering that the tortoises may not view the trained yawn as a real yawn, another experiment used video-recorded stimuli (real yawn, trained yawn and empty background), again showing no significant difference. This null result suggests that contagious yawning is not the result of a fixed action pattern but involves more complex social processes.

Finally, Reimers and Eftestol (2012) investigated the response behaviour of reindeer towards humans and humans disguised as polar bears. They measured response distances (alert, flight initiation and escape) for reindeer from a stalking polar bear and improvised approaches from a person disguised as a polar bear for comparison with human encounters. Alert distance is the distance from the approacher when the reindeer exhibited an increased alert response while staring at the approacher. Flight initiation distance is the distance from the approacher when the reindeer initially took flight. Escape distance is the shortest straight-line distance from where the reindeer took flight to where it resumed grazing or bedded down. It was found that these response distances, measured using a laser rangefinder, were up to 2.5 times longer when reindeer were encountered by a person disguised as a polar bear compared to a person in hiking gear, showing a higher perceived threat level regarding polar bears. The similar reindeer response behaviour observed from one encounter with a real polar bear and five encounters with persons disguised as polar bears indicated a predator-prey relationship between the two species. This was explained by a polar bear population increase and sea-ice cover decrease during summer, resulting in more frequent interactions with reindeer.

Conclusion

The selected studies have provided entertaining and somewhat unexpected insights into animal behaviour and ecology, often employing spatial tools and innovative approaches to data collection and analysis. It is hoped that these important research efforts will continue, so we can further advance our understanding of the animal kingdom, allow animal conservation practices to be enhanced, and have some fun along the way. In particular, further research is required to fill the current knowledge gap related to mysterious animals such as the bunyip, hoop snake or gravel shark.

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Satellite based assessment of the damage caused by Tauktae cyclone in Gir protected area

Cyclone 'Tauktae' hit the Gujarat coast, India on May 17, 2021, which affected the Gir National Park, a wildlife sanctuary for Asiatic lions. In order to do a quick assessment of the affected area, a suite of optical and microwave satellite datasets were analysed for pre and post cyclone periods

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Image fusion of microwave and optical remote sensing data for damage assessment in windswept forests is one of the best strategy.

Abstract

A cyclone named, 'Tauktae' hit the Gujarat coast of India on May 17, 2021, which affected the Gir protected area. The Gir Forest National Park is a wildlife sanctuary in western India that was established in 1965 to protect Asiatic lions. In order to do an assessment of the affected habitat of lion, a suite of optical and Synthetic Aperture Radar (SAR) space borne satellite datasets were analysed. Pre and post cyclone periods were acquired along with past years historical datasets of same periods to study the deviations of signals from the mean of normal years. Vegetation indices with textural measures (entropy) were considered for the damage assessment. Finally, the fusion of optical and SAR data was done for assessment on varying degree of damages. Around 30 per cent area was found affected while estimated damaged area had inherent error margin of ± 5 per cent, with a confidence level of 95 per cent. Deriving the average density of the trees in Gir protected area with drone-based survey, it was predicted that around 3.3 million trees were affected (under moderate to high category). This technique of damage assessment for a large protected area is very useful for the park managers.

Introduction

A very powerful tropical cyclone was born over the Arabian Sea on May 13,

2021, later named as "Tauktae" which subsequently made landfall in the Indian state of Gujarat (approx. 27 km east of Diu) on May 17, 2021. After making landfall, moving further inland it gradually weakened and ended as a low-pressure area on May 19, 2021 (fig.1A). At the time of landfall on the Gujarat coast, Tauktae reached its peak intensity with maximum 3-minute sustained winds of 195 km/h and maximum 1-minute sustained winds of 220 km/h, and a minimum central pressure of 950 millibars making the storm the equivalent of a Category-4 tropical cyclone on the Saffir–Simpson scale[1]. The districts of Junagadh, Gir-Somnath, Amreli and Bhavnagar were highly affected by heavy rainfall and winds (fig.1B). The high wind velocity in Gir forest area reportedly overturned a large number of trees.

The major objective of this study was to have a quick assessment of damage caused using space-borne optical and synthetic aperture radar data. Vegetation indices (VIs) in optical and synthetic aperture radar (SAR) domains were derived for pre-cyclone and post cyclone periods

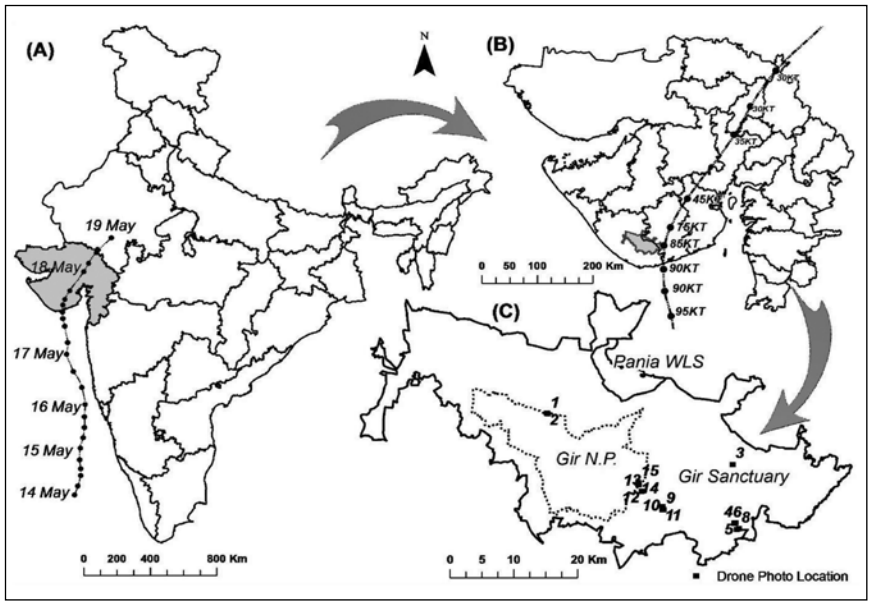

Figure 1. Study area showing (A). Track of Cyclone Tauktae over Arabian Sea and India, (B). Track of Cyclone Tauktae with speed in Knots (1KT = 1.852km/h) (C).Study area with Gir protected area boundary including Gir national park, Gir sanctuary and Pania wildlife sanctuary.

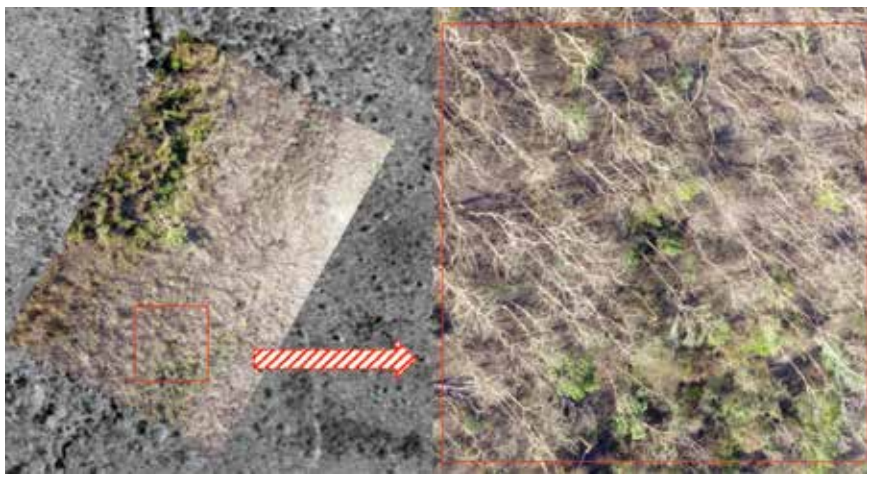

Figure 2. Drone photograph (no. 10 of fig.1C) registered using high-resolution Cartosat data for quantification of trees affected in 1 ha plot (red box area).

Gir National Park and Wildlife Sanctuary, also known as Sasan Gir, is a forest and wildlife sanctuary to conserve the Asiatic Lion. It was established in 1965 with a total area of 1,412 km^2 of which 258 km^2 is fully protected as national park and 1,153 km^2 as wildlife sanctuary. Pania wildlife sanctuary (39.63 km^2) was also included in the study area as it's an integral part of Gir protected area (fig.1C). Altitudinal range of the area varies between 83 - 524 m above mean sea level. The area is a dry deciduous open scrub forest with dry savannah. *Acacia, Butea, Diospyros, Ficus, Syzygium, Tectona, Zizyphus* etc are the main tree species of the area. Approximately, 63.5 per cent area has forest canopy density < 10–40 per cent, and about 35.89 per cent forest has density > 40 per cent to > 70 per cent (Alam et al., 2014). Phenology of this dry deciduous forest is marked with leaf fall in the winter months and maximum senescence is observed in the summer months (March – May).

Materials and methods

The major objective of this study was to have a quick assessment of damage caused using space-borne optical and synthetic aperture radar data. Vegetation indices (VIs) in optical and synthetic aperture radar (SAR) domains were derived for pre-cyclone and post cyclone periods. Sentinel-2B MSI (Multispectral Instrument) band 4 – Red and band 8 – NIR datasets at 10 m spatial resolution with acquisition dates of 10 and 20 May 2021 (pre and post cyclone), 20 May 2020,

18 May 2019, 18 May 2018 and 23 May 2017 (historical data of post cyclone dates) were used. Sentinel-1A C-Band SAR datasets at 10 m spatial resolution with acquisition dates of 9 and 21 May 2021 (pre and post cyclone), 26 May 2020, 20 May 2019, 25 May 2018 and 18 May 2017 (historical data of post cyclone dates) were also used. The standard pre-processing techniques were used for arriving at the Normalized Difference Vegetation Index (NDVI, eq.1) and Radar Vegetation Index (RVI, eq.2) followed by computation of anomalies from mean trends of the past years. All the standard pre-processing and post-processing steps were followed using open domain software suits. In order to remove the incidence angle effect in SAR data, the backscattering across the range was normalized using the calibration coefficients. The backscatter coefficient in the normal unit domain was used for computation and then finally converted into log domain, to avoid arithmetical errors. The scattering characteristics of forest vegetation and other land use types were studied using dual-pol data over the study site, both in pre and post cyclone phases.

Care was taken to understand the forest – SAR interactions under the given conditions with respect to the canopy, vegetation structure and background information. Both the vegetation indices (NDVI and RVI) were subjected to slicing (thresholding) based on post cyclone field photographs (drone survey pictures provided by Gujarat forest department, see the locations in fig.1C) and statistical distributions of the data, in order to come out with qualitative assessment on affected areas. The drone survey photographs were registered with archived Cartosat-2C (60 cm spatial resolution) and were used (with 10 - 13 cm spatial resolution) in the analysis as the ground truth information (fig.2). From the limited set of photographs obtained, the tree density over the area was also computed.

$$NDVI = \frac{(\varrho NIR - \varrho R)}{(\varrho NIR + \varrho R)} \qquad (1)$$

Where, ϱNIR = Reflectance of Near Infrared band and ϱR = Reflectance of Red band

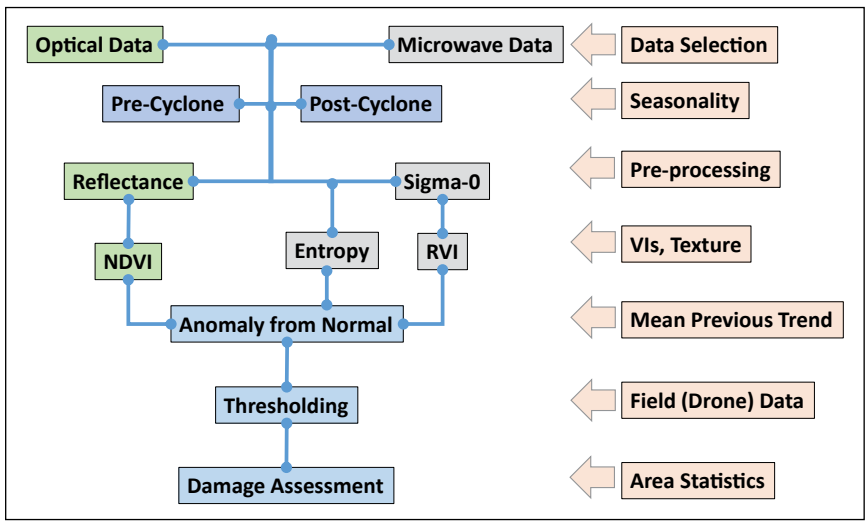

Figure 3. Methodology flowchart for assessment of apparent damage in Gir protected area.

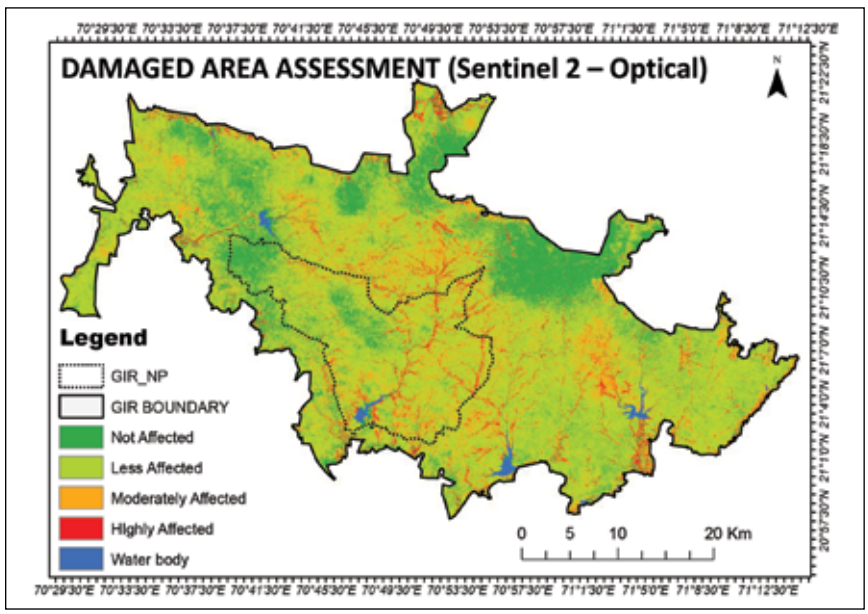

Figure 4. Map showing affected areas with varying degree due to Tauktae cyclone in Gir protected area as assessed from mean NDVI anomaly observed in post-cyclone data from Sentinel-2 (Optical).

The observations derived from optical remote sensing data relied mainly on detecting the changes in greenness level considering the fact that some of the areas along the moisture zone (drainages) which were having leaf-on trees may have changed after being uprooted due to cyclone

Table 1: Area statistics on damage due to Tauktae Cyclone in Gir protected area as assessed from [A] mean NDVI anomaly from post-cyclone data of Sentinel-2B MSI, [B] mean RVI anomaly from post-cyclone data of Sentinel-1A SAR and [C] ensemble of optical and SAR products.

SN	Class	[A] Area in km² (per cent)	[B] Area in km² (per cent)	[C] Area in km² (per cent)
1	Not Affected	291 (20)	470 (32.7)	104 (7.2)
2	Less Affected	834 (57.4)	651 (45.1)	895 (61.6)
3	Moderately Affected	255 (17.6)	196 (13.3)	401 (27.6)
4	Highly Affected	60 (4.2)	123 (8.1)	40 (2.8)
5	Water body	12 (0.8)	12 (0.8)	12 (0.8)
	Total	1452 (100)	1452 (100)	1452 (100)

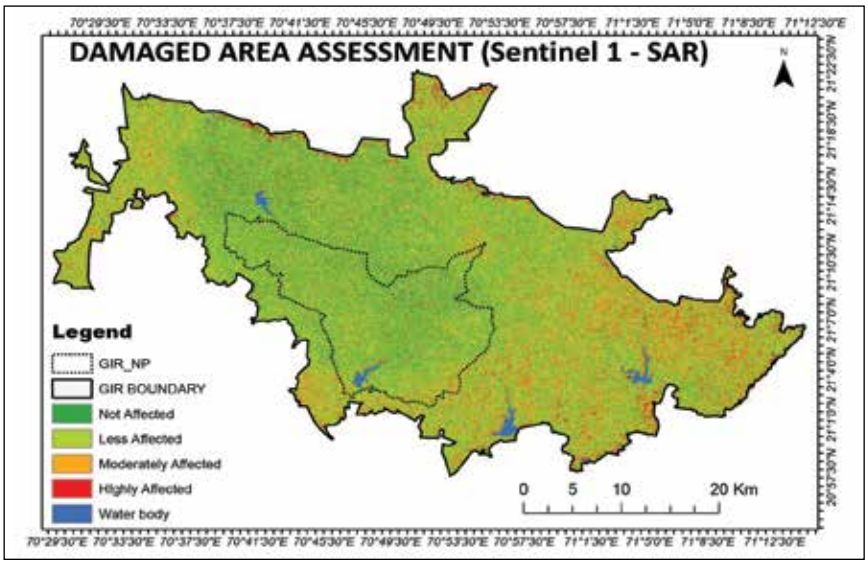

Figure 5. Map showing affected areas with varying degree due to Tauktae cyclone in Gir protected area as assessed from mean RVI anomaly from Sentinel-1 (SAR).

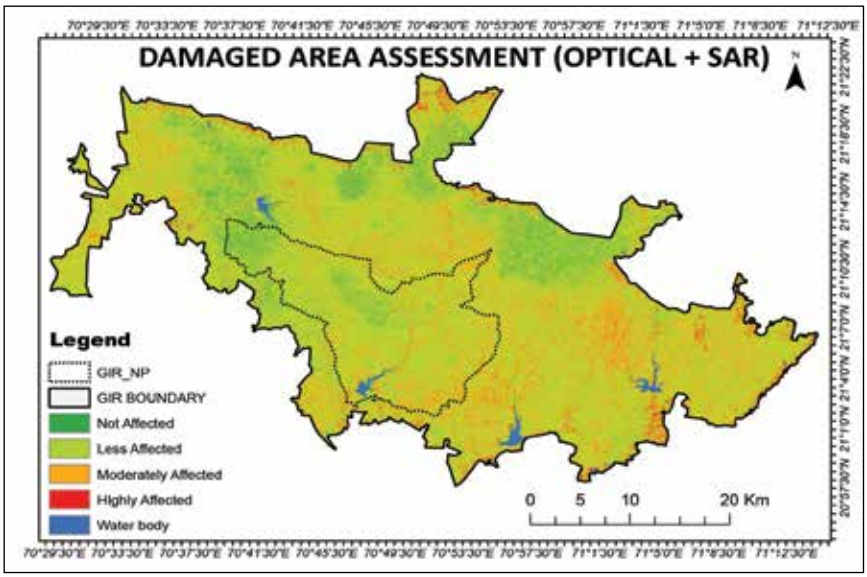

Figure 6. Map showing affected areas due to Tauktae cyclone in Gir protected area as assessed from combination of NDVI anomaly from Sentinel-2 (Optical), RVI anomaly from Sentinel-1 (SAR) data, Entropy difference and VH polarisation difference.

$$RVI = \frac{(4 * \sigma^{o}_{VH})}{(\sigma^{o}_{VH} + \sigma^{o}_{VV})} \qquad (2)$$

Where, σ^{o} = Sigma-nought, VH = vertical transmit and horizontal receive and VV = vertical transmit and vertical receive

SAR data was also used for computation of change in entropy of the study site in post cyclone period as compared to pre cyclone. Grey Level Co-occurrence Matrix (GLCM) based measure of entropy with direction invariant relationships were considered. A window size of 15x15 was used for the construction of the GLCM on SAR data. The entropy could not reveal the subtle textural variations through the entire study area. However, the information layer from entropy was used in conjunction with the cross polarisation ratio of VH/VV and VH to demarcate zones of potentially affected areas as a preliminary guide to the analysis. The RVI anomaly was then used in conjunction with the optical data based NDVI anomaly to do a conformity analysis and to ascertain the actual affected area. Combining these two sets of information, also eliminated bias and uncertainty as both the sensors view the target differently. The overall methodology flowchart is given in fig.3.

Results and discussion

Since two different methods of evaluation having different physical basis of observations were adopted, the results were first analyzed separately. The

SAR backscatter values from the forest vegetation during the driest months of the year tend to show a decrease, which is more prominent in the VH polarization

It is evident from the analysis that the Tauktae cyclone has affected approximately 30 per cent (441 sq km) of the Gir protected area with moderate to severe impact, primarily distributed across eastern Gir to Central Gir. Considering the average density of the trees in Gir forest of 75 Trees / 10,000 square meters (estimated from drone photographs), it is predicted that around 3.3 million trees would have been affected

observations derived from optical remote sensing data relied mainly on detecting the changes in greenness level considering the fact that some of the areas along the moisture zone (drainages) which were having leaf-on trees may have changed after being uprooted due to cyclone. The area affected due to cyclone were mainly found scattered around the moisture zone in the Gir protected areas as seen in fig.4. The area statistics is provided in table.1[A], which indicates that around 21.8 per cent area was affected under moderate to high category.

SAR backscatter values from the forest vegetation during the driest months of the year tend to show a decrease, which is more prominent in the VH polarization. The affected areas showed anomaly in backscatter, which could be due to two main reasons, the structural changes in the tree orientation and the underlying soil. As scattering from soil under the uniform roughness conditions can be considered nearly similar, both under very dry and very wet conditions. It was assumed to contribute marginally to the mean difference of RVI pre and post cyclone. The changes in the backscatter can be attributed more to the trunk and branches. To further the analysis, the post cyclone RVI was compared against the mean RVI of the preceding five years data and the anomaly in the RVI revealed the significant changes in the backscatter, which are indicative of the affected area. From the difference of the RVI it was found that most of the sanctuary was affected. The changes in SAR based RVI anomaly data is mainly attributed to change in structural component (vertical trees in pre-cyclonic period to horizontal trees in post cyclonic period), assuming that moisture in the area due to rains remain same. The result of the anomaly in RVI is shown in fig. 5 and areas statistics is given in table.1[B], which indicates that around 21.4 per cent area was affected under moderate to high category.

Though, the figures in both the assessments for moderate to highly affected areas (21.8 per cent in optical and 21.4 per cent in SAR) look similar, the spatial disturbance zones do not have exact match. Therefore, a map was constructed from the synergistic use of NDVI anomaly, RVI anomaly, entropy difference (pre – post) and difference in backscatter (pre – post) from target in VH polarization so that, the mutually exclusive affected areas could be identified. The ensemble product of optical and SAR data was subjected to thresholding based on quantile (by dividing the histogram into areas of equal probability) to arrive at qualitative assessment on varying degree of damages caused by Tauktae cyclone, as shown in figure 6 and table.1[C]. Though the whole sanctuary was affected, the eastern part shows slightly higher magnitude than the west. The estimated area has inherent error margin of ± 5 per cent, with a confidence level of 95 per cent arising due to mapping inaccuracies and thresholding.

Conclusion

It is evident from the analysis that the Tauktae cyclone has affected approximately 30 per cent (441 sq km) of the Gir protected area with moderate to severe impact, primarily distributed across eastern Gir to Central Gir. Considering the average density of the trees in Gir forest of 75 Trees / 10,000 square meters (estimated from drone photographs), it is predicted that around 3.3 million trees would have been affected (under moderate to high category). More analysis with very high-resolution data may be taken up to assess quantitative damages and loss of trees.

Endnote

[1]Special Tropical Cyclone Outlook for Cyclone Tauktae No. 19, https://mausam.imd.gov.in. India Meteorological Department. Accessed on: 17 May 2021.

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Spatial dependencies in land use and irrigation access in Northern Peru

Spatial relations are explicitly modelled using spatial weighting matrices which can be applied to the dependent, independent or error terms in regressions

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Abstract

The potential existence of spatial dependencies in land use and irrigation access in mountainous areas like the Peruvian Andes is a relevant issue for designing and implementing more effective policies for landscape management. In this paper we explore some of these potential interactions in the northern Andean region of Cajamarca (Peru) using a "spatial econometrics" approach. Spatial relations are explicitly modelled using spatial weighting matrices which can be applied to the dependent, independent or error terms in regressions. We estimate alternative specifications of spatial models assessing their statistical robustness. We find evidence of the importance of upstream land use decisions for increasing irrigation access.

Introduction

In this study we evaluate factors shaping access to irrigation in the northern region of Cajamarca, one of the most agrarian (and poorest) areas of Peru. The potential for developing more irrigation in the Peruvian Andes is a key issue in the ongoing discussion about possibilities for eradicating poverty in the most deprived regions of the country. In this work we find evidence on the importance of geographical, institutional, and some farmers' attributes influencing irrigation access, and these should be taken into account to make policy more effective and sustainable over time.

In particular, we are interested in finding evidence about the potential existence of spatial dependencies in land use and irrigation access in mountainous areas like the Peruvian Andes. This issue is key for designing and implementing effective irrigation policies and landscape planning strategies. With land and water use ranging from 0 to 4,000 meters above sea level (m.a.s.l) within the same Andean basin, the possibility of multiple spatial and social dependencies becomes a key factor for understanding and assessing options and policies for expanding irrigation access, a key factor for increasing agricultural productivity and income. Access to irrigation is a topic in which these interactions may be especially important in the Andean context as water is stored (naturally or artificially) in upstream snowy peaks (*nevados*), ponds, lakes or dams, and must travel downstream through a set of rivers, tributaries and channels to reach a myriad of (mostly clustered) irrigators.

In this study we explore some of these interactions in the northern Andean region of Cajamarca (Peru) using a "spatial econometrics" approach. Spatial relations are explicitly modelled using spatial weights matrices which can be applied to the dependent, independent or error terms in regressions. To our knowledge, there has not been previous applications of this approach to the Andean

We are interested in finding evidence about the potential existence of spatial dependencies in land use and irrigation access in mountainous areas like the Peruvian Andes. This issue is key for designing and implementing effective irrigation policies and landscape planning strategies

environment, which offers a promising venue for improving knowledge and policy options for land and water management (Lewis et al, 2008).

Our study fits into an increasing amount of research using a geographical or spatial analysis to assess irrigation access around the world. For instance, Lozano-Espitia and Ramirez-Villegas (2016) use geo-referenced information at municipality level in Colombia to assess the impacts of various rural infrastructures (including irrigation) in the productivity of crops. Lobell et al (2010) use satellite data for identifying factors affecting yields in India, finding that the distance to irrigation canals has statistically significant impacts on increasing crop yields.

Literature review

There are thousand of entries in the international literature regarding irrigation and its role in economic and social development. For the purposes of this study, we distinguish some approaches that seem to us are most useful. First, there are many studies assessing the impact of irrigation on various measures of well-being, asset value and productivity of farmers. Joshi et al (2017) estimated an increase of 46% in the value of the land associated with the irrigation versus those that do not have this status in Nepal. Dillon (2011) estimated that access to irrigation increases the consumption of households in 27-30% in rural Mali, with increases in the accumulation of livestock assets as well. For Ethiopia, Gebregziabher et al (2009) calcalated an impact of more than 50% in farmers' income from irrigation, whereas Yasuyuki et al (2014) show for Sri Lanka that access to irrigation not only raises incomes, but also changes the flows of these, reducing the likelihood of being credit constrained in financial markets. For Peru, using the National Household Survey-ENAHO, Zegarra (2014) found significant impacts on the incomes of farmers in the three natural regions. For the coast, the expected income impact is 1,584 annual soles per capita; in the sierra of 593 soles and in the jungle of 1,267 annual soles per capita. In all these studies, focusing on impacts on income, consumption or some assets, the evaluation is done at the level of agricultural households, usually with comparison to control groups. In these cases, it less common to find geographic variables playing some role as critical determinants for access or impacts of irrigation.

A related entry of interest are the ones analyzing diverse factors that determine access to irrigation, both at the level of individual farmers and at different levels of social or geographic aggregation. It should be noted that some of the previous studies that assess impacts, also perform some micro-economic analysis of factors that determine individual access. This analysis is needed to establish the comparability between the treatment and control groups. An example of this type of analysis is Sinyolo et al (2014) for South Africa. The authors find statistical relevance for factors influencing irrigation access in variables like perceived fertility of the soil, size of households and access to support services, that they consider as good predictors of access to irrigation in a sample of farmers.

There is another set of works that take a more geographical or spatial approach both for the estimation of impacts and, sometimes also for identifying factors influencing irrigation, which is the approach that we adopt in the present study. For instance, Lozano-Espitia and Ramirez-Villegas (2016) use geo-referenced information at municipality level in Colombia to assess the impacts of various rural infrastructures (including irrigation) in the productivity of crops. Lobell et al (2010) use satellite data for identifying factors affecting yields in India, finding that the distance to irrigation canals has statistically significant impacts on increasing crop yields.

There are also studies relating climate change and irrigation in different contexts. Causality in these studies may go from the effects of climate change to the patterns and practices of irrigation (Ponce et al, 2015; Zhang et al, 2015; Skarbo and VanderMolen, 2014), or from irrigation adoption and practices into climatic variables and their interaction with the process of climate change (Im et al, 2014; Okada, 2015).

Another line of work (of most interest to us) is the assessment of various geographical, economic and institutional variables to estimate and predict access to irrigation. A still small branch of research is related to institutional factors (such as communal organization, levels and types of land tenure) in access to irrigation. A study of this type is Saldias et al (2013) for Bolivia, who assess the variability in access to irrigation for various forms of community organization in a large rural area of Bolivia. A more qualitative analysis was carried out for the Sierra Colca Valley (Arequipa) in Peru by Delgado and Linden (2013).

A related branch of research seeks to estimate the potentials for irrigation development in particular geographical contexts. You et al (2014), for example,

use geographic models to identify areas with the greatest potential for the development of irrigation in Kenya. A previous work of this type (You et al, 2011) generated estimates for the entire African continent, based on a composition of different layers with geographical information on water availability, topography, expected yields and existing and planned water storage capacity. A similar exercise for Ethiopia is the one of Worqlul et al (2015); and the development of irrigation with groundwater from Ghorbani et al (2017) in Iran.

A general trait of these studies is that, even as these are geographical, the spatial interactions of observational units are not explicitly modelled. This is what distinguishes the so called spatial econometric approach (Anselin, 2003; Kelejian and Piras, 2017). In this approach spatial dependencies are explicitly modelled using weighting matrices with some associated parameters that account for the strength of the spatial dependency. A critical advantage of this modelling (over standard non spatial linear regressions) is that spatial autocorrelation (for example in errors) is generally reduced or eliminated, rendering more consistent estimates of coefficients.

Area of study and data description

The northern Peruvian region of Cajamarca (limiting with Ecuador) may be considered as the most agrarian region in the country: it has the largest number of farmers, 340,000 or 16% of total according to the last agricultural census (CENAGRO, INEI, 2012). It is also one of the poorest regions, with very high incidence of poverty and extreme poverty. The agricultural sector is characterized by severe difficulties for farmers to accessing infrastructure, markets and services (Zegarra and Calvelo, 2006).

In terms of irrigated land, Cajamarca ranks 13 of 20 among sierra regions, with 66,000 Ha. of irrigated land, representing 21% of cropped agricultural area. The per capita area under irrigation of Cajamarca is only 0.289 Ha per farmer, well below some of the most important regions of Sierra. The average allocation of area under irrigation in Cajamarca can hide important variations within the region, as can be seen in Figure 1 with the location of census tracts and their percentage of cropped land under irrigation.

Access to irrigation is heterogeneous across the region, with more relative access in the lower western areas of San Miguel, San Pablo, Chota and Jaén and in the eastern areas of Jaén and in less extent Celendín. The southern side of Cajamarca province and central parts of Cajabamba also show more relative access to irrigation. Some provinces like San Ignacio, Cutervo, Hualgayoc and most of eastern Chota do not have irrigation at

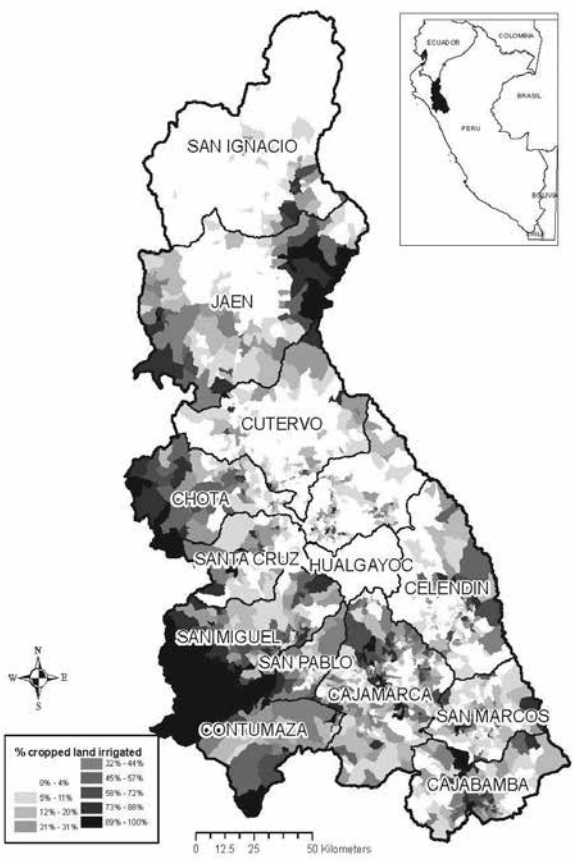

Figure 1: Cajamarca: percentage of cropped land with irrigation (%)

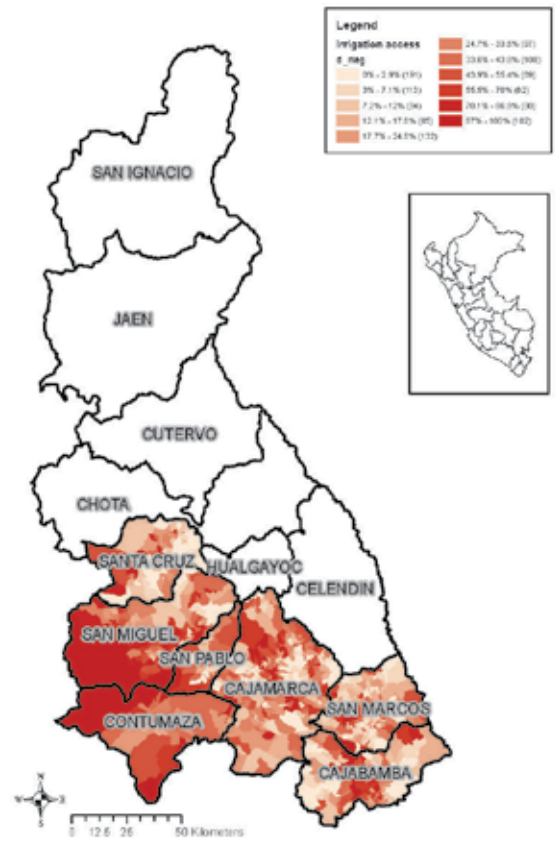

Figure 2: Study Area

Table 1. Mean values of variables based on percentage of irrigated area (quintiles)

	Quintiles of % irrigated land					Total
	1Q	2Q	3Q	4Q	5Q	
Irrigated area (%)	1.4	10.0	23.7	45.8	83.8	32.9
Geographical						
Altitude (m.a.s.l)	2,940	2,941	2,866	2,796	2,392	2,787
Slope (degrees)	17.8	18.3	18.6	17.8	14.8	17.5
Distance to river (km)	1.5	1.4	1.3	1.0	0.8	1.2
Distance to dam (km)	16.6	19.5	18.3	17.2	16.4	17.6
Climate						
Rainfall dry season (mm)	33.5	28.4	26.8	25.3	25.9	28.0
Rainfall year (mm)	72.1	68.1	67.4	67.1	65.4	68.0
Temperature (max)	22.3	22.3	22.0	21.5	21.7	21.9
Land use						
Forest (has)	33.1	36.3	74.4	60.7	159.0	72.6
Pasture (has)	98.4	406.4	324.6	288.6	230.0	269.6
Permanent (has)	3.2	1.6	3.2	5.8	16.1	6.0
Institutional and socioeconomic						
Distance to city (km)	12.1	11.4	11.1	10.4	8.5	10.7
Number of farmers	121.2	117.3	123.2	124.7	128.6	123.0
No titled land (%)	28.0%	27.2%	31.4%	25.9%	23.5%	27.2%
Age	45.9	47.2	48.0	47.9	49.1	47.6
Education level	3.5	3.4	3.5	3.5	3.8	3.6

all. For this study we focus on seven southern provinces of the region as shown in Figure 2 which also displays the percentage of agricultural land under irrigation in each agricultural census tract.

Access to irrigation is heterogeneous across the study area, with more access in the low altitude coastal zones. Table 1 shows means (by agricultural tract) of geographical, climate, land use and socio-economic variables. Mean values are measured across quintiles according to the proportion of cropped area under irrigation.

As basic geographical variables[1] we include altitude, slope and the shortest Euclidean distances from census tracts' centre points to water sources like rivers and dams (excluding dams related to mining). As rainfall and temperature variables we projected data from meteorological stations to the overall study area. These variables are potentially important in influencing both the water supply and the demand for irrigation. From the 2012 agricultural census we calculated land use (forest, pasture and permanent crops) and other socio-economic variables like number of farmers, percentage without land title, age and education that are factors potentially affecting irrigation patterns as well. We also estimated Euclidean distances to the nearest city (of more than 3,000 inhabitants) to account for distance to market.

Descriptive figures in Table 1 show some potential patterns along irrigation quintiles. Less irrigation is more likely to occur with higher altitude, and longer distances to rivers and to dams, and also with steeper slopes and more rainfall (both yearly and in the dry season). Relationships of irrigation with land use variables like presence of forest and permanent crops appear to be positive whereas the relationship with pastures is ambiguous. More distance to markets appears to be negatively related to irrigation, whereas lack of land title may also influence irrigation. Finally, some variables directly related to farmers as age and educational attainment were considered. Apparently, there is a positive relationship between age and education with more irrigation access.

While this initial analysis suggests some potential relationships, it is necessary to evaluate the whole set of explanatory variables using a more formal model and a regression framework that will allow us to establish relationships in a more comprehensive manner, taking into account potential causalities and spatial dependencies. This is what we present in the following section.

Modelling access to irrigation with geographic models

The literature review that was presented earlier summarized different approaches to the quantitative analysis of irrigation under separate socio-economic and geographic contexts. The existence of irrigation will depend not only on geographical factors – such as topography, type of soil, availability of water, precipitation, and distance to alternative sources – but also on several socio-economic and institutional conditions, including public investment, institutional and organizational capacity, and access by the various actors to resources. For this work our goal is to combine these elements into one coherent analytical model that includes with the greatest possible precision some of these geographical and socio-economic factors. Naturally, we proceed cautiously because of the possibility that these 'measurable' empirical variables may not represent adequately or appropriately the theoretical variables.

The most important consideration is the exogeneity of the explanatory variables, and their orthogonality relative to the corresponding error terms. Nevertheless, equally important in models incorporating geographical variables, is the basic assumption about the area or unit of analysis, which in our case will be the agricultural census tracts. It is assumed that our level of analysis is sufficiently detailed to permit the identification of relevant spatial patterns that can explain the phenomenon of interest, namely the extension of irrigation in this territory. With these assumptions we can produce consistent estimates, and – at the same time – generate predictions about the level of irrigation that could exist in the conglomerates, according to the structural conditions, as functions of the independent variables.

Thus, historic, geographic and institutional factors influence irrigation location and expansion. Feasibility of irrigation depends on the topography, soil type, availability of water, distance to alternate water sources, but also on socio-economic

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and institutional factors like past public investment, institutional capacity and social organization, available resources, among others (Kang, 2017; Tsukasa et al, 2013). A key point is that irrigation tends to locate in specific sites, forming clusters. This is expected as irrigation infrastructure shows economies of scale: it is more efficient to build one large integrated irrigation system (reservoirs and canal networks) in one location than many small and dispersed units in a given basin (Zegarra, 2002).

Given these specific features, we need to model access to irrigation as a combination of geographic, climate, land use and socio-economic factors that would reflect--as accurately as possible--some of these characteristics in a particular landscape. For this we consider a very general spatial model like the one described by Kelejian and Piras (2017) for N observations (census tracts):

$$y=\lambda(W_1 y)+X_1\beta_1+(W_2X_2)\beta_2+u \quad (1)$$

$$u=\rho W_3 u+\epsilon \quad (2)$$

where:

y is a Nx1 vector of observations of the dependent variable (irrigation access);

W_i are NxN spatial weighting matrices (with 0 diagonal elements);

(W_1y) and (W_3u) are Nx1 vectors typically referred to as spatial lags, and λ and ρ are the corresponding scalar parameters typically referred to a spatial autocorrelation parameters;

X_1 is an NxK matrix of observations on K exogenous variables and β_1 the corresponding parameter vector;

(W_2X_2) is an NxJ matrix of observations on J spatially lagged exogenous variables and β_2 the corresponding Jx1 parameter vector;

ϵ is an Nx1 vector of random disturbances, uncorrelated with X.

Matrices W's are very important for the explicit spatial specification of the model as these will represent the expected degree of interaction between any observations and neighboring (or more or less closer) units in the same territory. The values (weights) in these matrices try to represent spatial interactions among observations, and parameters λ, ρ and β_2 measure the direction and intensity of these interactions. In terms of an econometric specification, when λ and ρ are assumed equal to 0, the model is the traditional non spatial Ordinary Least Square (OLS). If the "true" model has strong spatial autocorrelation, an OLS estimation of (1)-(2) will generate inconsistent estimates of parameters given the endogeneity of the autoregressive term (Drucker *et al,* 2013).

The matrix (W_2X_2) and vector of parameters β_2 are also important to account for specific spatial dependencies among some specific exogenous variables and the dependent variable. In particular, in our case we will use β_2 the coefficients to estimate the expected effect of exogenous land use variables in the upstream areas on the endogenous irrigation access.

Spatial weights matrices

As discussed in the previous section, a key element in any spatial modelling is the spatial weighting matrix that will identify spatial interactions. How these matrices are specified and used is a central tenet of spatial modelling. In the spatial weighting matrix we define which units are spatially interacting and the intensity of such interaction. It is generally assumed that closer units will have a stronger interaction with a given unit. In summary, the spatial matrix will define which units interact (are considered "neighbours") and what weight will be given to its "influence" on the observed unit (generally depending on distance).

In our case we have two types of weighting matrices in our modelling. First there are the W_1 and W_3 type of matrices as shown in expression (1) which are used for spatially lagging the dependent variable and/or the error term, respectively. For these matrices we generated the standard weighting matrix ($W=W_1=W_3$) based on distance, with a distance decay function for neighbours of up to 20 Km distance from each census tract. This is the matrix we will use for different specifications of (1)-(2).

But we also considered a spatial matrix for lagging some of the independent variables (W_2 type of matrix). This is particularly important for modelling spatial interactions in which we expect that some of the independent variables will have a certain type of spatial relationship with the dependent variable. In the case of irrigation, the ideal data for modelling spatial interactions would be detailed network data, i.e., to know what units are

connected along the irrigation networks. However, this type of data is not easily available, especially for large areas as the one we want to model. Instead, we propose as a feasible option to use the altitude variable for restricting the spatial weighting matrix in order to better reflect the relationship between irrigated and upstream areas in the Andean context.

To operationalize this idea we order the census tracts according to increasing altitude. After doing this we can impose the constraint that no neighbouring unit (within a given distance) can have a lower altitude than the reference unit. This is equivalent to defining that only upstream units are considered as neighbours to each observation.

Thus, we can think of two types of matrices for the study area. The first type of matrix is the normal circle around each

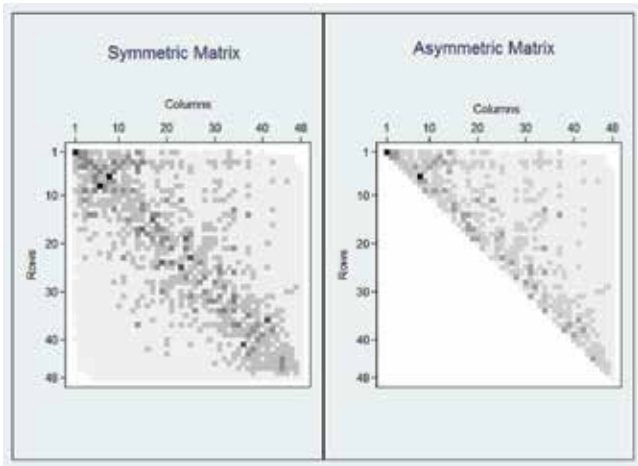

Figure 3. Spatial matrices with and without restriction based on altitude

Table 2. Descriptive statistics of variables used for model estimation

Variable	Mean	Std. Dev.	Min	Max
Log(irrigated area)	2.954	1.559	0.000	9.760
Slope	17.451	6.067	2.558	35.162
Maximum temperature	21.940	1.819	16.422	26.874
Rainfall in dry season	27.989	10.046	4.680	73.947
Log(altitude)	7.901	0.281	5.682	8.279
Log(agricultural area)	4.744	0.900	1.128	9.760
Log(number of farmers)	4.779	0.279	3.611	6.165
Distance to neareast dam	17.607	9.702	0.000	42.850
Distance to nearest river	1.216	1.496	0.000	7.241
Distance to nearest city (>3,000 inh.)	10.711	6.550	0.000	32.786
Log(area with forest)--spatially lagged	1.215	0.697	0.000	3.769
Log(are with pasture)--spatially lagged	1.886	1.054	0.000	7.723
Log(area with permanent crops) spatially lagged	0.223	0.351	0.000	2.806
Percentage without title	0.272	0.253	0.000	1.000
Farmers' age	47.593	5.155	33.188	63.276
Farmers' education	3.557	0.595	1.895	5.809

Table 3. Global models of access to irrigation (dependent variable: log of irrigated area)

	OLS	YLAG	ERRLAG	ERRLAG(W)
Slope	-0.032***	-0.030***	-0.027***	-0.030***
	0.007	0.007	0.007	0.007
Maximum temperature	-0.044*	-0.001	-0.08	-0.11
	0.025	0.025	0.067	0.072
Rainfall in dry season	-0.038***	-0.020***	-0.062***	-0.067***
	0.004	0.005	0.014	0.015
Log(altitude)	-0.084	0.205	0.068	-1.706***
	0.231	0.264	0.519	0.261
Log(agricultural area)	0.784***	0.686***	0.783***	0.777***
	0.048	0.043	0.045	0.046
Log(number of farmers)	0.109	0.227*	0.197	0.183
	0.124	0.124	0.121	0.122
Distance to neareast dam	-0.008	-0.011**	0.003	0.002
	0.005	0.005	0.009	0.01
Distance to nearest river	-0.062**	-0.071***	-0.073***	-0.092***
	0.026	0.024	0.026	0.026
Distance to nearest city (>3,000 inhabitants)	-0.007	-0.009	-0.007	-0.012
	0.006	0.006	0.01	0.011
Log(area with forest)--spatially lagged	0.953***	0.482***	0.785***	-0.375*
	0.147	0.159	0.201	0.226
Log(are with pasture)--spatially lagged	-0.409***	-0.064	-0.241*	0.483**
	0.094	0.107	0.132	0.197
Log(area with permanent crops) spatially lagged	0.502***	0.297	0.265	-0.171
	0.173	0.201	0.244	0.251
Percentage without title	-0.003	-0.047	-0.036	-0.077
	0.144	0.132	0.133	0.135
Farmers' average age	0.024***	0.016**	0.023***	0.025***
	0.008	0.008	0.009	0.009
Farmers' average education	0.098	0.09	0.226***	0.271***
	0.068	0.062	0.072	0.072
Constant	0.292	-4.637*	-0.702	13.809***
	2.32	2.558	4.912	3.049
rho			0.911***	0.939***
			0.04	0.028
lambda		0.535***		
		0.066		
sigma2		1.106***	1.200***	1.120***
		0.046	0.049	0.046
Number of observations	1183	1183	1183	1183
Degrees of freedom	16	18	18	18
Log-likelihood (model)	-1819.4	-1789.8	-1753.9	-1763.2
Akaike's Information Criterion (AIC)	3670.9	3615.5	3543.8	3562.3
Bayesian Information Criterion (BIC)	3752.1	3706.9	3635.1	3653.7
* p<0.1, **p<0.05, ***p<0.01				
Standard errors below coefficients				

observation that can be considered "symmetric" in terms of altitude ($W=W_1=W_3$). The neighbours of a given unit may be at higher or lower altitude, and being a neighbour only depends on Euclidean distances to the observed unit (in a circular area of influence). The second type of matrix (W_2) is asymmetric in terms of altitude as we impose the restriction that a neighbour for a given unit can only be located at higher altitude within a given distance. A graphic comparison of both types of matrices can be seen in the figure 3.

Notice that in the restricted version there are no neighbours below the matrix's diagonal, as these are located at a lower altitude (neighbours can only be located at a higher altitude). We apply the W_2 spatial lagging matrix to the land use variables we think may influence access to irrigation in the downstream areas: area if land with forest, pasture and/or permanent crops. These are the only exogenous variables which will be spatially lagged in our estimations.

Estimating alternative specifications

We will use as dependent variable the log of irrigated area in each census tract. For some of the continuous X variables we also adopted logarithmic transformations[2]. The descriptive statistics and units of measurement of the variables used for estimating the models[3] is presented in Table 2. We include the log of total agricultural land per tract as an independent variable in order to control for any spurious scale effect coming from using as dependent variable the (log of) total irrigated land per tract.

We estimate three specifications of the global model: (i) non spatial OLS, assuming no spatial autocorrelation (ג and ρ are equal to 0); (ii) LAGY, spatial correlation only in the dependent variable ρ =0, known as SAR model, and (iii) LAGERR, spatial correlation only in the error terms so ג =0. We also include a fourth column (iv) in which the LAGERRR model is run with the symmetric W matrix for lagging the land use variables (to check if the choice of W is important). The results are presented in Table 3.

An important issue is how to select the best specification given the data we used for the estimation. In this case the literature recommends using the information criteria such as the Akaike Information Criteria (AIC) and Schwarz's Bayesian Information (BIC). The specification with the lowest value for these criteria is considered the best specification. In this case, the LAGERR specification has the lowest values in both criteria so it is the best specification we can get from these alternative spatial models. We also tried the model selection criteria proposed by Anselin (2005) based on Lagrange Multiplier tests where the OLS specification is compared to alternative spatial models. Using the robust version of the tests as suggested by Anselin[4] we find that only the error lag model is statistically significant and is indeed the best of the three alternative specifications for these data.

Most geographic variables have significant coefficients and expected signs in all the specifications. Altitude and slope have

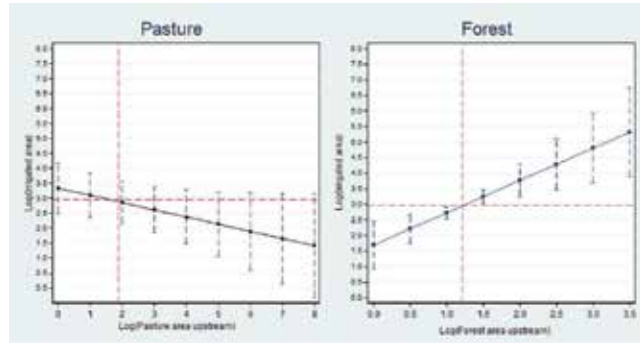

Figure 4. Marginal effects of pasture and forest land use on downstream irrigated land

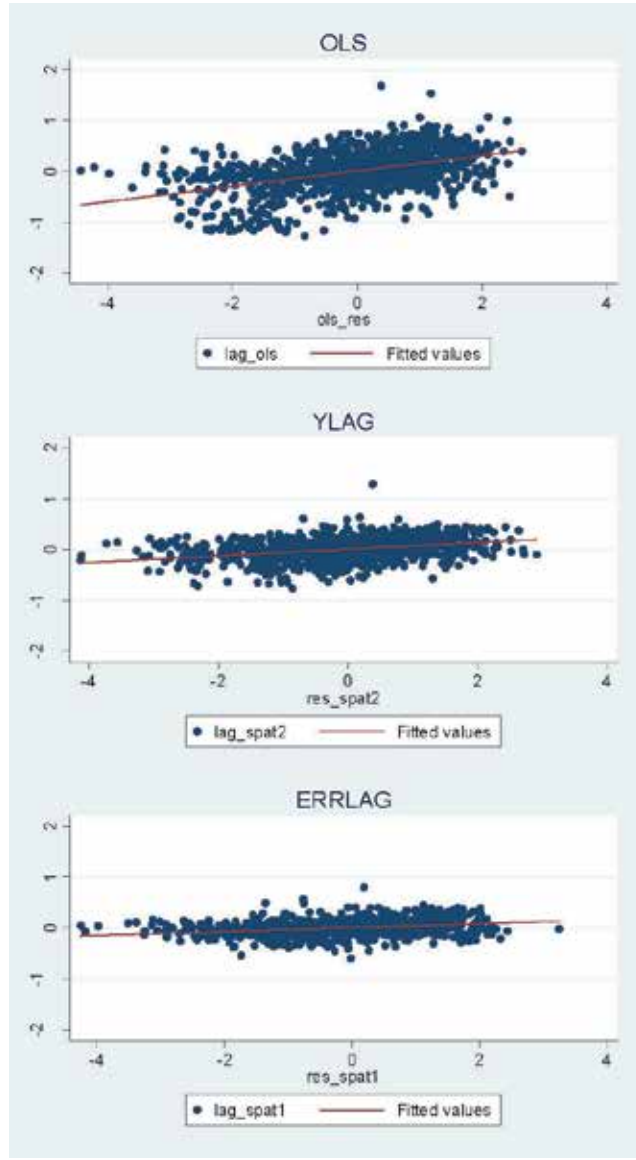

Figure 5. Spatial autocorrelation in residuals

In this study we estimate spatial models for irrigated land in Northern Andes of Peru considering geographic, climate and socio-economic factors. Most geographic variables show significant coefficients an d expected signs. Higher altitudes and steeper slopes have negative impacts on irrigated land as well as distance to rivers. In the climate variables, less rainfall in the dry season is important in explaining more irrigation and this can be interpreted as a demand effect

negative impacts on irrigated land as well as distance to rivers, as expected. Less rainfall in the dry season is important in explaining more irrigation (so this can be interpreted as a crop demand effect). Mean rainfall for the whole year, however, appears as no significant as well as maximum temperature. These results may be related to the limited spatial variability of these variables after smoothing the data with geographic interpolation algorithms based on few meteorological stations (10 for temperature, 13 for rainfall).

In the land use variables, the area with forest is positively associated with irrigation whereas the one with pasture decreases irrigation access. This can be expected as more forest tends to generate better conditions (less erosion) for water regulation in the upper parts of Andean basins, whereas more pasture (linked to more cattle) will have the opposite effect.

Given that the dependent and independent variables are in logs, the coefficients can be interpreted as elasticities. The value of the irrigated land to forest elasticity is 0.785, and for pasture is -0.241. This implies that an increment of 10% in forest land in the upper parts of the basins will increase irrigated land in 7.8%. In the case of pasture, an increase of 10% in land devoted to this use will reduce irrigated land by 2.4%. These are important effects and are plotted in Figure 4 for alternative values of the covariates. The mean of the dependent and each independent variable are also shown in the figure 4.

Also notice that in the fourth column of Table 3—where the spatial lagging of land use variables is based on a symmetric W_2 that does not considers altitude for choosing neighbors—the signs of these two coefficients are reversed and potentially misleading. This is an indirect proof of the importance of a correct specification of W_2 in order to capture the spatial dependencies in this context.

In terms of socio-economic variables, age and education appear with positive and significant coefficients in the (preferred) error lag specification. Life cycle and human capital considerations seems to be important for this result. Note that the education effect is not picked up neither by the OLS or YLAG models.

The estimated spatial coefficients ρ and λ are significant in both spatial specifications indicating that global spatial dependencies modelled with the spatial weight matrices are important explanatory factors. The estimated error lag coefficient is 0.91, indicating strong spatial autocorrelation in the data. The high value and significance of this spatial autocorrelation parameter indicate that the OLS estimates are very likely to be inconsistent.

In Figure 5 we present Moran's scatter diagrams of estimated residuals (versus spatially lagged residuals using the same 20 Km weight matrix) for the first three specifications.

In Table 4 we report the estimated Moran's I coefficients for each model.

From the table and the graph we see that ERRLAG is the most effective in reducing the strong spatial autocorrelation found in the global OLS. However, notice that the Moran I's coefficient is statistically significant for the ERRLAG, so some spatial autocorrelation in residuals still remains even with these explicit spatial specifications[5].

Table 4. Moran's I for models' estimated residuals

	I	E(I)	sd(I)	z	p-value*
OLS	0.087	-0.001	0.005	17.142	0.00
YLAG	0.070	-0.001	0.005	13.817	0.00
ERRLAG	0.033	-0.001	0.005	6.596	0.00
*1-tail test					

Conclusion

In this study we estimate spatial models for irrigated land in Northern Andes of Peru considering geographic, climate and socio-economic factors. Most geographic variables show significant coefficients an d expected signs. Higher altitudes and steeper slopes have negative impacts on irrigated land as well as distance to rivers. In the climate variables, less rainfall in the dry season is important in explaining more irrigation and this can be interpreted as a demand effect. Neither mean rainfall for the whole year nor maximum temperature appear to be important for explaining irrigated land in this context.

We also find strong statistical evidence that land use practices (forest and pasture) in the upper areas of Andean basins have high influence in explaining irrigation in the lower zones of the same basin. The irrigated land to forest elasticity is almost 0.8 and for pasture is -0.24 (although less precise), which are important magnitudes. This finding suggests that promoting the adoption of more forest (trees) in the upper basins will be really effective for facilitating or/and ensuring more irrigation downstream. Also, it is clear that more cattle and pastures in the upper highlands of Cajamarca will have a negative effect on irrigation in the lowlands. Both findings will also support potential benefits coming from implementing mechanisms of payments for ecosystem services, for instance between irrigation organizations and upper land communities. These schemes are only viable with the participation of local and national authorities and with clear normative instruments and incentives for both parties

Our study also has some contributions in terms of methodology. We find that a correct specification of the spatial weighting matrix for lagging the land use variables is crucial for getting correct results in a context where we do not have detailed information on the shape and real water interactions within irrigation networks like spatial dependencies. However, in the Andean context we were able to correctly detect and estimate some of these spatial relationships using the altitude variable for constraining the weighting spatial matrix.

Finally. we also found for these data and context that the error lag model is the best spatial specification for the estimations, obviously better than the non spatial OLS but also than the autoregressive dependent variable specification.

End notes

[1] All geographic and climate data for this research were processed and analysed with © ESRI ArcMap 10.1.

[2] For any "x" that is log transformed we used ln(x+1) to avoid the occurrence of missing values when x is zero.

[3] For the econometric estimation of (1)-(2) we use © Stata, version 13.0, with its module for estimating spatial regressions with the maximum likelihood option. The software allows users to build matrices W and M based on spatial data.

[4] For carrying these tests we used GeoDaTM, a software developed by Luc Anselin, version 1.14.0 updated August 24, 2019.

[5] It should be noticed that the Moran's I may be also picking heteroskedasticy in error term as pointed out by Anselin (2005)

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We find that a correct specification of the spatial weighting matrix for lagging the land use variables is crucial for getting correct results in a context where we do not have detailed information on the shape and real water interactions within irrigation networks like spatial dependencies

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Package of ITU-R Recommendations on RNSS systems agreed by ITU-R Study Group 4

At its November 2021 meeting, the ITU-R Study Group 4 considered and agreed on a package of three ITU-R Recommendations on radionavigation-satellite service (RNSS) systems as listed below.

Draft revision of Recommendation ITU-R M.1787-3 - Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz

The information on orbital parameters, navigation signals and technical characteristics of systems and networks in the radionavigation-satellite service (RNSS) (space-to-Earth, space-to-space) operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz, and 1 559-1 610 MHz are presented in this Recommendation. This information is intended for use in the assessment of the interference impact between systems and networks in the RNSS and with other services and systems.

This Recommendation is revised mainly in its Annexes 2, 3, 7 and 11, in order to reflect updates in the characteristics, applications and signal structure of corresponding systems. Other editorial revisions and updates are made as well.

Draft revision of Recommendation ITU-R M.1901-2 - Guidance on ITU-R Recommendations related to systems and networks in the radionavigation-satellite service operating in the frequency bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz, 5 000-5 010 MHz and 5 010-5 030 MHz

This Recommendation is intended to provide guidance on other ITU-R Recommendations related to the technical characteristics and protection criteria of radionavigationsatellite service (RNSS) receiving earth stations and characteristics of RNSS transmitting space stations planned or operating in the frequency bands 1 164-1 215 MHz, 1 2151 300 MHz, 1 559-1 610 MHz, 5 000-5 010 MHz and 5 010-5 030 MHz. In addition, this Recommendation gives a brief overview of those Recommendations.

This Recommendation is revised to update references to ITU-R Recommendations and Reports related to the technical characteristics and protection criteria of radionavigation-satellite service (RNSS) receiving earth stations and characteristics of RNSS transmitting space stations planned or operating in the frequency bands 1 1641 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz, 5 000-5 010 MHz and 5 010-5 030 MHz.

Draft revision of Recommendation ITU-R M.1902-1 - Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) operating in the band 1 215-1 300 MHz

Characteristics and protection criteria for radionavigation-satellite service (RNSS) receiving earth stations operating in the band 1 215-1 300 MHz are presented in this Recommendation. This information is intended for performing analyses of radio-frequency interference impact on RNSS (space-to-Earth) receivers operating in the band 1 215-1 300 MHz from radio sources other than in the RNSS.

This Recommendation is revised in order to describe and to provide the technical characteristics and protection criteria of new types of receivers for certain RNSS systems.

These ITU-R Recommendations will now follow the formal approval procedure in accordance with Resolution ITU-R 1-8. Once formally approved, all these ITU-R recommendations will be freely accessible online. The related studies are continuously evolving based on contributions to and participation at the meetings of ITU-R Working Party 4C, the responsible group within ITU-R Study Group 4, where all the related work is currently being conducted, so that those ITU-R Recommendations can always reflect the most recent developments related to systems and networks in the RNSS.

– Nelson Malaguti
Counsellor, ITU-R Study Group 4 and CCV
Radiocommunication Bureau
International Telecommunication Union.

Galileo satellites arrive at Europe's Spaceport

Galileo atellites crossed the Atlantic from ESA's ESTEC Test Centre in Noordwijk, the Netherlands to Cayenne in French Guiana. These are the first of the last batch of Galileo First Generation satellites, known as 'Batch 3', made up of 12 satellites in all. They are built by OHB SE in Bremen, Germany, with their navigation and search and rescue payloads contributed by Surrey Satellite Technology Ltd in Guildford in the UK. *www.esa.int*

No foreign components in Glonass satellites

All Glonass-K2 satellites will be made exclusively of Russian-made components by 2026, with the import substitution to be expanded to other spacecraft, the satellite›s manufacturer told Sputnik.

"We are on schedule. We are only talking about the Glonass-K2 satellites, with regard to which the work has been launched. The rest of our spacecraft will copy solutions tested on the navigation systems. The component base, microassemblies, and individual subsystems will then be borrowed for other devices.

All Glonass-K2 satellites will be made of Russian components from 2026,» Nikolay Testoedov, CEO of Information Satellite Systems - Reshetnev Company, said.

Foreign-made components will however continue to be used in commercial spacecraft assembled in Russia.

Ginan: Analysis Centre Software

Geoscience Australia has developed an open-source Analysis Centre Software GNSS toolkit to process real-time geodetic data and deliver positioning, navigation and timing (PNT) services to Australians. This capability is called Ginan. It will enable positioning accurate to within 5 cm or better, when a user has access to equipment that can obtain a precise carrier phase

observation and internet connection to access the positioning products. This toolkit will manage the acquisition, processing and delivery of multi-GNSS.

Users have access to open-source software and products that enhance the accuracy of positioning. Industry, innovators and system integrators can use this system to develop new products and applications that use precise positioning, delivering the benefits to their customers and to the Australian public. The software is currently under development. In 2022, a production version of the software will be made available as an open source. This will be in addition to Geoscience Australia's existing real-time precise point positioning product files and correction streams. *www.ga.gov.au*

Michibiki-1R navigation satellite launched by Japan

Japan's Quasi-Zenith Satellite System (QZSS) launched a replacement for its first satellite, Michibiki-1, on October 26. QZS-1R, to be known as Michibiki-1R, flew up on a Mitsubishi Heavy Industries rocket and all went smoothly.

QZSS functions as a regional satellite-based augmentation system (SBAS0, improving GPS and Galileo accuracy for Japanese users in urban areas. It uses one geostationary satellite and three satellites in highly inclined, slightly elliptical, geosynchronous orbits. Each orbit is 120° apart from the other two and their ground traces are asymmetrical figure-8 patterns designed so that one is almost directly overhead (elevation 60° or more) over Japan at all times.

In December of last year, QZSS inaugurated a Centimeter Level Augmentation Service (CLAS), broadcasting a signal for nationwide open PPP-RTK service in Japan and providing centimeter positioning accuracy in a minute. This increased the number of available GNSS satellites up to 17: GPS, Galileo and Quasi-Zenith Satellite System (QZS) satellites all-in-view are corrected by the QZS L6 signal.

Designed for a 15-year lifetime, QZS-1R becomes one of four in the current QZSS system, which began offering services in November 2018. *https://spaceflightnow.com*

Test capability for Galileo HAS By Spirent

Spirent Communications plc has launched the industry's first commercially available simulation test solution for the Galileo High Accuracy Service (HAS), via a beta interface implementation based on HAS ICD version 1.2. During the development of the solution, Spirent collaborated with GMV. Galileo HAS will provide free-of-charge high-accuracy Precise Point Positioning corrections through the Galileo E6-B signal, with accuracy under two decimeters, offering real-time improved user positioning performance. Developers need to be able test their devices against this new service to ensure they can optimally capture the emerging capability when it becomes available. *www.spirent.com*

Thales and CS GROUP partnership

Thales and CS GROUP have combined their complementary expertise to offer a high-performance, resilient and cybersecure navigation system. The system comprises Thales's TopAxyz inertial navigation unit, which has delivered outstanding performance in the especially rigorous conditions of civil aviation, clocking up over 20 million hours of operation. The naval version of the unit was integrated on a Navy vessel in less than a day by CS GROUP and has already proven its operational value for maritime navigation.

GLONASS ground station in India by 2022

The construction of a ground station for correcting the GLONASS navigation signal in India will begin next year, Sergey Savelyev, deputy general director of state space corporation Roscosmos for international cooperation, told Sputnik.

Exploring England's Hidden Archaeological Landscape

From Roman ruins to Cold War bunkers, England is home to countless hidden archaeological landscapes spanning thousands of years. An interactive map published by Historic England allows users to take "virtual flights" over these treasures of the past.

Researchers used more than 500,000 aerial photographs captured over the past 30 years, as well as 3-D laser scans, to piece together a digital mosaic described by Historic England as "a huge archaeological jigsaw puzzle." The online map features heritage sites covering more than half of the country. This new aerial archaeology mapping tool lets people fly virtually over England and drink in its many layers of history," says Duncan Wilson, chief executive of Historic England, in a statement. "It will allow everyone to explore the hidden heritage of their local places and what makes them special."

Similar surveys conducted by Historic England have yielded extensive maps and images of ancient sites dotted across the country, including Hadrian's Wall, a Roman fortification built in the second century C.E. to keep out marauding Gaelic warriors from what is now Scotland.

Recent light detection and ranging (LiDAR) surveys of Wallingford Estate, a sprawling preserve in Northumberland maintained by the National Trust, show historic farming systems, gardens and Iron Age settlements, as well as former areas of woodland. The scans were taken ahead of the replanting of 75,000 native trees at Wallingford.

Each site included in the Historic England map includes a description with links to historic environment records, as well as reports about highlights and new discoveries. The government agency is continuing to map other regions and make more detailed analyses of known sites to see what new history might be uncovered. *www.smithsonianmag.com*

Improving safety and reliability of Metro Rail Services in Singapore

Bentley Systems, Incorporated and SMRT Trains, Mass Rapid Transit (MRT) operator in Singapore, have successfully completed the implementation of a Predictive Decision Support System (PDSS) for Singapore's North-South and East-West lines, the oldest MRT lines in the country. SMRT Trains' PDSS, which is based on Bentley's AssetWise Linear Analytics, contributes to improving the reliability of the two lines across 282 kilometers of track and has helped SMRT Trains achieve more than 1 million kilometers between failure (MKBF). MKBF is a measure of reliability used by train operators around the world, where a failure is defined as a service delay of more than five minutes. *www.bentley.com*

Lucknow, India to roll out GIS mapping system

The Lucknow Development Authority (LDA) will soon roll out the GIS mapping system to check illegal constructions across the city. Recently, Pawan Gangwar, secretary, LDA, reviewed the ongoing process of superimposition of development authority's master plan for Lucknow, 'shajra map' and satellite images.

The LDA secretary directed officials to go through the land audit carried out by the development authority in 2016 under the Uttar Pradesh Nagar Yojana and Vikas Adhinayam, the all development authorities are required to make their zonal development plans. In a bid to ensure uniformity in zonal development plans prepared by development authorities, the housing development board has made various changes in bylaws. Now, using GIS tool is also a part of these changes. *www.hindustantimes.com*

Call for governments to recognize value of location in climate change action

EuroGeographics pan-European datasets and their role in cross-border climate action are highlighted in a COP26 briefing paper calling on governments to recognise the value of official location data.

'Applying Geospatial Information to Climate Challenges' is published on behalf of delegates participating in the 2021 the Cambridge Conference organised by Ordnance Survey. As a member of the Conference International Advisory Group, the association for Europe's National Mapping, Cadastral and Land Registration Authorities (NMCAs) is a key contributor to the paper which sets out how official sources of geospatial data can support the United Nations four goals for COP26.

EuroGeographics has also signed the Cambridge Conference COP26 pledge, which commits to enabling nations to respond better to climate challenges by using trusted location data and to act now to become a sustainable organisation. *https://eurogeographics.org*

OceanProtect Data Protection Solution

Huawei has launched the OceanProtect Data Protection Solution, covering both Disaster Recovery (DR) and backup fields to offer comprehensive protection for diversified types of data throughout the lifecycle. It belongs to the Huawei All-Flash Data Center Solution to build the fast, green, reliable, and intelligent infrastructure for various industries. The solution is built on the concept of "full DR of hot data, and quick backup and restore of warm data", which ensures zero service interruption, zero data loss, and long-term data retention.

The solution is firstly designed to offer full DR of hot data. This means it integrates DR for SAN and NAS, and provides worry-free device upgrade to maximize return on investment (ROI). The solution can also flexibly adopt the Huawei active-active DR design to reduce customers' initial investment and meet their evolving DR requirements. This design also guarantees the non-disruptive upgrade from one system to active-active or active-passive dual-system deployment, and then to three-data-center (3DC) or even multi-DC four-copy solution. This allows equipment to be upgraded online as and when required. *e.Huawei.com*

ESA and NASA launch revolutionary open-source platform

ESA and NASA have publicly released the first globally-harmonized assessment of above ground biomass – information that is vital for managing global climate change. The Multi-Mission Algorithm and Analysis Platform (MAAP) provides seamless access to above ground biomass information from both NASA and ESA Earth observation data. The revolutionary open-science tool is now fully operational and accessible online.

MAAP is the culmination of a two-year NASA and ESA effort and reflects the cooperation between the two agencies under the NASA and ESA JPPG (Joint Program and Planning Group) Joint Working Group (WG) on Ground Segment and Operations.

The MAAP platform enables international scientists and researchers to collaboratively develop algorithms and code as well as analyse and visualise large datasets acquired from sources including satellite instruments, the International Space Station, and airborne and ground campaigns. The large data and high-performance computing required for MAAP, along with a shared code repository and catalog, are stored and managed in the cloud. MAAP capabilities are supported and shared between NASA and ESA.

Very high-resolution imagery from Airbus Pléiades Neo Satellites

Very high-resolution optical imagery from the Airbus Pléiades Neo constellation on the UP42 geospatial marketplace and developer platform is now available. Pléiades Neo's unique combination of 30cm native spatial resolution, daily revisit, and faster tasking/ data delivery will benefit end users in all sectors. *https://up42.com*

Hancom Group to launch Sejong-1 satellite in 2022

In the first half of 2022, Hancom InSpace, an affiliate of Hancom Group, working in cooperation with Spire Global, will launch Korea's first private satellite for Earth observation. With this event, Hancom Group will be the first non-governmental entity in South Korea to put into space a satellite weighing less than 100 kg.

With the launch of Sejong-1, Hancom Group will complete the first step in creating a worldwide remote sensing data service belt linking space, the aerial area, and the ground, using satellites and drones equipped with ultra-high-resolution sensors. *www.hancomglobal.com*

Research contract with US Army for Capella Space

Capella Space has signed a Cooperative Research and Development Agreement (CRADA) with the US Army Space and Missile Defense Technical Center (SMDTC). Through this agreement, it integrates its Synthetic Aperture Radar (SAR) data into the US Army's Payload Development Lab, exploring this and other space-based technology concepts within both simulated and test environments. Capella's SAR data is unique in that it collects high-quality imagery easily, quickly, and securely. It is the first US commercial SAR constellation operator.*www.capellaspace.com*

New high resolution Pelican Satellites and Fusion with SAR

At its Explore 2021 user conference, Planet announced two major new products: Pelican, a next-generation fleet of satellites for very high resolution imagery that will begin launching next year and be operational in 2023, and Fusion with SAR, a cutting-edge data enhancement to its existing Fusion Monitoring product.

When fully operational, the Pelican constellation replenishes and upgrades Planet's existing high resolution SkySat fleet with better resolution, more frequent image revisit times, and reduced reaction time and latency. The Fusion line will now include SAR (synthetic aperture radar) data, enabling customers to see through clouds with a data stream of continuous landscape monitoring. *www.planet.com*

Expanding Vexcel Aerial Imagery Collection Program Into Japan

Vexcel is expanding its aerial imagery collection into Japan. This new addition increases the footprint of the Urban Area program, an ultra-high-resolution collection focused on major metro areas around the globe. Japan's largest cities, encompassing more than 68% of the population, will be collected under the expanded program.

Customers from insurers to smart city planners, utility providers to HD map developers, will see Japan urban centers from multiple perspectives in a higher resolution. Products from the collection include Oblique and True Ortho aerial imagery, as well as Digital Surface Models and Multispectral imagery with a ground sample distance resolution of 7.5 centimeters (2.9 inches).

This Urban Area information is collected by fixed-wing aircraft while carrying the award-winning UltraCam Osprey 4.1 sensors, designed and manufactured by Vexcel Imaging.

Vexcel collects the largest aerial program worldwide annually, delivering geospatial data at a resolution, clarity, and accuracy that's never been delivered on a global scale. Vexcel is the only aerial information program with ultra-high resolution urban area and wide area data collected annually around the globe.

RedTail delivers LiDAR system to DoD

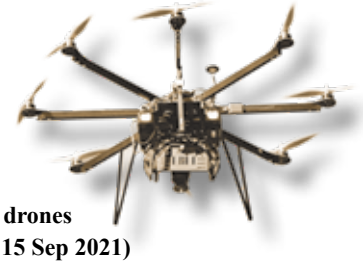
RedTail LiDAR Systems has delivered six LiDAR systems to the 707th Ordnance Company stationed at Joint Base Lewis-McChord. These systems will provide Explosive Ordnance Disposal (EOD) technicians an opportunity to assess how LiDAR can be used to enhance their operations.

The RedTail LiDAR Systems RTL-450 was integrated onto the Teledyne FLIR SkyRaider Unmanned Aerial System (UAS) to address a broad range of the EOD community's 3D mapping needs. The underlying LiDAR technology used in the RTL-450 was licensed from the Army Research Laboratory (ARL). The MEMS mirror-based design provides enhanced 3D imagery due to the fact that the laser pulses are steered to the ground in a very well-defined and controlled scan pattern. The LiDAR technology is ideal for applications where Artificial Intelligence and Machine Learning (AI/ML) algorithms can be used for target detection and classification due to the high point density of the point clouds. *www.redtaillidar.com*

Carbon neutral farming in Northern Ireland

A European Innovation Partnership project to accelerate the move towards net carbon zero farming is using specially commissioned LiDAR data to create a baseline for future measurements. Working with ARCZero (Accelerating Ruminant Carbon Zero) aerial mapping company Bluesky recorded LiDAR measurements for seven commercial farms across Northern Ireland. This data is being used to calculate above ground carbon storage, which will be combined with the results from a whole business Life-Cycle Analysis calculator to inform future farming practices.

Each farm is supplying input and output data at the start and the end of project, which will be analysed using the AgReCalc carbon footprint tool. The farms will also undertake soil analysis to measure carbon content and bulk density. The Bluesky LiDAR data is being processed by researchers at the Agri-Food and Biosciences Institute, using ArcGIS, to locate and measure above ground carbon storage. *arczeroni.org*



Ministry of Civil Aviation releases India's airspace map for drone operations

The drone airspace map comes as a follow-through of the liberalized Drone Rules, 2021 released by the Central Government on 25 August 2021, the PLI scheme for drones released on 15 September 2021 and the Geospatial Data Guidelines issued on 15 Feb 2021. All these policy reforms will catalyse super-normal growth in the upcoming drone sector.

Given its traditional strengths in innovation, information technology, frugal engineering and its huge domestic demand, India has the potential of becoming a global drone hub by 2030.

Top 10 features of the drone airspace maps

- The drone airspace map is an interactive map of India that demarcates the yellow and red zones across the country.
- Green zone is the airspace upto 400 feet that has not been designated as a red or yellow zone; and upto 200 feet above the area located between 8-12 km from the perimeter of an operational airport.
- In green zones, no permission whatsoever is required for operating drones with an all-up weight upto 500 kg.
- Yellow zone is the airspace above 400 feet in a designated green zone; above 200 feet in the area located between 8-12 km from the perimeter of an operational airport and above ground in the area located between 5-8 km from the perimeter of an operational airport.
- Drone operations in yellow zone require permission from the concerned air traffic control authority – AAI, IAF, Navy, HAL etc. as the case may be.
- Yellow zone has been reduced from 45 km earlier to 12 km from the airport perimeter.
- Red zone is the 'no-drone zone' within which drones can be operated only after a permission from the Central Government.
- The airspace map may be modified by authorised entities from time to time.
- Anyone planning to operate a drone should mandatorily check the latest airspace map for any changes in zone boundaries.
- The drone airspace map is freely available on the digital sky platform to all without any login requirements.

Top 15 features of drone rules, 2021 (Notified on 25 Aug 2021)

- Based on a premise of trust, self-certification and non-intrusive monitoring.
- Several permissions and approvals abolished. Number of forms reduced from 25 to 5. Types of fee reduced from 72 to 4.
- Digital sky platform being developed as a user-friendly online single-window system.
- Interactive drone airspace map with red and yellow zones to be released by 24 September 2021.
- No permission required for operating drones in green zones.
- Yellow zone, where ATC permission is required, has been reduced from 45 km to 12 km from the airport perimeter.
- No remote pilot licence required for micro drones (for non-commercial use) and drones.
- No security clearance required before issuance of any registration or licence.
- Coverage of drones under drone rules, 2021 increased from 300 kg to 500 kg. This will cover drone taxis also.
- No restriction on foreign ownership in Indian drone companies.
- No requirement of import clearance from DGCA.
- Remote pilot licence to be issued by DGCA within 15 days of pilot receiving the remote pilot certificate from an authorised drone school.
- Maximum penalty for violations reduced to INR 1 lakh. Was several lakhs earlier.
- Drone corridors will be developed for cargo deliveries.
- Drone promotion council to be set up by government with participation from academia, startups and other stakeholders.

Top 15 features of the pli scheme for drones (Approved on 15 Sep 2021)

- The total amount allocated for the PLI scheme for drones and drone components is INR 120 crore spread over three financial years. This amount is nearly double the combined turnover of all domestic drone manufacturers in FY 2020-21.
- The incentive for a manufacturer of drones and drone components shall be as high as 20% of the value addition made by her.
- The value addition shall be calculated as the annual sales revenue from drones and drone components (net of GST) minus the purchase cost (net of GST) of drone and drone components.
- The Government, has agreed to keep the PLI rate constant at 20% for all three years, an exceptional treatment given only to the drone industry. In PLI schemes for other sectors, the PLI rate reduces every year.
- The proposed tenure of the PLI scheme is three years starting in FY 2021-22. The PLI scheme will be extended or redrafted after studying its impact in consultation with the industry.
- The Government has agreed to fix the minimum value addition norm at 40% of net salesfor drones and drone components instead of 50%, another exceptional treatment given to the drone industry. This will allow widening the number of beneficiaries.
- The PLI scheme covers a wide variety of drone components:
  - Airframe, propulsion systems(engine and electric), power systems, batteries and associated components, launch and recovery systems;
  - Inertial Measurement Unit, Inertial Navigation System, flight control module, ground control station and associated components;
  - Communications systems (radio frequency, transponders, satellite-based etc.)
  - Cameras, sensors, spraying systems and related payload etc.;
  - 'Detect and Avoid' system, emergency recovery system,

trackers etc. and other components critical for safety and security.
- The list of eligible components may be expanded by the Government from time to time, as the drone technology evolves.
- The Government has agreed to widen the coverage of the incentive scheme to include developers of drone-related IT products also.
- The Government has kept the eligibility norm for MSME and startups in terms of annual sales turnover at a nominal level - INR 2 cr (for drones) and INR 50 lakhs (for drone components). This will allow widening the number of beneficiaries.
- Eligibility norm for non-MSME companies in terms of annual sales turnover has been kept at INR 4 crore (for drones) and INR 1 crore (for drone components).

https://digitalsky.dgca.gov.in

CGI to develop 5G for UAV positioning

CGI has been awarded a contract by the European Space Agency to develop a proof of concept to enhance the navigational capabilities of airspace users in areas where traditional navigation systems alone cannot provide sufficient performance. Future aircraft, such as UAV and innovative air mobility solutions, will need to safely operate beyond visual line of sight (BVLOS) within cities and other built-up areas, where the signals of GNSS are often disrupted.

The concept being developed by CGI and its partners leverages 5G networks, alongside traditional navigation systems, to provide hybrid-positioning solutions. In addition to secure communications for command and control of vehicles, and delivery of high-quality streaming video for BVLOS operations, 5G networks can also be used as a source for navigational bearings that will improve the accuracy, integrity and availability beyond that which satellite navigation systems alone can provide. The service will also offer greater resilience against natural or intentional disruption of Positioning, Navigation and Timing (PNT) services. *www.cgi.com*

FIXAR enters the Indian market with Paras Aerospace

EU-based commercial drone design and software developer FIXAR, has signed an exclusivity agreement with the leading Indian technology development company Paras Aerospace, a subsidiary of Paras Defense and Space Technologies Limited, for FIXAR unmanned solution distribution in India.

Both companies will collaborate to ensure access to efficient and cost-effective unmanned aerial solutions offering an autonomous vertical take-off and landing model FIXAR 007 and a professional multirotor FIXAR INDOOR. Paras Aerospace will be the Master Certification Compliance partner for FIXAR in India. *https://fixar.pro*

Autonomous remote UAV operations solution

SkyGrid, a Boeing, SparkCognition company has released a new autonomous remote UAV operations capability to allow flight managers and operators to control and execute flights from remote locations. Using artificial intelligence and a broad array of airspace-related data feeds, SkyGrid is enabling safe remote operations for missions involving single and multiple drones. *http://skygrid.com*

Aquiline Drones to transport human tissue and organs

Aquiline Drones (AD), an American drone manufacturer and cloud technology enterprise has recently announced the culmination of its extensive effort and official formation of AD Airlines after being awarded its Air Carrier Certificate by the FAA on September 16, 2021, which enables AD to commercialize its lifesaving tissue and organ delivery service.

Specifically, AD Airlines will implement its patent-pending and unique Mixed Modal Transport Model (R2M2), starting with the use of manned aircraft, and gradually incorporating drones as FAA approvals are realized. R2M2 is an Artificial Intelligence (AI)-driven transportation logistics platform supported by the AD Cloud. It uses AI algorithms embedded in AD's cognitive agent "Spartacus' to manage a hyper-ledger blockchain platform to optimize transportation logistics. Essentially, AD Airlines plans on using both drones and planes on its Air Carrier Certificate to provide a first-ever comprehensive solution to the human organ and tissue transplant delivery system within the medical industry. *www.aquilinedrones.com*

'Go-To' UTM provider for India BVLOS trials

Altitude Angel UTM (Unified Traffic Management) technology provider, has announced its Guardian UTM Enterprise platform will be utilized by a further three consortiums trialing Beyond Visual Line of Sight (BVLOS) drone operations in India.

The platform is now powering half of the eight consortiums involved in trials approved by the Ministry of Civil Aviation, Govt. of India along with other security and regulatory agencies.

Following recent announcement that the Blue Dart consortium would be deploying Guardian UTM Enterprise as part of the 'Medicine from the Sky' initiative during which drones, operating BVLOS, will deliver vaccines and emergency medical supplies from a district hospital to a primary healthcare center, Altitude Angel has been retained by two consortiums headed by Dunzo and one by Flipkart Air.

Dunzo Med Air and FlipKart Air are also both participating in the 'Medicine from the Sky' trials. Altitude Angel will provide GuardianUTM Enterprise platform to both consortiums as they conduct BVLOS drone operations which will include the delivery of life saving vaccines. The impetus of the project will be to enable healthcare deliveries, including COVID-19 vaccines, to different districts in the State of Telangana. *www.altitudeangel.com*

NovAtel enhances the performance of the GAJT-710

NovAtel have announced an update to their GPS Anti-Jam Technology (GAJT) portfolio. As the leading provider of assured positioning, navigation and timing (APNT) products, it has introduced the new GAJT-710 product line that features several enhancements over the previous generation.

The GAJT-710 product line is the next evolution of NovAtel's battle-proven anti-jam technology for land and marine platforms. The new jammer direction-finding capability of GAJT enables situational awareness and a new silent mode feature reduces its thermal signature. *novatel.com*

VERIPOS introduces low SWaP anti-jamming protection and RF interference mitigation

The biggest thing in anti-jam just got smaller: introducing GAJT-410MS, the newest addition to the GPS Anti-Jam Technology (GAJT) portfolio from Hexagon | VERIPOS. This low size, weight and power (SWaP) model of the field-proven GAJT-710MS protects against RF interference with adaptive nulling, including jammer direction-finding and up to three simultaneous nulls for multi-jammer scenarios.

The GAJT-410MS protects against RF interference, jamming and spoofing activities to enable assured positioning, navigation and timing (APNT). The low SWaP unit is optimized for space-constrained vessels like unmanned and autonomous platforms. The Power Injector Data Converter (PIDC) simplifies installation by connecting the GAJT-410MS to the user's existing GNSS receiver through a single RF cable. *veripos.com*

Hexagon Power Portfolio 2022

Hexagon's Safety, Infrastructure & Geospatial division have announced the launch of Power Portfolio 2022, the latest version of its leading GIS, remote sensing, photogrammetry and geospatial data management products.

The latest release increases efficiency for users of ERDAS IMAGINE, ImageStation and GeoMedia with automated workflows and the ability to extract point clouds from larger stereoimagery files up to three times faster. GeoMedia WebMap also enhances productivity by empowering field personnel to access and edit data anywhere, anytime with new mobile capabilities. *www.hexagongeospatial.com*

ViaLite supports Raytheon

A new project sees ViaLite supplying Raytheon Technologies, the world leading mil-aero corporation, with its cutting edge 'GPS over Fiber Extension Kit' for Microsemi GPS servers. The Kit provides mission critical GPS timing and synchronization for systems requiring extremely accurate clock signals.

Standard transmission distances for the extension kit can be up to 10 km, while solutions are available for distances as long as 50 km. *www.vialite.com*

Smallest 5GNR, WiFi-6E and GNSS Combination 9-in-1 Antennas

2J Antennas introduces the new Stellar Series that is designed for a large suite of devices with a focus on sub 6 GHz, 5G NR, 4G LTE, 3G, 2G, WiFi-6E and GNSS technologies. This series includes single or up to 9-in-1 configuration choices within the range of 617 MHz to 7125 MHz frequency bands.

The cutting-edge patent pending technology reduces the antenna footprint by 55% while implementing a new double trifilar design and longitudinal resonances for MIMO/ ARRAY configurations that traditionally have more complex size restrictions (i.e. B71 Band/ 600 MHz). Each antenna configuration uses symmetrical or asymmetrical resonators for negative sections of the antenna resulting in maximum performance at low and mid frequencies. *https://www.2j-antennas.com*

Orolia signs an agreement to acquire Seven Solutions

Orolia has entered into a definitive agreement to acquire Seven Solutions, a global innovator in White Rabbit sub-nanosecond time transfer and synchronization technology. This transaction is subject to customary closing conditions and approvals required by the Spanish government and is expected to close before the end of the year. *www.orolia.com*

Trimble releases turnkey autonomous robotic scanning solution

Trimble has released the Trimble® X7 3D laser scanner and Trimble FieldLink software fully integrated with Boston Dynamics' Spot® robot. This exclusive turnkey solution from Trimble, jointly developed with Boston Dynamics, facilitates autonomous operation on construction sites and takes advantage of the robot›s unique capabilities to navigate challenging, dynamic and potentially unsafe environments. Trimble›s 3D data capture technology, integrated with Spot, enables a continuous flow of information between the field and the office for consistent, on-going documentation of jobsite progress. *www.trimble.com*

Trimble and Microsoft partnership

Trimble and Microsoft have announced a strategic partnership to advance technology adoption and accelerate the digital transformation of the construction, agriculture and transportation industries. By leveraging the Microsoft cloud, Trimble and Microsoft will collaborate to develop, build and deliver industry cloud platforms and solutions that connect people, technology, tasks, data, processes and industry lifecycles.

This collaboration represents a significant milestone to advance Trimble's Connect and Scale 2025 strategy, which centers on building industry-leading cloud platforms. Initially, Trimble and Microsoft will focus on building the Trimble Construction Cloud powered by Microsoft Azure.

In addition to cloud engineering development, Microsoft and Trimble will partner on joint go-to-market strategies and deliver innovative solutions to multinational and regional enterprises. *www.trimble.com*

Advanced Navigation releases next generation satellite compass

Advanced Navigation has released the second generation of their highly successful satellite compass. It is a plug-and-play solution that provides accurate position, heading, and time in a self-contained unit. The new system provides significantly higher heading performance, combined with a reduction in price to under USD 2K, opening up the advanced technology to cost-sensitive applications previously dependent on magnetic heading.

The new system significantly improves the availability and accuracy of heading under difficult conditions, such as under bridges, when there is limited visibility of the sky and in the presence of RF interference. This is achieved through a new multi-frequency GNSS receiver, cutting-edge antenna design, and algorithm improvements. *www.advancednavigation.com*

World's highest-performing radio occultation satellite

PlanetIQ officials are ecstatic with the weather data collected by the company's first operational satellite, which was launched in June. In fact, the company is soliciting funds to speed up its quest to construct a 20-satellite radio occultation constellation for the GNSS (Global Navigation Satellite System) by 2024.

PlanetIQ's GNSS Navigation and Occultation Measurement Satellite (GNOMES) 2, deployed on SpaceX Falcon 9 Transporter-2 rideshare flight on June 30, achieved that aim. GNOMES-2 uses a radio occultation antenna, which has a large-aperture, to collect 2,500 soundings of daily radio occultation that follow the four GNSS constellations: the GPS, Galileo, Glonass, and Beidou. Because, like weather balloons, radio occultation soundings display temperature, pressure, and humidity via an atmospheric column, they are important inputs for the numerical weather models. Satellite soundings also reach into the ionosphere and give global coverage, particularly over oceans where very few weather balloons are launched.

Radio occultation missions that intend to give data near the Earth's surface require a high signal-to-noise ratio. Radio occultation signals for the lowest 2 kilometers of the Earth's atmosphere are frequently dismissed by numerical weather prediction centers due to concerns about their accuracy. *https://thehostonline.co.uk*

Naurt has launched a REST API

Geo-location startup Naurt has launched embedded software that can provide centimetre accuracy in satellite navigation systems both indoors and out.

After a year of beta testing with a pilot group, it has now made their software accessible to any businesses through a hardware-agnostic web API, served via REST. It collects the location data and improves it with a series of algorithms including sensor fusion to provide better coordinates.

Naurt's software does not replace the satellite location services businesses currently use. Instead, it simply integrates seamlessly with it and fixes the problems that cause the location data to be inaccurate. *www.nuart.com*

NextNav and Qualcomm collaboration

NextNav is collaborating with Qualcomm Technologies, Inc., to enable NextNav's Pinnacle 911 z-axis software and network-based services for use with the Qualcomm Location Suite. This effort makes it easy for device and original equipment manufacturer (OEM) vendors to integrate z-axis capabilities into existing carrier infrastructure for 911 purposes. *https://nextnav.com*

Virtual 3D model baseline survey for GoviEx Uranium

Delta Drone International is set to enter the Niger market for the first time with uranium explorer and developer, GoviEx Uranium, to perform a virtual 3D model baseline survey for its potential new Madaouela mine in the West African country. *www.deltadrone.com*

ModalAI releases new Seeker micro-development drone

ModalAI released two new products – the VOXL CAM perception engine and the Seeker micro-development drone, the world's first micro-development drone optimized for development of both indoor and outdoor autonomous navigation.

The VOXL CAM is an all-in-one compute and perception engine that makes it easier to develop smaller, smarter and safer drones, robots and Internet of Things (IoT) devices with GPS-denied navigation, depth mapping, unmanned aircraft systems (UAS) flight control and cellular connectivity. The credit card-sized VOXL CAM powers the Seeker micro-development drone, ModalAI's newest and smallest drone to date. *www.modalai.com*

New tethered drone system enables Mavic 2

Firefighters and police drone teams have been using the V-Line tethered system for the Mavic 2 drone in a variety of situations on land. Volarious has now launched a new product called the V-Line boat mode. It can also be used in coastline surveillance, search & rescue operations. A drone can take off, follow, and land on small vessels autonomously while providing a real-time elevated view of high resolution thermal & RGB images and video streams at the comfort of the cabin. *www.volarious.com*

Electric robots are mapping the seafloor

For centuries, humans have explored the Earth's mountains, jungles and deserts.

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But despite covering more than 70% of the Earth›s surface, the ocean is still a relative mystery. In fact, we know more about the surface of Mars than we do about the sea floor; just over 20% of the ocean bed has been mapped.

Getting a fuller picture would enable us to navigate ships more safely, create more accurate climate models, lay down telecommunication cables, build offshore windfarms and protect marine species -- all part of what's known as the "blue economy," projected to be worth $3 trillion by 2030.

Underwater robotic vehicles equipped with sensors are helping gather that data quicker and more cheaply than ever before. But many of these vehicles rely on batteries with a limited lifespan, and need to return to a boat or the shore to recharge, making it difficult for them to map more remote parts of the sea.

A five-year-old startup called Seatrec is rising to the challenge, founded by oceanographer Yi Chao. While working at NASA, he developed technology to power ocean robots by harnessing "the naturally occurring temperature difference" of the sea, Chao told

The power module can be installed on existing data-gathering robots or Seatrec's own floating device. This dives a kilometer down to examine the chemistry and shape of the seabed, using sonar to create a map of the surrounding area. The robot returns to the surface to send back its findings via satellite. Launched in 2017, the Seabed 2030 Project has increased awareness about the importance of the ocean floor, and given researchers and companies a clear goal to work towards: map the entire seafloor by the end of this decade. *CNN.com*

Drones to map 700 villages in Assam

The Assam-government has launched the process of mapping 700 odd villages through drones, which in future could help in demarcating borders with other states in the region.

There are around 22,724 villages in Assam, of which 700 had no maps so far and so posed hurdles in executing government projects and buying and selling of land. The project, assisted by the Survey of India, started recently

While the Survey of India has given the drones for the exercise, the rest of the work is being done by the Kamrup administration and Assam Survey. Under Mission Vasundhara, Singimari is the first village to be mapped. *https://timesofindia.indiatimes.com*

MARK YOUR CALENDAR

December 2021

SIRGAS2021 (virtual)
Nov 29 to Dec 1
www.sirgas.org/en/sirgas-symposia/symp_2021
www.geobusinessshow.com

February 2022

Geo Week
6-8 February, 2022
Denver, CO, USA
www.geo-week.com

DGI Geospatial Intelligence for National Security 2022.
London on 08-09 February 2022.
https://dgi.wbresearch.com

March 2022

Munich Satellite Navigation Summit 2022
7-9 March
Munich, Germany
munich-satellite-navigation-summit.org

IGRSM 2022
8-9 March
Virtual Conference
Kuala Lumpur Malaysia
www.igrsm.org

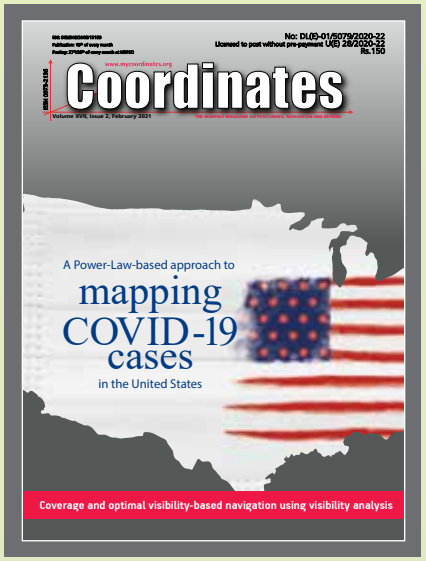
The 10th Land Administration Domain Model Workshop
31 March - 2 April 2022
Dubrovnik, Croatia
http://isoladm.org/LADM2022Workshop

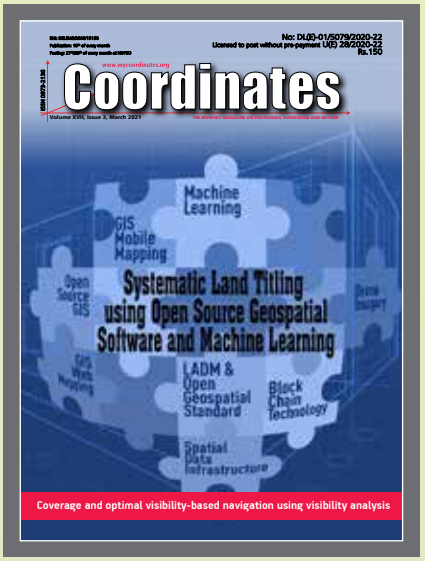
October 2022

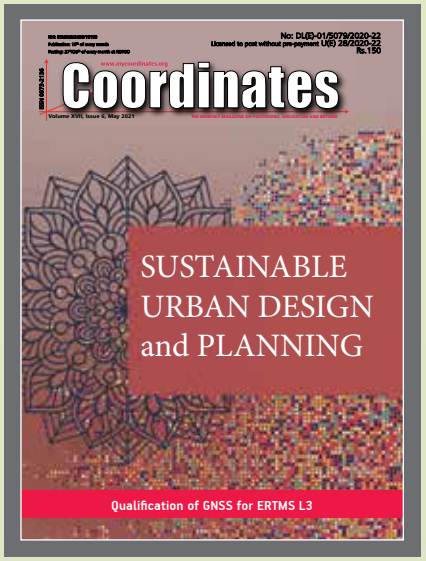
Intergeo Hybrid
18-20 October 2022
Essen, Germany
www.intergeo.de

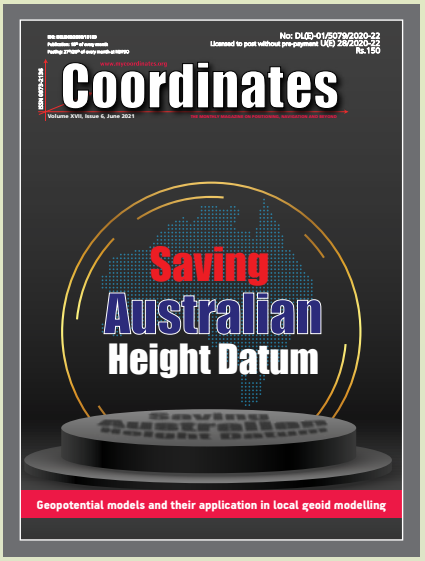
November 2022

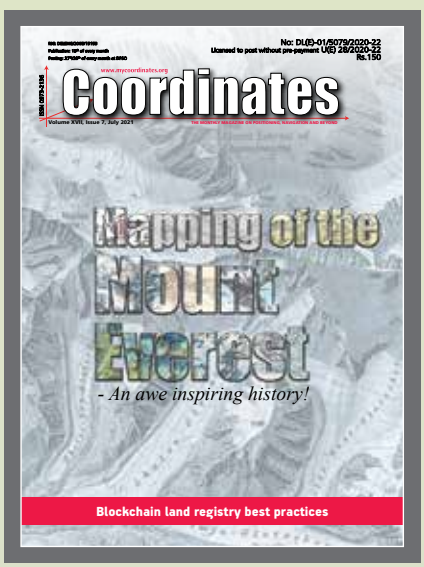
Trimble Dimensions+
7-9 November 2022
Las Vegas, USA
https://dimensions.trimble.com

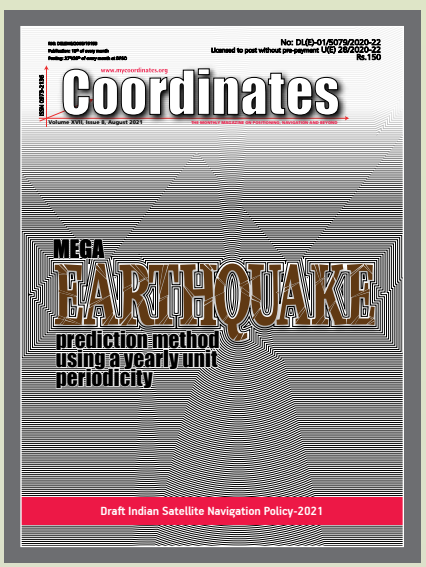


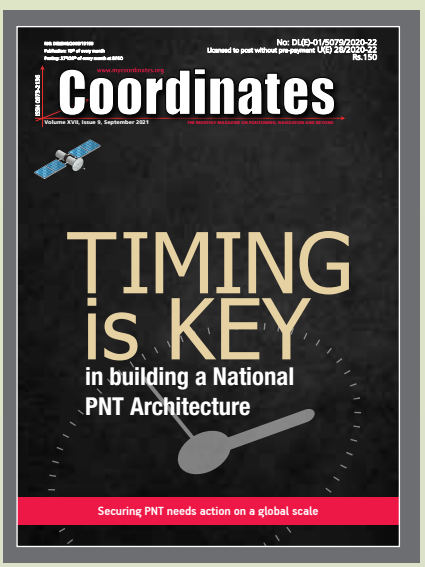












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